

March 2007



منظمة الأغذية
والزراعة
للأمم المتحدة

联合国
粮食及
农业组织

Food
and
Agriculture
Organization
of
the
United
Nations

Organisation
des
Nations
Unies
pour
l'alimentation
et
l'agriculture

Organización
de las
Naciones
Unidas
para la
Agricultura
y la
Alimentación

Item 3.1(c) of the Draft Provisional Agenda

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Eleventh Regular Session

Rome, 11-15 June 2007

**THE STATE OF THE WORLD'S ANIMAL GENETIC RESOURCES
FOR FOOD AND AGRICULTURE**

FINAL VERSION

For reasons of economy, this document is produced in a limited number of copies. Delegates and observers are kindly requested to bring it to the meetings and to refrain from asking for additional copies, unless strictly indispensable. The documents for this meeting are available on Internet at <http://www.fao.org/ag/cgrfa/cgrfa11.htm>

W0000

Contents

| | |
|--|----|
| Acknowledgements | i |
| Preface..... | iv |
| The reporting and preparatory process..... | 1 |

Part 1

The state of agricultural biodiversity in the livestock sector

Introduction

SECTION A: ORIGIN AND HISTORY OF LIVESTOCK DIVERSITY

| | |
|---|----|
| 1 Introduction..... | 10 |
| 2 The livestock domestication process..... | 11 |
| 3 Ancestors and geographic origins of our livestock | 14 |
| 4 Dispersal of domesticated animals..... | 18 |
| 5 Transformations in livestock following domestication..... | 21 |
| 6 Conclusions..... | 22 |
| 7 References..... | 23 |

SECTION B: STATUS OF ANIMAL GENETIC RESOURCES

| | |
|---|----|
| 1 Introduction..... | 27 |
| 2 State of reporting..... | 28 |
| 3 Species diversity | 30 |
| 3.1 The big five..... | 31 |
| 3.2 Other widespread species..... | 34 |
| 3.3 Species with a narrower distribution..... | 34 |
| 4 Breed diversity | 35 |
| 4.1 Overview..... | 35 |
| 4.2 Local breeds..... | 39 |
| 4.3 Regional transboundary breeds..... | 40 |
| 4.4 International transboundary breeds..... | 41 |
| 5 Risk status of animal genetic resources | 41 |
| 6 Trends in breed status | 47 |
| 6.1 Changes in the number of breeds in the different breed groups | 47 |
| 6.2 Trends in genetic erosion..... | 48 |
| 7 Conclusions..... | 51 |

SECTION C: FLOWS OF ANIMAL GENETIC RESOURCES

| | |
|---|----|
| 1 Introduction..... | 53 |
| 2 Driving forces and historical phases in gene flows..... | 53 |
| 2.1 Phase 1: prehistory to the eighteenth century | 54 |
| 2.2 Phase 2: nineteenth to mid-twentieth centuries | 55 |
| 2.3 Phase 3: mid-twentieth century to the present | 55 |
| 3 The big five..... | 57 |
| 3.1 Cattle..... | 59 |
| 3.2 Sheep..... | 64 |
| 3.3 Goats..... | 68 |

| | |
|--|----|
| 3.4 Pigs | 70 |
| 3.5 Chickens | 72 |
| 3.6 Other species..... | 73 |
| 4 Impacts of gene flows on diversity | 74 |
| 4.1 Diversity-enhancing gene flow | 74 |
| 4.2 Diversity-reducing gene flow | 75 |
| 4.3 Diversity-neutral gene flow | 75 |
| 4.4 The future..... | 75 |
| 5 References..... | 76 |

SECTION D: USES AND VALUES OF ANIMAL GENETIC RESOURCES

| | |
|---|----|
| 1 Introduction..... | 79 |
| 2 Contribution to national economies | 79 |
| 3 Patterns of livestock distribution..... | 82 |
| 4 Food production | 85 |
| 5 Production of fibre, skins, hides and pelts | 87 |
| 6 Agricultural inputs, transport and fuel | 88 |
| 7 Other uses and values..... | 91 |
| 7.1 Savings and risk management..... | 91 |
| 7.2 Sociocultural roles | 92 |
| 7.3 Environmental services..... | 95 |
| 8 Roles of livestock for the poor..... | 97 |
| 9 Conclusions..... | 99 |
| 10 References..... | 99 |

SECTION E: ANIMAL GENETIC RESOURCES AND RESISTANCE TO DISEASE

| | |
|--|-----|
| 1 Introduction..... | 101 |
| 2 Disease resistant or tolerant breeds | 102 |
| 2.1 Trypanosomiasis | 104 |
| 2.2 Ticks and tick-borne diseases | 104 |
| 2.3 Internal parasites | 105 |
| 2.4 Foot rot..... | 106 |
| 2.5 Bovine leukosis..... | 107 |
| 2.6 Diseases of poultry..... | 107 |
| 3 Opportunities for within-breed selection for disease resistance..... | 108 |
| 4 Conclusions..... | 110 |
| 5 References..... | 110 |

SECTION F: THREATS TO LIVESTOCK GENETIC DIVERSITY

| | |
|--|-----|
| 1 Introduction..... | 113 |
| 2 Livestock sector trends: economic, social and policy factors | 114 |
| 3 Disasters and emergencies | 119 |
| 4 Epidemics and disease control measures | 124 |
| 5 Conclusions..... | 128 |
| 6 References..... | 129 |

Part 2

Livestock Sector Trends

Introduction

SECTION A: DRIVERS OF CHANGE IN THE LIVESTOCK SECTOR

| | | |
|-----|--|-----|
| 1 | Changes in demand | 137 |
| 1.1 | Purchasing power | 139 |
| 1.2 | Urbanization | 139 |
| 1.3 | Consumer taste and preference | 139 |
| 2 | Trade and retailing | 140 |
| 2.1 | Flows of livestock and their products | 140 |
| 2.2 | The rise of large retailers and vertical coordination along the food chain | 142 |
| 3 | Changing natural environment | 143 |
| 4 | Advances in technology | 144 |
| 5 | Policy environment | 145 |

SECTION B: LIVESTOCK SECTOR'S RESPONSE

| | | |
|-----|--|-----|
| 1 | Landless industrialized production systems | 150 |
| 1.1 | Overview and trends | 150 |
| 1.2 | Environmental issues | 154 |
| 2 | Small-scale landless systems | 157 |
| 2.1 | Overview | 157 |
| 2.2 | Environmental issues | 158 |
| 2.3 | Trends | 158 |
| 3 | Grassland-based systems | 159 |
| 3.1 | Overview | 159 |
| 3.2 | Environmental issues | 160 |
| 3.3 | Trends | 161 |
| 4 | Mixed farming systems | 164 |
| 4.1 | Overview | 164 |
| 4.2 | Environmental issues | 165 |
| 4.3 | Trends | 166 |
| 5 | Issues in mixed irrigated systems | 167 |

SECTION C: IMPLICATIONS OF THE CHANGES IN THE LIVESTOCK SECTOR FOR GENETIC DIVERSITY

| | |
|------------------|-----|
| References | 171 |
|------------------|-----|

Part 3

The state of capacities in animal genetic resource management

Introduction

SECTION A: INSTITUTIONS AND STAKEHOLDERS

| | | |
|-----|---|-----|
| 1 | Introduction..... | 176 |
| 2 | Analytical framework | 177 |
| 2.1 | Stakeholders' involvement and background at country level | 177 |
| 2.2 | Assessment of institutional capacities at country level..... | 177 |
| 2.3 | Organizations and networks with a potential role in regional and international collaboration | 179 |
| 3 | Stakeholders, institutions, capacities and structures | 179 |
| 3.1 | Stakeholder involvement in the State of the World process at country level | 179 |
| 3.2 | Assessment of institutional capacities at country and regional level..... | 180 |
| 3.3 | Organizations and networks with a potential role in subregional, regional and international collaboration | 185 |
| 4 | Conclusions..... | 189 |
| 5 | References..... | 191 |
| 6 | Annex..... | 192 |

SECTION B: STRUCTURED BREEDING PROGRAMMES

| | | |
|-----|--|-----|
| 1 | Introduction..... | 202 |
| 2 | Species priorities and breeding objectives | 203 |
| 2.1 | Cattle..... | 203 |
| 2.2 | Buffaloes..... | 205 |
| 2.3 | Sheep and goats | 205 |
| 2.4 | Pigs | 205 |
| 2.5 | Poultry..... | 205 |
| 2.6 | Other species..... | 206 |
| 3 | Organizational structures | 206 |
| 4 | Tools and implementation..... | 208 |
| 5 | Overview of breeding programmes by region | 210 |
| 5.1 | Africa | 211 |
| 5.2 | Asia | 212 |
| 5.3 | Europe and the Caucasus | 214 |
| 5.4 | Latin America and the Caribbean | 215 |
| 5.5 | Near and Middle East | 217 |
| 5.6 | North America and Southwest Pacific | 217 |
| 6 | Conclusions and future priorities | 218 |
| 7 | References..... | 220 |
| 8 | Annex..... | 220 |

SECTION C: CONSERVATION PROGRAMMES

| | | |
|-----|---|-----|
| 1 | Introduction..... | 225 |
| 2 | Global status..... | 226 |
| 3 | Stakeholders..... | 227 |
| 3.1 | National governments | 227 |
| 3.2 | Universities and research institutes..... | 227 |
| 3.3 | Civil society organizations and breeders' associations..... | 228 |
| 3.4 | Farmers | 228 |
| 3.5 | Part-time or hobby farmers | 228 |
| 3.6 | Breeding companies..... | 228 |

| | | |
|-----|--|-----|
| 4 | Conservation at species level – status and opportunities | 229 |
| 4.1 | Cattle..... | 229 |
| 4.2 | Sheep..... | 230 |
| 4.3 | Goats | 230 |
| 4.4 | Pigs | 230 |
| 4.5 | Chickens | 230 |
| 4.6 | Horses | 231 |
| 5 | <i>In vivo</i> and <i>in vitro</i> conservation programmes at regional level | 231 |
| 5.1 | Africa..... | 231 |
| 5.2 | Asia..... | 234 |
| 5.3 | Europe and the Caucasus | 235 |
| 5.4 | Latin America and the Caribbean | 237 |
| 5.5 | Near and Middle East | 238 |
| 5.6 | North America | 238 |
| 5.7 | Southwest Pacific..... | 239 |
| 6 | Opportunities for improving conservation programmes | 240 |
| 7 | Conclusions and priorities..... | 241 |
| 8 | References..... | 242 |

SECTION D: REPRODUCTIVE AND MOLECULAR BIOTECHNOLOGY

| | | |
|-----|---------------------------------------|-----|
| 1 | Introduction..... | 243 |
| 2 | Global overview..... | 243 |
| 2.1 | Africa..... | 244 |
| 2.2 | Asia..... | 245 |
| 2.3 | Europe and the Caucasus | 246 |
| 2.4 | Latin America and the Caribbean | 248 |
| 2.5 | Near and Middle East | 249 |
| 2.6 | North America | 249 |
| 2.7 | Southwest Pacific..... | 249 |
| 3 | Conclusions..... | 250 |
| 4 | References..... | 250 |

SECTION E: LEGISLATION AND REGULATION

| | | |
|-----|--|-----|
| 1 | International legal framework – major instruments | 251 |
| 1.1 | Introduction..... | 251 |
| 1.2 | Legal framework for the management of biodiversity..... | 251 |
| 1.3 | Access and benefit sharing | 253 |
| 1.4 | Legal framework for international trade | 254 |
| 1.5 | Intellectual property rights..... | 255 |
| 1.6 | Legal framework for biosecurity | 256 |
| 1.7 | Conclusions..... | 258 |
| 1.8 | References..... | 259 |
| 2 | Emerging legal issues | 259 |
| 2.1 | Patenting | 259 |
| 2.2 | Livestock Keepers’ Rights..... | 264 |
| 3 | Regulatory frameworks at regional level | 265 |
| 3.1 | Introduction..... | 265 |
| 3.2 | European Union legislation: an example of a comprehensive regional legal framework | 266 |
| 3.3 | Conclusions..... | 274 |
| 3.4 | Legislation cited..... | 274 |
| 4 | National legislation and policy | 280 |
| 4.1 | Introduction..... | 280 |
| 4.2 | Methods | 280 |
| 4.3 | Implementation of AnGR legislation and programmes | 281 |

| | |
|-----------------------------------|-----|
| 4.4 Country Reports analysis..... | 281 |
| 4.5 Conclusions..... | 303 |
| 4.6 References..... | 304 |

Part 4

State of the art in the management of animal genetic resources

Introduction

SECTION A: BASIC CONCEPTS

| | |
|---|-----|
| 1 Animal genetic resources and breeds..... | 306 |
| 2 Management of animal genetic resources..... | 307 |
| 3 Risk status classification..... | 309 |
| 4 References..... | 311 |

SECTION B: METHODS FOR CHARACTERIZATION

| | |
|--|-----|
| 1 Introduction..... | 313 |
| 2 Characterization – as the basis for decision-making..... | 313 |
| 3 Tools for characterization..... | 316 |
| 3.1 Surveying..... | 316 |
| 3.2 Monitoring..... | 319 |
| 3.3 Molecular genetic characterization..... | 320 |
| 3.4 Information systems..... | 320 |
| 4 Conclusions..... | 323 |
| 5 References..... | 323 |

SECTION C: MOLECULAR MARKERS – A TOOL FOR EXPLORING GENETIC DIVERSITY

| | |
|---|-----|
| 1 Introduction..... | 325 |
| 2 The roles of molecular technologies in characterization..... | 326 |
| 3 Overview of molecular techniques..... | 327 |
| 3.1 Techniques using DNA markers to assess genetic diversity..... | 329 |
| 3.2 Using markers to estimate effective population size..... | 331 |
| 3.3 Molecular tools for targeting functional variation..... | 331 |
| 4 The role of bioinformatics..... | 336 |
| 5 Conclusions..... | 336 |
| 6 References..... | 339 |

SECTION D: GENETIC IMPROVEMENT METHODS TO SUPPORT SUSTAINABLE UTILIZATION

| | |
|--|-----|
| 1 Introduction..... | 344 |
| 2 The context for genetic improvement..... | 344 |
| 2.1 Changing demand..... | 344 |
| 2.2 Diverse production environments..... | 344 |
| 2.3 Increasing recognition of the importance of genetic diversity..... | 345 |
| 2.4 Scientific and technological advances..... | 345 |
| 2.5 Economic considerations..... | 350 |

| | | |
|-----|---|-----|
| 3 | Elements of a breeding programme | 350 |
| 3.1 | Breeding goals | 352 |
| 3.2 | Selection criteria | 353 |
| 3.3 | Design of the breeding schemes | 354 |
| 3.4 | Data recording and management | 355 |
| 3.5 | Genetic evaluation | 356 |
| 3.6 | Selection and mating | 357 |
| 3.7 | Progress monitoring | 357 |
| 3.8 | Dissemination of genetic progress | 357 |
| 4 | Breeding programmes in high-input systems | 358 |
| 4.1 | Dairy and beef cattle breeding | 358 |
| 4.2 | Sheep and goat breeding | 363 |
| 4.3 | Pig and poultry breeding | 364 |
| 5 | Breeding programmes in low-input systems | 367 |
| 5.1 | Description of low-input systems | 367 |
| 5.2 | Breeding strategies | 369 |
| 6 | Breeding in the context of conservation | 380 |
| 6.1 | Methods for monitoring small populations | 380 |
| 6.2 | Conservation through breeding | 381 |
| 7 | Conclusions | 382 |
| 8 | References | 383 |

SECTION E: METHODS FOR ECONOMIC VALUATION

| | | |
|-----|--|-----|
| 1 | Introduction | 388 |
| 2 | Development of methodologies for economic analysis | 389 |
| 3 | Application of economic methodologies in AnGR management | 392 |
| 3.1 | Value of livestock genetic resources to farmers | 392 |
| 3.2 | Costs and benefits of conservation | 393 |
| 3.3 | Targeting of farmers for participation in <i>in situ</i> breed conservation programmes | 394 |
| 3.4 | Priority setting in livestock conservation programmes | 395 |
| 3.5 | Priority setting in livestock-breeding strategies | 396 |
| 3.6 | General policy analysis development | 396 |
| 4 | Implications for policies and future research | 397 |
| 5 | References | 398 |

SECTION F: METHODS FOR CONSERVATION

| | | |
|-----|--|-----|
| 1 | Introduction | 400 |
| 2 | Arguments for conservation | 401 |
| 2.1 | Arguments related to the past | 401 |
| 2.2 | Safeguarding for future needs | 402 |
| 2.3 | Arguments related to the present situation | 403 |
| 3 | The unit of conservation | 405 |
| 4 | Conservation of plant versus animal genetic resources | 405 |
| 5 | Information for conservation decisions | 408 |
| 6 | <i>In vivo</i> conservation | 410 |
| 6.1 | Background | 410 |
| 6.2 | Genetic management of populations | 411 |
| 6.3 | Self-sustaining strategies for local breeds | 412 |
| 6.4 | <i>In situ</i> versus <i>ex situ</i> approaches to <i>in vivo</i> conservation | 415 |
| 7 | Current status and future prospects for cryoconservation | 418 |
| 7.1 | Gametes | 418 |
| 7.2 | Embryos | 419 |
| 7.3 | Cryoconservation of somatic cells and somatic cell cloning | 420 |
| 7.4 | Choice of genetic material | 421 |
| 7.5 | Security in genebanks | 422 |

| | | |
|-----|--|-----|
| 8 | Resource allocation strategies in conservation | 422 |
| 8.1 | Methods for setting priorities..... | 422 |
| 8.2 | Optimization strategies for planning conservation programmes | 423 |
| 9 | Conclusions..... | 426 |
| 10 | References..... | 429 |

SECTION G: RESEARCH PRIORITIES

| | | |
|---|---|-----|
| 1 | Information for effective utilization and conservation..... | 432 |
| 2 | Information systems..... | 432 |
| 3 | Molecular methods..... | 432 |
| 4 | Characterization | 433 |
| 5 | Genetic improvement methods | 433 |
| 6 | Conservation methods..... | 434 |
| 7 | Decision-support tools for conservation | 434 |
| 8 | Economic analysis | 435 |
| 9 | Access and benefit sharing..... | 435 |

Part 5

Needs and challenges in animal genetic resources management

Introduction

| | | |
|-----|--|-----|
| 1 | Knowledge of animal genetic diversity: concepts, methods and technologies | 438 |
| 2 | Capacity in animal genetic resources management | 441 |
| 2.1 | Capacity in characterization, sustainable use and conservation of AnGR..... | 441 |
| 2.2 | Capacity in institutions and policy-making | 443 |
| 3 | Major challenges for livestock development and animal genetic resources management.... | 445 |
| 4 | Accepting global responsibility | 447 |

| | | |
|--|---------------------------------|-----|
| | Abbreviations and Acronyms..... | 449 |
|--|---------------------------------|-----|

CD-ROM

1. Country Reports
2. Reports from International Organizations
3. Subregional Synthesis Reports
4. Thematic Studies
5. List of breeds documented in the Global Databank for Animal Genetic Resources
6. List of breeds at risk
7. List of authors, reviewers and their affiliations

BOXES

| | |
|--|-----|
| 1 The domestication process..... | 12 |
| 2 Molecular characterization – a tool to understand livestock origin and diversity | 14 |
| 3 The history of African pastoralism | 19 |
| 4 What is new compared to the World Watch List for Domestic Animal Diversity? | 27 |
| 5 Glossary: populations – breeds –regions | 28 |
| 6 Glossary: risk status classification..... | 42 |
| 7 Gene flows resulting from colonization | 55 |
| 8 Nelore cattle..... | 63 |
| 9 Continuous repackaging of genes –Dorper sheep..... | 67 |
| 10 Hybrid pigs | 71 |
| 11 The chicken breeding industry..... | 73 |
| 12 Linguistic links between cattle and wealth | 92 |
| 13 The history of Hungarian Grey cattle – changing uses over time..... | 97 |
| 14 Genetic resistance to African swine fever | 109 |
| 15 Mongolian reindeer under threat | 116 |
| 16 Policy distortions influencing the erosion of pig genetic resources in Viet Nam..... | 117 |
| 17 Which dairy breeds for tropical smallholders?..... | 119 |
| 18 War and rehabilitation in Bosnia and Herzegovina | 124 |
| 19 The concept of productivity..... | 136 |
| 20 Sustainable utilization of the Iberian pig in Spain – a success story | 140 |
| 21 Overcoming constraints to the development of small-scale market oriented dairying..... | 142 |
| 22 Facts and trends in the emerging world food economy | 147 |
| 23 Suggestions for strengthening national structures | 190 |
| 24 Research and breed development in Africa | 211 |
| 25 Sheep breeding in Tunisia | 212 |
| 26 Buffalo breeding in India..... | 213 |
| 27 Goat breeding in the Republic of Korea | 213 |
| 28 Duck breeding in Viet Nam..... | 214 |
| 29 Pig breeding in Hungary | 215 |
| 30 Horse breeding – tradition and new requirements | 215 |
| 31 Beef cattle breeding in Brazil | 216 |
| 32 Breeding llamas in Argentina | 217 |
| 33 Influence of market forces on livestock breeding in the United States of America | 218 |
| 34 Sheep breeding in Australia..... | 218 |
| 35 Mali – role of the government | 227 |
| 36 Ethiopia – <i>in situ</i> conservation | 232 |
| 37 Morocco’s Plan Moutonnier – designated breeding areas to sustain local sheep breeds | 233 |
| 38 Conservation strategies in China | 235 |
| 39 Denmark – opportunities for <i>in vivo</i> conservation..... | 236 |
| 40 Brazil – implementation of a genebank | 238 |
| 41 United States of America – priorities in conservation programmes | 239 |
| 42 Australia – involvement of diverse stakeholders..... | 240 |
| 43 Impact of international zoosanitary regulations on animal genetic resources management – the example of FMD..... | 257 |
| 44 The first patented animal | 261 |
| 45 The African Union Model Law | 266 |
| 46 Malawi’s Environmental Management Act..... | 282 |
| 47 Turkey’s Law on Pastures No. 4342 (1998)..... | 284 |
| 48 Slovenia’s Livestock Breeding Act (2002)..... | 284 |
| 49 Mozambique’s Livestock Development Policy and Strategies | 285 |
| 50 Slovenia’s regulation on Conservation of Farm Animal Genetic Resources..... | 287 |
| 51 Uganda’s National Animal Genetic Resources Programme | 288 |
| 52 Ukraine’s Law on Animal Breeding..... | 289 |

BOXES - continued

| | |
|--|-----|
| 53 Turkey's Regulation on Protection of Animal Genetic Resources (2002) | 289 |
| 54 Lesotho's Importation and Exportation of Livestock and Livestock Products Proclamation | 291 |
| 55 Malaysia's Animals Ordinance..... | 291 |
| 56 Hungary's Decree No 39 | 292 |
| 57 Botswana's Stock Diseases (Semen) Regulations | 292 |
| 58 Barbados's incentive programme | 293 |
| 59 Uganda's Animal Breeding Act (2001)..... | 294 |
| 60 Guatemala – decentralization of the registration of pure-bred animals | 295 |
| 61 Mongolia's White Revolution Programme..... | 297 |
| 62 The Philippine's White Revolution | 297 |
| 63 Russian Federation – Veterinary and Sanitary Requirements No. 13-8-01/1-8 (1999)..... | 299 |
| 64 India – rules for transportation | 300 |
| 65 West Africa – pastoralist crossing borders | 300 |
| 66 The Islamic Republic of Iran's Act of National Veterinary System (1971) | 302 |
| 67 Definition of breed adopted by FAO | 306 |
| 68 Production environment descriptors for animal genetic resources | 316 |
| 69 Information systems at global level..... | 322 |
| 70 DNA, RNA and protein | 325 |
| 71 The new “-omics” scientific disciplines..... | 326 |
| 72 Recent developments in molecular biology..... | 326 |
| 73 Extraction and multiplication of DNA and RNA | 327 |
| 74 Commonly used DNA markers | 328 |
| 75 Sampling genetic material | 328 |
| 76 QTL mapping | 332 |
| 77 The population genomics approach..... | 333 |
| 78 Databases of biological molecules..... | 336 |
| 79 Glossary: molecular markers | 338 |
| 80 The changing body size of beef cattle in United States of America..... | 354 |
| 81 Calving problems in Belgian White Blue cattle | 358 |
| 82 Cross-breeding to address inbreeding-related problems in Holstein cattle..... | 359 |
| 83 Norwegian Red Cattle - selection for functional traits | 361 |
| 84 Community-based sheep management in the Peruvian Andes | 368 |
| 85 Genetic improvement of an indigenous livestock breed – Boran cattle in Kenya..... | 369 |
| 86 A llama breeding programme in Ayopaya, Bolivia..... | 370 |
| 87 Pastoralists' breeding criteria – insights from a community member | 372 |
| 88 The Bororo Zebu of the WoDaaBe in Niger – selection for reliability in an extreme environment | 373 |
| 89 Community-driven breeding programmes for local pig breeds in north Viet Nam..... | 375 |
| 90 The cost of heterosis | 378 |
| 91 Nigeria's Village Poultry Improvement Scheme..... | 378 |
| 92 A community-based and participatory dairy goat cross-breeding programme in a low-input smallholder system in the eastern highlands of Kenya..... | 379 |
| 93 Economic values..... | 389 |
| 94 Glossary: conservation | 400 |
| 95 Red Maasai sheep – accelerating threats | 401 |
| 96 Lleyn sheep of Wales – revival in fortunes in tune with modern demands..... | 403 |
| 97 Decision-making in conservation and utilization – use of genetic diversity data..... | 409 |
| 98 Spatial analysis of genetic diversity | 410 |
| 99 <i>In situ</i> conservation of the Norwegian Feral Sheep..... | 413 |
| 100 Examples of incentive payment schemes at the national level..... | 414 |
| 101 An index of economic development potential for targeting <i>in situ</i> conservation investments | 415 |
| 102 Community-based <i>in situ</i> conservation programme – a case from Patagonia | 416 |
| 103 Changes in production systems leading to replacement of local buffaloes – a case from Nepal | 417 |

BOXES - continued

| | |
|--|-----|
| 104 Revival of the native Red and White Friesian cattle in the Netherlands | 421 |
| 105 Revival of the Enderby cattle in New Zealand | 421 |
| 106 Glossary: objective decision aids..... | 424 |
| 107 Optimum allocation of conservation funds – an example featuring African cattle breeds..... | 425 |
| 108 The Svalbard Global Seed Vault: an international seed depository in the Arctic..... | 428 |

TABLES

| | |
|---|-----|
| 1 Regional overview of Country Reports | 2 |
| 2 Country Reports received | 3 |
| 3 Reports from international organisations..... | 4 |
| 4 Origin and domestication of livestock species | 12 |
| 5 Status of information recorded in the Global Databank for Animal Genetic Resources | 28 |
| 6 Distribution of mammalian species by region | 30 |
| 7 Distribution of avian species by region | 31 |
| 8 Proportion of the world's population size (2005) and number of local and regional transboundary breeds (January 2006) of the major livestock species by region..... | 38 |
| 9 Mammalian species – number of reported local breeds | 39 |
| 10 Avian species – number of reported local breeds | 39 |
| 11 Mammalian species – number of reported regional transboundary breeds | 40 |
| 12 Avian species – number of reported regional transboundary breeds | 40 |
| 13 Mammalian species – number of reported international transboundary breeds | 41 |
| 14 Avian Species – number of reported international transboundary breeds | 41 |
| 15 Number of extinct mammalian breeds..... | 47 |
| 16 Number of extinct avian breeds | 47 |
| 17 Years of extinction..... | 47 |
| 18 Reclassification of regional and international transboundary breeds from 1999 to 2006 | 48 |
| 19 Changes in risk status of transboundary breeds from 1999 to 2006..... | 49 |
| 20 Risk status of transboundary breeds reported after 1999..... | 49 |
| 21 Changes in risk status of local breeds (1999) reclassified as transboundary breeds (2006)..... | 50 |
| 22 Changes in risk status of local breeds from 1999 to 2006..... | 50 |
| 23 Risk status of local breeds reported after 1999..... | 51 |
| 24 Workforce employed in agriculture and land area per agricultural worker..... | 81 |
| 25 Number of animals by species/1000 human population..... | 84 |
| 26 Number of animals by species/1000 ha agricultural land..... | 84 |
| 27 Production of food of animal origin (kg/person/year)..... | 85 |
| 28 Production of fibres skins and hides (1000 mt/year) | 88 |
| 29 Trends in the use of animals for draught power | 89 |
| 30 Roles of livestock by livelihood strategy..... | 98 |
| 31 Selected studies indicating breed difference in resistance/tolerance to specific diseases..... | 102 |
| 32 Mammalian breeds reported to DAD-IS as having resistance/tolerance to specific diseases or parasites | 104 |
| 33 Breeds reported to DAD-IS as showing resistance/tolerance to trypanosomiasis..... | 104 |
| 34 Breeds reported to DAD-IS as showing resistance/tolerance to tick-burden..... | 105 |
| 35 Breeds reported to DAD-IS as showing resistance/tolerance to tick-borne diseases | 105 |
| 36 Breeds reported to DAD-IS as showing resistance/tolerance to internal parasites/worms..... | 106 |
| 37 Breeds reported to DAD-IS as showing resistance/tolerance to foot rot..... | 107 |
| 38 Cattle breeds reported to DAD-IS as showing resistance/tolerance to leukosis..... | 107 |
| 39 Breeds reported to DAD-IS as showing resistance/tolerance to avian diseases | 108 |
| 40 Impact of recent disease epidemics | 126 |
| 41 Examples of breeds affected by the FMD outbreak in the United Kingdom in 2001..... | 127 |

TABLES - continued

| | | |
|----|--|-----|
| 42 | Projected trends in meat consumption from 2000 to 2050 | 138 |
| 43 | Projected trends in milk consumption from 2000 to 2050..... | 138 |
| 44 | Standards in the livestock market and implications for small-scale producers | 143 |
| 45 | Trends in production of meat and milk in developing and developed countries | 150 |
| 46 | Livestock numbers and production of the world's livestock production systems – averages for 2001-2003 | 151 |
| 47 | The developing countries with the highest meat and milk production (2004) | 151 |
| 48 | Agriculture's contribution to global greenhouse gas and other emissions | 156 |
| 49 | Estimated number of pastoralists in different geographic regions..... | 160 |
| 50 | Land with rainfed crop production potential | 164 |
| 51 | Main crop–animal interactions in crop-based livestock systems..... | 165 |
| 52 | Shares of irrigated production in total crop production of developing countries | 168 |
| 53 | Sources of information (Country Report sections) for the national level assessments..... | 178 |
| 54 | Institutional assessment – infrastructure and capacities and participation | 181 |
| 55 | Institutional assessment – research and knowledge..... | 182 |
| 56 | Institutional assessment – state of policy development | 183 |
| 57 | Organizations and networks that play or may play a role in animal genetic resources management at regional/subregional level..... | 186 |
| 58 | Institutional assessment at country level | 195 |
| 59 | List of international organizations and contributed reports on their activities | 201 |
| 60 | Countries prioritizing breeding activities (by species) | 203 |
| 61 | Structured breeding activities for the main livestock species | 204 |
| 62 | Strategies and tools used in cattle breeding | 204 |
| 63 | Training, research and farmers' organizations in current policies..... | 207 |
| 64 | Stakeholder involvement in the development of animal genetic resources | 208 |
| 65 | Number of countries reporting the use of artificial insemination | 209 |
| 66 | Importance of species and locally adapted versus exotic breeds in current policies | 210 |
| 67 | List of subsample countries that provided information in predefined tables | 220 |
| 68 | Strategies and tools used in sheep breeding..... | 221 |
| 69 | Strategies and tools used in goat breeding | 221 |
| 70 | Strategies and tools used in pig breeding..... | 222 |
| 71 | Strategies and tools used in chicken breeding | 222 |
| 72 | Countries reporting structured breeding activities in minor animal species..... | 223 |
| 73 | Stakeholder involvement in structured cattle breeding activities | 223 |
| 74 | Stakeholder involvement in structured sheep breeding activities..... | 223 |
| 75 | Stakeholder involvement in structured goat breeding activities | 224 |
| 76 | Stakeholder involvement in structured pig breeding activities..... | 224 |
| 77 | Number of countries with conservation programmes..... | 226 |
| 78 | Conservation activities at the global level | 229 |
| 79 | Conservation activities in Africa | 232 |
| 80 | Conservation activities in Asia | 234 |
| 81 | Conservation activities in Europe and the Caucasus | 236 |
| 82 | Conservation activities in Latin America and the Caribbean | 237 |
| 83 | Conservation activities in the Near and Middle East..... | 238 |
| 84 | Conservation activities in North America | 239 |
| 85 | Conservation activities in the Southwest Pacific | 239 |
| 86 | Use of biotechnologies by region | 243 |
| 87 | Use of biotechnologies by species | 244 |
| 88 | Instruments for sustaining livestock production systems | 285 |
| 89 | Instruments in the field of conservation | 288 |
| 90 | Instruments in the field of genetic improvement | 290 |
| 91 | Instruments related to institutions active in genetic improvement | 295 |
| 92 | Instruments in the field of standard setting..... | 296 |

TABLES - continued

| | |
|--|-----|
| 93 Instruments for promoting trade in livestock products..... | 298 |
| 94 Instruments regulating import and export of genetic material..... | 298 |
| 95 Instruments regulating livestock movements and import and export of live animals and livestock products..... | 301 |
| 96 Regulations in the field of animal health..... | 301 |
| 97 Information recorded for mammalian species in the Global Databank for Animal Genetic Resources..... | 317 |
| 98 Information recorded for avian species in the Global Databank for Animal Genetic Resources ... | 318 |
| 99 Breeding objectives in ruminants | 360 |
| 100 Breeding objectives in pigs..... | 364 |
| 101 Breeding objectives in poultry..... | 365 |
| 102 Overview of valuation methodologies..... | 391 |
| 103 Conservation benefits and costs under a range of valuation methodologies – the case of the Box Keken pig (Yucatan, Mexico)..... | 393 |
| 104 Comparisons of biological, operational, and institutional factors influencing plant and animal genetic resources conservation..... | 407 |
| 105 Current status of cryoconservation techniques by species..... | 420 |

FIGURES

| | |
|--|----|
| 1 Assignment of countries to regions and subregions in this report..... | 7 |
| 2 Archaeological map of agricultural homelands and spread of Neolithic/Formative cultures, with approximate radiocarbon dates..... | 11 |
| 3 Major centres of livestock domestication – based on archaeological and molecular genetic information..... | 15 |
| 4 Origin and migration routes of domestic cattle in Africa..... | 20 |
| 5 Proportion of national breed populations for which population figures have been reported..... | 29 |
| 6 Regional distribution of major livestock species in 2005..... | 32 |
| 7 Distribution of the world’s mammalian breeds by species..... | 33 |
| 8 Distribution of the world’s avian breeds by species..... | 34 |
| 9 Number of local and transboundary breeds at global level..... | 36 |
| 10 Number of local and transboundary breeds at regional level..... | 37 |
| 11 Proportion of the world’s breeds by risk status category..... | 42 |
| 12 Risk status of the world’s mammalian breeds in January 2006: absolute (table) and percentage (chart) figures by species..... | 43 |
| 13 Risk status of the world’s avian breeds in January 2006: absolute (table) and percentage (chart) figures by species..... | 44 |
| 14 Risk status of the world’s mammalian breeds in January 2006 absolute (table) and percentage (chart) figures by region..... | 45 |
| 15 Risk status of the world’s avian breeds in January 2006 absolute (table) and percentage (chart) figures by region..... | 46 |
| 16 Local, regional and international breeds in 1999 and 2006..... | 48 |
| 17 Changes in risk status of transboundary breeds from 1999 to 2006..... | 49 |
| 18 Changes in risk status of local breeds from 1999 to 2006..... | 50 |
| 19 Distribution of transboundary breeds..... | 58 |
| 20 Distribution of Holstein-Friesian cattle..... | 60 |
| 21 Distribution of Charolais cattle..... | 60 |
| 22 Distribution of transboundary cattle breeds with Latin American, African or South Asian origin.. | 62 |
| 23 Distribution of transboundary sheep breeds..... | 65 |
| 24 Gene flow of improved Awassi and Assaf sheep from Israel..... | 68 |
| 25 Distribution of Saanen goats..... | 69 |
| 26 Distribution of Boer goats..... | 69 |

FIGURES - continued

| | |
|---|-----|
| 27 Distribution of Large White pigs..... | 71 |
| 28 Contribution of agriculture and livestock to total GDP by region..... | 80 |
| 29 Contribution of livestock to agricultural GDP..... | 80 |
| 30 Percentage of permanent pasture in total agricultural land..... | 81 |
| 31 Livestock density in relation to human population..... | 82 |
| 32 Livestock density per square kilometre of agricultural land..... | 83 |
| 33 Net exports – meat..... | 86 |
| 34 Net exports – milk equivalent..... | 86 |
| 35 Net exports – eggs..... | 87 |
| 36 Number of disasters by type and year..... | 120 |
| 37 Changes in the meat consumption of developing and developed countries..... | 137 |
| 38 Distribution of livestock production systems..... | 149 |
| 39 Meat production from ruminants versus monogastrics in developing and developed countries.... | 150 |
| 40 Changes in the quantity of cereals used as feed (1992-1994 and 2020)..... | 152 |
| 41 Changes in the distribution of the size of pig farms in Brazil (1985 to 1996)..... | 153 |
| 42 Estimated contribution of livestock to total phosphate supply on agricultural land in areas presenting a phosphate mass balance of more than 10 kg per hectare in selected Asian countries (1998 to 2000)..... | 155 |
| 43 State of institutions – regional comparison..... | 184 |
| 44 State of institutions – subregional comparison within Africa..... | 193 |
| 45 State of institutions – subregional comparison within Asia..... | 193 |
| 46 State of institutions – subregional comparisons within Latin America and the Caribbean..... | 194 |
| 47 Information required to design management strategies..... | 314 |
| 48 Structure of the poultry breeding industry..... | 351 |

Acknowledgements

This report could not have been prepared without the assistance of the many individuals who generously contributed their time, energy and expertise. FAO would like to take this opportunity to acknowledge these contributions.

The core of the information for the State of the World's Animal Genetic Resources for Food and Agriculture was provided by the 169 governments that submitted Country Reports; the first and most important acknowledgement therefore goes to these governments and to all those individuals in each country who contributed to these reports, in particular the National Coordinators for the Management of Animal Genetic Resources and the National Consultative Committees. The development of training materials the conduct of training workshops, the preparation and analysis of the Country Reports, the follow-up workshops and the various international, regional and national consultations were facilitated by the following team: Daniel Benitez-Ojeda, Harvey D. Blackburn, Arthur da Silva Mariante, Mamadou Diop, M'Naouer Djemali, Anton Ellenbroek, Erling Fimland, Salah Galal, Andreas Georgoudis, Peter Gulliver, Sipke-Joost Hiemstra, Yusup Ibragimov, Jarmo Juga, Ali Kamali, Sergeij Kharitonov, Richard Laing, Birgitta Malmfors, Moketal Joel Mamabolo, Peter Manuelli, Elzbieta Martyniuk, Carlos Mezzadra, Rafael Morales, Ruben Mosi, Siboniso Moyo, David R. Notter, Rafael Núñez-Domínguez, Dominique Planchenault, Geoffrey Pollott, Adrien Raymond, Peter Saville, Hermann Schulte-Coerne, Louise Setshwaelo, Paul Souvenir Zafindrajaona, David Steane, Arunas Svitojus, Lutfi Tahtacioglu, Vijay Taneja, Frank Vigh-Larsen, Hans-Gerhard Wagner, Mateusz Wieczorek, Hongjie Yang and Milan Zjalic. An FAO-WAAP (World Association for Animal Production) agreement assisted a large number of developing countries in report preparation. This important contribution to the reporting process could not have been accomplished without the coordination and hard work of Jean Boyazoglu and his colleagues at WAAP.

The State of the World's Animal Genetic Resources for Food and Agriculture was prepared and coordinated by Barbara Rischkowsky with the assistance of Dafydd Pilling. The preparation was facilitated and supported by the Service Chief of Animal Production, Irene Hoffmann, and current and former officers of the Animal Genetic Resources Group: Badi Besbes, David Boerma, Ricardo Cardellino, Mitsuhiro Inamura, Pal Hajas, Keith Hammond, Manuel Luque Cuesta, Beate Scherf, Kim-Anh Tempelman and Olaf Thieme. Administrative and secretarial support was provided by Carmen Hopmans and Kafia Fassi-Fihri. The finalization, layout and printing was supervised by Beate Scherf.

The sections of the report were prepared and reviewed by individual experts or expert teams who will be acknowledged below by section. This form of acknowledgement intends to thank the authors for contributing their time, expertise and energy, both in the process of writing and in reviewing and editing. It will also allow the interested public to identify resource persons for specific topics. This is facilitated by an alphabetical list of authors and reviewers on the attached CD-ROM.

Case studies were prepared by: Camillus O. Ahuya, Tony Bennett, Ismail Boujenane, Achilles Costales, Erling Fimland, Cary Fowler, John Gibson, Alexander Kahi, John M. King, Saverio Krätli, Maria Rosa Lanari, Ute Lemke, Thomas Loquang, Manuel Luque Cuesta, Paolo Ajmone Marsan, André Markemann, Marnie Mellencamp, Okeyo Mwai, Kor Oldenbroek, John Bryn Owen, Vincente Rodríguez-Estévez, Hans Schiere, Marianna Siegmund-Schulze, Henner Simianer, David Steane, Angelika Stemmer, Kim-Ahn Tempelman, Hongjie Yang and Anne Valle Zárate.

Additional material for the preparation of text boxes was provided by Brian Donahoe, Morgan Keay, Juhani Mäki-Hokkonen, Kirk Olson and Dan Plumley.

Data entry into the Global Databank was carried out by Ellen Geerlings and Lucy Wigboldus. Analysis of the Global Databank was performed by Mateusz Wieczorek, Alberto Montironi, Justyna Dybowska, Kerstin Zander and Beate Scherf. All maps (if not otherwise stated) were prepared by Thierry Lassueur with support from Tim Robinson and Pius Chilonda.

Thematic studies were coordinated by Beate Scherf and Irene Hoffmann and prepared by: Erika Alandia Robles, Simon Anderson, Kassahun Awgichew, Roswitha Baumung, P.N. Bhat, Stephen

Bishop, Kwame Boa-Amponsem, Ricardo Cardellino, Arthur da Silva Mariante, Mart de Jong, Adam G. Drucker, Christian Gall, Michael Goe, Elisha Gootwine, Douglas Gray, Claire Heffernan, Sipke-Joost Hiemstra, Sabine Homann, Christian G. Hülsebusch, Le Thi Thanh Huyen, Antonella Ingrassia, Ute Lemke, Nils Louwaars, Daniele Manzella, Jacobus Hendrik Maritz, Elzbieta Martyniuk, Marcus Mergenthaler, Klaus Meyn, Giulietta Minozzi, H. Momm, Katinka Musavaya, David R. Notter, Kor Oldenbroek, Marta Pardo Leal, Roswitha Roessler, Cornelia Schäfer, Kim-Anh Tempelman, Morton W. Tvedt and Anne Valle Zárate.

Subregional factsheets presented on the attached CD-ROM were prepared by Marieke Reuver, Marion De Vries, Harvey Blackburn, Campbell Davidson, Salah Galal and Ellen Geerlings. Reports on subregional priorities were compiled by Milan Zjalic.

Listing every person by name is not easy, and carries with it the risk that someone may be overlooked. Apologies are conveyed to anyone who may have provided assistance whose name has been inadvertently omitted. Any errors or omissions in this work are the responsibility of those who compiled it. None of the contributors should be considered responsible for such defects. In this regard, FAO appreciates any corrections.

| Part / Section | Authors | Reviewers |
|---|--|--|
| PART 1: The state of agricultural biodiversity in the livestock sector | | |
| Origin and history of livestock diversity | Olivier Hanotte | Ilse Koehler-Rollefson |
| Status of animal genetic resources | Barbara Rischkowsky, Dafydd Pilling, Beate Scherf | Mateusz Wieczorek |
| Flows of animal genetic resources | Evelyn Mathias, Ilse Koehler-Rollefson, Paul Mundy | Beate Scherf, Annette von Lossau |
| Uses and values of animal genetic resources | Dafydd Pilling, Barbara Rischkowsky with Manuel Luque Cuesta | |
| Animal genetic resources and disease resistance | Dafydd Pilling, Barbara Rischkowsky | Steve Bishop, Jan Slingenbergh |
| Threats to livestock genetic diversity | Dafydd Pilling, Claire Heffernan, Michael Goe | Anni McLeod, Simon Mack, Jan Slingenbergh |
| PART 2: Livestock sector trends | | |
| | Pierre Gerber, Dafydd Pilling, Barbara Rischkowsky | Hans Schiere |
| PART 3: The state of capacities in animal genetic resource management | | |
| Institutions and stakeholders | Maria Brockhaus | Irene Hoffmann, Beate Scherf., Ricardo Cardellino, Jean Boyazoglu, Annette von Lossau, Ilse Koehler-Rollefson |
| Structured breeding programmes | Olaf Thieme | Juhani Mäki-Hokkonen |
| Conservation programmes | Kor Oldenbroek with Milan Zjalic | |
| Reproductive and molecular biotechnology | Dafydd Pilling with Milan Zjalic | Salah Galal |

| Part / Section | Authors | Reviewers |
|--|---|---|
| Legislation and regulation | | |
| International legal framework - major instruments | Dafydd Pilling drawing on FAO legislative study No 89 | Clive Stannard, Niels Louwaars |
| Patenting – an emerging legal issue | Dafydd Pilling with Claudio Chiarolla | Niels Louwaars, Morten Walløe Tvedt |
| Regulatory frameworks at regional level | Dafydd Pilling drawing on FAO legislative study No 89 | Olivier Diana, Sipke Joost Hiemstra, Danielle Manzella, Hermann Schulte-Coerne, Kai-Uwe Sprenger |
| National legislation and policy | Susette Biber-Klemm with Cari Rincker | |
| PART 4: The state of the art in animal genetic resources management | | |
| Basic concepts | Barbara Rischkowsky, Dafydd Pilling | Beate Scherf, Ricardo Cardellino |
| Methods for characterization | Workneh Ayalew, Beate Scherf, Barbara Rischkowsky | Ed Rege |
| Molecular markers – a tool for exploring genetic diversity | Paolo Ajmone Marsan with Kor Oldenbroek | Han Jianlin Paul Boettcher |
| Genetic improvement methods to support sustainable utilization | Badi Besbes, Victor Olori, Jim Sanders | Beate Scherf, Ricardo Cardellino, Keith Hammond |
| Methods for economic valuation | Adam Drucker | Gianni Cicia |
| Methods for conservation | Jean-Pierre Brillard, Gustavo Gandini John Gibson David Notter Dafydd Pilling Barbara Rischkowsky Henner Simianer | Workneh Ayalew, Harvey Blackburn, Jean Boyazoglu, Ricardo Cardellino, Coralie Danchin, Sipke Joost Hiemstra, Elzbieta Martyniuk, Roger Pullin, Beate Scherf, Michele Tixier-Boichard |
| Research priorities | all authors | all reviewers |
| PART 5: Needs and challenges in animal genetic resources management | | |
| | Barbara Rischkowsky Irene Hoffmann | Animal Genetic Resources Group and CGRFA Secretariat |

Preface

Agricultural biodiversity is the product of thousands of years of activity during which humans have sought to meet their needs in a wide range of climatic and ecological conditions. Well-adapted livestock have been an essential element of agricultural production systems, particularly important in harsh environments where crop farming is difficult or impossible.

The capacity of agro-ecosystems to maintain and increase their productivity, and to adapt to changing circumstances, remains vital to the food security of the world's population. For livestock keepers, animal genetic diversity is a resource to be drawn upon to select stocks and develop new breeds. More broadly, genetically diverse livestock populations provide society with a greater range of options to meet future challenges.

The Food and Agriculture Organization of the United Nations (FAO) has, since the early 1960s, provided assistance to countries to characterize their animal genetic resources for food and agriculture (AnGR) and develop conservation strategies. In 1990, FAO's Council recommended the development of a comprehensive programme for the sustainable management of AnGR at the global level. A meeting of experts in 1992, and subsequent sessions of FAO's governing bodies, provided impetus to the development of the Global Strategy for the Management of Farm Animal Genetic Resources, which was initiated in 1993. The Animal Production and Health Division of FAO was designated as the Global Focal Point for Animal Genetic Resources, and given the role of coordinating further development of the Global Strategy. In 1995, the Twenty-eighth Session of the FAO Conference took the decision to broaden the mandate of the Commission on Plant Genetic Resources to cover all aspects of agro-biodiversity of relevance to food and agriculture; (the Commission, originally established in 1983, was the first permanent intergovernmental forum dealing with agricultural genetic resources). Work on AnGR was the first element of this expanded role. The Commission was renamed the Commission on Genetic Resources for Food and Agriculture (CGRFA).

The international agenda

FAO's commitment to maintaining agricultural biodiversity is consistent with the increasing prominence of biodiversity on the agenda of the international community. This development is the result of a recognition that threats to biodiversity are increasing, whether measured in terms of the extinction of species, the destruction of ecosystems and habitats, or the loss of genetic diversity within the species utilized for agriculture. The 1992 United Nations Conference on Environment and Development (Earth Summit) held in Rio de Janeiro was an important landmark. The Convention on Biological Diversity (CBD), signed in Rio by 150 governments, committed the nations of the world to conserve their biodiversity, to ensure its sustainable use, and to provide for equitable sharing of the benefits arising from its use. By 2005, 188 countries had become Parties to the CBD. The Conference of Parties (COP) of the CBD (the governing body of the convention) has specifically recognized the special nature of agricultural biodiversity and the need for distinctive solutions in this field (see for example decision V/5, taken at the Fifth Meeting of the COP in 2000).

Agenda 21, adopted by 179 governments at the time at Rio Earth Summit in 1992, is a plan of action to be undertaken at global, national and local levels by governments, the organizations of the United Nations System and other stakeholders, to address all areas of human impact on the environment. The Agenda's Chapter 14, "Promoting Sustainable Agriculture and Rural Development", addressed the question of increasing food production and enhancing food security in a sustainable way. It included programme areas related to the conservation and development of AnGR.

The threat to food security posed by the loss of biodiversity was noted in the Plan of Action adopted at the 1996 World Food Summit held in Rome. Under Objective 3.2(f) of the Rome Declaration, the governments of the world affirmed that they would "promote the conservation and sustainable utilization of animal genetic resources."

Meeting the Millennium Development Goals, adopted by the United Nations in 2000, presents another great challenge to the international community. The adverse effects of biodiversity loss on progress

towards the achievement of these goals are cause for concern (UNDP, 2002)¹. As well as underpinning food security, biological diversity is the basis of many economic activities, and is vital to ecosystem functioning. Declining biodiversity tends to be associated with greater shocks and fluctuations in ecosystems, and it is the poor that are usually the most vulnerable to these effects. Many poor people are closely dependent on natural resources for their livelihoods, and frequently have a wealth of knowledge regarding the plants and animals with which they work. It has been suggested that this knowledge could be a source of income for the poor if it leads to the development and marketing of unique biological products. In reality, the extent to which the benefits of such developments actually accrue to the poor is often limited – highlighting the need not only for conservation of biodiversity, but for equitable frameworks for its utilization.

Within the international framework for the management and conservation of biological diversity, the work of CGRFA focuses on the particular features and problems associated with the management of agro-biodiversity, and the need for distinctive solutions for this field.

¹ UNDP. 2002. *Building on hidden opportunities to achieve the Millenium Development Goals. Poverty reduction through sustainable biodiversity use.* by I Koziell & C.I. McNeill. New York.

The reporting and preparatory process

In 1999, the CGRFA during its Eighth Regular Session agreed that FAO should coordinate the preparation of a country-driven report on the State of the World's Animal Genetic Resources for Food and Agriculture (SoW-AnGR)². In 2004, the Intergovernmental Technical Working Group on Animal Genetic Resources (ITWG-AnGR) – a subsidiary body established by the Commission to address issues relevant to the conservation and sustainable use of AnGR, reviewed progress in the preparation of the SoW-AnGR and endorsed a draft outline including a Report on Strategic Priorities for Action. The CGRFA subsequently endorsed this outline at its Tenth Regular Session. The agreed timetable for the preparation of the SoW-AnGR was that a draft would be available for review by the CGRFA at its Eleventh Regular Session in 2007, and that the report would be finalized at the first International Technical Conference on Animal Genetic Resources.

The first draft of the SoW-AnGR was made available to the Fourth Session of the ITWG-AnGR in December 2006. The Working Group requested more time to undertake a review of the report. It was agreed that members of the Working Group would provide comments on the draft to FAO by 31 January 2007, in order for FAO to undertake any necessary revisions prior to the presentation of the SoW-AnGR to the CGRFA at its Eleventh Regular Session. The Working Group further agreed that the review process should be open to all Member Countries of the Commission. FAO, therefore, invited all CGRFA Member Countries to submit comments within the agreed time frame.

Inputs to the State of the World's Animal Genetic Resources reporting process

The process of preparing the SoW-AnGR included a number of elements through which the information required was gathered and analysed.

Country Reports

In order to ensure the country-driven nature of the process, FAO in March 2001, invited 188 countries to submit Country Reports assessing their AnGR. Guidelines for the preparation of the Country Reports were produced, including a proposed structure. Regional training and follow-up workshops were conducted between July 2001 and November 2004. The overall objectives of the Country Reports were to analyse and report on the state of AnGR, on the status and trends of these resources, and on their current and potential contribution to food, agriculture and rural development; to assess the state of countries' capacity to manage AnGR, in order to determine priorities for future capacity building; and to identify national priorities for action in the field of conservation and sustainable utilization of AnGR, and related requirements for international cooperation. The first Country Reports were received in the second half of 2002, with the majority being submitted during 2003 and 2004. The latest Country Report was submitted in October 2005, bringing the total to 169 (Tables 1 and 2).

The fact that the submission of the Country Reports was spread over several years meant that as the process of preparing the SoW-AnGR progressed, more information became available for analysis. For this reason, it should be noted that the latest arrivals among the Country Reports could not be fully included in the process of analysis and report preparation. The length of the reporting process also means that the information presented in the SoW-AnGR does not necessarily reflect the very latest developments in the state of institutions and capacity at the national level.

² The term animal genetic resources (AnGR) as applied throughout the report is an abbreviation of animal genetic resources used for food and agriculture and excludes fish.

Table 1
Regional overview of Country Reports

| Region ³ | COUNTRY REPORTS | | |
|---------------------------------|-----------------|-----------|------------|
| | Submitted | | Total |
| | Final | Draft | |
| Africa | 45 | 4 | 49 |
| Asia | 22 | 4 | 26 |
| Europe and the Caucasus | 38 | 3 | 41 |
| Latin America and the Caribbean | 21 | 9 | 30 |
| Near and Middle East | 6 | 3 | 9 |
| North America | 2 | 0 | 2 |
| Southwest Pacific | 9 | 3 | 12 |
| Total | 143 | 26 | 169 |

Reports received by 31 December 2005

³ Note that these regions do not correspond to the usual FAO regions; see below for further explanation.

Table 2
Country Reports received

| Region | Countries |
|---|--|
| Africa (49) | Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Côte d'Ivoire, Democratic Republic of the Congo, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Swaziland, Togo, Tunisia, Uganda, United Republic of Tanzania, Zambia, Zimbabwe |
| Asia (26) | Afghanistan, Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Iran (Islamic Republic of), Japan, Kazakhstan, Kyrgyzstan, Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Sri Lanka, Tajikistan, Turkmenistan, Uzbekistan, Viet Nam |
| Europe and the Caucasus (41) | Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia and Montenegro ⁴ , Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Turkey, Ukraine, United Kingdom |
| Latin America and the Caribbean (30) | Antigua and Barbuda, Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Suriname, Trinidad and Tobago, Uruguay, Venezuela (Bolivarian Republic of) |
| Near and Middle East (9) | Egypt, Iraq, Jordan, Lebanon, Libyan Arab Jamahiriya, Oman, Sudan, Syrian Arab Republic, Yemen |
| North America (2) | Canada, United States of America |
| Southwest Pacific (12) | Australia, Cook Islands, Fiji, Kiribati, Niue, Northern Mariana Islands, Palau, Samoa, Solomon Islands, Tonga, Tuvalu, Vanuatu |

Reports received by 31 December 2005

⁴ Since June 2006 Serbia and Montenegro have become independent states. However, in the SoW-AnGR they are still treated as one country as in Country Report submitted to FAO.

Reports from international organizations

Following a request from the ITWG, in August 2004, FAO invited 77 international organizations to submit a report of their work in the field of AnGR as a contribution to the SoW-AnGR. These reports were to cover activities such as research, extension, education, training, public awareness, communications and advocacy, and also to include a description of the organization and information on institutional capacities which support activities in AnGR. Specific subjects to be described included (if applicable) inventory and characterization, sustainable use and development, conservation, valuation, policy and legislation, documentation and information databases, animal and human health, and food safety, as well as opportunities and proposals for interaction with other organizations and United Nations agencies. As of June 2006, nine organizations had submitted reports (Table 3). Reports were received from four international non-governmental organizations, three intergovernmental organizations, and two research organizations. A further three international organizations informed FAO that they were not engaged in AnGR-related activities.

Table 3
Reports from international organisations

| Organization | Title of the submission | Received |
|-----------------|--|---------------------------------|
| CGIAR Centres | Consultative Group on International Agricultural Research (CGIAR) Centres Report to FAO for input into the SoW and the draft report on strategic priorities for action on FAnGR Section I: Description of the CGIAR Institutes and Programmes | May 2004 |
| SAVE Foundation | SAVE Foundation (Safeguard for Agricultural Varieties in Europe) Brief Portrait April 2004 | May 2004 |
| D8 Countries | Report on Animal Genetic Resources in the D-8 Countries – Strategic Priorities for Action; and Reports D8 Seminar on Conservation of Farm Animal Genetic Resources Cairo, Egypt, 11–13 January 2004 D8 Seminar on Conservation of Farm Animal Genetic Resources, Islamabad, Pakistan, 1–3 August 2003; Report on Workshop on Food Security in D 8 countries, Babolsar, Islamic Republic of Iran, 16–20 October 2000 Report on Workshop on Food Security in D 8 countries, Islamabad, Pakistan, 24–26 November 1999 | June 2004 September 2004 |
| LPP | League for Pastoral Peoples Report on Activities of the League for Pastoral Peoples | November 2004 |
| OIE | World Organisation for Animal Health (OIE) Oral presentation to the Commission on Genetic Resources for Food and Agriculture, 10th Session (to be used thereafter as the OIE input in reply to the FAO AN21/47 request) | November 2004 |
| ACSAD | Arab Center for the Studies of Arid zones and Dry lands (ACSAD) The Activities of the Arab Center for the Studies of Arid zones and Dry lands concerning the Animal Genetic Resources | December 2004 |
| IAMZ | The Mediterranean Agronomic Institute of Zaragoza (IAMZ) Report on Training activities | January 2005 |
| EAAP | EAAP (European Association for Animal Production) Report of the Working Group on Animal Genetic Resources | February 2005 |
| ISAG | International Society for Animal Genetics (ISAG) Report of the ISAG/FAO advisory group on animal genetic diversity | March 2005 |

Thematic studies

In addition to the Country Reports and the reports from international organizations, a number of thematic studies were commissioned by FAO. These studies were intended to contribute to the understanding of specific topics likely not to be covered in Country Reports, but relevant to the preparation of the SoW-AnGR. During the period 2002 to 2006, 12 thematic studies were prepared:

- *Opportunities for incorporating genetic elements into the management of farm animal diseases: policy issues.* A review paper on the potential of genetic elements in the management of disease, technical opportunities, and benefits arising from the incorporation of these elements in effective disease management⁵ (2002);
- *Measurement of domestic animal diversity (MoDAD) – a review of recent diversity studies.* A survey evaluating the current status of molecular genetic research in domestic animal species, with emphasis on characterization of AnGR⁶ (2004);
- *The economics of farm animal genetic resource conservation and sustainable use: why is it important and what have we learned?* A study on the valuation of AnGR, summarizing methodological approaches and knowledge gaps⁷ (2004);
- *Conservation strategies for animal genetic resources.* A study contrasting opportunities, challenges, biological characteristics, institutional infrastructure and operational considerations influencing management of plant and animal genetic resources⁸ (2004);
- *Environmental effects on animal genetic resources.* An evaluation and synthesis of the evidence available on a spectrum of environmental factors and their effects on AnGR at the individual animal and the breeding population levels⁹ (2004);
- *The legal framework for the management of animal genetic resources.* An introductory study of policy and legal frameworks for the management of AnGR including a survey of countries in different world regions¹⁰ (2004, printed revised version 2005);
- *The impact of disasters and emergencies on animal genetic resources.* A study which provides an overview of potential disasters and their possible impact on AnGR. It also provides an analysis of the effects of emergency responses. It proposes decision support guidelines for disaster management¹¹ (2006);
- *The state of development of biotechnologies as they relate to the management of animal genetic resources and their potential application in developing countries.* An introductory study of biotechnology applications and their use in developing countries, which includes information provided in Country Reports¹² (2006);
- *Exchange, use and conservation of animal genetic resources: policy and regulatory options.* A study which identifies how exchange practices related to AnGR affect the various stakeholders in the livestock sector (2006);
- *A strategic approach for conservation and continued use of farm animal genetic resources.* A study which outlines patterns of change in AnGR use and their impact on conservation. It summarizes current experience, and the capacity of alternative conservation measures, considering the needs and aspirations of the various stakeholders whose livelihoods depend on animal production¹³ (2006);

⁵ Background Study Paper No. 18

⁶ CGRFA/WG-AnGR-3/04 inf. 3

⁷ Background Study Paper No. 21

⁸ Background Study Paper No. 22

⁹ Background Study Paper No.28

¹⁰ Background Study Paper No. 24

¹¹ Background Study Paper No. 32

¹² Background Study Paper No. 33

¹³ CGRFA/WG-AnGR-4/06/Inf.6

- *People and animals. Traditional livestock keepers: guardians of domestic animal diversity.* A documentation of 13 case studies from all over the world on how communities manage their local AnGR, demonstrating the value of local knowledge in preserving the equilibrium between farmers, animals and environment¹⁴ (2007);
- *Gene flow in animal genetic resources. A study on status, impact and trends.* A study providing analysis of the magnitude and direction of movement of genetic material of the four major farm animal species: cattle, pigs, goats, and sheep. Determining factors are identified and selected; examples of impacts on economic development, poverty reduction and biodiversity in developing countries are presented (2007).

Preparation of the report

Sources of information

Different sections of the SoW-AnGR required different approaches. Some sections were largely based on the information provided in the 148 Country Reports available by June 2005. Other sections drew heavily on the wider literature or on expert knowledge rather than on the information gathered specifically for the SoW-AnGR process. FAO's Domestic Animal Diversity Information System (DAD-IS)¹⁵ and the FAOSTAT¹⁶ statistical database were also utilized. Regional e-mail consultations, organized by FAO in late 2005 to review the draft Report on Strategic Priorities for Action, provided an additional source of information, particularly on institutional capacities.

Part 1 describes the state of agricultural diversity in the livestock sector. The chapter draws on a number of sources. The description of AnGR inventory and of the extent of genetic erosion is based on information drawn from DAD-IS. This information system, which was launched in 1996, enables National Coordinators to update their national breed databank via the Internet. The guidelines for the development of Country Reports encouraged countries to report breed-related data and information directly to DAD-IS, and not to include details on breeds in the Country Reports. Nonetheless, the Country Reports contained a wealth of breed-related information that was not reported to DAD-IS. As a result of this development, and in order to ensure that the analysis for the SoW-AnGR was based on the most up-to-date information available, FAO provided for the extraction of these data from Country Reports and their entry into DAD-IS. National Coordinators were then requested to validate and further complete their national breed databanks. It was also thought desirable to enable the analysis for the SoW-AnGR to be based on breeds and not only on national breed populations; i.e. so that populations of the same breed in different countries were not counted as separate breeds. To this end, linkages between breed populations in different countries were introduced into the Global Databank, based on information on names, origin and development, importation and geographic location. Lists of all national breed populations and their proposed linkages were sent to National Coordinators for review. The analysis of the data for the purposes of the SoW-AnGR was carried out in January 2006, by which time data from all 169 Country Reports had been entered into the system.

The section on uses and values of AnGR is based on FAOSTAT for population and production statistics, and on the Country Reports for more qualitative information on livestock functions. The section on genetic resistance to disease draws on DAD-IS and the wider scientific literature. Broader sources were also used to describe the origin and domestication of AnGR, sharing and exchange of AnGR, and threats to AnGR.

Part 2 describes livestock sector trends and their implications for AnGR, and draws on a wide range of literature and statistics.

Part 3 describes the state of human capacity, breeding and conservation strategies, legislation and the use of biotechnologies. This part of the report is largely based on the information in the Country Reports. However, the sections on regional and international legislation, and emerging legal and policy issues draw on wider sources.

¹⁴ FAO Inter-Departmental Working Group on Biological Diversity for Food and Agriculture

¹⁵ <http://www.fao.org/dad-is/>

¹⁶ <http://faostat.fao.org/>

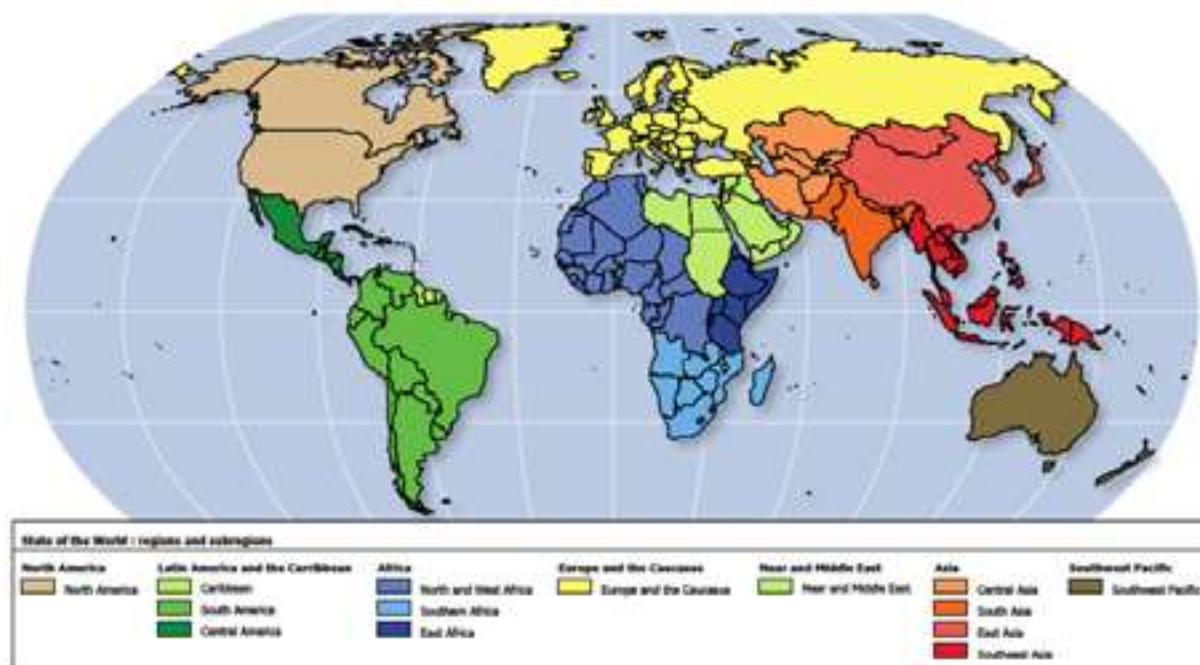
Part 4 on the state of the art in AnGR management is largely based on the wider scientific literature. For the preparation of the section on the state of the art in the AnGR conservation, an expert meeting was convened at FAO in Rome, in July 2005. The participants discussed the approach to the section and allocated writing tasks. The first draft was reviewed by all members in the writing group in October 2005. In November 2005, a workshop “Options and Strategies for the Conservation of Farm Animal Genetic Resources” took place in Montpellier, France. The participants at this workshop were given the opportunity to review the revised version of the conservation section.

Part 5 analyses the needs and challenges for AnGR management, based on the evidence provided in the other chapters of the report. This analysis relates the current state of erosion and threats to AnGR to current capacities in AnGR management, and the state of knowledge regarding methodologies and their application.

Regional classification of countries

The assignment of countries to the regions and subregions used for the purposes of the SoW-AnGR was based on a number of factors that influence biodiversity, including production environments, cultural specificities and the distribution of shared AnGR. Future collaboration in the establishment of Regional Focal Points was also considered, as was the experience gained from the process of convening SoW-AnGR subregional follow-up workshops in 2003 and 2004. Thus, the assignments do not follow exactly the standard FAO regions used in FAO statistics or for FAO election purposes (although for most countries the assignment does not differ from the standard classification). The proposed classification was reviewed at a meeting of Regional Facilitators on “Strategy for Regional Consultations” held in August 2005. The resulting classification distinguishes seven regions, of which three regions were further subdivided: Africa (East Africa, North and West Africa, Southern Africa); Asia (Central Asia, East Asia, Southeast Asia, South Asia); Europe and the Caucasus; Latin America and the Caribbean (Caribbean, Central America, South America); the Near and Middle East; North America; and the Southwest Pacific.

Figure 1
Assignment of countries to regions and subregions in this report



Part 1

The state of agricultural biodiversity in the livestock sector

Introduction

The importance of the world's biodiversity – the variety of its plants, animals and micro-organisms, and of the ecosystems of which they form a part, is increasingly recognized. Agricultural biodiversity encompasses the diversity of the cultivated plants and domestic animals utilized by humankind for the production of food and other goods and services. More broadly, it includes the diversity of the agro-ecosystems on which this production depends. The capacity of agro-ecosystems to maintain and increase their productivity, and to adapt to changing circumstances, is vital to the food security of the world's population.

The 40-plus livestock species contributing to today's agriculture and food production are shaped by a long history of domestication and development. Selection pressures resulting from environmental stress factors, and the controlled breeding and husbandry imposed by humans, have combined to produce a great variety of genetically distinct breeds¹. This diversity, developed over thousands of years, is a valuable resource for today's livestock keepers. Genetically diverse livestock populations provide a greater range of options for meeting future challenges, whether associated with environmental change, emerging disease threats, new knowledge of human nutritional requirements, fluctuating market conditions or changing societal needs.

Part 1 of the Report begins by describing the origin of the diversity of today's animal genetic resources for food and agriculture (AnGR) – the domestication and history of livestock species. This is followed by a description of the current status of AnGR diversity on a global scale, and the extent to which this diversity is threatened by genetic erosion. The next section describes patterns of international exchange of AnGR. The roles and values of AnGR, and their direct and indirect contributions to livelihoods and economic output in the various regions of the world are then outlined. The importance of genetic resistance to disease as a resource in the field of animal health is also introduced. In the final section of Part 1, the nature of threats to the world's AnGR diversity is discussed.

SECTION A: ORIGIN AND HISTORY OF LIVESTOCK DIVERSITY

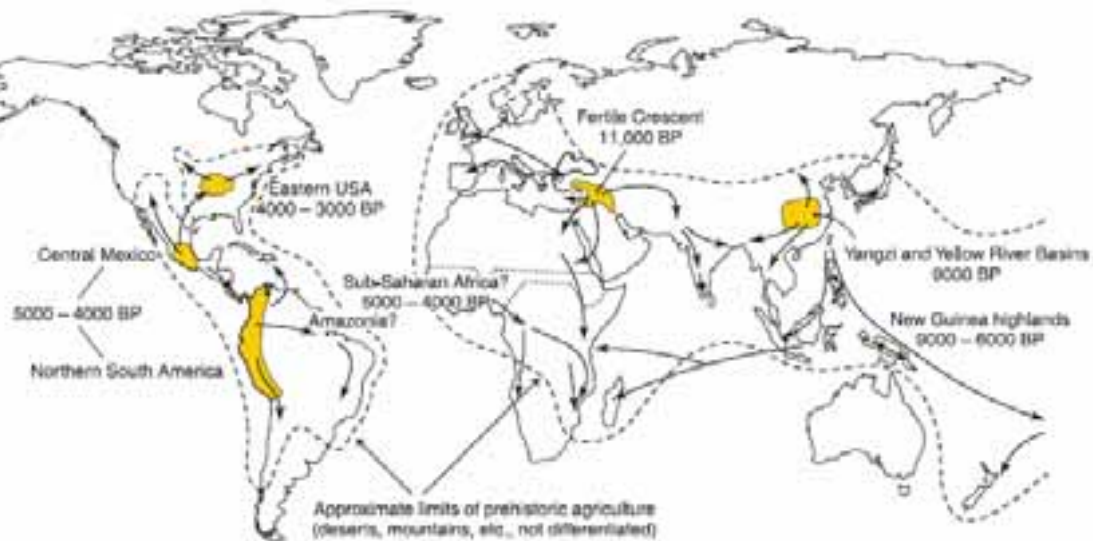
1 Introduction

The history of AnGR started around 12 000 to 14 000 years ago, during the agricultural revolution of the early Neolithic, with the domestication of major crop and livestock species. This control of food production led to major demographic, technological, political and military changes. The domestication of animals and plants is considered to be one of most important developments in history, and one of the prerequisites for the rise of human civilizations (Diamond, 2002). After the initial domestication events, the spread of farming into nearly all terrestrial habitats followed rapidly (Diamond and Bellwood, 2003; Figure 2). Thousands of years of natural and human selection, genetic drift, inbreeding and cross-breeding have contributed to AnGR diversity and have allowed the development of sustainable livestock production in a variety of environments (agro-ecological zones) and production systems.

AnGR diversity is vital to all production systems. It provides the raw material for breed improvements, and for adaptation to changing circumstances. As revealed by recent molecular studies, the diversity found in today's indigenous livestock populations and breeds greatly exceeds that found in their commercial counterparts. Unravelling the origin and distribution of livestock diversity is central to its current utilization, and to its long-term conservation (Hanotte *et al.*, 2006).

¹ Central to the description of livestock diversity is the notion of the breed (see Part 4 – Section A: 1 for a discussion of the definition of the term “breed”).

Figure 2
Archaeological map of agricultural homelands and spread of Neolithic/Formative cultures, with approximate radiocarbon dates



Source: Diamond and Bellwood (2003)

2 The livestock domestication process

Very few animal species have been successfully domesticated. Domestication was a complex and gradual process, which altered the behaviour and morphological characteristics of the ancestral animals (Box 1). The circumstances and pressures that triggered the domestication of animals remain uncertain, and may have varied from one geographic area to another and from one species to another.

The roots of animal domestication are probably related to the ubiquitous tendency of hunter gatherers (presumably shared by early humans) to try to tame or manage wild animals (Diamond, 2002). It was, however, at the end of the Pleistocene that the process of domestication actually got underway. At this time, changes in the climate, which became more unpredictable, warmer and/or more seasonal in some areas, led to localized expansion of human populations. These developments triggered the uptake of crop farming, and affected the distribution and density of the wild species hunted for food. In these circumstances, the main driver of animal domestication may have been the desire to secure the availability of “favourite” foods – with the potential of some domesticated species to provide support to crop farming (e.g. ploughing with oxen or buffalo), or as pack and riding animals (e.g. llamas, dromedaries, Bactrian camels, horses, donkeys and even cattle) being realized later.

Among the world’s 148 non-carnivorous species weighing more than 45 kg, only 15 have been domesticated. Thirteen of these species are from Europe and Asia, and two originate from South America. Moreover, only six have become widespread on all continents (cattle, sheep, goats, pigs, horses, and donkeys), while the remaining nine (dromedaries, Bactrian camels, llamas, alpacas, reindeer, water buffalo, yaks, Bali cattle, and mithun) are important in more limited areas of the globe (adapted from Diamond, 1999). The proportion is even lower in the case of birds, with only ten species (chickens, domestic ducks, Muscovy ducks, domestic geese, guinea fowl, ostriches, pigeons, quails, and turkeys) currently domesticated out of around 10 000 avian species (the list excludes the many birds domesticated for ornamental or recreational purposes).

Box 1**The domestication process**

Domesticated animals are here considered to be those species that are bred in captivity, and modified from their wild ancestors to make them more useful to humans, who control their reproduction (breeding), care (shelter, protection against predators) and food supply (Diamond, 2002; Mignon-Grasteau, 2005). Domestication includes the following steps: initial association with free breeding; confinement; confinement with breeding in captivity; and selective breeding and breed improvement (modified from Zeuner 1963). Archaeologists and animal geneticists use various means to unravel the history of domestication, including study of morphological changes to the teeth, cranium and skeleton; and the construction of demographic age and sex curves which allow the identification of patterns indicative of domestication (Zeder, *et al.*, 2006).

With the exception of the wild boar (*Sus scrofa*) the ancestors and wild relatives of major livestock species are either extinct or highly endangered as a result of hunting, changes to their habitats, and in the case of the wild red jungle fowl, intensive cross-breeding with the domestic counterpart. In these species, domestic livestock are the only depositories of the now largely vanished diversity of the wild ancestors (Table 4). This is a major difference from crop species, in many of which the wild ancestors are commonly found at the centres of origin and represent an important source of variation and adaptive traits for future breeding programmes.

Table 4
Origin and domestication of livestock species

| Domestic species | Wild Ancestor | MtDNA clades | Domest. events* | Time B.P. | Location |
|------------------------------------|--------------------------------------|--------------|-----------------|-----------|--|
| Cattle | Aurochs (3 subspecies) (extinct) | | | ~ | |
| <i>Bos taurus taurus</i> | <i>B. primigenius primigenius</i> | 4 | 1 | 8000 | Near and Middle East (west Asia) |
| | <i>B. p. opisthonomus</i> | 2 | 1 | 9500 | northeast Africa |
| <i>Bos taurus indicus</i> | <i>B. p. nomadicus</i> | 2 | 1 | 7000 | northern Indian subcontinent |
| Yak | Wild yak | | | ~ | |
| <i>Poephagus grunniens</i> | <i>P. mutus</i> | 3 | 1 | 4500 | Qinghai-Tibetan Plateau |
| Goat | Bezoar | | | ~ | |
| <i>Capra ferus</i> | <i>Capra aegragus</i> (3 subspecies) | 5 | 2 | 10000 | Near and Middle East, northern Indian subcontinent |
| Sheep | Asian mouflon | | | ~ | |
| <i>Ovis aries</i> | <i>Ovis orientalis</i> | 4 | 2 | 8500 | Near and Middle East/Turkey (Central Anatolia) |
| Water buffalo | Asian wild buffalo | | | ~ | |
| Riverine <i>B. bubalus bubalus</i> | | ND | 1 | 5000 | Islamic Republic of Iran/Iraq, Indian subcontinent |
| Swamp <i>B. bubalus carabensis</i> | | ND | 1 | 4000 | Southeast Asia, China |
| Pigs | Wild boar | | | ~ | |
| <i>Sus scrofa domestica</i> | <i>Sus scrofa</i> (16 subspecies) | 6 | 6 | 9000 | Europe, Near and Middle East, China Indian subcontinent, Southeast Asia |

| | | | | | | |
|----------------------------|--|----|----------|-----------|---|--|
| Horse | Extinct | | | | | |
| <i>Equus caballus</i> | | 17 | multiple | ~ 6500 | Eurasian steppe | |
| Donkey | African wild donkey | | | | | |
| <i>Equus asinus</i> | <i>Equus africanus</i> | | | ~ 6000 | northeast Africa | |
| | Nubian wild ass <i>E. a. africanus</i> | 1 | 1 | | | |
| | Somali wild ass <i>E. a. somali</i> | 1 | 1 | | | |
| Llama | | | | | | |
| <i>Lama glama</i> | 2 subspecies | ND | 1 | ~ 6500 | Andes | |
| | <i>L. guanicoe guanicoe</i> | | | | | |
| | <i>L. guanicoe cacsiliensis</i> | | | | | |
| Alpaca | | | | | | |
| <i>Vicugna pacos</i> | 2 subspecies | ND | 1 | ~ 6500 | Andes | |
| | <i>V. vicugna vicugna</i> | | | | | |
| | <i>V. vicugna mensalis</i> | | | | | |
| Bactrian Camel | Extinct** | | | | | |
| <i>Camelus bactrianus</i> | <i>C. b. ferus</i> | ND | 1 | ~ 4500 | Central Asia (eastern Republic of Iran) | |
| Dromedary | Extinct | | | | | |
| <i>Camelus dromedarius</i> | | ND | 1 | ~ 5000 | southern Arabian Peninsula | |
| Domestic chicken | Red Junglefowl | | | | | |
| <i>Gallus domesticus</i> | <i>Gallus gallus</i> (4 subspecies) | 5 | 2 | ~ 5000 | Indian subcontinent | |
| | <i>G. g. spadiceus</i> , <i>G. g. jabouillei</i> | | | ~ 7500 | China – Southeast Asia | |
| | <i>G. g. murghi</i> , <i>G. g. gallus</i>) | | | | | |

Source: adapted and updated from Bruford et al. (2003); Hanotte and Jianlin (2005)

*Minimum number of domestication events; **Recent genetic evidence suggests that the endangered wild population are not the ancestral maternal populations of today's domestic Bactrian (Jianlin et al., 1999), ND = not determined

The small number of animal species successfully domesticated is largely explained by the characteristics required (or advantageous) for domestication, which are rarely found together in a single species. All major livestock species were domesticated several thousand years ago. It is improbable that further large mammalian species will be domesticated, at least in the near future, as illustrated by the failure, or at best only partial success, of twentieth century attempts to domesticate new species (e.g. oryx, zebras, African buffaloes and various species of deer). However, the coming years may see further development of the captive breeding of small and “non-conventional” species (sometimes called microlivestock) for human consumption, which may become more important, at least locally or regionally (BOSTID, 1991; Hanotte and Mensah, 2002).

Important or essential characteristics for successful domestication include behavioural traits such as a lack of aggression towards humans; a strong gregarious instinct, including “follow the leader” dominance hierarchies which allow the possibility of a human substitute as leader; a tendency not to panic when disturbed; the ability to breed in captivity; physiological traits such as a diet that can easily

be supplied by humans (domestication of herbivores rather than carnivores); a rapid growth rate; relatively short intervals between births; and large litter size (Diamond, 2002).

The ancestral species of the majority of livestock species have now been identified (Table 4). It is also known that many current domestic animal populations and breeds originate from more than one wild ancestral population, and that in some cases there has been genetic admixture or introgression between species that do not normally hybridize in the wild. These admixture and hybridization events probably occurred after the initial domestication. They were often linked to human migration, trading or simply the result of the requirement of agricultural societies for new livestock phenotypes. Examples include admixture between taurine and Zebu cattle, the presence of cattle genetic background in yaks and Bali cattle, Asian pig hybridization with European breeds, cross-breeding between dromedaries and Bactrian camels, and (as revealed by recent genetic studies) intensive admixture between the two South American domestic camelids (llamas and alpacas) (Kadwell *et al.*, 2001).

Box 2

Molecular characterization – a tool to understand livestock origin and diversity

Recent major developments in molecular genetics have provided powerful new tools, called molecular markers, to assess the origins of livestock species and the geographic distribution of their diversity. Protein polymorphisms were the first molecular markers used in livestock. A large number of studies, particularly during the 1970s, documented the characterization of blood group and allozyme systems. However, the level of polymorphism observed in proteins is often low, which reduces the general applicability of protein typing in diversity studies.

DNA-based polymorphisms are now the markers of choice for molecular-based surveys of genetic diversity. Importantly, polymorphic DNA markers showing different patterns of Mendelian inheritance can be studied in nearly all major livestock species. Typically, they include D-loop and cytochrome B mitochondrial DNA (mtDNA) sequences (maternal inheritance), Y chromosome-specific single nucleotide polymorphisms (SNPs) and microsatellites (paternal inheritance), and autosomal microsatellites (bi-parental inheritance). Autosomal microsatellites have been isolated in large numbers from most livestock species, and FAO/ISAG (International Society of Animal Genetics) recommended lists of autosomal microsatellite markers for genetic diversity studies are publicly available (<http://dad.fao.org>).

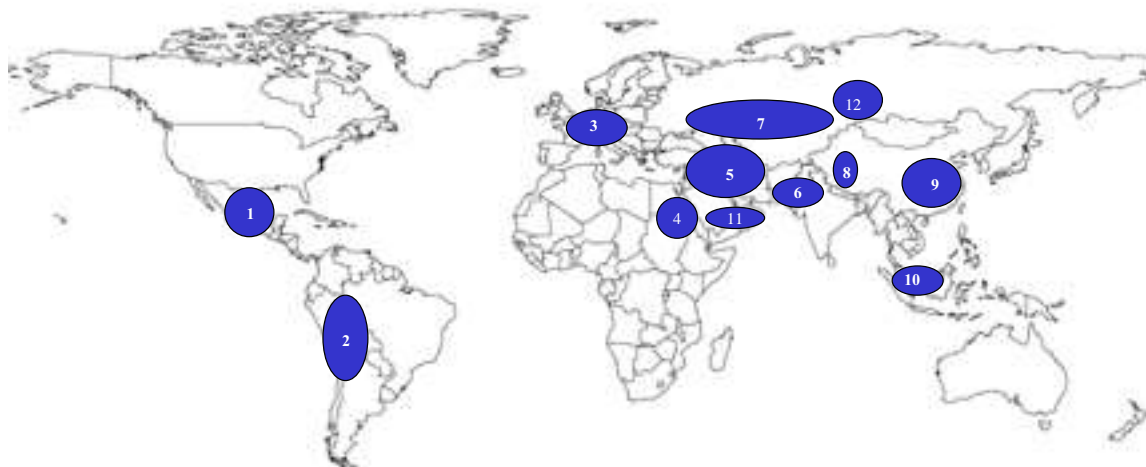
Different genetic markers provide different levels of genetic diversity information. Autosomal microsatellite loci are commonly used for population diversity estimations, differentiation of populations, calculation of genetic distances, estimation of genetic relationships, and the estimation of population genetic admixture. MtDNA sequences are the markers of choice for domestication studies, as the segregation of an mtDNA lineage within a livestock population will only have occurred through the domestication of a wild female, or through the incorporation of a female into the domestic stock. More particularly, mtDNA sequences are used to identify putative wild progenitors, the number of maternal lineages and their geographic origins. Finally, the study of a diagnostic Y chromosome polymorphism is an easy and rapid way to detect and to quantify male-mediated admixture.

Reproduced and adapted from Hanotte and Jianlin (2005)

3 Ancestors and geographic origins of our livestock

One of the most exciting areas of intersection between archaeology and genetics has been in documenting the locations of livestock domestication (Zeder *et al.*, 2006), with archaeology guiding genetic research, and genetics providing support to some controversial archaeological theories or revealing possible new geographic origins for livestock species and their diversity. More particularly, it is now known that nearly all major livestock species are the result of multiple domestication events in distinct geographic areas (Table 4 and Figure 3); and that subsequent to the initial domestication events, genetic introgression between wild relatives and their domestic counterparts often occurred.

Figure 3
Major centres of livestock domestication – based on archaeological and molecular genetic information



(1) turkey (2) guinea pig, llama, alpaca, (3) pig, rabbit (4) cattle, donkey, (5) cattle, pig, goat, sheep, Bactrian camel (6) cattle, goat, chicken, river buffalo, (7) horse, (8) yak, (9) pig, swamp buffalo, chicken, (10) chicken, pig, Bali cattle (11) dromedary, (12) reindeer

It should be noted that apparently independent livestock domestication events were not necessarily culturally independent. Some independent domestication events may have represented the movement of a few domesticated individuals into a new area, with the genetic signatures of the introduced founders subsequently submerged by the recruitment of local wild animals (Zeder *et al.*, 2006). Alternatively, ancient signatures of local domestication events may now be hidden by more recent arrivals of livestock from other centres of origin. Osteometric information from archaeological sites, and ancient livestock DNA studies are important tools to address these questions.

Livestock domestication is now thought to have occurred in at least 12 areas of the world (Figure 3). Interestingly, not all centres of domestication are closely associated with the homelands of our crop species (see Figure 2). While in some cases (e.g. the Fertile Crescent), domestication centres of both crops and livestock are intermingled, in others (e.g. the African continent) crop and livestock domestication seem largely to have occurred independently. While uncertainties still surround the existence of some domestication centres for some species, the following geographic areas are important primary centres of origin and, therefore, diversity of livestock species: the Andean chain of South America (llamas, alpacas, guinea pigs); central America (turkeys, Muscovy ducks); northeast Africa (cattle, donkeys); southwest Asia including the Fertile Crescent (cattle, sheep, goats, pigs); the Indus valley region (cattle, goats, chickens, riverine buffaloes); Southeast Asia (chickens, Bali cattle); east China (pigs, chicken, swamp buffaloes); the Himalayan plateau (yaks); and north Asia (reindeer). Additionally, the southern part of the Arabian Peninsula is thought to be the region of origin of the dromedary, while the Bactrian camel may originate from the area that is now the Islamic Republic of Iran, and the horse from the Eurasian steppes.

While domestication occurred in several places, it also happened at different times. Exact dating of domestication events has, however, proved particularly challenging. Animals undergoing the initial process of domestication would not have been significantly different in morphology from their wild ancestors, and dates relying on morphological markers will undoubtedly underestimate the age of domestication events (Dobney and Larson, 2006). The process of molecular dating, while independent of morphological changes, is typically characterized by large error rates, and often relies on uncertain calibration points. Approaches including demographic profiling techniques for identifying initial attempts at livestock management by humans, and calibration of molecular clocks using ancient DNA information, are providing new avenues for pinpointing the dates of domestication (Zeder *et al.*, 2006).

New archaeological and genetic information is constantly improving our understanding of the origin of livestock species. The first animal to be domesticated was the dog. This probably occurred at least 14 000 years ago – the animals being used for hunting and as watchdogs. It is unclear where the initial

domestication took place, but many maternal lineages have been found in modern dogs – indicating multiple introgressions from their wild ancestor the grey wolf (*Canis lupus*) in the Old World. Domestic dogs were, apparently, not independently domesticated in the New World; the mitochondrial lineages identified so far in the Americas are of European origin (Wayne *et al.*, 2006).

Goats were domesticated as early as 10 000 years ago in the Zagros Mountains of the Fertile Crescent (Zeder and Hesse, 2000). The bezoar (*Capra aegragus*) was probably one of the ancestors of the domestic goat, but it is possible that other species such as *C. falconeri*, contributed to the genetic pool of the domestic species. Today, five distinct maternal mitochondrial major lineages have been identified in domestic goats (Luikart *et al.*, 2001; Sultana *et al.*, 2003; Joshi *et al.*, 2004). One of these lineages predominates numerically, and is present worldwide, while a second seems to be of contemporary origin. They probably reflect the primary caprine domestication process in the Fertile Crescent, where archaeological information suggests two to three areas of domestication (Zagros Mountains, Taurus Mountains, Jordan Valley). The other lineages are more restricted in their geographic distribution, and may correspond to additional domestications or introgressions in other areas including the Indus Valley (Fernández *et al.*, 2006).

Sheep were also probably first domesticated in the Fertile Crescent, approximately 8 000 to 9 000 years ago. Archaeological information suggests two independent areas of sheep domestication in Turkey – the upper Euphrates valley in eastern Turkey, and central Anatolia (Peters *et al.*, 1999). Three species of wild sheep (the urial, *Ovis vignei*; the argali, *O. ammon*; and the Eurasian mouflon, *O. musinom/orientalis*) have been proposed as ancestors of domestic sheep (Ryder, 1984) or at least to have introgressed some local breeds. However, recent genetic work has indicated no contribution from the urial or argali (Hiendleder *et al.*, 1998). This supports the view that the Asian mouflon (*O. orientalis*), which is found in a wide region stretching from Turkey at least as far as the Islamic Republic of Iran, is the only progenitor of domestic sheep. The European mouflon *O. musinom* is now considered to be a descendant of feral sheep. Four major maternal mitochondrial DNA lineages have been recorded in domestic sheep (Hiendleder *et al.*, 1998; Pedrosa *et al.*, 2005; Tapio *et al.*, 2006) one or two of which could correspond to distinct domestication events, and the others to subsequent wild introgression. To date, no clear associations have been described between these mitochondrial DNA lineages and phenotypic sheep varieties (e.g. fat-tailed, thin-tailed or fat-rumped sheep).

The ancestor of the domestic pig is the wild boar (*Sus scrofa*). Extensive zooarchaeological findings indicate that pigs were domesticated around 9 000 years ago in the Near East. Material from several sites in eastern Anatolia indicates gradual changes in pig morphology and demographic profiles over several thousand years, providing evidence of the domestication process and its morphological consequences. Both archaeological and genetic evidence indicate a second major independent domestication centre in East Asia (China) (Guiffra *et al.*, 2000). At least 16 distinct subspecies of wild boar have been described in Eurasia and North Africa and, perhaps not surprisingly, a recent survey of mitochondrial DNA diversity among Eurasian domestic pigs and wild boar revealed a complex picture of pig domestication, with at least five or six distinct centres across the geographic range of the wild species (Larson *et al.*, 2005).

Domestication of cattle has been particularly well documented, with clear evidence of three distinct initial domestication events for three distinct aurochs (*Bos primigenius*) subspecies. *B. primigenius primigenius*, domesticated in the Fertile Crescent around 8 000 years ago, and *B. p. opisthonomus*, possibly domesticated as early as 9 000 years ago in the northeastern part of the African continent (Wendorf and Schild, 1994), are the ancestors of the humpless *B. taurus* cattle of the Near East and Africa respectively. Humped Zebu cattle (*Bos indicus*), are now believed to have been domesticated at a later date, around 7 000 to 8 000 years ago, in the Indus Valley region of modern-day Pakistan (Loftus *et al.*, 1994; Bradley *et al.*, 1996; Bradley and Magee, 2006). Recently, a fourth domestication centre has been suggested in East Asia (Mannen *et al.*, 2004), but it is unclear whether it occurred independently or represents local aurochs introgression in cattle of Near Eastern origin.

The ancestor of the domestic water buffalo (*Bubalus bubalus*) is undoubtedly the wild buffalo of Asia. Two main types are recognized, based on their phenotypes, karyotypes and recent mitochondrial DNA work (Tanaka *et al.*, 1996): the riverine buffalo found in the Indian subcontinent, the Near and Middle

East, and eastern Europe; and the swamp buffalo found in China and Southeast Asian countries. The two types hybridize in the northeastern part of the Indian subcontinent. They were probably domesticated separately, with possible centres of domestication of the riverine buffalo in the Indus Valley and/or the Euphrates and Tigris valleys some 5 000 years ago, and of the swamp buffalo in China, where it was domesticated at least 4 000 years ago in association with the emergence of rice cultivation.

There is an ongoing debate as to when and where the horse (*Equus caballus*) was domesticated. The ancestor of the domestic horse is extinct. Two species have been regarded as putative wild ancestors – the tarpan (*E. ferus*) and the Przewalski horse (*E. przewalskii*). The Przewalski horse, although very closely related to the wild ancestor, is probably not the direct progenitor of the domestic species (Olsen *et al.*, 2006; Vilà *et al.*, 2006). It is difficult to assess whether archaeological horse remains are wild or domestic. Substantial evidence from north Kazakhstan (Botai culture) supports the view that horses were domesticated in this area during the Copper Age around 3700 to 3100 BC (Olsen, 2006). Recent molecular studies indicate that the diversity of the horse on the maternal side probably originates from several populations in different geographic areas. However, the data are not yet conclusive as to whether there was a single domestication event and subsequent introgression, or multiple independent domestication events (Vilà *et al.*, 2001; Jansen *et al.*, 2002).

In contrast, the domestication of the donkey *Equus asinus* seems to have followed a much simpler process. Mitochondrial DNA studies have confirmed an African origin for the domestic donkey, and have ruled out the Asiatic wild ass as a possible progenitor (Beja-Pereira *et al.*, 2004). Two mitochondrial lineages suggest two domestication events. One lineage is closely linked to the Nubian wild ass (*E. asinus africanus*), which is still found today living wild in northeastern Sudan close to the Red Sea. The other lineage shows some affinities to the Somali wild ass (*E. asinus somaliensis*). It could, therefore, also have an African origin, although domestication in a neighbouring area (Arabian Peninsula or Fertile Crescent) cannot be excluded. Archaeological evidence from Egypt supports an African centre of domestication for the donkey, and suggests a domestication date of around 6 000 to 6 500 years ago (Clutton-Brock, 1999).

The domestic yak (*Poephagus grunniens*) is endemic to Central Asia and well adapted to a cold and high-altitude environment. Yak pastoralism is widespread in the Central Asian Highlands, and the introduction of yak pastoralism was crucial to the development of year-round sustainable occupation of the higher altitude zones of the Himalaya Plateau. It may have been connected with the establishment of Tibetan–Burman populations in this region. Today, some wild yaks (*P. mutus*) are still found on the Qinghai-Tibetan Plateau, but they may have been heavily introgressed with feral domestic yak. Three mitochondrial DNA lineages have been identified. However, similar geographic distributions of mitochondrial DNA diversity suggest a single domestication event in the eastern part of the Qinghai-Tibetan Plateau rather than multiple domestication events (Qi, 2004; Guo *et al.*, 2006). Molecular findings also indicate that the dispersal of domestic yaks followed two separate migratory routes from their centre of domestication: the yak reached the “Pamir Knot” by following a westward route through the Himalaya and Kunlun Mountains; and reached Mongolia, and what is now the Russian Federation, by following a northward route through the Mongolian South Gobi and Gobi Altai Mountains (Qi *et al.*, in press).

As in the case of the yak, the domestication of the reindeer (*Rangifer tarandus*) has allowed pastoral communities to occupy habitats that would otherwise be largely unsuitable for livestock keeping. Very little is known about reindeer domestication. The wild reindeer was possibly the latest large mammalian species to be domesticated. The oldest definitive archaeological evidence of reindeer domestication was discovered in the Altai Mountains of Siberia, and has been dated to about 2 500 years ago; it indicates that reindeer riding was practised at the time (Skjenneberg, 1984). There is no reliable information as to how reindeer domestication reached Europe; it could have developed independently in Scandinavia, or may have been adopted by the Saami people through contact with other north Eurasian pastoral communities. Reindeer husbandry is believed to have developed among the Saami sometime after 1600 AD. The wild reindeer is known as the caribou in North America; it is believed never to have been domesticated on this continent (Clutton-Brock, 1999).

The domestication of the Bactrian camel (*Camelus bactrianus*) may have occurred in the area that is now the Islamic Republic of Iran/Turkmenistan, or further east, in southern Kazakhstan, northwestern Mongolia or northern China (Bulliet, 1975; Peters and von den Driesch, 1997). The earliest evidence of domestic Bactrian camels is from the site of Sahr-i Sokta in the central part of the Islamic Republic of Iran, from where camel bones, dung, and woven fibres dating from approximately 2600 BC have been recovered (Compagnoni and Tosi, 1978).

Recent genetic work indicates that the wild camel (*C. ferus*) populations of the Gobi Desert, which successfully hybridize with the domestic species, are probably not the direct maternal ancestors of domestic or feral camels (Jianlin, *et al.*, 1999). The wild ancestor of the one-humped dromedary (*C. dromedarius*) is now extinct. Domestication of the species is believed to have started around 5 000 years ago in the southeastern part of the Arabian Peninsula.

The origin of the South American Camelidae has now been unravelled, with the guanaco (*Lama guanicoe*) and the vicuña (*Vicugna vicugna*) being the ancestral species of the domestic llama (*Lama glama*) and alpaca (*Vicugna pacos*) respectively (Kadwell *et al.*, 2001). Archaeozoological evidence points to the central Peruvian Andes as the centre of origin of the alpaca, 6 000 to 7 000 years before present. The llama was probably domesticated at the same period in the Andes around Lake Titicaca. Large-scale introgressions between the two domestic species have been revealed (Wheeler *et al.*, 2006) – an ongoing hybridization process which probably began with the Spanish conquest, which destroyed the traditional breeding structures and management of the two species.

The ancestor of Bali cattle is the banteng (*Bos javanicus*), of which three endangered subspecies have been recognized. The domestication of the species did not, in fact, occur on the Island of Bali, where there is no evidence for the presence of the wild ancestor. The species could have been domesticated in Java and/or on the Indo–Chinese Peninsula. *B. taurus* and *B. indicus* introgression has been found in Bali cattle, and Bali cattle genetic background has also been inferred in several Southeast Asian cattle breeds, suggesting that the domestic species once had a wider distribution than it has today (Felius, 1995).

The ancestor of the mithun (*B. frontalis*) is the gaur (*B. gaurus*). As in the case of Bali cattle, the centre of domestication of the species is unknown. Archaeological excavation in northeastern Thailand (Non Nok Tha) suggests that both species might have been domesticated as early as 7 000 years ago (Higham (1975) in Felius, 1995).

The domestic chicken (*Gallus domesticus*) is descended from the wild red jungle fowl (*Gallus gallus*), with five possible progenitor subspecies. While previous molecular studies suggested a single domestic origin in Southeast Asia (Thailand) (Fumihito *et al.*, 1994; 1996), at least six distinct maternal genetic lineages have now been identified (Liu *et al.*, 2006), suggesting more than one domestication centre. Archaeological information indicates a centre of chicken domestication around the Indus Valley 5 000 years ago, and another in eastern China maybe as early as 7 500 to 8 000 years ago (West and Zhou, 1988).

4 Dispersal of domesticated animals

If the domestication process was the major initiating event in the development of today's livestock diversity, the subsequent dispersion and migration of domesticated species across all five continents was equally important. This process played a major role in the emergence of the current geographic distribution of livestock diversity. The main factors at the root of the early dispersion of livestock species were the expansion of agriculture, trade, and military conquests.

The exact mechanisms through which agricultural expansion occurred are still debated. The process probably varied from one region to another (Diamond and Bellwood, 2003). It certainly involved both the movement of human populations, and cultural exchanges between populations – as illustrated by the adoption of farming by many hunter–gatherer societies. Important examples of agricultural expansions include that of the Neolithic, which brought cattle, sheep and goats into Europe, and may have triggered the local domestication of the wild boar. Domesticated livestock followed two distinct

major routes into Europe – the Danubian and the Mediterranean (Bogucki, 1996; Cymbron *et al.*, 2005).

The Bantu expansion which started around 2000 BC was a major event in African history, and was probably responsible for the adoption of pastoralism (cattle, sheep and goats) by the Khoisan peoples of the Southern Africa region about 2 000 years ago (Hanotte *et al.*, 2002) (Box 3). The origins of the indigenous pigs and chickens of the African continent remain largely undocumented.

European colonization of the Americas led to the arrival of cattle, sheep, goats, pigs, horses and chickens in the New World. In the case of cattle there is genetic evidence for some African ancestry (Liron *et al.*, 2006), which maybe a legacy of the slave trade between the two continents.

Box 3

The history of African pastoralism

Until recently, the history of African pastoralism was controversial and poorly understood. However, genetic marker analysis of indigenous cattle populations from all over the continent have now unravelled the major events in the history of pastoralism in Africa (Figure 4). The earliest African cattle originated within the continent, possibly as early as around 8000 BC. The exact centre(s) of domestication remain(s) unknown, but archaeological information suggests that it might have taken place in the northeastern part of the continent (Wendorf and Schild, 1994). These first African cattle were humpless *Bos taurus* animals. They initially dispersed north, as well as south to the borders of the tropical rainforests. Today, the only remaining descendants of these indigenous African taurine cattle are the trypanotolerant West African breeds (e.g. N'Dama and Baoulé), the Kuri, and the Sheko breed from Ethiopia. All these populations are now being intensively cross-bred with Zebu cattle (*Bos indicus*), and their unique genetic make-up is disappearing through unbalanced genetic admixture.

Zebu cattle arrived in Africa much later. The earliest evidence for the presence of humped cattle is provided by Egyptian tomb paintings dating from the Twelfth Dynasty of the second millennium BC. It is probable that these animals were brought to Egypt in limited numbers as war treasure and, therefore are not connected to the later presence of Zebu cattle in Africa. It is, however, thought that the Zebu was present in small numbers in the eastern part of the continent perhaps as early as 2 000 years ago as a result of early Arab contact or long-distance sea trade, and that this initial arrival resulted in the first introgression of Zebu genes into African taurine cattle. The major wave of Zebu arrival probably started with the Arab settlements along the East Coast of Africa from about the seventh century AD. The major inland dispersal of Zebu cattle probably followed the movement of pastoralists (e.g. Fulani throughout the Sahel), and was certainly accelerated by the rinderpest epidemics of the late nineteenth century.

Southern Africa was the last area of the continent to acquire cattle pastoralism. Genetic data are now excluding a movement of cattle from the western part of the continent. It appears that herding spread southward from the Great Lakes region, which 2 000 years ago was the site of an Eastern Bantu core area. These farmers ultimately came into contact with San hunter-gatherers who acquired livestock from them. Influences from the Near East centre of cattle domestication are today found in the northeastern, northwestern and southern parts of the continent. The latter is probably a result of the settlement of European farmers in this part of the continent.

Adapted from Hanotte et al. (2002)

In Asia, the arrival of domestic livestock in the Japanese archipelago probably followed the establishment of farmers of Korean origin around 400 BC, but ancient influences from other geographic areas are also likely. In the Pacific, pigs and chickens had been spread across western Polynesia by 900 to 700 BC, and the later Polynesian expansion carried these species as far as Rapa Nui (Easter Island) by 900 AD.

Figure 4
Origin and migration routes of domestic cattle in Africa



Source: Graphics unit, ILRI (2006)

Beside human migrations, ancient overland trading networks played an important role in the dispersion of livestock species. The domestication of livestock enabled large-scale overland trading between civilizations, and livestock were themselves often a traded product. The main livestock species used as pack animals in the Old World were the donkey, horse, dromedary and Bactrian camel, and in South America, the llama. It is believed that domestication of the horse led to military

expansion of horse-riding nomadic pastoralists in the Eurasian steppe, and subsequent dispersion of the species across the Old World. Bactrian camels were also used in warfare to a limited extent (Clutton-Brock, 1999), and the dromedary played an important role in the expansion of Arab civilization.

There is increasing evidence of the importance of ancient sea trading routes in the dispersion of livestock. For example, recent molecular genetic studies in cattle have revealed that Zebu animals were introduced into Africa via an Indian Ocean corridor rather than overland through the Isthmus of Suez or the Sinai Peninsula (Hanotte *et al.*, 2002; Freeman *et al.*, 2006). Similarly, both archaeological and genetic information suggest that the spread of pastoralism in the Mediterranean basin followed not only terrestrial coastal routes, but also maritime routes (Zilhão, 2001; Beja-Pereira *et al.*, 2006).

A loss of diversity is to be expected following the dispersion and movement of livestock populations from their centres of origin. However, molecular markers have revealed a more complex picture, with some movements resulting in an increase in diversity following admixture between populations originating from different centres of domestication. Additionally, detailed molecular studies indicate not only that cross-breeding between livestock populations was common, but also that genetic introgression from wild populations occurred after the initial domestication events. When they occurred outside the species' geographic area of origin and after its initial dispersion, these wild introgressions may have resulted in localized livestock genetic populations with unique genetic backgrounds. Examples include local aurochs introgression in European (Götherström *et al.*, 2005; Beja-Pereira *et al.*, 2006) and possibly also in Asian cattle (Mannen *et al.*, 2004).

Unravelling the geographic pattern and history of the dispersal of livestock is essential to the identification of geographic areas with high levels of diversity, which are potential priority areas for conservation efforts. This requires extensive mapping of genetic diversity. Up to now, very few studies have been undertaken in this field. However, a recent study of cattle, covering Europe, Africa and West Asia, indicates that the highest degree of diversity is found in areas that are at the crossroads of admixture between populations from different centres of domestication (Freeman *et al.*, 2006). An extensive survey of goat diversity in Europe and the Near and Middle East clearly indicates a geographical partitioning of goat diversity, with a large proportion of the genetic diversity among breeds explained by their geographic origins (Cañón *et al.*, 2006).

Today, local and regional, as well transcontinental movement of livestock genotypes is accelerating as a result of the development and marketing of high-yielding breeds, new breeding technologies, and the increasing demand for livestock products. This modern dispersion, essentially restricted to a few breeds, and almost exclusively involving transfers from developed to developing countries, represents a major threat to the conservation and utilization of indigenous AnGR (see Section C for a further discussion of current gene flows).

5 Transformations in livestock following domestication

Mutation, selective breeding, and adaptation have shaped the diversity of livestock populations. The domestication process resulted in many changes some of which may still be ongoing. Particularly important have been morphological changes. Domestic animals are generally smaller than their wild ancestral counterparts (the notable exception being the chicken). Smaller animals are easier to manage and to handle, they may reach puberty sooner, and large flocks or herds can be kept more easily (Hall, 2004). The small West African cattle, sheep and dwarf goats are extreme examples of size reduction, possibly the result of genetic bottlenecks following adaptation to the tropical humid environment and its parasitic disease challenges. In some cases, human selection has deliberately resulted in extreme size differences – illustrated by the small size of the Shetland pony and the large size of the Shire horse (Clutton-Brock, 1999).

The body conformation of domestic animals may also be distinct from that of the wild ancestors – adapting, for example, to satisfy demand for meat products (e.g. European beef breeds), or to cope with new environmental pressures (e.g. Sahelian goats). Selection for muscular mass has often resulted in greater muscular development of the hind quarters relative to the shoulders (Hall, 2004). An

extreme example of selection for muscular mass is the double-muscling trait observed in some European beef breeds, and in some sheep and pigs breeds. In cattle, the trait results from mutation at a single gene – the myostatin gene (Grobet *et al.*, 1998). In sheep, it involves the callipyge gene (Cockett *et al.*, 2005).

The pattern of fat deposition may also show changes following domestication. For example, reduced predation has encouraged fat deposition in domestic poultry. In domesticated mammals, the hump of the Zebu and the tails of fat-tailed and fat-rumped sheep are striking examples of selection for fat deposition. This exaggerated fat deposition may be quite ancient, with fat-tailed sheep already common in western Asia by 3000 BC, and humped cattle depicted on cylinder seals from the ancient civilizations of Mohenjo-Daro and Harappa in the Indus Valley about 2500 to 1500 BC (Clutton-Brock 1999).

Great variation is found in the wool and hair coats of most domestic species. For example, sheep breeds of alpine regions have particularly thick woolly coats, while breeds from the African Sahel lack wool. It is probable that these changes were the result of mutations followed by artificial selection, perhaps as early as 6000 BC, as illustrated by a statuette of a woolly sheep found in the Islamic Republic of Iran (Clutton-Brock, 1999).

Coat and plumage coloration were also selected by the environment, with light coloured animals being more adapted to hotter environments and dark coloured animals to cooler environments (Hall 2004). Coat colours have also been influenced by cultural selection. Livestock breeders in the developed world often favour uniformity in coat colour, but in the tropics diversity in coat colour may be preferred for ceremonial reasons, or simply to facilitate the identification of individual animals. An illustration of the latter is the great diversity in coat colours and patterns observed among the Nguni cattle of the Zulu people (Poland *et al.*, 2003).

It is important to realize that local adaptation, human and/or natural selection will not always result in reduced genetic variation or functional diversity in the livestock population. For example, natural selection may favour adaptive diversity within herds kept in changing environments (e.g. as a result of climatic variation). A recent study of the genetic diversity of the six most important milk proteins in cattle revealed higher diversity in a relatively restricted geographic area of northern Europe, with selection pressure imposed by early (milk drinking) pastoralists being the most likely explanation (Beja-Pereira *et al.*, 2003).

6 Conclusions

Understanding of the origin and subsequent history and evolution of AnGR diversity is essential to the design of sustainable conservation and utilization strategies. Livestock diversity originates from the wild ancestors, and was subsequently shaped through the processes of mutation, genetic drift, and natural and human selection. Only a subset of the diversity present in the ancestral species survived, in the domestic counterparts. However, domestic livestock diversity has been continuously evolving. Reshuffling of genes at each generation, mutation, and cross-breeding or admixture of different gene pools has offered new opportunities for natural and human selection. This has been the basis of the enormous gains in output achieved in commercial breeds, and of the adaptation of indigenous livestock to highly diverse and challenging environments.

However, the world's livestock diversity is currently shrinking – with rapid and uncontrolled loss of unique and often uncharacterized AnGR. If a breed or population becomes extinct, this means the loss of its unique adaptive attributes, which are often under the control of many interacting genes, and are the results of complex interactions between the genotype and the environment.

7 References

- Beja-Pereira, A., Caramelli, D., Lalueza-Fox, C., Vernesi, C., Ferrand, N., Casoli, A., Goyache, F., Royo, L.J., Conti, S., Lari, M., Martini, A., Ouragh, L., Magid, A., Atash, A., Zsolnai, A., Boscato, P., Triantaphylidis, C., Ploumi, K., Sineo, L., Mallegni, F., Taberlet, P., Erhardt, G., Sampietro, L., Bertranpetit, J., Barbujani, G., Luikart, G. & Bertorelle, G.** 2006. The origin of European cattle: evidence from modern and ancient DNA. *Proceedings of the National Academy of Sciences USA*, 103(21): 8113–8118.
- Beja-Pereira, A., England, P.R., Ferrand, N., Jordan, S., Bakhiet, A.O., Abdalla, M.A., Maskour, M., Jordana, J., Taberlet, P. & Luikart, G.** 2004. African origin of the domestic donkey. *Science*, 304(5678): 1781.
- Beja-Pereira, A., Luikart, G., England, P.R., Bradley, D.G., Jann, O.C., Bertorelle, G., Chamberlain, A.T., Nunes, T.P., Metodiev, S., Ferrand, N. & Erhardt, G.** 2003. Gene-culture coevolution between cattle milk protein genes and human lactase genes. *Nature Genetics*, 35(4): 311–313.
- Bogucki, P.** 1996. The spread of early farming in Europe. *American Science*, 84: 242–253.
- BOSTID.** 1991. *Microlivestock: little-known small animals with a promising economic future.* Washington, DC. National Academic Press.
- Bradley, D.G., MacHugh, D.E., Cunningham, P. & Loftus, R.T.** 1996. Mitochondrial DNA diversity and the origins of African and European cattle. *Proceedings of the National Academy of Sciences USA*, 93(10): 5131–5135.
- Bradley, D.G. & Magee, D.** 2006. Genetics and the origins of domestic cattle. In M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigm*, pp. 317–328. California, USA. University of California Press.
- Bruford, M.W., Bradley, D.G. & Luikart, G.** 2003. DNA markers reveal the complexity of livestock domestication. *Nature Reviews Genetics*, 4(11): 900–909.
- Bulliet, R.W.** 1975. *The Camel and the wheel.* Massachusetts, USA. Harvard University Press.
- Cañón, J., Garcia, D., Garcia-Atance, M.A., Obexer-Ruff, G., Lenstra, J. A., Ajmone-Marsan, P., Dunner, S. & the ECONOGENE Consortium.** 2006. Geographical partitioning of goat diversity in Europe and the Middle East. *Animal Genetics*, 37(4), 327–334.
- Clutton-Brock, J.** 1999. *A natural history of domesticated mammals.* 2nd Edition. Cambridge, UK. Cambridge University Press.
- Cockett, N.E., Smit, M.A., Bidwell, C.A., Segers, K., Hadfield, T.L., Snowden, G.D., Georges, M. & Charlier, C.** 2005. The callipyge mutation and other genes that affect muscle hypertrophy in sheep. *Genetic Selection and Evolution*, 37(Suppl 1): 65–81.
- Compagnoni, B. & Tosi, M.** 1978. The camel: its distribution and state of domestication in the Middle East during the third millennium B.C. in light of finds from Shahr-i Sokhta. In R.H. Meadow, & M.A Zeder, eds. *Approaches to faunal analysis in the Middle East.* Peabody Museum Bulletin 2, pp. 91–103. Cambridge MA, USA. Peabody Museum.
- Cymbron, T., Freeman, A.R., Malheiro, M.I, Vigne, J.-D. & Bradley, D.G.** 2005. Microsatellite diversity suggests different histories for Mediterranean and Northern European cattle populations. *Proceedings of the Royal Society of London B*, 272: 1837–1843.
- Diamond, J.** 1999. *Guns, germs and steel: the fates of human societies.* New York, USA. Norton.
- Diamond, J.** 2002. Evolution, consequences and future of plant and animal domestication. *Nature*, 418: 700–707.
- Diamond, J. & Bellwood, P.** 2003. Farmers and their languages: the first expansions. *Science*, 300: 597–603.
- Dobney, K. & Larson, G.** 2006. Genetics and animal domestication: new windows on an elusive process. *Journal of Zoology*, 269: 261–271.
- Felius, M.** 1995. *Cattle breeds – an encyclopedia.* Doetinchem, The Netherlands. Misset.

- Fernández, H., Hughes, S., Vigne, J.-D., Helmer, D., Hodgins, G., Miquel, C., Hänni, C., Luikart, G. & Taberlet, P.** 2006. Divergent mtDNA lineages of goats in an early Neolithic site, far from the initial domestication areas. *Proceedings of the National Academy of Sciences USA*, 103(42): 15375–15379.
- Freeman, A.R., Bradley, D.G., Nagda, S., Gibson, J.P. & Hanotte, O.** 2006. Combination of multiple microsatellite datasets to investigate genetic diversity and admixture of domestic cattle. *Animal Genetics*, 37(1): 1–9.
- Fumihito, A., Miyake, T., Sumi, S., Takada, M., Ohno, S. & Kondo, N.** 1994. One subspecies of the red junglefowl (*Gallus gallus gallus*) suffices as the matriarchic ancestor of all domestic breeds. *Proceedings of the National Academy of Sciences USA*, 91(26): 12505–12509.
- Fumihito, A., Miyake, T., Takada, M., Shingu, R., Endo, T., Gojobori, T., Kondo, N. & Ohno, S.** 1996. Monophyletic origin and unique dispersal patterns of domestic fowls. *Proceedings of the National Academy of Sciences USA*, 93(13): 6792–6795.
- Götherström, A., Anderung, C., Hellborg, C., Elburg, R., Smith, C., Bradley, D.G. & Ellegren, H.** 2005. Cattle hybridization in the Near East was followed by hybridization with auroch bulls in Europe. *Proceedings of the Royal Society of London B*, 272: 2345–2350.
- Grobet, L., Poncet, D., Royo, L.J., Brouwers, B., Pirottin, D., Michaux, C., Menissier, F., Zanotti, M., Dunner, S. & Georges, M.** 1998. Molecular definition of an allelic series of mutations disrupting the myostatin function and causing double-muscling in cattle. *Mammalian Genome*, 9(3): 210–213.
- Guiffra, E., Kijas, J.M.H., Amarger, V., Calborg, Ö., Jeon, J.T. & Andersson, L.** 2000. The origin of the domestic pigs : independent domestication and subsequent introgression. *Genetics*, 154(4): 1785–1791.
- Guo, S., Savolainen, P., Su, J., Zhang, Q., Qi, D., Zhou, J., Zhong, Y., Zhao, X. & Liu, J.** 2006. Origin of mitochondrial DNA diversity in domestic yak. *BMC Evolutionary Biology*, 6: 73.
- Hall, S.J.G.** 2004. *Livestock biodiversity: genetic resources for the farming of the future*. Oxford, UK. Blackwell Science Ltd.
- Hanotte, O., Bradley, D.G., Ochieng, J., Verjee, Y., Hill, E.W. & Rege, J.E.O.** 2002. African pastoralism: genetic imprints of origins and migrations. *Science*, 296(5566): 336–339.
- Hanotte, O. & Mensah, G.A.** 2002. Biodiversity and domestication of ‘non-conventional’ species: a worldwide perspective. *Seventh World Congress on Genetics Applied to Livestock Production*, 19–23 August 2002, Montpellier, France. 30: 543–546.
- Hanotte, O. & Jianlin, H.** 2005. Genetic characterization of livestock populations and its use in conservation decision making. Proceeding of the international workshop: The role of biotechnology for the characterization and conservation of crop, forestry, animal and fishery genetic resources, 5–7 March 2005, Turin, Italy, pp. 131–136.
- Hanotte, O., Toll J., Iniguez L. & Rege, J.E.O.** 2006. Farm animal genetic resources: Why and what do we need to conserve. *Proceeding of the IPGRI–ILRI–FAO–CIRAD workshop: Option for in situ and ex situ conservation of AnGR*, 8–11 November 2005, Montpellier, France.
- Hiendleder, S., Mainz, K., Plante, Y. & Lewalski, H.** 1998. Analysis of mitochondrial DNA indicates that the domestic sheep are derived from two different ancestral maternal sources: no evidences for the contribution from urial and argali sheep. *Journal of Heredity*, 89: 113–120.
- Higham, C.** 1975. *Non Nok Tha, the funeral remains from the 1966 and 1968 excavations at Non Nok Tha Northeastern Thailand*. Studies in Prehistoric Anthropology Volume 6. Otago, New Zealand. University of Otago.
- Jansen, T., Foster, P., Levine, M.A., Oelke, H., Hurles, M., Renfrew, C., Weber, J. & Olek, K.** 2002. Mitochondrial DNA and the origins of the domestic horse. *Proceedings of the National Academy of Science USA*, 99(16): 10905–10910.
- Jianlin H., Quau J., Men Z., Zhang Y. & Wang W.** 1999. Three unique restriction fragment length polymorphisms of *EcoR* I, *Pvu* II and *Sca* I digested mitochondrial DNA of wild Bactrian camel (*Camelus bactrianus ferus*) in China. *Journal of Animal Science*, 77: 2315–2316.

- Joshi, M.B., Rout, P.K., Mandal, A.K., Tyler-Smith, C., Singh, L. & Thangaraj, K.** 2004. Phylogeography and origins of Indian domestic goats. *Molecular Biology and Evolution*, 21(3): 454–462.
- Kadwell, M., Fernández, M., Stanley, H.F., Baldi, R., Wheeler, J.C., Rosadio, R. & Bruford, M.W.** 2001. Genetic analysis reveals the wild ancestors of the llama and alpaca. *Proceedings of the Royal Society of London B*, 268: 2675–2584.
- Larson, G., Dobney, K., Albarella, U., Fang, M., Matisoo-Smith, E., Robins, J., Lowden, S., Finlayson, H., Brand, T., Willerslev, E., Rowley-Conwy, P., Andersson, L. & Cooper, A.** 2005. Worldwide phylogeography of wild boar reveals multiple centers of pig domestication. *Science*, 307(5715): 1618–1621.
- Liron J. P., Bravi C. M., Mirol P.M., Peral-Garcia P. & Giovambattista G.** 2006. African matrilineages in American Creole cattle: evidence of two independent continental sources. *Animals Genetics*, 37(4): 379–382.
- Liu, Y.P., Wu, G.-S., Yao, Y.G., Miao, Y.W., Luikart, G., Baig, M., Beja-Pereira, A., Ding, Z.L., Palanichamy, M.G. & Zhang, Y.-P.** 2006. Multiple maternal origins of chickens: out of the Asian jungles. *Molecular Phylogenetics and Evolution*, 38(1): 12–19.
- Loftus, R.T., MacHugh, D.E., Bradley, D.G., Sharp, P.M. & Cunningham, P.** 1994. Evidence for two independent domestication of cattle. *Proceedings of the National Academy of Sciences USA*, 91(7): 2757–2761.
- Luikart, G.L., Gielly, L., Excoffier, L., Vigne, J.-D., Bouvet, J. & Taberlet, P.** 2001. Multiple maternal origins and weak phylogeographic structure in domestic goats. *Proceedings of the National Academy of Sciences USA*, 98(10): 5927–5930.
- Mannen, H., Kohno, M., Nagata, Y., Tsuji, S., Bradley, D.G., Yea, J.S., Nyamsamba, D., Zagdsuren, Y., Yokohama, M., Nomura, K. & Amano, T.** 2004. Independent mitochondrial DNA origin and historical genetic differentiation in North Eastern Asian cattle. *Molecular Phylogenetic and Evolution*, 32(2): 539–544.
- Mignon-Grasteau, S., Boissy, A., Bouix, J., Faure, J.-M., Fisher, A.D., Hinch, G.N., Jensen, P., Le Neindre, P., Mormède, P., Prunet, P., Vandeputte, M. & Beaumont, C.** 2005. Genetics of adaptation and domestication in livestock. *Livestock Production Science*, 93(1): 3–14.
- Olsen, S.L.** 2006. Early horse domestication on the Eurasian steppe. In M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms*, pp. 245–269. California, USA. University of California Press.
- Pedrosa, S., Uzun, M., Arranz, J.J., Gutiérrez-Gil, B., San Primitivo, F. & Bayon, Y.** 2005. Evidence of three maternal lineages in Near Eastern sheep supporting multiple domestication events. *Proceedings of the Royal Society of London B*, 272(1577): 2211–2217.
- Peters, J., Helmer, D., von den Driesch, A. & Segui, S.** 1999. Animal husbandry in the northern Levant. *Paléorient*, 25: 27–48.
- Peters, J. & von den Driesch, A.** 1997. The two-humped camel (*Camelus bactrianus*): new light on its distribution management and medical treatment in the in the past. *Journal of Zoology*, 242: 651–679.
- Poland, M., Hammond-Tooke, D. & Leigh, V.** 2003. *The abundant herds: a celebration of the cattle of the Zulu people*. Vlaeberg, South Africa. Fernwood Press.
- Qi, X.** 2004. *Genetic diversity, differentiation and relationship of domestic yak populations: a microsatellite and mitochondrial DNA study*. Lanzhou University, China. (PhD Thesis)
- Ryder, M.L.** 1984. Sheep. In I.L. Mason, ed. *Evolution of domesticated animals*, pp. 63–65. London. Longman.
- Skjenneberg, S.** 1984. Reindeer. In I.L. Mason, ed. *Evolution of domesticated animals*, pp. 128–138. London. Longman.
- Sultana, S., Mannen, H. & Tsuji, S.** 2003. Mitochondrial DNA diversity of Pakistani goats. *Animal Genetics*, 34(6): 417–421.

- Tanaka, K., Solis, C.D., Masangkay, J.S., Maeda, K., Kawamoto, Y. & Namikawa, T.** 1996. Phylogenetic relation among all living species of the genus *Bubalus* based on DNA sequences of the cytochrome B gene. *Biochemical Genetics*, 34(11–12): 443–452.
- Tapio, M., Marzanov, N., Ozerov, M., Činkulov, M., Gonzarenko, G., Kiselyova, T., Murawski, M., Viinalass, H. & Kantanen, J.** 2006. Sheep mitochondrial DNA in European Caucasian and Central Asian areas. *Molecular Biology and Evolution*, 23(9): 1776–1783.
- Vilà, C., Leonard, J.A., Götherström, S., Marklund, S., Sanberg, K., Lindén, K., Wayne, R.K. & Ellegren, H.** 2001. Widespread origins of domestic horse lineages. *Science*, 291(5503): 474–477.
- Vilà, C., Leonard, J.A. & Beja-Pereira, A.** 2006. Genetic documentation of horse and donkey domestication. In M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms*, pp. 342–353. California, USA. University of California Press.
- Wayne, R.K., Leonard, J.A. & Vilà, C.** 2006. Genetic analysis of dog domestication. In M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms*, pp. 279–293. California, USA. University of California.
- Wendorf, F. & Schild, R.** 1994. Are the early Holocene cattle in the Eastern Sahara domestic or wild? *Evolutionary Anthropology*, 3: 118–128.
- West, B. & Zhou, B-X.** 1988. Did chickens go north? New evidence for domestication. *Journal of Archaeological Science*, 15: 515–533.
- Wheeler, J.C., Chikni, L. & Bruford, M.W.** 2006. Genetic analysis of the origins of domestic South American Camelids. In M.A. Zeder, E. Emshwiller, B.D. Smith & D.G. Bradley, eds. *Documenting domestication: new genetics and archaeological paradigms*, pp. 279–293. California, USA. University of California Press.
- Zeder, M.A., Emshwiller, E., Smith, B.D. & Bradley, D.G.** 2006. Documenting domestication: the intersection of genetics and archaeology. *Trends in Genetics*, 22(3): 139–155.
- Zeder, M.A. & Hesse, B.** 2000. The initial domestication of goats (*Capra hircus*) in the Zagros mountains 10,000 years ago. *Science*, 287(5461): 2254–2257.
- Zeuner, F.E.** 1963. *A history of domesticated animals*. London. Hutchinson.
- Zilhão, J.** 2001. Radiocarbon evidences for maritime pioneer colonization at the origin of farming in West Mediterranean Europe. *Proceedings of the National Academy of Sciences USA*, 98(24): 14180–14185.

SECTION B: STATUS OF ANIMAL GENETIC RESOURCES

1 Introduction

This section presents a global overview of the diversity and status of AnGR. The analysis is based on FAO's Global Databank for Animal Genetic Resources for Food and Agriculture (Global Databank), as it is the only such resource that provides worldwide coverage. It serves as an updated (but condensed) version of the World Watch List for Domestic Animal Diversity² (WWL–DAD), the previous (third) edition of which was published in 2000. Box 4 outlines changes in the approach to reporting and data analysis that have been introduced for the State of the World's Animal Genetic Resources for Food and Agriculture (SoW-AnGR) preparation process. The section begins by describing the state of reporting on AnGR, and the progress made during the period December 1999 to January 2006. A description of the current regional distribution of livestock species and breeds is then presented, followed by an overview of the risk status of the world's livestock breeds. Finally, trends in risk status over this six year period are assessed.

Box 4

What is new compared to the World Watch List for Domestic Animal Diversity?

In 1991, FAO initiated Global Breed Surveys to report on the seven major mammalian domestic animal species (ass, buffalo, cattle, goat, horse, pig and sheep). Additional surveys were initiated in 1993 to include yaks, the six camelid species and the 14 major avian species. Collection of data for deer species and rabbits followed, and these species were included in the third edition of the World Watch List for Domestic Animal Diversity (WWL–DAD:3) published in 2000. In order to produce a more complete inventory, FAO provided, during 2005, for the extraction of breed-related data from 169 Country Reports, and the entry of these data into the Global Databank for Animal Genetic Resources. Subsequently, National Coordinators (NCs) were requested to validate and further complete their national breed databanks.

The WWL–DAD:3 (2000) was criticized for overestimating the number of breeds categorized as being “at risk”. This overestimation occurred because risk status was assigned to each national breed population based on the population size in the particular country. Thus, in the case of breeds that occur in more than one country, there was a danger that the categorization was not a true reflection of risk status. This problem had previously been recognized, but at the time the emphasis of reporting was on local breeds. For the SoW-AnGR process, countries decided to consider all their AnGR (both local and imported). The number of breeds wrongly categorized as being at risk would, therefore, have greatly increased. The new analysis attempts to correct this bias by linking national breed populations that belong to a common gene pool. This linkage was implemented based on expert knowledge and revised by NCs. However, a clear definition of what constitutes a common gene pool is still lacking. The linked breeds are referred to as transboundary breeds (Box 5). Risk status for these breeds is estimated based on the overall number of animals belonging to the breed in question.

The method of assessing breed diversity at regional and global levels has also been adapted: at the regional level, breeds that reside in more than one country, but only within the SoW-AnGR region in question, are now counted only once for the region regardless of how many national-level populations there may be. International transboundary breeds, which occur in many regions, are counted only once at the global level.

When comparing the WWL–DAD:3 with the figures provided in this Report, it must be noted that the classification of regions has also been changed. Southwest Pacific and Asia are here considered to be separate regions, while “Asia and the Pacific” was considered a single region in WWL–DAD 3. Moreover, it should be noted that the regional classification used in this Report is also different from the standard FAO regional classification.

² FAO/UNEP 2000. World watch list for domestic animal diversity, 3rd edition, edited by B.D. Scherf, Rome. (also available at <http://dad.fao.org/en/>)

2 State of reporting

The total number of breed records in the Global Databank has increased greatly since the publication of the WWL–DAD:3 (Table 5). The total number of entries rose from 6 379 in December 1999 to 14 017 in January 2006. The increase was particularly marked in the case of avian breed populations, for which the number of records increased from 1 049 to 3 505. In the case of mammalian species the number rose from 5 330 to 10 512. Nearly all breed populations reported (94 percent) are domesticated livestock, only 1 percent are feral, and less than 1 percent are wild populations (for the remaining 4 percent no specification was given).

Box 5

Glossary: populations – breeds –regions

Wild populations: represent either wild relatives of domesticated livestock, wild populations that are used for food and agriculture, or populations undergoing domestication.

Feral populations: animals are considered to be feral if they or their ancestors were formerly domesticated, but they are now living independently of humans; for example, dromedaries in Australia.

Local breeds: breeds that occur only in one country.

Transboundary breeds: breeds that occur in more than one country. These are further differentiated as:

– **Regional transboundary breeds:** transboundary breeds that occur only in one of the seven SoW-AnGR regions.

– **International transboundary breeds:** transboundary breeds that occur in more than one region.

SoW-AnGR regions: seven regions were defined for the SoW-AnGR: Africa, Asia, Europe and the Caucasus, Latin America and the Caribbean, the Near and Middle East, North America, and the Southwest Pacific.

While the number of breeds recorded has increased, the percentage of breeds for which population data are available, decreased from 77 to 39 percent for avian breeds, and from 63 to 43 percent for mammalian breeds (Table 5 and Figure 5). Furthermore, where population figures are reported, they may not have been updated recently. The large discrepancy between the number of breed entries and the number for which population data are available is in part accounted for by the fact that much of the latest data entered into the Global Databank were extracted from Country Reports. These reports often mention the existence of breeds, but do not include details of population size.

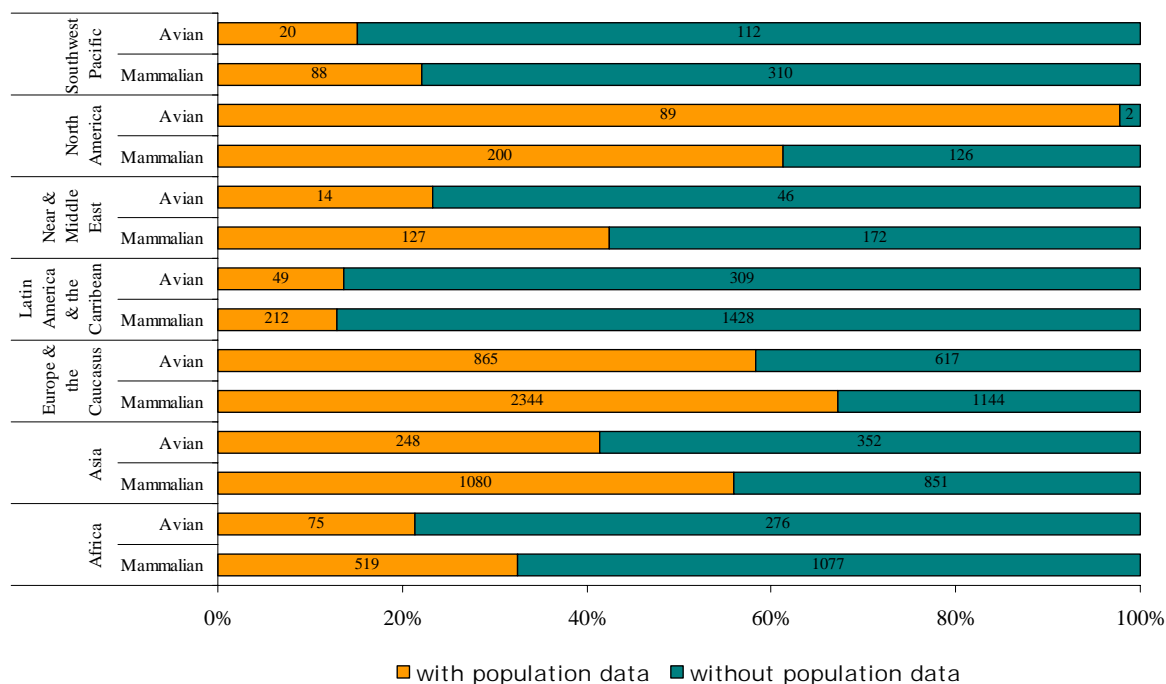
Table 5

Status of information recorded in the Global Databank for Animal Genetic Resources

| Year of analysis | Mammalian species | | | Avian species | | Countries covered |
|------------------|--------------------------------------|------------------------|--|--------------------------------------|------------------------|-------------------|
| | Number of national breed populations | % with population data | | Number of national breed populations | % with population data | |
| 1993 | 2 719 | 53 | | - | - | 131 |
| 1995 | 3 019 | 73 | | 863 | 85 | 172 |
| 1999 | 5 330 | 63 | | 1 049 | 77 | 172 |
| 2006 | 10 512 | 43 | | 3 505 | 39 | 182* |

*No data recorded for Andorra, Brunei Darussalam, Gaza Strip, Holy See, Liechtenstein, Marshall Islands, Federated States of Micronesia, Monaco, Nauru, Qatar, San Marino, Singapore, Timor-Leste, United Arab Emirates, West Bank, Western Sahara

Figure 5
Proportion of national breed populations for which population figures have been reported



Before analysis of the global state of breed diversity and risk status could be undertaken, some adjustments to the raw figures for the number of breed populations were required. Four hundred and eighty entries classified as “strains” or “lines” were excluded from the analysis (in the case of avian species, further validation by national and regional experts to link lines and strains to the respective breeds is needed). Furthermore, 209 breed populations that obviously belonged to the same breed, but had been reported twice from the same country were excluded. These adjustments left a total of 13 328 breed populations for inclusion in the analysis of diversity and risk status.

Slightly more than half of the total number of recorded national breed populations (6 792 entries) occur in more than one country. These breed populations have been linked and are defined as “transboundary” breeds (Box 5). The risk status assigned to a transboundary breed takes into account all reported populations for the breed in question. Breed populations occurring only in one country are defined as “local” breeds. Transboundary breeds are classified as either “regional” or “international”, depending on the extent of their distribution (Box 5).

3 Species diversity

Only about 40 of the 50 000 known avian and mammalian species have been domesticated. DAD-IS now reports breed-related information on 18 mammalian species (Table 6), 16 avian species (Table 7) and two fertile interspecies crossings (Bactrian camel × dromedary, and duck × Muscovy duck). On a global scale, five species – cattle, sheep, chickens, goats, and pigs – show widespread distribution and particularly large numbers. The first three are the most widely distributed domestic species globally, while the latter two are less evenly spread (Figure 6, Tables 6 and 7). Goats are much less numerous in the Americas, and Europe and the Caucasus, than in other regions; and, for religious reasons, pigs are notably lacking in Muslim countries.

Table 6
Distribution of mammalian species by region

| Mammalian species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific |
|--|--------|------|-----------------------|-------------------------------|--------------------|---------------|-------------------|
| % of countries in a region reporting breed-related information for the species | | | | | | | |
| Buffalo | 8 | 57 | 25 | 27 | 25 | 0 | 8 |
| Cattle | 98 | 96 | 100 | 94 | 75 | 100 | 77 |
| Yak | 0 | 32 | 2 | 0 | 0 | 0 | 0 |
| Goat | 96 | 96 | 93 | 94 | 83 | 100 | 69 |
| Sheep | 92 | 86 | 100 | 91 | 100 | 100 | 31 |
| Pig | 70 | 82 | 91 | 91 | 8 | 100 | 92 |
| Ass | 38 | 46 | 36 | 39 | 50 | 50 | 8 |
| Horse | 46 | 93 | 91 | 64 | 58 | 100 | 23 |
| Bactrian camel | 0 | 25 | 5 | 0 | 0 | 0 | 0 |
| Dromedary | 32 | 25 | 2 | 0 | 58 | 0 | 8 |
| Alpaca | 2 | 0 | 0 | 12 | 0 | 0 | 8 |
| Llama | 0 | 0 | 0 | 15 | 0 | 0 | 0 |
| Guanaco | 0 | 0 | 0 | 9 | 0 | 0 | 0 |
| Vicuña | 0 | 0 | 0 | 12 | 0 | 0 | 0 |
| Deer* | 2 | 25 | 14 | 9 | 0 | 50 | 15 |
| Rabbit | 38 | 39 | 39 | 48 | 8 | 0 | 0 |
| Guinea pig | 8 | 0 | 0 | 15 | 0 | 0 | 0 |
| Dog | 2 | 7 | 5 | 0 | 0 | 0 | 0 |

Shading: dark grey: $\geq 50\%$ of countries; middle grey: $< 50\%$ of the countries and $> 10\%$ of countries; light grey $\leq 10\%$ of countries, white: no country

*The main deer species under domestication are the Red deer (*Cervus elaphus elaphus*), Sika deer (*C. nipon nipon*), Wapiti (*C. elaphus canadensis*), Sambar (*C. unicolor unicolor*), Hog deer (*Axis porcinus*), Fallow deer (*Dama dama*), Rusa or Javan deer (*C. timorensis russa*), Chital or Axis deer (*Axis axis*), Reindeer/Caribou (*Rangifer tarandus*), Musk deer (*Moschus moschiferus*), Pere David's deer (*Elaphurus davidianus*) and the Moose/Elk (*Alces alces*).

Table 7
Distribution of avian species by region

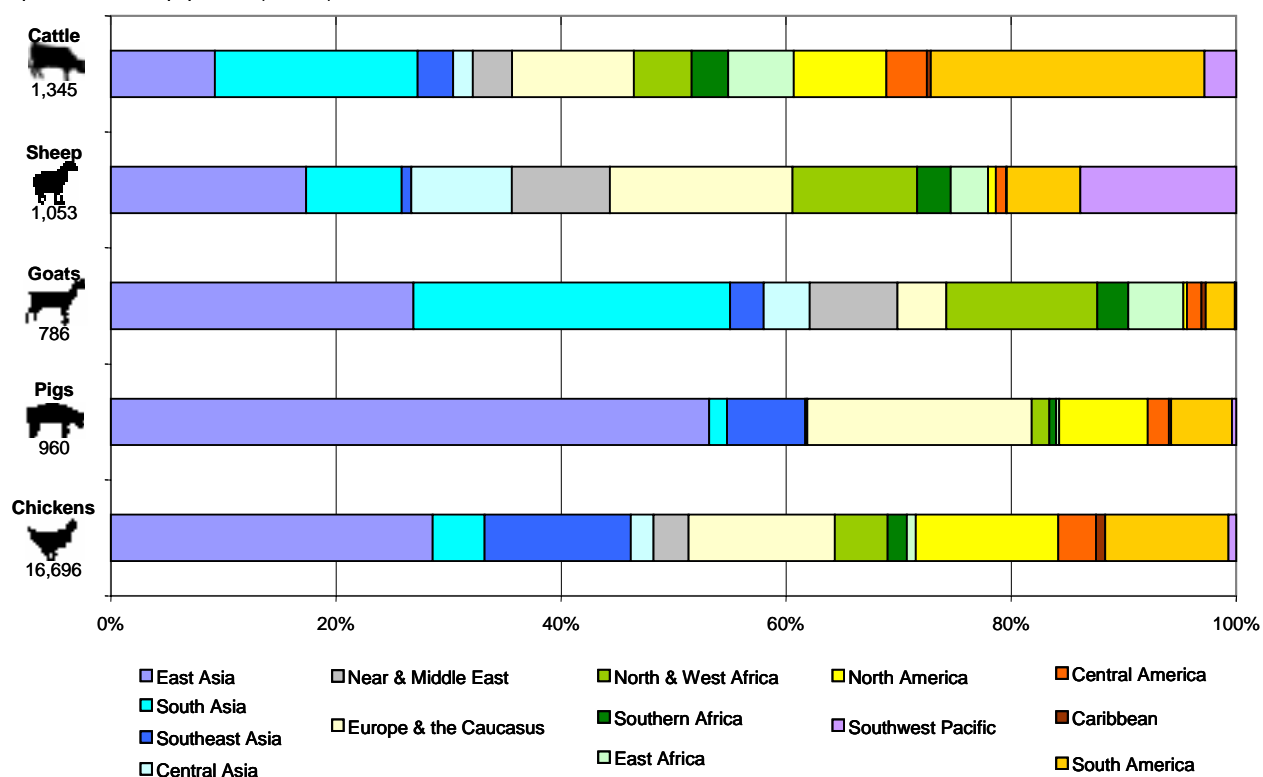
| Avian species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific |
|------------------|--|------|-----------------------|-------------------------------|--------------------|---------------|-------------------|
| | % of countries in a region reporting breed-related information for the species | | | | | | |
| Chicken | 78 | 93 | 86 | 70 | 50 | 100 | 85 |
| Duck (domestic) | 32 | 61 | 50 | 33 | 17 | 0 | 46 |
| Turkey | 24 | 43 | 57 | 30 | 17 | 100 | 8 |
| Goose (domestic) | 16 | 39 | 61 | 21 | 17 | 50 | 8 |
| Muscovy duck | 16 | 39 | 20 | 18 | 17 | 0 | 62 |
| Guinea fowl | 28 | 18 | 11 | 9 | 8 | 0 | 0 |
| Partridge | 4 | 7 | 7 | 0 | 0 | 0 | 0 |
| Pheasant | 0 | 7 | 9 | 6 | 0 | 0 | 0 |
| Quail | 2 | 39 | 14 | 6 | 0 | 50 | 0 |
| Peacock | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Pigeon | 10 | 21 | 9 | 6 | 17 | 0 | 15 |
| Swallow | 0 | 4 | 0 | 0 | 0 | 0 | 0 |
| Cassowary | 0 | 4 | 2 | 0 | 0 | 0 | 0 |
| Emu | 2 | 4 | 2 | 3 | 0 | 0 | 8 |
| Ñandu | 0 | 0 | 2 | 6 | 0 | 0 | 0 |
| Ostrich | 12 | 11 | 7 | 0 | 0 | 0 | 8 |

Shading: dark grey: >49% of countries; middle grey: <50% of countries and >9% of countries; light grey <10% of countries; white: no country

3.1 The big five

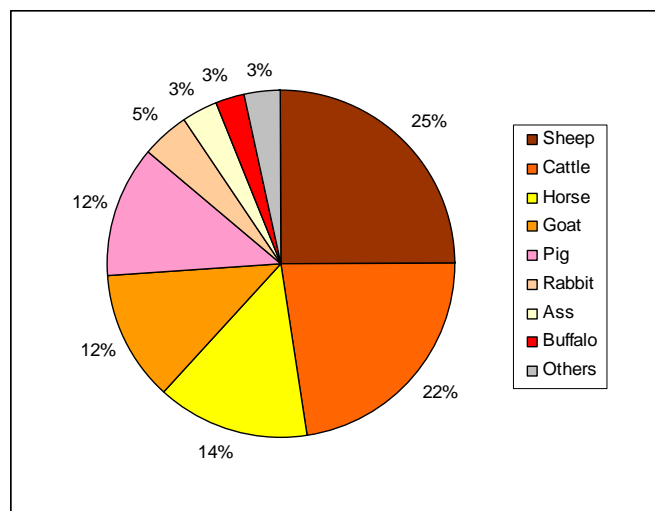
The world has over 1.3 billion cattle – about one for every five people on the planet. Cattle are important in all seven regions. Asia (most notably India and China) with 32 percent of the world total, and Latin America with 28 percent (Brazil has the world’s largest cattle population), are the dominant regions for this species (Figure 6). Large cattle populations are also found in Africa (highest numbers in the Sudan and Ethiopia), and Europe and the Caucasus (highest numbers in the Russian Federation and France). Elsewhere, the United States of America and Australia have large national herds. Cattle breeds contribute 22 percent of the world’s total number of recorded mammalian livestock breeds (Figure 7).

Figure 6
Regional distribution of major livestock species in 2005
Species and world population (millions)



Source: FAOSTAT (available at <http://faostat.fao.org/site/291/default.aspx>)

Figure 7
Distribution of the world's mammalian breeds by species



Mammalian species with more than 100 recorded breeds are displayed separately; the remaining mammalian species are aggregated as others.

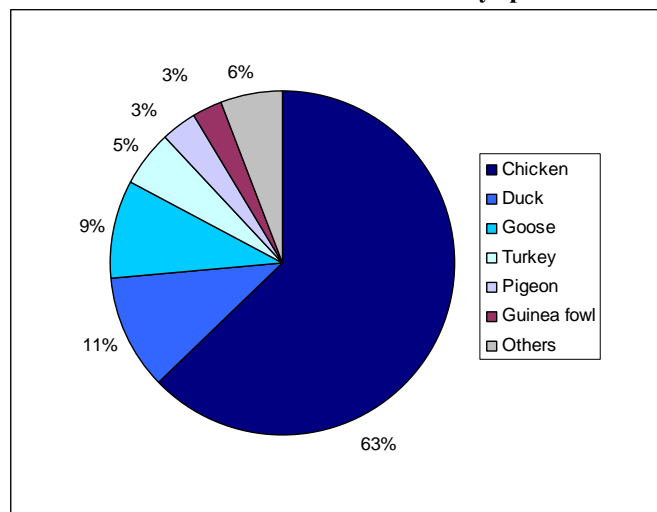
The world's sheep population is just over one billion – one for roughly every six people. Nearly half are found in Asia and the Near and Middle East (largest populations in China, India and the Islamic Republic of Iran); Africa, Europe and the Caucasus, and the Southwest Pacific have around 15 percent each; and 8 percent are found in Latin America and the Caribbean. In contrast to goats, which are largely restricted to developing regions, several developed countries, most notably Australia, New Zealand and the United Kingdom, also have large sheep populations. Sheep are the species with the highest number of recorded breeds (contributing 25 percent to the global total for mammals).

There are about a billion pigs in the world – one for every seven people. About two-thirds are found in Asia – the vast majority in China, with significant numbers also in Viet Nam, India and the Philippines. Europe and the Caucasus has a fifth of the world's pigs, and the Americas another 15 percent. Pig breeds contribute 12 percent to the total number of recorded mammalian breeds in the world.

Goats are the least numerous of the five major livestock species. There are about 800 million worldwide – one for every eight people. Some 70 percent of the world's goats are in Asia and the Near and Middle East, with the largest populations being found in China, India and Pakistan. Africa accounts for most of the rest of the world's goats, with only about 5 percent being found in Latin American and the Caribbean, and Europe and the Caucasus. Goat breeds contribute 12 percent to the total number of recorded mammalian breeds in the world.

Chickens outnumber humans by 2.5 to 1 worldwide. There are nearly 17 billion, about half of which are in Asia, and another quarter in Latin America and the Caribbean. Europe and the Caucasus has a further 13 percent of the world's flock, followed by Africa with 7 percent. Chicken breeds make up a large majority of the total number of avian breeds in the world (Figure 8).

Figure 8
Distribution of the world's avian breeds by species



Avian species with more than 50 recorded breeds are displayed separately; the remaining avian species are aggregated as others.

3.2 Other widespread species

Horses, asses and ducks are also found in all regions; however, they are less numerous than the five species discussed above, and show a less even distribution than cattle, sheep and chickens.

The world's 54 million horses are widely distributed. The country with the largest number is China, followed by Mexico, Brazil, and the United States of America. Other countries with over a million horses are Argentina, Colombia, Mongolia, the Russian Federation, Ethiopia and Kazakhstan. The contribution of horse breeds to the total number of mammalian breeds in the world (14 percent) far outweighs their contribution in terms of animal numbers.

Asses are the transport animal of the poor and of areas that lack a well-developed transport infrastructure. As such, they are predominantly found in the developing regions of the world. The largest numbers are in Asia, Africa, and Latin America and the Caribbean. They are also widely distributed in the Near and Middle East. The country with the largest ass population is China, where Mao Zedong popularized the animal to decrease the drudgery of rural women. Breed diversity is thought to be less than in other species; asses contribute only 3 percent to the world's total number of recorded mammalian breeds. However, asses – and research on them – are often stigmatized, so it is likely that many breeds have not yet been reported.

Domestic ducks show an even less homogenous pattern of distribution than asses. They have a long history of domestication, and were kept in ancient Egypt, Mesopotamia, China and the Roman Empire. However, production is now concentrated in China, which has 70 percent of the world's domestic duck population. Other major producers are Viet Nam, Indonesia, India, Thailand and other countries in Southeast Asia. Among European countries, France and Ukraine have large numbers of ducks. Duck breeds (excluding Muscovy ducks) contribute 11 percent to the total number of recorded avian breeds in the world.

3.3 Species with a narrower distribution

Some mammalian species, such as buffaloes, yaks, camelids and rabbits, and some avian species, such as domestic geese and turkeys, have a narrow distribution and are of particular importance in one or two regions or in a specific agro-ecological zone.

The domestic buffalo is originally an Asian animal – 98 percent of the world's herd of 170 million animals are found in this region, principally in India, Pakistan, China and Southeast Asia. It has been

introduced to south and southeastern Europe, as well as to Egypt, Brazil, Papua New Guinea and Australia. Buffaloes are now reported from 41 countries worldwide. There are two main types of buffalo: riverine (from South Asia), an important dairy producer especially in South Asia; and swamp (from East Asia) which played a major role as a working animal in wet rice cultivation in Southeast Asia until the introduction of the “iron buffalo” – the hand tractor. Buffalo breeds contribute 3 percent to the world’s total number of recorded mammalian breeds.

The yak is endemic to the Tibetan plateau. The largest populations are in China and Mongolia, with small numbers also present in the Russian Federation, Nepal, Bhutan, Afghanistan, Pakistan, Kyrgyzstan and India. In many parts of the Himalaya, yak hybrids with cattle are extremely important. Yaks have also been introduced to the Caucasus, North America (3 000 animals), and many countries in Europe. The total number of recorded yak breeds is small, which reflects the narrow geographical and agro-ecological distribution of the species.

Dromedaries, and particularly Bactrian camels, also have quite a narrow geographical distribution, and are confined to more arid agro-ecological zones. Accordingly, their share of breed diversity is relatively small. The dromedary, or one-humped camel, plays an important role in the Near and Middle East, Africa and in Asia. In Asia, the camel population is currently in stark decline, although it is stable in Africa. In Africa, Somalia, the Sudan, Mauritania and Kenya have the largest populations, while India and Pakistan account for most Asian camels. The two-humped Bactrian camel is confined largely to Central and East Asia, with Mongolia and China having the largest populations.

Four species of camelids originate in South America: the domesticated llama and alpaca, and the wild guanaco and vicuña. The vast majority of llamas are found in Peru and Bolivia; small numbers are found in zoos and among hobbyists in other countries. Guanacos and vicuñas are utilized for fibre, hide and meat production. The total number of recorded camelid breeds is also small compared to many other livestock species. The South American species are very largely restricted to the one region and to high altitudes.

The majority of the world’s farmed rabbits are found in Asia, with the largest population being in China. Large populations are also found in several Central Asian countries and in the Democratic People’s Republic of Korea. In Europe and the Caucasus, the largest population is found in Italy. Rabbit breeds make up 5 percent of the total number of recorded mammalian breeds in the world. Guinea pigs are significant only in the Latin American and the Caribbean region, largely in Peru and Bolivia.

Domestic geese and turkeys also have a relatively narrow distribution. This distribution can be explained by tradition and consumer preferences rather than by agro-ecological conditions. Nearly 90 percent of the world’s domestic geese are found in China. Egypt, Romania, Poland and Madagascar together have more than half of the rest. Turkeys originated in Central America. They were brought to Europe shortly after their discovery by colonists, and many distinct breeds were developed in Europe. Europe and the Caucasus is the region with the largest population of domestic turkeys (43 percent), while North America has over one-third of population. Goose and turkey breeds contribute 9 and 5 percent respectively to the global total of avian breeds.

4 Breed diversity

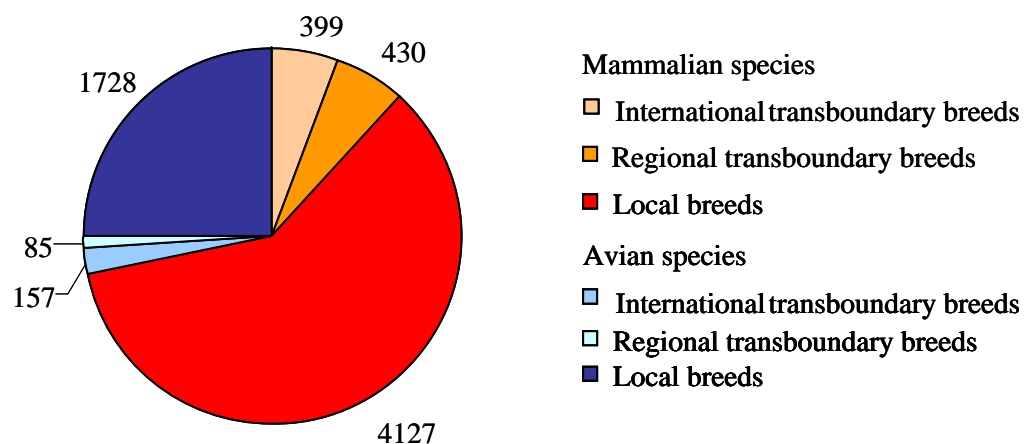
4.1 Overview

A global total of 7 616 breeds have been reported; 6 536 are local breeds and 1 080 are transboundary breeds. Among the transboundary breeds, 523 are regional transboundary breeds occurring only in one region (1 413 national-level entries); and 557 are international transboundary breeds with a wider distribution (5 379 national-level entries). A total of 690 breeds are classified as extinct, of which nine are transboundary breeds. In the following analysis of breed diversity, extinct breeds are excluded.

Figure 9 shows the share of local, regional transboundary and international transboundary breeds among the mammalian and avian breeds of the world (excluding extinct breeds). More than two-thirds

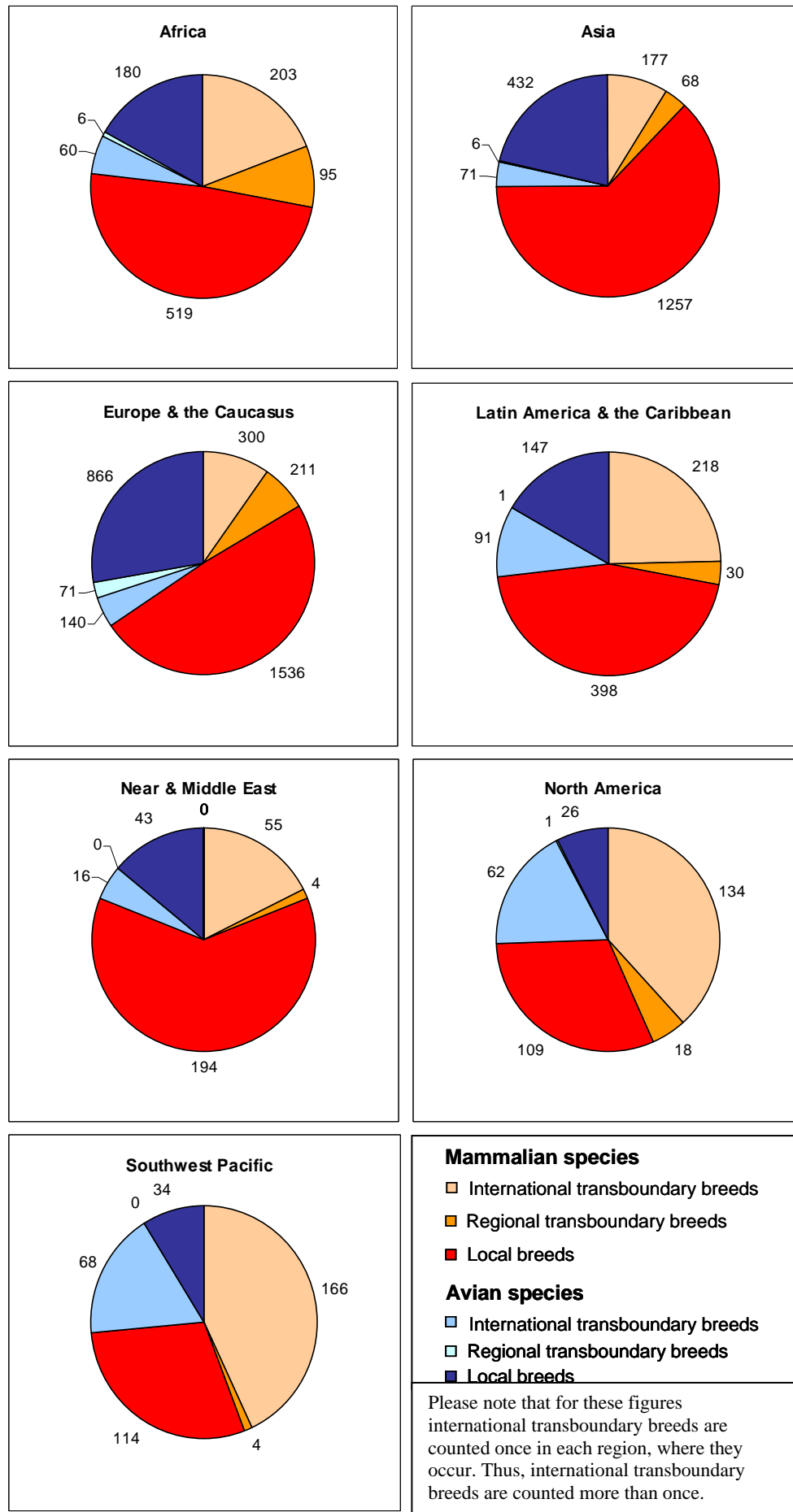
of reported breeds belong to mammalian species. The numbers of regional and international transboundary breeds are quite similar in mammalian species, while in avian species there are twice as many international transboundary breeds as there are regional transboundary breeds.

Figure 9
Number of local and transboundary breeds at global level



In all regions of the world, mammalian breeds outnumber avian breeds. In all regions except for Europe and the Caucasus, mammalian breeds make up nearly three-quarters of all breeds reported. There is, however, considerable variation between regions in terms of the share of the three breed categories in the total number of breeds (Figure 10). In Europe and the Caucasus, Asia, and the Near and Middle East, local breeds make up about three-quarters of all breeds. In Africa, and Latin America and the Caribbean, the share of local breeds is smaller, but still exceeds two-thirds of all breeds. Conversely, international transboundary avian and mammalian breeds dominate in the Southwest Pacific and North America. Regional transboundary mammalian breeds are relatively numerous in Europe and the Caucasus, Africa, and to lesser extent Asia, while it is only in Europe and the Caucasus that there are a significant number of regional transboundary avian breeds.

Figure 10
Number of local and transboundary breeds at regional level



Values show the number of breeds belonging to each group present in the respective region

For the assessment of the breed diversity being maintained in the regions, international transboundary breeds were excluded, as they cannot be assigned to a particular region. Europe and the Caucasus, and Asia are home to the largest share of breeds of most of the world's major livestock species (Table 8). Camels are the exception, with the largest number of breeds being found in Africa. In terms of population size, Asia is the dominant region for most species. Exceptions include camels (Africa), turkeys (Europe and the Caucasus) and horses (44 percent of which are found in Latin America and the Caribbean).

Table 8
Proportion of the world's population size (2005) and number of local and regional transboundary breeds (January 2006) of the major livestock species by region

| Species | Africa | | Asia | | Europe & the Caucasus | | Latin America & the Caribbean | |
|----------------------------|--------------------|-----------|---------------|-----------|-----------------------|-----------|-------------------------------|--------------|
| | pop (%) | breed (%) | pop (%) | breed (%) | pop (%) | breed (%) | pop (%) | breed (%) |
| Buffalo | 0 | 2 | 97 | 73 | 0 | 9 | 1 | 9 |
| Cattle | 14 | 19 | 32 | 26 | 11 | 31 | 28 | 14 |
| Goat | 22 | 18 | 62 | 35 | 4 | 33 | 4 | 5 |
| Sheep | 16 | 12 | 36 | 25 | 18 | 48 | 7 | 4 |
| Pig | 2 | 9 | 62 | 41 | 20 | 32 | 8 | 12 |
| Ass | 27 | 14 | 38 | 28 | 4 | 28 | 20 | 15 |
| Horse | 6 | 7 | 25 | 24 | 13 | 48 | 44 | 11 |
| Bactrian camel & dromedary | 40 | 47 | 20 | 24 | 2 | 3 | 0 | 0 |
| South American camelids | 0 | 0 | 0 | 0 | 0 | 0 | 100 | 100 |
| Rabbit | 0 | 7 | 74 | 8 | 24 | 76 | 1 | 7 |
| Chicken | 6 | 8 | 48 | 22 | 14 | 58 | 15 | 8 |
| Duck & Muscovy duck | 1 | 9 | 90 | 38 | 7 | 36 | 2 | 11 |
| Turkey | 3 | 13 | 1 | 13 | 43 | 42 | 18 | 13 |
| Goose | 1 | 6 | 90 | 24 | 6 | 65 | 0 | 3 |
| Species | Near & Middle East | | North America | | Southwest Pacific | | World | |
| | Pop (%) | breed (%) | pop (%) | breed (%) | pop (%) | breed (%) | pop (million head) | breed number |
| Buffalo | 2 | 6 | 0 | 0 | 0 | 2 | 174 | 132 |
| Cattle | 3 | 4 | 8 | 3 | 3 | 3 | 1 355 | 990 |
| Goat | 8 | 6 | 0 | 1 | 0 | 2 | 808 | 559 |
| Sheep | 9 | 5 | 1 | 3 | 14 | 3 | 1 081 | 1 129 |
| Pig | 0 | 0 | 8 | 3 | 0 | 2 | 960 | 566 |
| Ass | 12 | 11 | 0 | 3 | 0 | 2 | 41 | 150 |
| Horse | 0 | 2 | 11 | 4 | 1 | 4 | 55 | 633 |
| Bactrian camel & dromedary | 38 | 24 | 0 | 0 | 0 | 2 | 19 | 97 |
| South American camelids | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 13 |
| Rabbit | 2 | 2 | 0 | 0 | 0 | 0 | 537 | 207 |
| Chicken | 3 | 2 | 13 | 1 | 1 | 2 | 16 740 | 1 132 |
| Duck & Muscovy duck | 1 | 2 | 1 | 0 | 0 | 4 | 1 046 | 234 |
| Turkey | 1 | 4 | 33 | 13 | 1 | 2 | 280 | 85 |
| Goose | 3 | 1 | 0 | 0 | 0 | 1 | 302 | 166 |

It can be seen from Table 8 that the Europe and the Caucasus region's share of breeds is far higher than its population share in most species. The turkey is an exception to the pattern. Although the region's share of breeds is the highest in the world for this species, the population share is almost the same. The large number of breeds in Europe and the Caucasus is partly a result of the fact that many of these breeds are recognized as separate entities, but are in fact closely related genetically. It also reflects the more advanced state of breed recording and characterization in this region, compared for example, to most parts of sub-Saharan Africa where efforts are restricted by a lack of technical and human resources. Asia also accounts for a high proportion of the world's breeds in many species, but the region's share of the total population is in most cases even higher (exceptions are turkeys, and Bactrian camels and dromedaries).

4.2 Local breeds

Tables 9 and 10, respectively, show the number of local breeds of mammalian and avian species for each region of the world. For most livestock species, Europe and the Caucasus or Asia are the regions that have the highest number of local breeds. The dromedary, with most breeds located in Africa and the Near and Middle East regions, is an exception to this pattern.

Table 9
Mammalian species – number of reported local breeds

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific | World |
|-----------|--------|-------|-----------------------|-------------------------------|--------------------|---------------|-------------------|-------|
| Buffalo | 2 | 88 | 11 | 11 | 8 | 0 | 2 | 122 |
| Cattle | 154 | 239 | 277 | 129 | 43 | 29 | 26 | 897 |
| Yak | 0 | 26 | 1 | 0 | 0 | 0 | 0 | 27 |
| Goat | 86 | 182 | 170 | 26 | 34 | 3 | 11 | 512 |
| Sheep | 109 | 265 | 458 | 47 | 50 | 31 | 35 | 995 |
| Pig | 49 | 229 | 165 | 67 | 1 | 18 | 12 | 541 |
| Ass | 17 | 39 | 40 | 21 | 16 | 4 | 3 | 140 |
| Horse | 36 | 141 | 269 | 65 | 14 | 23 | 22 | 570 |
| Dromedary | 44 | 13 | 1 | 0 | 23 | 0 | 2 | 83 |
| Rabbit | 11 | 16 | 125 | 14 | 5 | 0 | 0 | 171 |
| Total | 508 | 1 246 | 1 519 | 380 | 194 | 108 | 113 | 4 068 |

Excludes extinct breeds; not shown: alpaca, deer, dog, dromedary × Bactrian camel, guanaco, guinea pig, llama, vicuña

Table 10
Avian species – number of reported local breeds

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific | World |
|--------------|--------|------|-----------------------|-------------------------------|--------------------|---------------|-------------------|-------|
| Chicken | 89 | 243 | 608 | 84 | 24 | 12 | 17 | 1 077 |
| Duck | 14 | 76 | 62 | 22 | 4 | 1 | 7 | 186 |
| Turkey | 11 | 11 | 29 | 11 | 3 | 11 | 2 | 78 |
| Goose | 10 | 39 | 100 | 5 | 2 | 0 | 2 | 158 |
| Muscovy duck | 7 | 10 | 10 | 3 | 1 | 0 | 3 | 34 |
| Partridge | 2 | 8 | 3 | 0 | 0 | 0 | 0 | 13 |
| Pheasant | 0 | 7 | 5 | 6 | 0 | 0 | 0 | 18 |
| Pigeon | 7 | 12 | 30 | 7 | 8 | 1 | 2 | 67 |
| Ostrich | 6 | 2 | 4 | 0 | 0 | 0 | 1 | 13 |
| Total | 146 | 408 | 851 | 138 | 42 | 25 | 34 | 1 644 |

Excludes extinct breeds; not shown: cassowary, duck × Muscovy duck, emu, guinea fowl, ñandu, peacock, quail, swallow

4.3 Regional transboundary breeds

For several species, including sheep, horses, pigs, and all avian species, Europe and the Caucasus, has the highest number of regional transboundary breeds. However, as Table 11 shows, a relatively large share of such breeds is also found in Africa. The latter region is dominant in terms of the numbers of regional transboundary breeds of cattle, goats and asses. Europe and the Caucasus, however, has by far the highest number of regional transboundary breeds among avian species (Table 12). The existence of significant numbers of regional transboundary breeds clearly has implications for management and conservation of AnGR, and highlights the need for cooperation at regional or subregional levels.

Table 11
Mammalian species – number of reported regional transboundary breeds

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific | World |
|-------------------------|--------|------|-----------------------|-------------------------------|--------------------|---------------|-------------------|-------|
| Buffalo | 0 | 8 | 1 | 1 | 0 | 0 | 0 | 10 |
| Cattle | 35 | 19 | 28 | 8 | 0 | 3 | 0 | 93 |
| Goat | 15 | 11 | 13 | 2 | 0 | 5 | 1 | 47 |
| Sheep | 27 | 13 | 79 | 2 | 4 | 6 | 3 | 134 |
| Pig | 2 | 2 | 17 | 3 | 0 | 1 | 0 | 25 |
| Ass | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 10 |
| Horse | 7 | 10 | 38 | 5 | 0 | 3 | 0 | 63 |
| Dromedary | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| South American camelids | | | | 6 | | | | 6 |
| Deer | | 1 | 1 | | | | | 2 |
| Rabbit | 3 | 0 | 32 | 1 | 0 | 0 | 0 | 36 |
| Guinea pig | | | | 1 | | | | 1 |
| Total | 95 | 68 | 211 | 30 | 4 | 18 | 4 | 430 |

Excluding extinct breeds

Table 12
Avian species – number of reported regional transboundary breeds

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | North America | World |
|---------|--------|------|-----------------------|-------------------------------|---------------|-------|
| Chicken | 6 | 2 | 45 | 1 | 1 | 55 |
| Duck | 0 | 2 | 12 | 0 | 0 | 14 |
| Turkey | 0 | 0 | 7 | 0 | 0 | 7 |
| Goose | 0 | 1 | 7 | 0 | 0 | 8 |
| Quail | 0 | 1 | 0 | 0 | 0 | 1 |
| Total | 6 | 6 | 71 | 1 | 1 | 85 |

Excluding extinct breeds

4.4 International transboundary breeds

Cattle, sheep, horses and chickens are the species that have the highest numbers of international transboundary breeds (Tables 13 and 14).

Table 13
Mammalian species – number of reported international transboundary breeds

| Species | Number of breeds |
|----------------|------------------|
| Buffalo | 5 |
| Cattle | 112 |
| Goat | 40 |
| Sheep | 100 |
| Pig | 33 |
| Ass | 6 |
| Horse | 66 |
| Bactrian camel | 2 |
| Dromedary | 2 |
| Deer | 10 |
| Rabbit | 23 |
| Total | 399 |

Excluding extinct breeds

Table 14
Avian Species – number of reported international transboundary breeds

| Species | Number of breeds |
|---------------------|------------------|
| Chicken | 101 |
| Duck | 12 |
| Turkey | 16 |
| Goose | 15 |
| Muscovy duck | 1 |
| Guinea fowl | 5 |
| Pigeon | 1 |
| Cassowary | 1 |
| Emu, Ñandu, Ostrich | 5 |
| Total | 157 |

Excluding extinct breeds

5 Risk status of animal genetic resources

A total of 1 491 breeds (or 20 percent) are classified as being “at risk” (Box 6). Figure 11 shows that for mammalian species, the proportion of breeds classified as at risk is lower overall (16 percent) than for avian species (30 percent). However, in absolute terms, the number of breeds at risk is higher for mammalian species (881 breeds) than for avian species (610 breeds).

Box 6**Glossary: risk status classification**

extinct: a breed is categorized as extinct when there are no breeding males or breeding females remaining. Nevertheless, genetic material might have been cryoconserved which would allow recreation of the breed. In reality, extinction may be realized well before the loss of the last animal or genetic material.

critical: a breed is categorized as critical if the total number of breeding females is less than or equal to 100 or the total number of breeding males is less than or equal to five; or the overall population size is less than or equal to 120 and decreasing and the percentage of females being bred to males of the same breed is below 80 percent, and it is not classified as extinct.

critical-maintained: are those critical populations for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

endangered: a breed is categorized as endangered if the total number of breeding females is greater than 100 and less than or equal to 1 000 or the total number of breeding males is less than or equal to 20 and greater than five; or the overall population size is greater than 80 and less than 100 and increasing and the percentage of females being bred to males of the same breed is above 80 percent; or the overall population size is greater than 1 000 and less than or equal to 1 200 and decreasing and the percentage of females being bred to males of the same breed is below 80 percent, and it is not assigned to any of above categories.

endangered-maintained: are those endangered populations for which active conservation programmes are in place or populations are maintained by commercial companies or research institutions.

breed at risk: a breed that has been classified as either critical, critical-maintained, endangered, or endangered-maintained.

Figure 11
Proportion of the world's breeds by risk status category

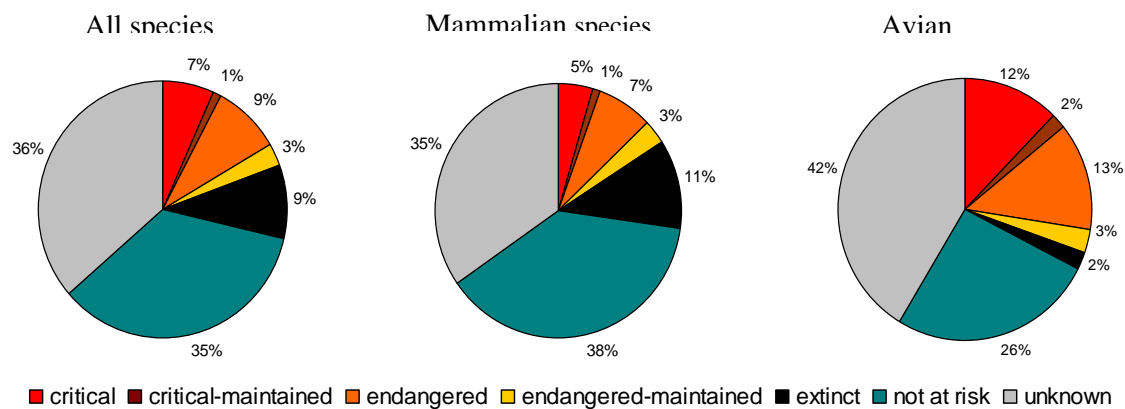
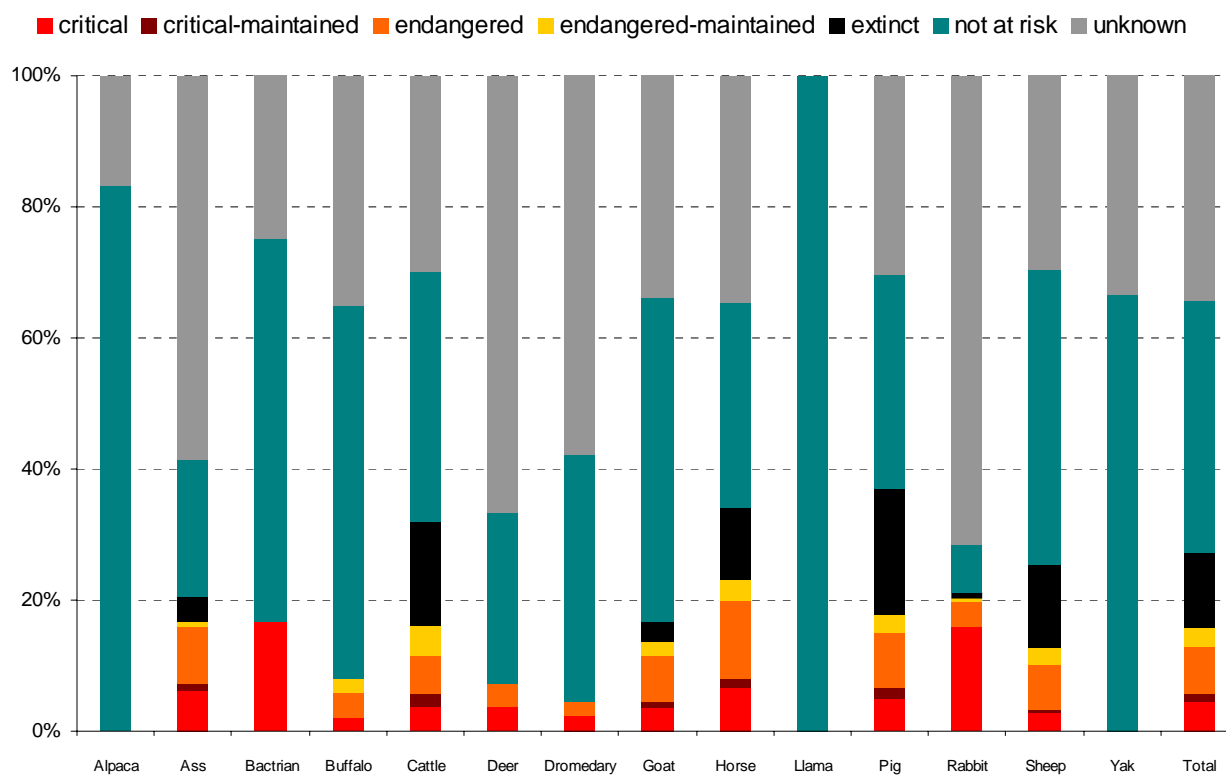


Figure 12 presents risk status data for mammalian species. It can be seen that cattle are the mammalian species with the highest number of breeds at risk. Horses (23 percent) followed by rabbits (20 percent) and pigs (18 percent) are, however, the species that have the highest proportions of at-risk breeds. Figure 12 also indicates the large number of breeds for which no risk status data are available. The problem is particularly significant in some species – 72 percent for rabbit breeds, 66 percent for deer, 59 percent for asses and 58 percent for dromedaries. This lack of data is a serious constraint to effective prioritization and planning of breed conservation measures. Cattle are the species with the highest number of breeds (209) reported as extinct. Large numbers of extinct pig, sheep and horse breeds are also reported. There is, however, clearly a possibility that there were breeds that became extinct before they were ever documented, and which are therefore missing from the analysis.

Figure 12
Risk status of the world's mammalian breeds in January 2006: absolute (table) and percentage (chart)
figures by species



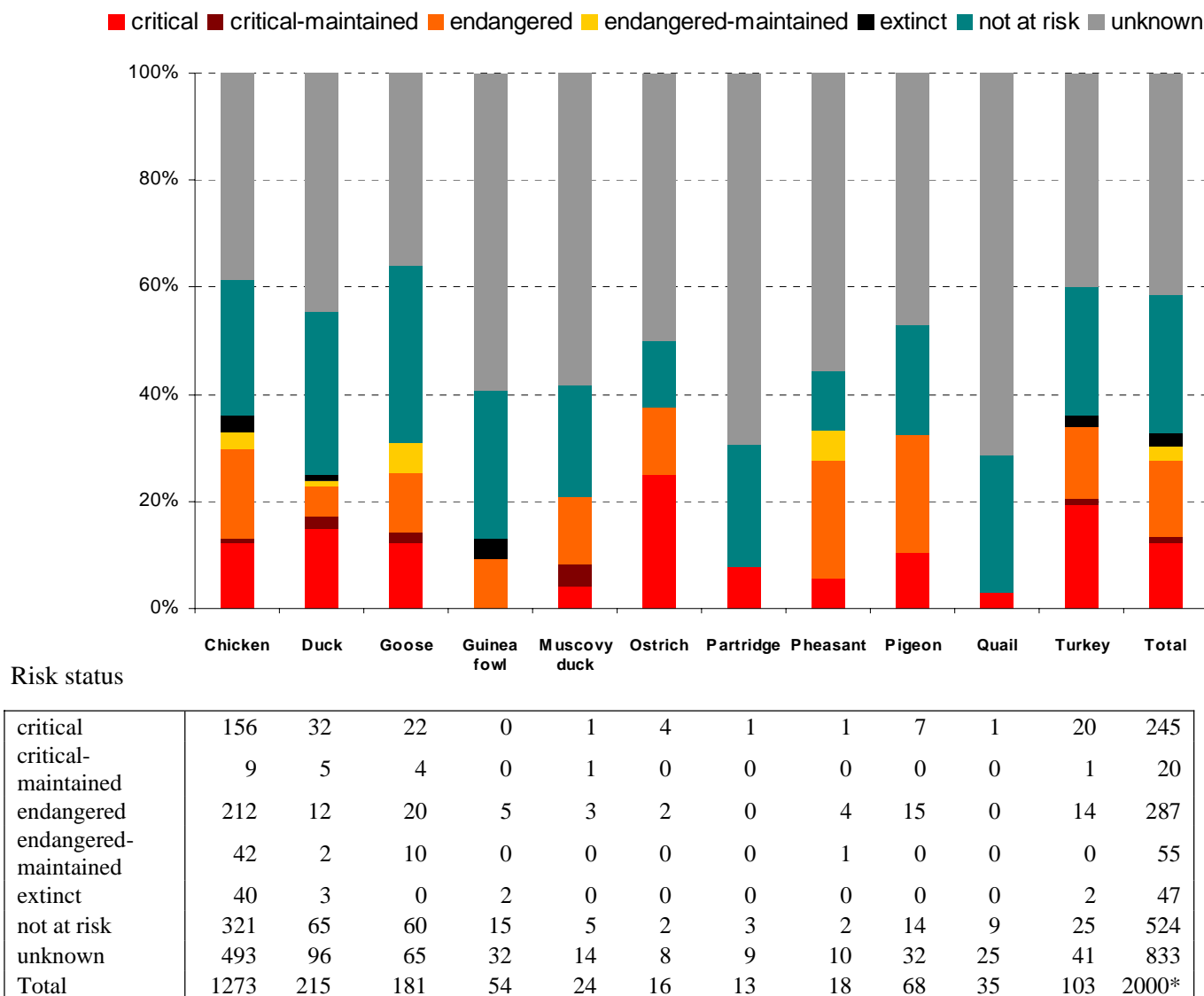
Risk status

| | | | | | | | | | | | | | | | |
|-----------------------|----------|------------|-----------|------------|-------------|-----------|-----------|------------|------------|----------|------------|------------|-------------|-----------|--------------|
| critical | 0 | 10 | 2 | 3 | 49 | 1 | 2 | 22 | 52 | 0 | 37 | 37 | 40 | 0 | 255 |
| critical-maintained | 0 | 2 | 0 | 0 | 26 | 0 | 0 | 5 | 10 | 0 | 11 | 0 | 5 | 0 | 59 |
| endangered | 0 | 14 | 0 | 5 | 75 | 1 | 2 | 44 | 95 | 0 | 63 | 9 | 98 | 0 | 406 |
| endangered-maintained | 0 | 1 | 0 | 3 | 60 | 0 | 0 | 13 | 24 | 0 | 22 | 1 | 36 | 0 | 160 |
| extinct | 0 | 6 | 0 | 0 | 209 | 0 | 0 | 19 | 87 | 0 | 140 | 2 | 180 | 0 | 643 |
| not at risk | 5 | 34 | 7 | 78 | 499 | 7 | 33 | 306 | 246 | 5 | 241 | 17 | 633 | 18 | 2129 |
| unknown | 1 | 95 | 3 | 48 | 393 | 18 | 51 | 209 | 272 | 0 | 225 | 166 | 417 | 9 | 1907 |
| Total | 6 | 162 | 12 | 137 | 1311 | 27 | 88 | 618 | 786 | 5 | 739 | 232 | 1409 | 27 | 5559* |

*The total number of breeds is actually higher than the number shown, as Bactrian camel × dromedary crosses, guanacos, vicuñas, guinea pigs and dogs (of which there are a total of 40 reported breeds) are not included.

Among avian species, chickens have by far the highest number of breeds at risk on a world scale (Figure 13). This is partly related to the large number of chicken breeds in the world, but the proportion of breeds at risk is also high in chickens (33 percent). Relatively high proportions and numbers of breeds at risk are also found among turkeys and geese. As in the case of mammalian species, there are a large number of breeds for which population figures are unavailable. Extinct breeds have mainly been reported among chickens. There are also a few cases among ducks, guinea fowls and turkeys.

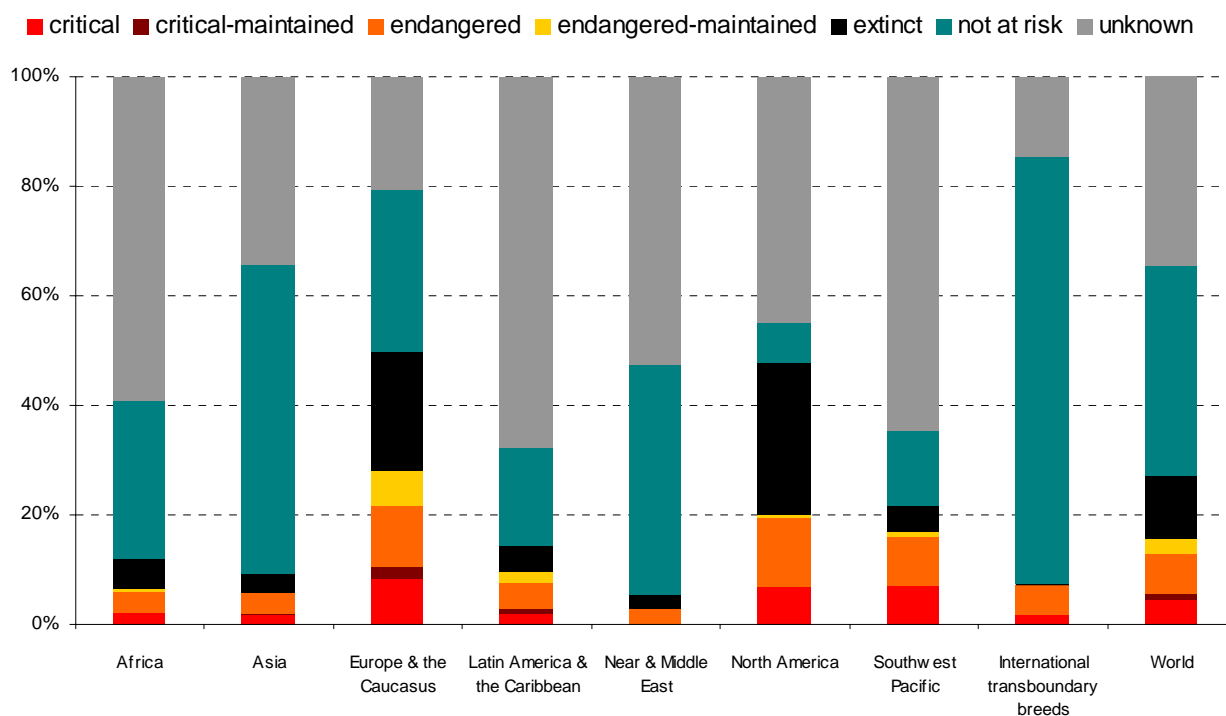
Figure 13
Risk status of the world's avian breeds in January 2006: absolute (table) and percentage (chart) figures by species



*The total number of breeds is actually higher than the number shown, as duck × Muscovy duck crossings, cassowaries, emus, ñandus, peacocks and swallows (of which there are a total of 17 reported breeds) are not included.

Figures 14 and 15 show the distribution of breeds at risk by region for mammalian and avian species respectively. The regions with the highest proportion of their breeds classified as at risk are Europe and the Caucasus (28 percent of mammalian breeds and 49 percent of avian breeds), and North America (20 percent of mammalian breeds and 79 percent of avian breeds). Europe and the Caucasus, and North America are the regions that have the most highly specialized livestock industries, in which production is dominated by a small number of breeds. In absolute terms, Europe and the Caucasus has by far the highest number of at-risk breeds. Despite the apparent dominance of these two regions, problems in other regions may be obscured by the large number of breeds with unknown risk status. In Latin America and the Caribbean, for example, 68 percent and 81 percent of mammalian and avian breeds, respectively, are classified as being of unknown risk status, while the figures for Africa are 59 percent for mammals and 60 percent for birds.

Figure 14
Risk status of the world's mammalian breeds in January 2006 absolute (table) and percentage (chart)
figures by region

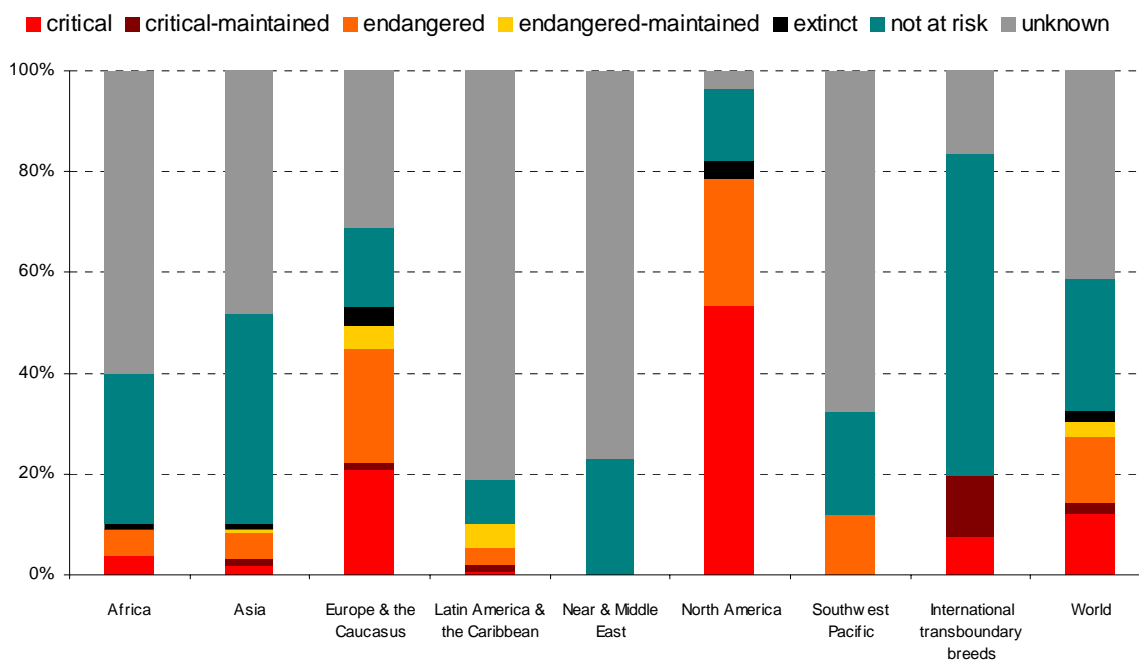


Risk status

| | | | | | | | | | |
|-----------------------|------------|-------------|-------------|------------|------------|------------|------------|------------|-------------|
| critical | 13 | 23 | 182 | 9 | 0 | 12 | 9 | 7 | 255 |
| critical-maintained | 0 | 4 | 51 | 4 | 0 | 0 | 0 | 0 | 59 |
| endangered | 26 | 50 | 249 | 21 | 6 | 22 | 11 | 22 | 407 |
| endangered-maintained | 4 | 3 | 142 | 9 | 0 | 1 | 1 | 0 | 160 |
| extinct | 35 | 45 | 481 | 21 | 5 | 49 | 6 | 1* | 643 |
| not at risk | 187 | 776 | 664 | 81 | 85 | 13 | 17 | 312 | 2135 |
| unknown | 384 | 469 | 459 | 304 | 107 | 79 | 80 | 58 | 1940 |
| Total | 649 | 1370 | 2228 | 449 | 203 | 176 | 124 | 400 | 5599 |

*African Aurochs, which once lived in parts of both the Africa and the Near and Middle East regions

Figure 15
Risk status of the world's avian breeds in January 2006 absolute (table) and percentage (chart) figures by region



Risk status

| | | | | | | | | | |
|-----------------------|------------|------------|------------|------------|-----------|-----------|-----------|------------|-------------|
| critical | 7 | 8 | 204 | 1 | 0 | 15 | 0 | 12 | 247 |
| critical-maintained | 0 | 6 | 12 | 2 | 0 | 0 | 0 | 19 | 39 |
| endangered | 10 | 23 | 220 | 5 | 0 | 7 | 4 | 0 | 269 |
| endangered-maintained | 0 | 3 | 45 | 7 | 0 | 0 | 0 | 0 | 55 |
| extinct | 2 | 5 | 39 | 0 | 0 | 1 | 0 | 0 | 47 |
| not at risk | 56 | 184 | 151 | 13 | 10 | 4 | 7 | 100 | 525 |
| unknown | 113 | 214 | 305 | 120 | 33 | 1 | 23 | 26 | 835 |
| Total | 188 | 443 | 976 | 148 | 43 | 28 | 34 | 157 | 2017 |

Tables 15 and 16 present the number of extinct mammalian and avian breeds by species and region. Europe and the Caucasus has by far the largest number of extinct mammalian and avian breeds – 16 percent of all reported breeds are extinct. However, it is the North America region that has the highest proportion of extinct breeds (25 percent) among its recorded breeds. The dominance of North America, and Europe and the Caucasus in terms of the numbers of extinct breeds, may relate to the greater levels of breed recording that have taken place in these two regions.

Table 15
Number of extinct mammalian breeds

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific | World |
|---------|--------|------|--------------------------|----------------------------------|-----------------------|------------------|----------------------|-------|
| Cattle | 23 | 18 | 141 | 19 | 1 | 4 | 2 | 209 |
| Goat | 0 | 2 | 16 | 0 | 0 | 1 | 0 | 19 |
| Sheep | 5 | 11 | 148 | 0 | 1 | 13 | 2 | 180 |
| Pig | 0 | 13 | 101 | 2 | 0 | 23 | 1 | 140 |
| Ass | 1 | 0 | 4 | 0 | 1 | 0 | 0 | 6 |
| Horse | 6 | 1 | 71 | 0 | 0 | 8 | 1 | 87 |
| Rabbit | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 |
| Total | 35 | 45 | 481 | 21 | 5 | 49 | 6 | 643 |

Table 16
Number of extinct avian breeds

| Species | Africa | Asia | Europe & the Caucasus | North America | World |
|-------------|--------|------|--------------------------|------------------|-------|
| Chicken | 0 | 5 | 34 | 1 | 40 |
| Duck | 0 | 0 | 3 | 0 | 3 |
| Turkey | 0 | 0 | 2 | 0 | 2 |
| Guinea fowl | 2 | 0 | 0 | 0 | 2 |
| Total | 2 | 5 | 39 | 1 | 47 |

The year of extinction has been reported for only 27 percent (188) of extinct breeds. Fifteen breeds became extinct before the year 1900, 111 between 1900 and 1999, and within the last six years another 62 breeds became extinct (Table 17).

Table 17
Years of extinction

| Year | Number of breeds | % |
|--------------|---------------------|-----|
| before 1900 | 15 | 2 |
| 1900–1999 | 111 | 16 |
| after 1999 | 62 | 9 |
| unspecified* | 502 | 73 |
| Total | 690 | 100 |

*unspecified = no year of extinction indicated

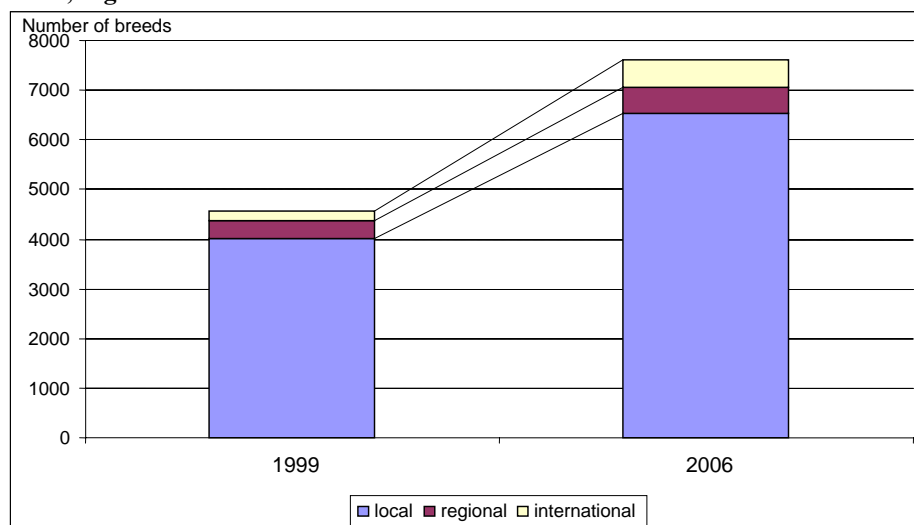
6 Trends in breed status

6.1 Changes in the number of breeds in the different breed groups

This subchapter describes the changes in the numbers of breeds classified as falling within each of the breed categories (local, regional transboundary and international transboundary) over the six years between December 1999 and January 2006³. The share of international transboundary breeds increased from 4 to 7 percent of the total during this period (from 197 to 557 breeds). This was accompanied by a slight decrease in the proportions of regional transboundary (absolute figures grew from 369 to 529 breeds) and local breeds (absolute figures grew from 4 013 to 6 536 breeds) (Figure 16).

³ Note that in 1999 the breed classification system (transboundary vs. local) had not been developed, and therefore the analysis presented here was carried out by applying the new procedure to the data from 1999 to allow comparison.

Figure 16
Local, regional and international breeds in 1999 and 2006



Had the classification existed in 1999, there would have been 369 regional transboundary breeds and 197 international transboundary breeds at this time. The higher proportion of international transboundary breeds in 2006 results partly from the fact that 86 breeds that would have been classified as regional transboundary breeds in 1999 were classified as international transboundary breeds in 2006 (283 remained as regional transboundary breeds) (Table 18). The other factor contributing to the increased proportion of international transboundary breeds is that among newly reported breeds there were more international transboundary breeds (274) than regional transboundary breeds (240) (Table 18). The changes can largely be accounted for by improved reporting, but also may also reflect the ongoing spread of breeds into new regions.

Table 18
Reclassification of regional and international transboundary breeds from 1999 to 2006

| Year | Category | 2006 | |
|-----------------------|---------------|----------|---------------|
| | | Regional | International |
| 1999 | Regional | 283 | 86 |
| | International | 0 | 197 |
| Newly reported breeds | | 240 | 274 |

6.2 Trends in genetic erosion

Because of the introduction of the new transboundary breed categories in 2006, a straightforward comparison of the total number of breeds in each risk status category is not possible. Thus, the comparison is presented in three parts. Trends among transboundary breeds are shown first, followed by trends among breeds that would have been classified as local in 1999 and (because of new reports) were classified as transboundary breeds in 2006. Finally, figures are presented for breeds that would have been classified as local in 1999 and were still classified as local in 2006.

Transboundary breeds

Comparison of the data in 1999 and 2006 shows a slight reduction in the proportion of breeds assigned to the unknown risk category. This indicates some improvement in data quality – about 20 percent of the 68 breeds previously classified as being of unknown risk status were reclassified in 2006 (Figure 17; Table 19). Table 19 also shows that more breeds moved from the at risk category into the not at risk category (25 out of 80, or 31 percent) than moved in the opposite direction (10 out of 411, or 3 percent). This can largely be explained by the fact that over the six years, further countries have reported the presence of some of the transboundary breeds, which has resulted in the breeds being

promoted into the not at risk category. The number of new transboundary breeds reported and their risk status categories are shown in Table 20.

Figure 17
Changes in risk status of transboundary breeds from 1999 to 2006

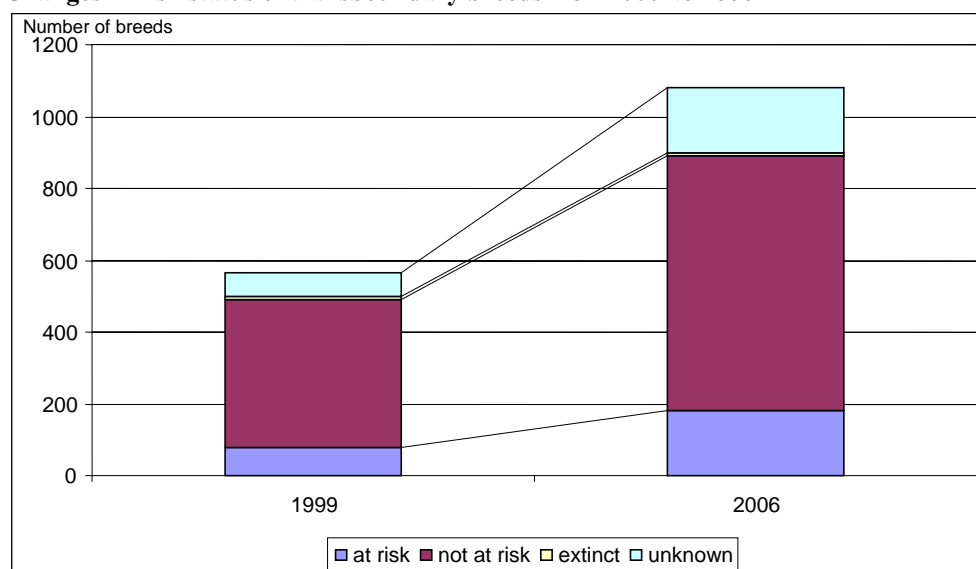


Table 19
Changes in risk status of transboundary breeds from 1999 to 2006

| Risk status in 1999 | No. of breeds in 1999 | Risk status in 2006 | | | |
|---------------------|-----------------------|---------------------|-------------|---------|---------|
| | | at risk | not at risk | extinct | unknown |
| at risk | 80 | 68% | 31% | 0% | 1% |
| not at risk | 411 | 3% | 97% | 0% | 0% |
| extinct | 7 | 0% | 0% | 100% | 0% |
| unknown | 68 | 6% | 15% | 0% | 79% |

Table 20
Risk status of transboundary breeds reported after 1999

| | Risk status in 2006 | | | | Total number |
|------------------|---------------------|-------------|---------|---------|--------------|
| | at risk | not at risk | extinct | unknown | |
| Number of breeds | 112 | 274 | 2 | 126 | 514 |

Local breeds (1999) reclassified as transboundary breeds (2006)

Had the classification system existed in 1999, 276 breeds classified as local 1999 would have been reclassified as transboundary breeds by 2006. Of the 87 such breeds that were classified as at risk in 1999, 39 (or 45 percent) were by 2006 classified as belonging to not at risk transboundary breeds (Table 21). This can largely be accounted for by the reporting of the breeds in question from additional countries. Table 21 also shows that there has been an improvement in data quality among this group of breeds – 61 percent (34 out of 56) of breeds with an unknown risk status in 1999 were assigned to a known risk status category by 2006.

Table 21
Changes in risk status of local breeds (1999) reclassified as transboundary breeds (2006)

| Risk status in 1999 | No. of breeds in 1999 | Risk status in 2006 | | | |
|---------------------|-----------------------|---------------------|-------------|---------|---------|
| | | at risk | not at risk | extinct | unknown |
| at risk | 87 | 51% | 45% | 0% | 5% |
| not at risk | 124 | 3% | 97% | 0% | 0% |
| extinct | 9 | 44% | 11% | 22% | 22% |
| unknown | 56 | 21% | 39% | 0% | 39% |

Local breeds

Over the 1999 to 2006 period, 20 percent of the breeds previously classified as being of unknown status were assigned to known risk status categories (Table 22, Figure 18) – an indication of improved reporting. Table 22 also shows that a slightly larger proportion of breeds moved from the at risk category into the not at risk category (7.4 percent) than vice versa (4.6 percent). However, this tendency is not reflected in absolute figures – 60 breeds moved from not at risk to at risk, and 59 breeds moved in the opposite direction. Of the local breeds at risk in 1999, 1.6 percent had become extinct by 2006, and among the local breeds not at risk in 1999 0.2 percent had become extinct.

Figure 18
Changes in risk status of local breeds from 1999 to 2006

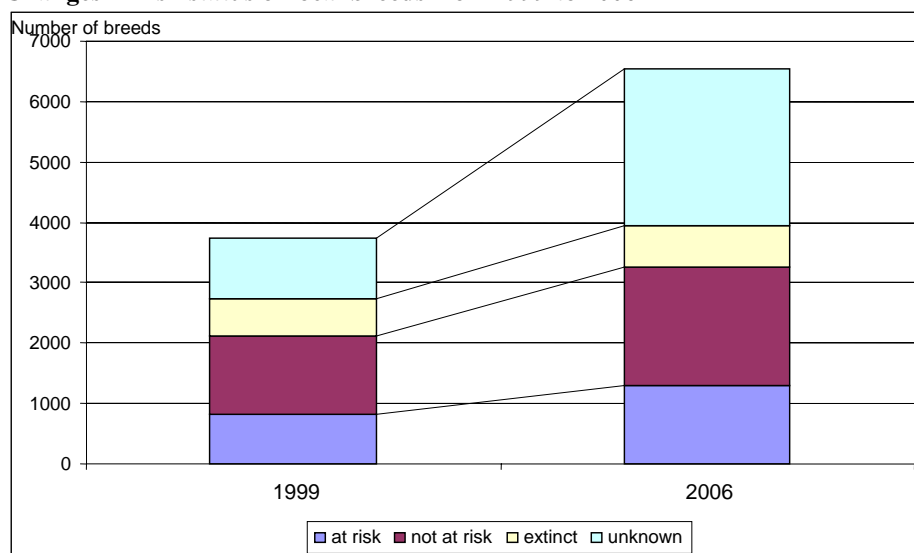


Table 22
Changes in risk status of local breeds from 1999 to 2006

| Risk status in 1999 | No. of breeds in 1999 | Risk status in 2006 | | | |
|---------------------|-----------------------|---------------------|-------------|---------|---------|
| | | at risk | not at risk | extinct | unknown |
| at risk | 815 | 91% | 7% | 2% | 0% |
| not at risk | 1295 | 5% | 93% | 0% | 2% |
| extinct | 623 | 2% | 0% | 97% | 0% |
| unknown | 999 | 8% | 10% | 1% | 81% |

The number of new local breeds reported, and their risk status categories are presented in Table 23. The relatively large number of breeds classified as being of unknown risk status is a result of the inclusion of breeds mentioned in the Country Reports, most of which did not include population data.

Table 23
Risk status of local breeds reported after 1999

| | Risk status in 2006 | | | | Total number |
|------------------|---------------------|-------------|---------|---------|--------------|
| | at risk | not at risk | extinct | unknown | |
| Number of breeds | 414 | 575 | 54 | 1758 | 2801 |

7 Conclusions

In the period from 1999 to 2006 the coverage of breed diversity in the Global Databank was further improved. However, breed-related information remains far from complete. For more than one-third of all reported breeds, risk status is not known because of missing population data. In Africa and the Southwest Pacific, for example, population size has not been reported for over two-thirds of breed populations.

The creation of the new transboundary breeds category (linking of national breed populations with a common gene pool) has eliminated unrealistic risk status denominations for these breeds – which previously occurred because estimates were based on population data at the level of the individual country. The linking of breeds was based on expert knowledge; more objective criteria for judging what constitutes a common gene pool need to be developed and applied in the future. The differentiation of transboundary breeds as regional or international was carried out in a formalized way, according to whether the respective breed is present in one or more than one SoW-AnGR region. Nonetheless, some breeds classified as international (e.g. those present on both sides of the border between the Africa and the Near and Middle East regions) have quite a limited distribution and would be better treated as regional transboundary breeds. Furthermore, in this first attempt to classify breeds according to their distribution, the population size of transboundary breeds in the respective countries was not considered, meaning that in some countries the report of a breed's presence may represent a small population that will only be temporarily present. A more differentiated distinction needs to be developed, as this classification has proved very useful for identifying patterns of AnGR exchange. It will also be useful for identifying cases in which regional collaboration in breed management is needed.

The two transboundary breed groups (regional and international) need to be distinguished with respect to their risk status. Breeds with a truly international distribution and exchange pattern are not under threat in terms of population size. However, in the case of breeds such as the Holstein-Friesian, a decline in the within-breed diversity that underlies efficient selection programmes may become a problem. Though regional transboundary breeds are found in several countries, some may be kept by marginalized ethnic groups and, thus, may become threatened along with the livelihood strategies of their keepers.

Measuring diversity on the basis of the number of breeds tends to overestimate genetic diversity in Europe and the Caucasus, where a long tradition of breeders' associations has led to the distinction of breeds that in some cases are very closely related. The contribution of some breeds to genetic diversity may, therefore, be quite small. It should, however, be noted that most studies of fancy breeds in developed countries reveal that these breeds add to overall diversity and may have a high conservation potential. The picture of diversity is further confounded by the advanced state of reporting in some regions, such as Europe and the Caucasus, and North America, where an almost complete coverage of existing breeds has been achieved.

For the identification of trends in erosion, local breeds give a clearer indication than do transboundary breeds (for which movement between categories and the higher number of national breed populations reported in 2006 confound the picture). The changes in risk status category among the local breeds already reported in 1999 were rather small, and do not indicate an improvement in the situation. The reasons for the movements between risk status categories are largely unknown. The question of whether conservation programmes have contributed to an increase in population size can only be answered on a case-by-case basis, as information as to which threatened breeds are covered by conservation programmes is incomplete. It is alarming that 45 percent of the newly reported local breeds for which population data are available are either at risk or already extinct.

Besides missing population data, a big weakness of the current monitoring of breed erosion is that it does not capture genetic dilution of local breeds by uncontrolled cross-breeding – a problem which is considered by many experts to be a major threat to AnGR diversity. Population size and structure as sole indicators of risk status may, therefore, be misleading. To arrive at a more comprehensive picture, more details of the geographical location of local breeds would be required, along with information on the distribution of imported live animals and genetic material in the country in question.

SECTION C: FLOWS OF ANIMAL GENETIC RESOURCES

1 Introduction

“Gene flow” (movements and exchange of animal breeds and germplasm) in livestock species has been taking place since prehistoric times, and has been driven by a range of factors. On a global scale, the most significant gene flows have involved the “big five” livestock species: cattle, sheep, goats, pigs and chickens. Focusing mainly on these five species, this section draws information from FAO’s DAD-IS Global Databank and selected literature to provide a description of the provenance and distribution the world’s major breeds.

The terms “North” and “South” are used here to refer to developed countries and developing countries respectively. The information available is often sketchy and incomplete. Statistics rarely specify both the source and the destination countries of breeding animals, and often differentiate data by species rather than breed. Other limitations include:

- there are no systematic records of breed population sizes – a breed’s presence in many countries does not necessarily mean it has a large global population;
- breeds from temperate zones are often better defined and documented than breeds from tropical regions and marginal areas;
- gene flows within large countries do not show up in the international statistics, unlike flows between small countries – a breed’s presence in many small countries may exaggerate its actual worldwide importance; and
- in contrast to plant genetic resources, no quantitative share of gene introgression can be given for livestock breeds due to the high levels of within-breed genetic variation.

These limitations mean that it is not possible to provide a comprehensive quantitative analysis of global exchanges between the North and the South. Despite these limitations, the data do allow the assessment of trends in, and the approximate magnitude of, movements and exchange of live animals, semen and embryos.

2 Driving forces and historical phases in gene flows

Gene flows have been determined and influenced by a wide range of factors – cultural, military, organizational, institutional, political, market, technological, research, disease and regulatory. The relative importance of these factors has changed during the course of history. Broadly speaking, three distinct periods can be distinguished in the pattern of global gene flow.

Prehistory to the eighteenth century: This phase spanned about 10 000 years, from the early days of domestication to the late eighteenth century. During this time, genes spread as a result of the dispersal of domestic animals by means of gradual diffusion, migration, warfare, exploration, colonization and trade.

Nineteenth to mid-twentieth centuries: During the period from the beginning of the nineteenth century until about the middle of the twentieth century, breeding organizations were established in the North. These organizations formalized the existence of numerous breeds, recorded their pedigrees and performance, and facilitated rapid improvements in output. The flow of genes was mainly among countries in the North (North–North flows), and from North to South. The driving forces behind this movement were technological developments, the demand for higher-producing animals, and the beginning of the commercialization of animal breeding in the North.

Mid-twentieth century to the present: During this phase, gene flows have been propelled by the existence of commercial breeding companies in the North, production differentials between North and South, and rapid globalization. Technological advances have made it possible to ship semen and

embryos instead of live animals. More recently, it has become possible to transfer entire production systems – to create controlled environments in other parts of the world. Furthermore, it is becoming feasible to identify and isolate genes. Focus is shifting to individual genes, rather than traits or entire genotypes. There are emerging international legal frameworks which regulate exchange mechanisms for genetic material, and intellectual property rights (IPRs) are beginning to be exerted.

These trends are ongoing, and have affected different parts of the world to different degrees. For example, in much of the world, breeding stock is still traded without any involvement of breeding organizations, much less of specialized breeding companies. Nevertheless, modern breeding approaches are increasingly being used in the South, and are promoting the spread of specialized breeds and production systems.

2.1 Phase 1: prehistory to the eighteenth century

In the early phases of stock breeding, domesticated animals were dispersed by gradual diffusion from their centres of domestication (see Section A). One major centre of domestication was in western Asia and the eastern Mediterranean. During what is now known as the “Neolithic revolution”, the four major mammalian livestock species – sheep, goats, cattle and pigs – were first domesticated in this region. Other centres of domestication were Southeast Asia (pigs, swamp buffaloes and possibly chickens), the Indus Valley (chickens and riverine buffaloes), North Africa (cattle and donkeys), and the Andes of South America (llamas, alpacas and guinea pigs). From these centres, domesticated animals spread gradually from neighbour to neighbour, and also as their keepers migrated to new areas. Livestock husbandry spread fairly rapidly throughout the Old World, with the exception of sub-Saharan Africa, where movement was much slower, probably because of endemic diseases (Clutton-Brock, 1999).

Domestication and dispersal contributed to increased variability within each species. As animals adapted to new environments and were subjected to different selection pressures, populations with new characteristics developed. Even in early historic times, selection was not only natural, but also influenced by cultural preferences. These processes led to the development of many local breeds (Valle Zárate *et al.*, 2006). Warfare and trade were important motors for the spread of animals such as horses and camels that are used for transport and riding. A supply of good horses was a vital element of military power, and this species dominated trade in genetic resources for centuries.

Colonization of new areas was another important vehicle for gene flow. The Romans invested in livestock breeding, and there is archaeological evidence that their improved, larger-sized breeds were disseminated to the countries that they occupied. However, with the decline of the Roman Empire, these improved animals faded away. Colonization also played an important role in later times: when Europeans colonized new continents they always brought their livestock with them (Box 7). It has been observed that Europeans managed to establish a permanent hold and cultural dominance only in temperate climates where European livestock also thrived (North America, southern South America, Australia, New Zealand and South Africa). These regions now dominate the export of livestock and animal products, although most had no cattle, sheep, pigs or goats 500 years ago (Crosby, 1986).

Box 7**Gene flows resulting from colonization**

The main domesticated species reached the New World and Australia only with the arrival of European explorers and colonizers. Columbus brought eight pigs from the Canary Islands to the West Indies in 1493, where they multiplied rapidly. Pigs then followed in the footsteps of Pizarro to the Inca Empire. Explorers and others released pigs on remote islands to ensure a food supply for the next generation of transient Europeans. Populations had often become established before the islands were named and documented.

Columbus also carried cattle, whose descendants were living as breeding herds in the West Indies (1512), Mexico (1520s), Incan region (1530s) and Florida (1565). In humid areas they took many generations to adapt, but in more favourable environments they doubled their populations every 15 years or so. The majority of cattle in the Americas were probably feral from the sixteenth to the nineteenth centuries. The cattle of Iberian descent had long horns and were more agile than the British and French breeds later introduced to North America.

Source: Crosby (1986)

2.2 Phase 2: nineteenth to mid-twentieth centuries

Until the end of the eighteenth century, European farmers did not generally put much emphasis on stock breeding. The introduction of the Arab horse into Britain stimulated livestock breeders to copy the Arab breeding practices of careful selection and maintaining pure lines. After the pioneering work of Robert Bakewell (1725–95), British breeders began to apply the same principles to their cattle and sheep, leading to the establishment of breeding societies and herd books in the early nineteenth century. From the 1850s onwards, gene flow in the form of registered pedigree animals became more commercial (Valle Zárate *et al.*, 2006). Breed societies initially focused on setting standards for external characteristics; performance testing began only in the early twentieth century.

Important prerequisites for selection for high performance were the intensification of agriculture, and the improvement of feeds. The exchange of genetic resources was facilitated by the invention of steamships. By the end of the nineteenth century, European countries had also developed specialized legislation to support and regulate animal breeding. Much of the gene flow was between European countries and their respective colonies, but there was also exchange within Europe, and from South to South. Because European cattle breeds did not do well in the humid tropics, Indian Ongole and Gir cattle were brought to Brazil, and Sahiwal cattle from India and Pakistan were introduced to Kenya.

2.3 Phase 3: mid-twentieth century to the present

Since about the middle of the twentieth century, a series of technological advances have facilitated gene flow. Commercial use of semen started in the 1960s, of embryos in the 1980s, and of sexed embryos in the mid-1990s (Valle Zárate *et al.*, 2006). Lack of artificial insemination (AI) coverage has meant slower gene flow in developing countries and in remote areas.

Towards the end of the twentieth century, gene flows to the South began to be fuelled by a growing number of consumers with a taste for, and who could afford, meat, milk, cheese and eggs – even in countries with no tradition of milk consumption. The resulting expansion of intensive livestock production systems in developing countries has been termed the “livestock revolution”. Monogastric animals (pigs and poultry) are increasing in numerical importance because they efficiently convert feed into meat or eggs. Small ruminants, especially sheep, are losing ground as grazing resources decline and the demand for wool decreases (FAO, 1999).

Various factors now shape the flow of livestock genes across national borders. These include the following:

Demand for optimal performance. Gene flows are driven by the desire of producers and breeders to obtain genotypes that perform optimally in a given production environment (Peters and Meyn, 2005). Both push and pull factors are involved. Exports generate profits, which help pay for breeding activities and can be reinvested in breeding programmes. At the receiving end, motives for importing genetics can vary. Countries such as China and Brazil are in the process of building up their own

intensive production systems and breeding programmes. Eastern European countries need to raise the performance of their dairy sectors, while Mediterranean, Near and Middle Eastern, and African countries traditionally import because of the high costs associated with developing their own breeding programmes.

Organization of breeding. The market for livestock genetics is highly competitive. Demand is based on proven performance – a supplier can sell a bull’s semen only if the bull has been shown to have sired superior calves. This means that efficient organization of breeding enterprises is decisive. It takes a long time to develop high-performing strains or hybrids, so a small number of companies and countries have established a lead and other actors find it difficult to catch up. Breeding and global gene flow in poultry and pigs has become dominated by a few large companies that have been in business since the 1960s. Concentration is also increasing in the cattle breeding sector. In sheep, multi-tiered hybrid production is less common at present. An example is Australia’s Awassi Joint Venture, established to supply live sheep to the Middle East for slaughter (Mathias and Mundy 2005). In many parts of the South, this pattern of large-scale structured commercial breeding has not yet taken hold.

Changes in consumer preferences. Changing consumer preferences and newly emerging market demands influence gene flow. For instance, demand for naturally grown beef has led to the importation of British and French beef breeds to Germany. There are predictions that pressure from the animal welfare lobby will promote the keeping of pigs in more extensive conditions, including in outdoor systems. This would require the development of new strains that are able to thrive under these conditions (Willis, 1998). Slackening demand for wool is promoting the spread of hair sheep.

Animal health and hygiene standards. High standards of hygiene and disease-free status enable a country to participate more easily in the market for genetic material. Australia, for example, is considered disease-free and faces no restrictions on exporting its genetic material. At the same time, it imposes strict quarantine standards to maintain this status and accepts semen and embryo transfers rather than live animals. Developing countries are at a disadvantage because they often cannot fulfil required standards. For instance, the Philippines imports milk buffalo germplasm from Bulgaria rather than from India – a closer and cheaper source – because the latter can not meet international sanitary standards.

Government policies. Governments often subsidize exports of their national genetics to assist their farmers, or they support the import of exotic genetics to build up national production systems. The latter has often been financed by bilateral and international aid. Alternatively, governments sometimes restrict export of their genetics in an attempt to monopolize them; examples include South American countries that have banned the export of camelids. History, however, shows that attempts to limit the spread of genetic resources are difficult to maintain. The Merino sheep spread throughout the world after the fall of the Spanish monopoly, Turkey was unable to prevent the global distribution of its Angora goat, and South Africa could not prevent the transfer of its ostrich genetic resources to other countries. History is now repeating itself in the commercial sector, as firms find it impossible to avoid the “leakage” of genes from primary customers to the whole industry, despite contractual arrangements prohibiting pure-breeding with the outsourced animals (Schäfer and Valle Zárate, 2006; Alandia Robles *et al.*, 2006; Musavaya *et al.*, 2006).

Ecological services. Use of livestock in landscape protection and biodiversity conservation – notably in Europe – has led to new demands for climate-tolerant, low-input breeds that can be kept outside even in harsh winters.

Search for specific characteristics. Scientific interest in specific genetic traits, related to disease resistance, fertility and product quality, also contributes to gene flow, though on a relatively small scale. Fayoumi chickens from Egypt, for example, were brought to the United States of America during the 1940s because of their resistance to viral diseases, and in 1996 the University of Göttingen imported frozen embryos of Dorper sheep to study their suitability for meat production in Germany (Mathias and Mundy, 2005). Similarly, Boer goats were brought to Gissen University (also in Germany).

3 The big five

During the past two centuries, global livestock numbers and the exchange of breeds and animal genetic material have greatly increased. North–North exchanges have prevailed. North–South and South–South exchanges have been more limited, and South–North flows have been the least frequent. Movements and exchanges have been particularly intensive in the dairy cattle, pig and chicken sectors (Mathias and Mundy, 2005; Valle Zárate *et al.*, 2006).

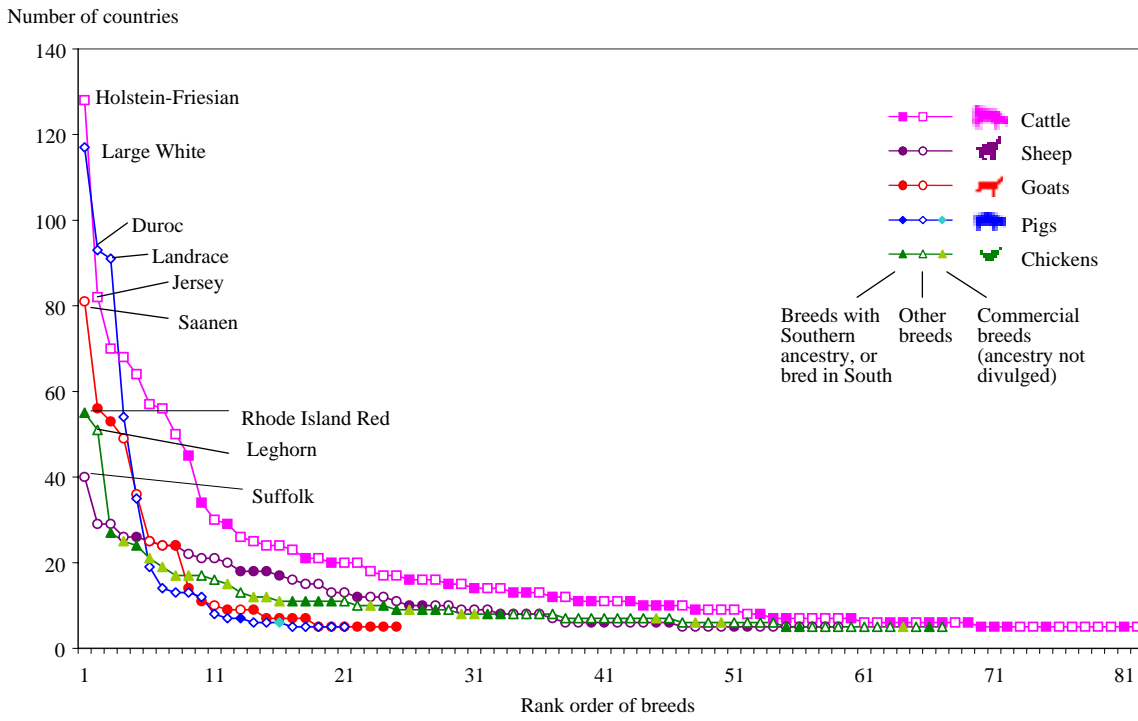
Very often, breeds have been developed or further improved outside their areas of origin, and then exported to third countries. Examples are the familiar Holstein-Friesian black and white dairy cow, the American Brahman and the Brazilian Nelore.

Nowadays, about 1 080 livestock breeds of all species are recorded as “transboundary” – meaning that they occur in more than one country (DAD-IS, 2006). Some 70 percent of these belong to five species – 205 breeds of cattle, 234 of sheep, 87 of goats, 59 of pigs, and 156 of chickens. Exchanges of these five species are discussed in detail below. A description of their current global distribution can be found in Section B.

Other livestock species (water buffalo, yak, horses, asses, camels, llamas, alpacas, reindeers, ducks, geese and turkeys) do not have such large populations, but are nevertheless important as they are crucial to the survival of millions of poor livestock keepers in developing countries and for the utilization of marginal areas.

Figure 19 shows the number of countries in which individual livestock breeds of the five major species are found. Note that the figure shows the numbers of countries where a breed is found, and not the size of the population. It is likely that in some countries an international breed is documented but has a small population. The graph shows all breeds reported from five or more countries. Each point in the graph corresponds to a single breed; the top few breeds of each species are named. For example, the most widespread dairy cattle breed, the Holstein-Friesian, is found in 128 countries worldwide.

Figure 19
Distribution of transboundary breeds



3.1 Cattle

Cattle genetics are exchanged in the form of live breeding animals (heifers, pregnant cows and bulls), semen and embryos. Large numbers of live animals are traded each year, but the majority are intended for fattening and slaughter rather than for breeding. The high cost of transport means that three zonal markets exist for live breeding animals: Europe, North America and the Southwest Pacific. From 1993 to 2003, the 15 countries that were then members of the European Union (EU-15) exported more than 150 000 breeding heifers a year. Roughly half of these stayed within the EU-15; almost all the rest went to North Africa, West Asia and Eastern Europe. At the same time, the EU-15 imported about 15 000 breeding heifers a year from outside, almost all from Eastern Europe and Switzerland, with small numbers coming from Canada and elsewhere. Imports from the United States of America were restricted because of disease considerations (Mergenthaler *et al.*, 2006).

The trade in semen is much larger than the trade in live animals – semen is easier to transport and is not subject to such stringent health and quarantine restrictions. According to Thibier and Wagner (2002), close to 20 million doses of semen were traded internationally in 1998. That was about 8 percent of the total number of deep-frozen doses produced worldwide. North America and Europe were the major exporters, and South America was the major importer. North America produced 70 percent of global semen exports, and the EU another 26 percent; the remainder came from other European countries, Australia, New Zealand and South Africa. The EU supplied about 3 million doses in 2003, mainly to other countries in Europe, Latin America, North Africa and North America. Asia (outside the Commonwealth of Independent States and Turkey) and sub-Saharan Africa received only 5 percent of the total (Eurostat, cited in Mergenthaler *et al.*, 2006). In 2003, EU countries imported about 6.8 million semen doses, most from other countries within the EU, and much of the remainder from the United States of America and Canada.

In 1991, three-quarters of global semen exports were of one breed – Holstein-Friesian. Other dairy breeds accounted for another 13 percent, beef breeds for about 10 percent, and tropical breeds, mainly Brahman, Red Sindhi and Sahiwal, for about 2 percent (Chupin and Thibier, 1995 cited in Mergenthaler *et al.*, 2006).

Trade in embryos has not reached the magnitude of trade in semen. Nevertheless, small numbers of embryos have sometimes sufficed to build up a large population. Examples are France's upgrading of its black and white cattle to Holstein-Friesian, which was achieved mainly through the import of fewer than 1 000 embryos from the United States of America (Meyn 2005 – personal communication cited in Mergenthaler *et al.*, 2006).

Breeds with European ancestry

Breeds of European descent account for eight of the top ten breeds, and 49 of the top 82 breeds (those distributed to five or more countries – see Figure 19). By far the most widespread breed is the Holstein-Friesian, which is reported in at least 128 countries, and in all regions (Figure 20). Next come Jersey (also a dairy breed, 82 countries), Simmental (dual-purpose, 70 countries), Brown Swiss (dual-purpose, 68 countries), and Charolais (beef, 64 countries – see Figure 21).

Figure 20
Distribution of Holstein-Friesian cattle



Figure 21
Distribution of Charolais cattle



Almost all the most successful European cattle breeds stem from northwestern Europe: principally the United Kingdom (11 breeds in the top 47), France (six breeds), Switzerland and the Netherlands. Relatively few come from the southern and eastern parts of the continent. Many of these are based on traditional breeds that emerged in the Middle Ages or earlier, often under the sponsorship of individual noblemen, wealthy individuals or monasteries. They were formalized in the nineteenth century with the formation of herd books and breeding societies. This occurred first in the United Kingdom, and then on the European continent, in the Americas and in the rest of the English speaking world (Valle Zárate *et al.*, 2006).

Several important breeds were developed on small islands (Jersey, Guernsey) or in remote mountainous areas (Simmental, Brown Swiss, Aberdeen Angus, Piedmont, Galloway, Highland) – areas which offered both isolation from other breeds and (in the case of mountains) the environmental stress needed to select for the hardiness prized in these breeds.

The spread accelerated in the 1800s. By 1950, most European breeds had been exported to other countries in the North. Exchange has continued right up to the present time: for example, the French Maine-Anjou breed was first imported into North America in 1969; Blonde d'Aquitaine, Salers and Tarentaise arrived in 1972. A breeders' association in the United States of America for the Parthenais breed was formed only in 1995.

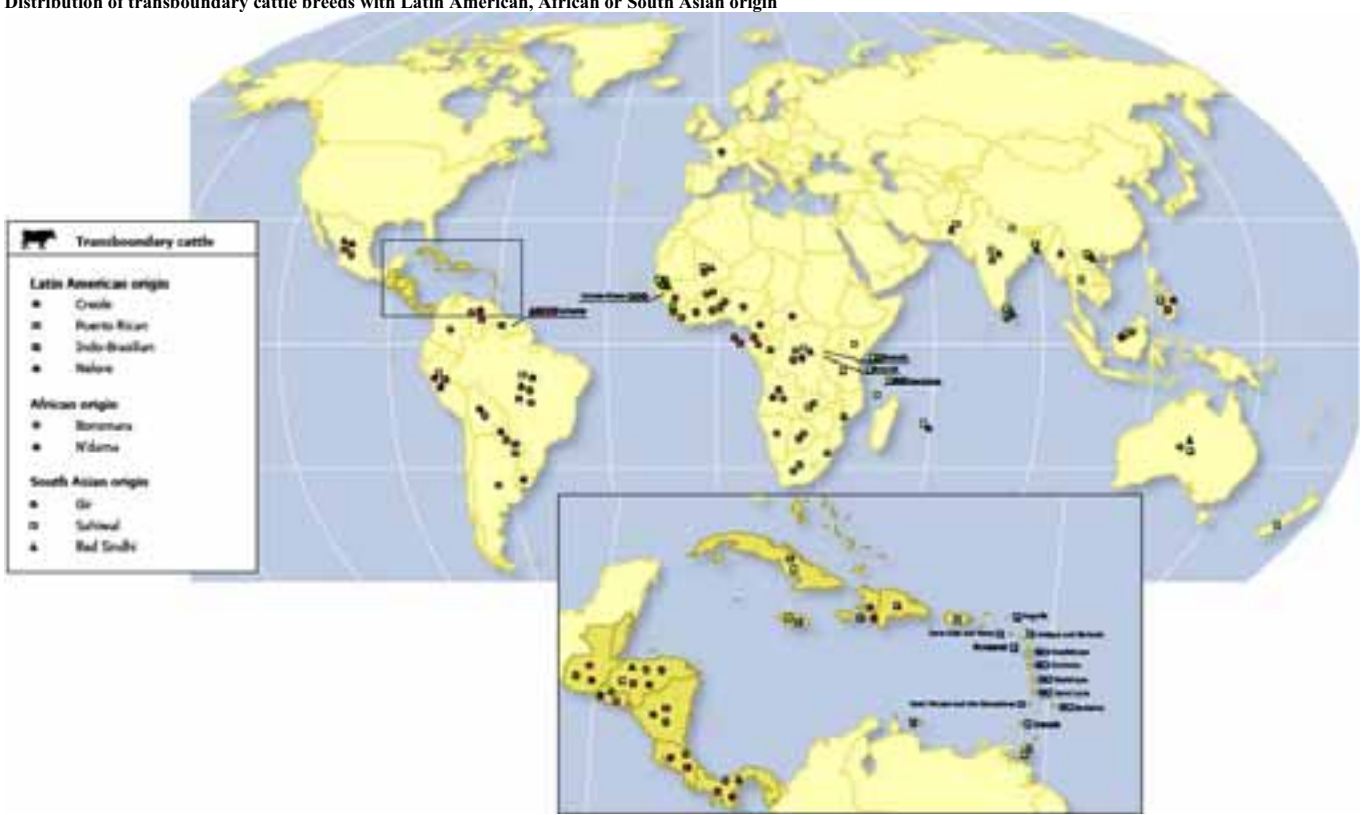
Particularly in the United States of America and Australia, European breeds have been further developed, and production of meat and milk often outstrips that achieved in their home areas. They have also been used as the basis of new breeds suited to temperate areas. Examples include Polled Hereford, Red Angus and Milking Devon in the United States of America. Indeed, North America has become an important source of genetic material for European livestock producers.

European breeds have also been successful in temperate areas of South America and in South Africa, as well as in the dry tropics. Numerous attempts have been made to introduce them into the humid tropics, but they have mostly failed (except in some highland and peri-urban areas) because the breeds are poorly adapted to the heat and low-quality forage, and often suffer from parasites and diseases. Nevertheless, the top five European breeds (Holstein-Friesian, Jersey, Simmental, Brown Swiss and Charolais) are reported in 11 or more countries in Africa, 16 or more in Latin America and the Caribbean, and five or more in Asia. In Latin America and the Caribbean, European cattle introduced by colonists developed into various breeds, the most prominent of which is the Creole. European breeds have been crossed with various tropical breeds to create new composite breeds that are more suited to the tropics (see under South Asian and African breeds below).

Breeds with South Asian ancestry

The second most successful group of breeds (in terms of their worldwide distribution) have South Asian ancestry. They include the Brahman (ranked ninth overall and found in 45 countries), Sahiwal (29 countries), Gir, Red Sindhi, Indo-Brazilian, Guzerat and Nelore. These breeds are all of the humped *Bos indicus* type, rather than the humpless *Bos taurus* (Figure 22).

Figure 22
Distribution of transboundary cattle breeds with Latin American, African or South Asian origin



Outside their home area, South Asian breeds have been most successful in tropical Latin America and Africa. The Sahiwal, the best Southern dairy breed, originates from Pakistan and India. It has been introduced to 12 African countries. Indeed, several South Asian breeds have been more successful abroad than at home (Box 8; Figure 22) – presumably because abroad they are prized for their meat (unlike in many areas of India, where cattle are mainly used for milk and draught, and for cultural reasons often cannot be sold for slaughter).

Box 8
Nelore cattle

The Nelore originates from Indian Zebu-type Ongole cattle which Brazil started to buy from India in the early 1900s. In Brazil the breed came to be known as Nelore, after the district of Nellore in present-day Andhra Pradesh, India. The breed thrived in South America, and in the 1950s Argentina started its own breeding programme for the “Nelore Argentino”. The Nelore was later exported to the United States of America and there became one of the progenitors of the Brahman. In 1995, the breed made up more than 60 percent of Brazil’s 160 million cattle and in 2005 some 85 percent of Brazil’s 190 million cattle, had Nelore blood.

Ironically, while the Ongole has been successfully established in a number of countries in North and South America, the Caribbean, Southeast Asia and Australia, its population has greatly declined in its original range in coastal Andhra Pradesh, and it is qualitatively inferior to the population in Brazil.

Source: Mathias and Mundy (2005)

Pure South Asian breeds have had little influence in most developed countries. However, breeds based on South Asian stock have had a major impact in the warmer parts of the United States of America and in northern Australia, where they have been bred primarily for beef production. From there, they have been exported to many tropical countries. The Brahman, for example (developed in the United States of America based on stock originally from India), is found in 18 countries in Latin America and 15 in Africa – figures similar to those for the Simmental, the most widely spread European dual purpose breed in these regions.

South Asian animals have also made a major contribution to composite breeds used elsewhere in the tropics. These include the Santa Gertrudis (descended from Shorthorn × Brahman crosses, and found in 34 countries around the world), Brangus (Angus × Brahman, 16 countries), Beefmaster (Shorthorn and Hereford × Brahman), Simbrah (Simmental × Brahman), Braford (Brahman × Hereford), Droughtmaster (Shorthorn × Brahman), Charbray (Charolais × Brahman) and Australian Friesian Sahiwal (Holstein-Friesian × Sahiwal). Virtually all this breeding work has been done in the southern United States of America and in Australia, beginning in the twentieth century. Many of these breeds have been re-exported to other countries, especially in the tropics, where they generally perform better than the European pure-breeds.

Other South Asian cattle breeds have not broken out of their home region. They include the Harijana, Siri, Bengali, Bhagnari, Kangayam and Khillari breeds – which are found in two or more countries in South Asia – along with numerous local breeds.

Breeds with African ancestry

African breeds account for relatively few of the breeds that have spread outside their home ranges. The N’dama, a trypanotolerant beef breed thought to have been developed in the Fouta-Djallon highlands of Guinea, is reported in 20 countries, all of them in West and Central Africa (Figure 22). It ranks only equal 20th among breeds in terms of the number of countries where it is reported. The Boran, a breed developed by Borana pastoralists in Ethiopia and improved by ranchers in Kenya (Homann *et al.*, 2006), is reported from 11 countries (nine in East, Central and Southern Africa, plus Australia and Mexico). The Africander is South Africa’s most popular native breed; it is reported from eight other countries in Africa, as well as from Australia. The Tuli from Zimbabwe is found in eight countries (four in Southern Africa, plus Argentina, Mexico, Australia and the United States of America).

African breeds have been crossed with European breeds to produce breeds such as the Bonsmara (the result of Africander × Hereford and Shorthorn crosses in South Africa – see Figure 22), Senepol (an

N'dama × Red Poll cross, bred in the US Virgin Islands and then imported into the United States of America) and Belmont Red (Africander × Hereford and Shorthorn crosses, bred in Australia). As the examples show, this cross-breeding has been carried out both in Africa (mainly South Africa) and elsewhere.

Breeds from other regions

Very few breeds from other parts of the world have spread far beyond their original ranges. Cattle from Central, East and Southeast Asia have had little impact on the world's herds.

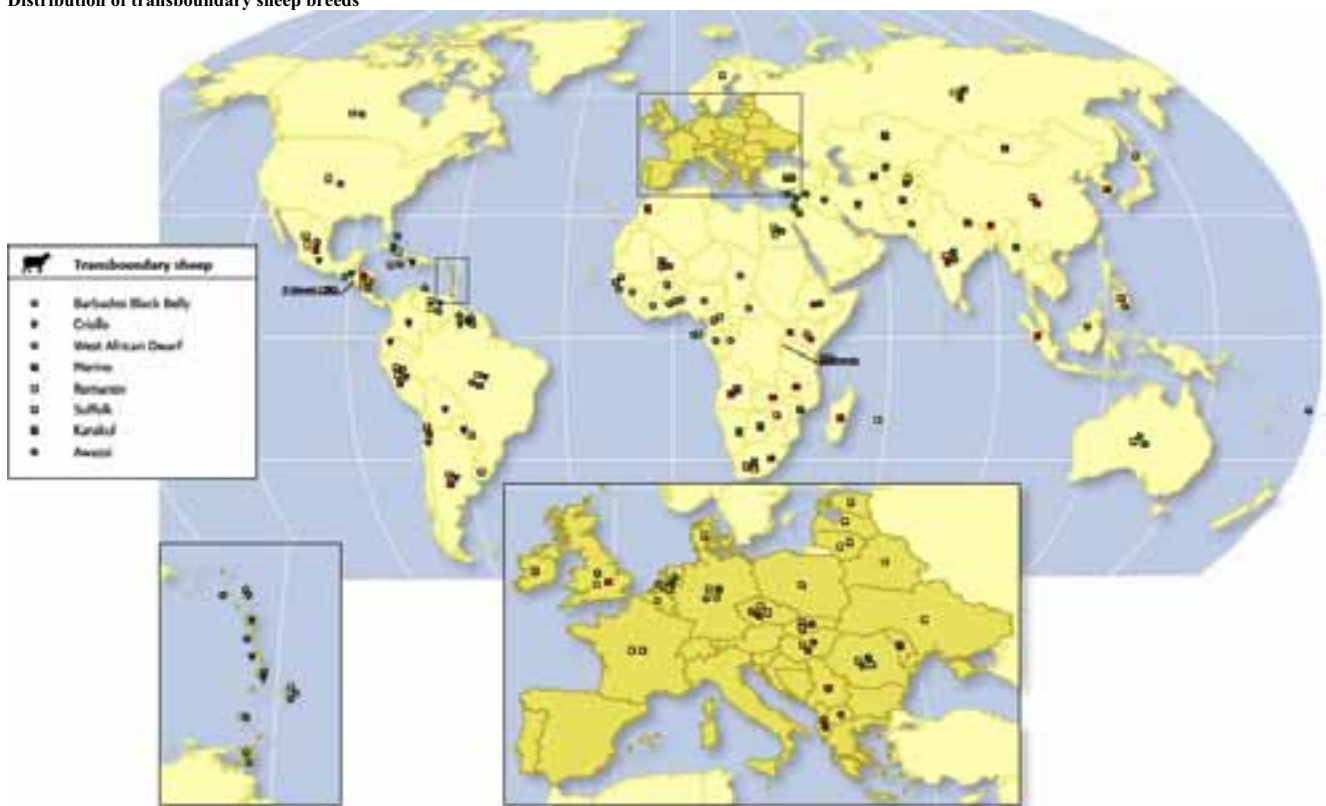
3.2 Sheep

Sheep are among the most widely distributed domestic species. They are multifunctional, adaptable, and there are no religious restrictions on their use for meat (at least among the dominant faiths). Breeding sheep are mainly exchanged as live animals. AI is less successful in sheep than in cattle. It requires capital-intensive production systems, and is important only where the use of fresh semen is practical, such as breeding programmes for dairy sheep in France, Italy and Spain (Schäfer and Valle Zárate, 2006). Some 59 breeds of sheep are reported from five or more countries. The most widely distributed breeds are the Suffolk, Merino and Texel, followed by the Corriedale and Barbados Black Belly.

Breeds with European ancestry

European sheep breeds are the most widespread in the world, but are not as dominant as European cattle breeds. They account for five of the top ten breeds worldwide, and 35 of the 59 breeds reported from ten or more countries (Figure 19). The top three breeds are all European in origin: Suffolk (a meat/wool breed from eastern England, found in 40 countries in all regions), Texel (a meat breed from the Netherlands, 29 countries) and Merino (a wool breed from Spain) (Figure 23). The Merino would probably rank first if all its many derivative breeds were counted – it has been widely cross-bred and selected to produce a multitude of new breeds.

Figure 23
Distribution of transboundary sheep breeds



Eight of the top European-origin breeds hail from southern and eastern England; three originated in France, while others came from Finland, Germany, the Netherlands, the Russian Federation and Spain. As with cattle, many of these breeds are traditional landraces that were formalized into breeds in the nineteenth century. European sheep breeds have spread to many other countries. They have been most successful in the temperate areas of North America and the Southwest Pacific. Transfers began with the first European settlement of these areas, and have continued up to the present. Canada is a frequent staging-post for European breeds before they are imported into the United States of America, presumably because of the latter country's regulations to prevent the spread of disease.

The EU-15 countries are net exporters of pure-bred sheep, with Spain playing a dominant role. Portugal, France and Germany also export small numbers of breeding sheep (Schäfer and Valle Zárate, 2006). Exchange takes place mainly among the EU-15 countries, with Eastern Europe as an important additional destination.

North America, Australia and New Zealand have active sheep breeding programmes. Three breeds developed in these areas have spread widely: the Corriedale, which is the fourth most widespread breed; the Katahdin (based on a cross between African and European breeds), and the Poll Dorset. All are based at least in part on European progenitors.

European breeds have been exported to only a few countries in the South, primarily the Merino (pure-breeds in 11 countries in Africa, six in Asia, and five in Latin America and the Caribbean), and the Suffolk (five African countries, four in Asia and 12 in Latin America and the Caribbean). Latin America and the Caribbean has been the destination of more European breeds than have other parts of the developing world. The Criollo, descended from early European imports, is present in nearly every country in Latin America and the Caribbean (Figure 23).

European breeds have contributed to many of the 440-plus composite breeds that have been developed during the past three to four centuries throughout the world (Shrestha, 2005, cited in Schäfer and Valle Zárate, 2006). Very widespread breeds with mixed European–non-European ancestry include the Barbados Black Belly and the Dorper.

African breeds

African sheep have been relatively successful. They (or their descendents) account for at least 11 of the 29 breeds found in ten or more countries. The West African Dwarf is found in 24 countries: 17 in Africa, three in Europe and four in the Caribbean (Figure 23). The Black Headed Persian, which comes from Somalia, has spread to 18 countries, including 13 in Africa. From South Africa it was exported to the Caribbean.

African breeds have also contributed to new breeds developed elsewhere in the world. The most successful is the Barbados Black Belly, a hair breed that emerged on the Caribbean island of Barbados in the mid-1600s and which has now found its way to 26 countries in the Caribbean and tropical America, and has also been exported to Europe, Malaysia and the Philippines. The South African Dorper breed is the second most common breed in South Africa, and has spread to 25 countries, mainly in Africa and Latin America. Its history illustrates the complex nature of gene flows (Box 9). The Katahdin was bred in the United States of America from crosses between West African Hair sheep and the Wiltshire Horn, and has been widely exported to Latin America. The St Croix is descended from West African Hair sheep (or possibly a Wiltshire Horn × Criollo cross). It was bred in the US Virgin Islands before being exported to other countries in the Americas and elsewhere.

Box 9**Continuous repackaging of genes –Dorper sheep**

The story of the Dorper sheep demonstrates the complex nature of gene flows, and the continuous recombination of traits which breeders undertake in response to changing market conditions. Dorper sheep were created in the 1930s in South Africa by crossing Black Headed Persians with Dorset Horns.

The Black Headed Persian breed actually has nothing to do with Persia, but was the result of four animals from Somalia that reached South Africa in 1868 on a ship that had originated in Persia, but which picked up the sheep in Somalia. One of the four sheep died, but the remaining animals formed the nucleus for a Black Headed Persian population which was registered in the South African stud book in 1906.

The Dorset Horn breed had originated from crossing Spanish sheep with native English stock during the sixteenth century. It had the unique property of producing lambs at any time of the year. These sheep were initially known as Portland sheep, but were then improved by mating with Southdown animals.

In 1995 Dorpers were imported to Germany, where they are gaining popularity because they do not require labour-intensive shearing in a situation where the market for wool has declined. Australian Dorper breeding animals are now exported to Viet Nam and India. Furthermore, the Dorper has been crossed with the Damara, a South African fat-tail breed to produce the Damper breed. Damper rams are crossed with Merino ewes to produce mutton animals which are shipped from Australia to the Middle East for slaughter.

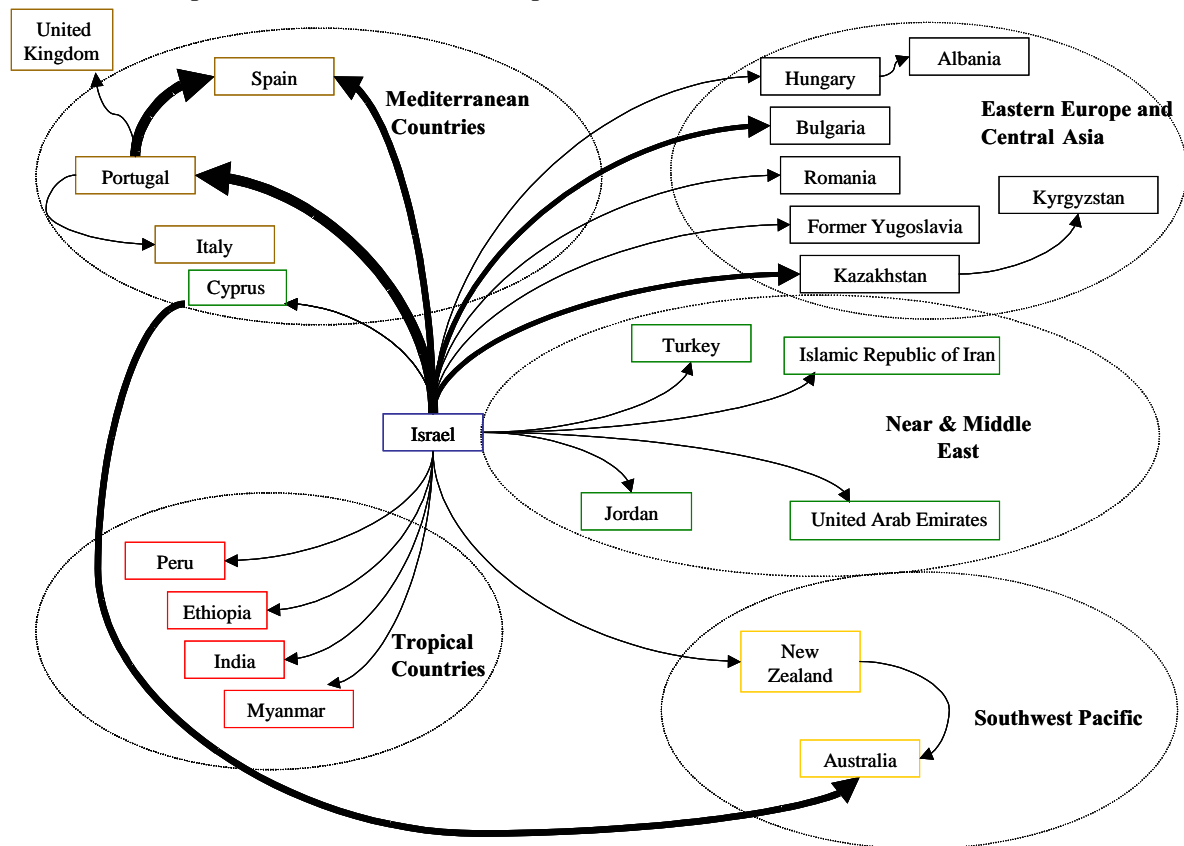
Source: Domestic Animal Genetic Resources Information System (DAGRIS) <http://dagris.ilri.cgiar.org/> (2006)

Other African breeds have remained more or less confined to the continent. Examples are the Fulani from West Africa (ten countries), the Uda from around Lake Chad (nine countries), and the Black Maure from Mauritania (six countries). All these breeds are kept by pastoralists, who migrate long distances and trade in livestock – accounting for the widespread distribution of these breeds in contiguous countries.

Breeds from Asia and the Near and Middle East

In contrast to Asian cattle, very few breeds from these regions have spread outside their home ranges – despite the fact that Asia has around 40 percent of the world's sheep. The exceptions are the Karakul and the Awassi. The Karakul, an ancient breed from Turkmenistan and Uzbekistan, is now found in substantial numbers in southern Africa, and has also spread to India, Australia, Brazil, Europe and the United States of America (Figure 23). The Awassi, a breed originally from Iraq, was improved in Israel around the 1960s, and has since spread to 15 countries in southern and eastern Europe, Central Asia, Australia and the Near and Middle East (Figures 23 and 24). Transfer to tropical countries in Africa and Asia has had only limited success (Rummel *et al.*, 2006).

Figure 24
Gene flow of improved Awassi and Assaf sheep from Israel



Source: Rummel *et al.* (2006)

3.3 Goats

Goats are of major economic significance for smallholders in the South, particularly in ecologically marginal areas such as drylands and mountains, where other domestic animals cannot easily be kept. They are of limited importance in Northern agriculture, though some high-yielding dairy breeds have been developed in central Europe through upgrading local stock with dairy breeds of Swiss origin. Rising living standards in the Near and Middle East, and the migration of people who prefer goat meat, have increased the demand for meat goats, furthering the spread of the Boer goat during the past few decades (Alandia Robles *et al.*, 2006).

With the exception of the top few widely distributed breeds, goat breeds are much less widespread than either cattle or sheep. The top eight breeds (Saanen, Anglo-Nubian, Boer, Toggenburg, Alpine, West African Dwarf, Angora and Creole) are all distributed in 24 or more countries and in several regions (Figure 19). However, there is then a sharp drop: the next most successful breed is the Sahelian, which is found in only 14 countries, all but one of which are in West Africa. All in all, fewer goat breeds have spread outside their home areas. Only three breeds (Saanen, Anglo-Nubian and Toggenburg) are reported from all regions of the world. In developed countries, the number of goat breeds fell drastically during the twentieth century as a result of the increasing importance of cattle.

Breeds with European ancestry

Purely European breeds account for only six of the top 25 breeds (those distributed in five or more countries). Most originate in the Alps, or were bred from stock coming from this area (Saanen, Toggenburg and various other Alpine breeds). Also among the top breeds (ranked seventh) is the Angora, a mohair breed from the area around Ankara in modern-day Turkey. This ancient breed fell out of fashion when Merino sheep became increasingly available for wool production, but with the

resurgence of interest in mohair in the 1970s, several countries started to improve their Angora populations (Alandia Robles *et al.*, 2006).

All the six top European breeds are also found outside Europe. The Saanen dairy goat is the most widely distributed breed – found in 81 countries and in all regions of the world (Figure 25). European goats have also provided breeding material for derivative breeds such as the Anglo-Nubian, Boer (Figure 26), Creole and Criollo.

Figure 25
Distribution of Saanen goats



Figure 26
Distribution of Boer goats



African breeds

African breeds make up seven of the 25 most widely distributed goat breeds. They fall into two groups: composites (usually developed through crosses with European breeds), which are widespread outside Africa; and breeds that have remained largely within Africa. In the former category are the Anglo-Nubian (developed in the United Kingdom by crossing British, African and Indian goats, and now reported from 56 countries all over the world), the Boer (bred in South Africa from indigenous,

European and Indian animals, and now found in 53 countries), and the Criollo (a Caribbean breed with African and European forebears). Breeds that have remained largely confined to Africa include the West African Dwarf (25 countries), Sahelian, Small East African and Tuareg. Where they have been exported to other countries, these breeds are kept in small numbers as experimental flocks or by hobby breeders.

Breeds from Asia and the Near and Middle East

The mountains of Southwest and Central Asia are the original home of goats. The wild bezoar and markhor are still found there. Other breeds from this region include the Angora (counted as European above), Cashmere, Damascus, Syrian Mountain, Russian Central Asian Local Coarse-Haired and its derivative the Soviet Mohair. The Damascus has recently been improved in Cyprus and has gained international recognition as an outstanding dairy breed for tropical and subtropical regions. While population numbers have remained small, the breed has spread around the Mediterranean basin (Alandia Robles *et al.*, 2006).

South Asia has over 200 million goats – one-quarter of the world’s population. However, South Asian breeds are confined largely to Asia. Only three make it into the top 25 breeds worldwide – the Jamnapari, Beetal and Barbari. East Asia has another quarter of the world’s goat population, but none of the world’s top 25 breeds (unless the Cashmere, whose range includes part of the subregion, is included).

Other breeds

Three breeds developed in the Americas make it into the top 25: the Creole, the Criollo and the La Mancha. All were developed from animals imported by European colonists.

3.4 Pigs

In the eighteenth century, small light-boned pigs from China and Southeast Asia were brought to Europe. The combination of European and Asian genetic material laid the foundation for the creation of modern European pig breeds.

After 1945, national, regional and commercial pig breeding programmes in Europe and North America began to develop. The primary focus was on home markets, but pure-breeds were also exported for cross-breeding: Hampshire, Duroc and Yorkshire from the United States of America to Latin America and Southeast Asia; and Large White (Figure 27) and Swedish Landrace from the United Kingdom to Australia, New Zealand, South Africa, Kenya and Zimbabwe (Musavaya *et al.*, 2006).

Figure 27
Distribution of Large White pigs



In the late 1970s, commercial operations started producing fattening pigs through hybrid breeding programmes (Box 10).

Box 10
Hybrid pigs

Hybrid breeding programmes use crosses between specialized sire and dam lines that have been developed through intense within-line selection of breeds including German Landrace, Piétrain, German Large White and Leicoma (Mathias and Mundy 2005). Whole herds of boars and gilts are exported as grandparent and great-grandparent stock for breeding programmes in other countries and regions – a process conducted under the supervision and often the ownership of the exporting company. The firms usually do not sell pure-bred pigs except under contracts that prohibit or control pure-breeding. Furthermore, the producers have to allow the breeding company to examine their record systems and to pay a “genetic royalty” every time a new breeding animal produced within the multiplication unit is transferred to the breeding unit (Alandia Robles *et al.*, 2006).

The largest commercial suppliers of breeding pigs are the British firm PIC (now Genus), which dominates the market in the United States of America, JSR (also based in the United Kingdom), and Topigs and Hyporc of the Netherlands.

For reasons of biosecurity, some companies sustain nucleus breeding herds in Canada. PIC, for example, has such a herd in Saskatchewan. Many international pig transfers originate from this herd, which contains breeds or lines sourced from all over the world (Alandia Robles *et al.*, 2006).

There are no public data on the export of hybrid pigs, but it is likely that they exceed the trade in pure-bred breeding animals reported in export statistics. The transfer of living animals dominates. The use of semen, embryos and other biotechnologies is increasing, but still plays only a small role. The main source countries of pig breeding material are the United Kingdom, the Netherlands, Denmark, Sweden, Belgium, Hungary and the United States of America. Strong breeding enterprises also exist in the South, for example in Thailand, the Philippines and China (Alandia Robles *et al.*, 2006).

European breeds

The worldwide distribution of pigs is dominated by just five breeds, all of them from Europe or the United States of America: the Large White (117 countries), Duroc (93 countries), Landrace (91 countries), Hampshire (54 countries) and Piétrain (35 countries). Breeds from Europe and United States of America also completely dominate the list of 21 pig breeds reported in five or more countries

– 15 are European breeds, all from northwest and central Europe: six from the United Kingdom, three from the Netherlands, two each from Belgium and Denmark, one from Germany, and one that originated in the former Austro-Hungarian Empire. Four of the remaining breeds are from the United States of America, and one is a commercial strain supplied by PIC, a large British pig breeder (see Box 10).

North American breeds

The most widespread breed from the United States of America is the Duroc (93 countries, ranked second worldwide). The origins of this reddish breed are unknown, but may include animals from Guinea in West Africa, Spain, Portugal and the United Kingdom. The other breeds from the United States of America in the top 21 worldwide are the Hampshire (developed in New Hampshire from British stock in the 1800s, 54 countries), the Poland China (from various sources, 13 countries), and the Chester White (from British stock, six countries).

Other breeds

The only other breed in the top 21 is the Pelon, a miniature from Central America found in seven countries. Despite the huge numbers of pigs in East Asia (more than half the world's total population), this region contributes none of the top 21 breeds. Asian pigs have, however, contributed to the world's most dominant pig breeds, as many European breeds are reputed to have some Chinese ancestry.

3.5 Chickens

Chickens are the oldest type of poultry. However, the most important breeds developed only in the second half of the nineteenth century, including the White Leghorn, New Hampshire and Plymouth Rock. White Leghorns are based on Italian country chickens that reached the United States of America in the 1820s, where they were selected for egg yield. They were re-imported to Europe after the First World War.

Chicken breeds are divided between layers (used mainly for egg production), broilers (for meat), dual-purpose breeds (meat and eggs), fighting breeds and ornamental breeds. In the North, commercial strains dominate the production of meat and eggs, while local breeds are restricted to the hobby sector. In the South, however, local breeds continue to play an important role; in some countries they make up 70–80 percent of the chicken population (Guèye, 2005; FAO, 2006). Chickens in the hobby sector look very different from each other, but that does not necessarily mean they are genetically very diverse (Hoffmann *et al.*, 2004). The same may be true for indigenous breeds in developing countries (FAO, 2006).

North American breeds

Chickens were introduced to North America by the Spanish and then by other Europeans in the 1500s. These birds gradually developed into distinct breeds. North American breeds now account for three of the top five most widely distributed breeds worldwide, and seven of the 67 breeds reported in five or more countries. The top three are Rhode Island Red, Plymouth Rock and New Hampshire. All three are dual-purpose layers/broilers developed in the northeastern United States of America.

European breeds

Breeds that definitively originated in Europe account for 26 of the 67 chicken breeds reported in five or more countries. The Leghorn mentioned above is the most widespread; it is found in 51 countries, and ranks second overall. It is also an important contributor to commercial strains. The second most common European breed is the Sussex from the United Kingdom, which is found in 17 countries (tenth overall).

Commercial strains

Commercial strains dominate the worldwide distribution of chickens, accounting for 19 of the top 67 breeds. Because the companies involved keep their breeding information secret, there is no information on the provenance of these strains. However, most appear to be derived from White

Leghorn, Plymouth Rock, New Hampshire and White Cornish (Campbell and Lasley, 1985). Commercial strains are controlled by a small number of transnational companies based in northwestern Europe and the United States of America. There has been further consolidation in the industry in recent years. Today, only two primary breeding companies (Erich Wesjohann based in Germany and Hendrix Genetics from the Netherlands) dominate the international layer market, and three primary breeders (Erich Wesjohann, Hendrix Genetics and Tyson, a company from the United States of America) dominate the market for broilers. The companies maintain many separate breeding lines (Box 11), and different units within a company may even compete with one another for market share (Flock and Preisinger, 2002; company websites).

Box 11

The chicken breeding industry

Breeding companies have developed a series of lines, each with a set of desirable characteristics, such as egg-laying ability or high growth rate. These lines are then crossed with each other, and then with still more lines, to produce hybrid birds that lay the eggs or produce the broilers that end up on consumers' tables. The companies closely guard their pure-line breeding stock. The structure of the industry is illustrated in Figure 48 (in Part 4 – Section D). Developing pure-lines with desirable characteristics is costly and time consuming; new entrants to the breeding industry would have to invest large sums to break into the market, so it is cheaper to rely on existing suppliers of breeding stock. The large breeding companies lack the local presence and expertise to penetrate new markets, and so often license local companies to act as distributors of their breeding stock to outgrowers.

Source: Mathias and Mundy (2005)

Breeds from other areas

The most widespread breed not included in the categories above is the Aseel, which hails from India, and is reported from 11 countries, ranking only 17th in the world. It is followed by several Chinese breeds: the Brahma and Cochin (which were developed further in the United States of America) and the Silkie (a breed with fur-like feathers). Other Asian breeds are considered as “ornamental” in the West: Sumatra (from Indonesia, eight countries), Malay Game and Onagadori (a long-tailed breed from Japan). Also worth mentioning is the Jungle Fowl (5 countries) from Southeast Asia, which is the ancestor of modern chickens.

The only Australian breed in the top 67 breeds is the Australorp, derived from the Black Orpington, a British breed. Reported from 16 countries, this breed ranks 12th overall in terms of distribution. Its claim to fame is that it holds the world record for egg-laying – a hen once laid 364 eggs in 365 days.

3.6 Other species

Gene flow has also been significant in other livestock species. Among horses, for example, the Arabian breed is the most successful on a world scale. It has had unique influence on horse breeds throughout Europe and has spread to 52 countries. The Pekin Duck breed originated in the 1870s in the United States of America, based on a founder population from China. It is now the most widespread duck breed, reported in 35 countries worldwide. In the nineteenth century, dromedaries were exported to Australia, North America, South Africa, Brazil, and even Java. While they immediately died of disease in Java, the Australian deserts were such a suitable environment that large feral herds established themselves. From their original home in Asia, yaks have been introduced to the Caucasus, North America (3 000 animals) and many countries in Europe. They were imported to Europe mainly as a curiosity, but have proved to have certain advantages for mountain husbandry systems as they require next to no inputs. Their meat can be marketed and they have tourist value. From the United States of America they were further disseminated to Argentina. Domesticated reindeer from Siberia were brought to Alaska in 1891, and from there were introduced to Canada. The species was introduced to Iceland between 1771 and 1787, and subsequently turned feral. In 1952 they were introduced from Norway into Greenland (Benecke, 1994).

4 Impacts of gene flows on diversity

Gene flow can both enhance and reduce diversity. The type of impact depends on a number of factors, which include the environmental suitability in the receiving country, and the organizational structures on both the receiving and the providing side (Mathias and Mundy, 2005). Importantly, the amount of material transferred is not indicative of its impact. There have been cases where the import of a handful of animals had an enormous effect on breed development. In other cases, large numbers of animals were imported without much effect.

During the first two phases of gene flow described above, which spanned the period from the beginning of animal husbandry in prehistory to the mid-twentieth century, gene flow generally enhanced diversity. However, during the past four to five decades the development and expansion of intensive livestock production and the export of entire production systems have led to a reduction in diversity through the large-scale replacement of local breeds with a small number of globally successful breeds.

This process has already run its course in North America and Europe, where 50 percent of documented breeds are classified as extinct, critical or endangered. It is now being replicated in those developing countries, such as China that give priority to intensive production systems and have the resources to establish them.

4.1 Diversity-enhancing gene flow

Throughout history, gene flow has been crucial to the development of diversity, which in turn enabled livestock keepers to adapt to new situations and requirements.

Gene flow enhances diversity in the following situations:

- **Imported animals or breeds adapt to the local environment, and a local variety of the imported breed develops.** One example was the introduction of Spanish and Portuguese breeds to South America, which eventually resulted in the hardy Criollo breeds. Another is the spread of Merino sheep through much of Europe and to many countries elsewhere in the world.
- **Imported animals or breeds are crossed with the local livestock, and synthetic breeds are developed which have characteristics of both parent breeds.** For example, the cross-breeding of Chinese and Southeast Asian pigs with European stock led to the development of fast-growing, precocious pig breeds in the 1880s. In South America, the beef industry developed after breeds such as Ongole and Gir were imported and cross-bred with the local Criollo. Structured cross-breeding programmes can also serve to reduce the loss of diversity if they create a justification for the maintenance of pure-bred populations of local breeds that would otherwise decline.
- **Selective use of “fresh blood” in herd book breeds.** Judicious infusion of “fresh blood” by discriminate use of sires from different breeds has often been used by breeders to maintain the vitality of otherwise closed gene pools. An example is the occasional introduction of English or Arabian thoroughbred sires into local German horse breeds.
- **Targeted transfer of gene(s) for specific characteristics.** This has become possible with advances in statistics and biotechnology. An example is the introduction of the Booroola gene encoding litter size into improved Awassi sheep in Israel to create the Afec Awassi. The gene can be traced to a flock of Indian Bengal sheep imported into Australia at the end of the eighteenth century. In 1993, the discovery of a genetic marker for the gene made it possible to identify carriers. The gene and its marker have since been patented (Mathias and Mundy, 2005; Rummel *et al.*, 2006).

The following quotation taken from Cemal and Karaca (2005) provides several other examples of such “major genes” (along with relevant references for further reading) “[in sheep, the] Inverdale gene affecting ovulation rate (Piper and Bindon, 1982; Davis *et al.*, 1988) and the callipyge gene affecting

meat production (Cockett *et al.*, 1993); in cattle, the double muscling gene affecting meat production (Hanset and Michaux, 1985a,b); in pigs, the halothane sensitivity and the RN genes affecting meat quality (Archibald and Imlah, 1985), and the oestrogen receptor locus affecting litter size (Rothschild *et al.*, 1996); and in poultry, the naked-neck gene affecting heat tolerance and the dwarf gene affecting body size (Merat, 1990).”

Markers for genes responsible for desirable traits make it possible to select carriers of the trait in question and use these animals for breeding in marker assisted introgression programmes. Experiences from the few existing programmes indicate that the method could bring economic benefits in developing countries. However, use of this technology should be decided on a case-by-case basis, and will work only against the background of a sound existing breeding programme and intensive data recording (FAO, 2007).

4.2 Diversity-reducing gene flow

Replacement of local breeds. Gene flow reduces diversity when high-performance breeds and intensive production systems replace local breeds and production systems. Since the mid-twentieth century, a few high-performance breeds, usually of European descent and including Holstein-Friesian and Jersey cattle, Large White, Duroc and Landrace pigs, Saanen goats, and Rhode Island Red and Leghorn chickens, have spread throughout the world, and have often crowded out the traditional breeds. This process is largely complete in Europe and North America, but is now being repeated in many developing countries that have so far retained a large number of indigenous breeds. It is difficult to quantify this effect, because the necessary data have not been compiled, and because other factors have also contributed to the erosion of diversity. However, it is no exaggeration to say that the South will be the hotspot of breed diversity loss in the twenty-first century (Mathias and Mundy, 2005).

- In Viet Nam, the percentage of indigenous sows declined from 72 percent of the total population in 1994 to only 26 percent in 2002. Of its 14 local breeds, five breeds are vulnerable, two are in a critical state, and three are facing extinction (Huyen *et al.*, 2006).
- In Kenya, introduction of the Dorper sheep breed has caused the almost complete disappearance of pure-bred Red Maasai sheep (see Box 95 in Part 4 – Section F).

Dilution and disintegration of local breeds. Local breeds have often been diluted by indiscriminate cross-breeding with imported stock, often without significant gains in production levels or other desirable characteristics. In India, for example, the government has supported cross-breeding with Holstein-Friesian, Danish Red, Jersey and Brown Swiss for many decades. This has led to dilution of local breeds, but often it has not had much effect on production levels. The increased milk production in India can largely be attributed to the greater use of buffaloes and structural changes in the dairy sector (Mathias and Mundy, 2005). Indiscriminate promotion of cross-breeding with exotic breeds can result in the total disintegration of local breeds. Upgrading of *Bos indicus* cattle breeds with Northern *Bos taurus* breeds often has negative effects on fertility.

4.3 Diversity-neutral gene flow

The flow of breeds and genes has often had no sustained effect on local biodiversity in the receiving country. Many efforts to introduce breeds into a new country have failed. This has been most apparent in the case of the import of European breeds into the humid tropics – large sums have been spent on shipping animals around the globe, but they have failed to become established in their new homes.

4.4 The future

How gene flow will affect diversity in the future will depend primarily on the policy and legislative frameworks that are now in the process of being developed. In the context of the ongoing “livestock revolution”, it seems likely that the transfer of pig and cattle breeding systems will continue and even increase in pace in the rapidly developing countries of the South. The crowding out of local breeds is,

thus, set to accelerate in many developing countries, unless special provisions are made for their *in situ* conservation by providing livestock keepers with appropriate support.

However, countries are becoming increasingly concerned about the effect of indiscriminate imports on their indigenous breeds. For example, Japan recently announced its intention to protect its Wagyu cattle breeds by according “geographic indications” (similar to trademarks) for products from pure-bred Wagyu animals. While for decades, governments of developing countries gave preference to exotic breeds, a move in the opposite direction can now be observed, with calls to prohibit farmers from using exotics (potentially resulting in negative impacts on the livelihoods of those who would benefit from using these breeds).

Possible dangers to the free exchange of genetic resources lie in the widespread adoption of the Access and Benefit Sharing (ABS) concept, since this would necessitate bilateral negotiations at government level, in order to work out the details of possible benefit-sharing arrangements, every time breeding stock moves across national borders. It can be expected that this will increase bureaucratic red tape, making it more difficult, or in some cases even impossible, to exchange genetic material. The (still limited) experience from plant genetic resources has shown that governments rather than farmers benefit from ABS regimes.

Implementation of such concepts would mean that governments would have to give permission for all transfers of genetic material across national borders and set the conditions under which these take place. This could reduce the ability to form new breeds and damage the business of livestock breeders, as well as harm agricultural economies. Because of fears of biopiracy, countries might be hesitant to give official access to their genetic resources.

The greater use of IPR regulations also has the potential to restrict the exchange of AnGR. Trade secrets and licensing agreements are already the rule in commercial poultry and pig breeding, leading to control over genes within a concentrated private sector. Use of the patent system to obtain control over breeding processes could further concentrate animal breeding in a few hands.

5 References

- Alandia Robles, E., Gall, C. & Valle Zárate, A.** 2006. Global gene flow in goats. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 229–240. FAO, GTZ, BMZ. (in press).
- Archibald, A.L. & Imlah, P.** 1985. The halothane sensitivity locus and its linkage relationships. *Animal Blood Groups and Biochemical Genetics*, 16: 253–263.
- Benecke, N.** 1994. *Der Mensch und seine Haustiere*. Stuttgart. Theiss Verlag.
- Campbell, J.R. & Lasley, J.F.** 1985. *The science of animals that serve humanity*. New York, USA. McGraw-Hill.
- Cemal, İ. & Karaca, O.** 2005. Power of some statistical tests for the detection of major genes in quantitative traits: I. Tests of variance homogeneity. *Hayvansal Üretim*, 46(2): 4046. (available from http://web.adu.edu.tr/akademik/icemal/Papers/34_HayvansalUretim-MajorGen-I.pdf (accessed 22 May 2006))
- Chupin, D. & Thibier, M.** 1995. Survey of the present status of the use of artificial insemination in developed countries. *World Animal Review*, 82: 58–68.
- Clutton-Brock, J.** 1999. *A natural history of domesticated mammals*. 2nd edition. Cambridge, UK. Cambridge University Press.
- Cockett, N.E., Jackson, S.P., Green, R.D., Shay, T.L. & George, M.** 1993. Identification of genetic markers for and the location of a gene (callipyge) causing muscle hypertrophy in sheep. *Proc. Texas Tech. Univ. Agric. Rep.*, No. T-5-327: 4–6.
- Crosby, A.** 1986. *Ecological imperialism*. Cambridge, UK. Cambridge University Press.
- DAD-IS.** 2006. *Domestic Animal Diversity Information System (DAD-IS)*. FAO (available at <http://www.fao.org/dad-is/>).

- DAGRIS.** 2006. *Domestic Animal Genetic Resources Information System*. International Livestock Research Institute (available at <http://www.dagris.ilri.cgiar.org>).
- Davis, G.H., Shackell, G.H., Kyle, S.E., Farquhar, P.A., McEwan, J.C. & Fennessy, P.F.** 1988. High prolificacy in screened Romney family line. *Proceedings of the Australian Association for Animal Breeding and Genetics*, 7: 406–409.
- FAO.** 1999. *Asian livestock to the year 2000 and beyond*, by D. Hoffman. Bangkok.
- FAO.** 2006. *Poultry gene flow study: the relative contribution of indigenous chicken breeds to poultry meat and egg production and consumption in the developing countries of Africa and Asia*, by R.A.E. Pym. Draft report for FAO. Rome.
- FAO.** 2007. Marker assisted selection in sheep and goats, by J.H.J. van der Werf. In E.P. Guimaraes, A. Sonnino & B.D. Scherf, eds. *Marker-assisted selection (MAS) in crops, livestock, forestry and fish: current status and the way forward*. Rome. (in press).
- Flock, D.K. & Preisinger, R.** 2002. Breeding plans for poultry with emphasis on sustainability. In *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production*, held 19–23 August 2002, Montpellier, France.
- Guèye, E.F.** 2005. Editorial: Family poultry must no longer be a ‘hidden harvest’. *INFPD Newsletter*, 15(1):1.
- Hanset, R. & Michaux, C.** 1985a. On the genetic determinism of muscular hypertrophy in the Belgian White and Blue cattle breed. I – Experimental data. *Genetics Selection Evolution*, 17:359–368.
- Hanset, R. & Michaux, C.** 1985b. On the genetic determinism of muscular hypertrophy in the Belgian White and Blue cattle breed. II - Population data. *Genetics Selection Evolution*, 17: 369–386.
- Hoffmann, I., Siewerdt, F. & Manzella, D.** 2004. *Research and investment: challenges and options for sustainable use of poultry genetic resources*. Paper presented at the XXII World Poultry Congress, Istanbul, 8–13 August 2004.
- Homann, S., Maritz, J.H., Hülsebusch, C.G., Meyn, K. & Valle Zárate, A.** 2006. Boran and Tuli cattle breeds – origin, worldwide transfer, utilisation and the issue of access and benefit sharing. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 395–458. FAO, GTZ, BMZ. (in press).
- Huyen, L.T.T., Roessler, R. Lemke, U. & Valle Zárate, A.** 2006. Impact of the use of exotic compared to local pig breeds on socio-economic development and biodiversity in Vietnam. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 459–508. FAO, GTZ, BMZ. (in press).
- Mathias, E. & Mundy, P.** 2005. *Herd movements*. Ober-Ramstadt. League for Pastoral Peoples and Endogenous Livestock Development.
- Merat, P.** 1990 Genes majeurs chez la poule (*Gallus gallus*): autres genes que ceux affectant la taille. *Productions Animales*, 3(5): 355–368.
- Mergenthaler, M., Momm, H. & Valle Zárate, A.** 2006. Global gene flow in cattle. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 241–280. FAO, GTZ, BMZ. (in press).
- Musavaya, K., Mergenthaler, M. & Valle Zárate, A.** 2006. Global gene flow of pigs. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 281–304. FAO, GTZ, BMZ. (in press).
- Peters, K.J. & Meyn, K.** 2005. Herausforderungen des internationalen Marktes für Tiergenetik. *Züchtungskunde*, 77(6): 436–356.
- Piper, L.R. & Bindon, B.M.** 1982. Genetic segregation for fecundity in Booroola Merino sheep. In R.A. Barton & D.W. Robinson, eds. *Proceedings of the World Congress on Sheep and Beef Cattle Breeding*, Volume 1, pp. 395–400. Palmerston North, New Zealand. The Dunmore Press Ltd.
- Rothschild, M., Jacobson, C., Vaske, D., Tuggle, C., Wang, L., Short, T., Eckardt, G., Sasaki, S., Vincent, A., McLaren, D., Southwood, O., van der Steen, H., Mileham, A. & Plastow, G.** 1996.

The estrogen receptor locus is associated with a major gene influencing litter size in pigs. *Proceedings of the National Academy of Science USA*, 93: 201–205.

Rummel, T., Valle Zárate, A. & Gootwine, E. 2006. The worldwide gene flow of the improved Awassi and Assaf sheep breeds from Israel. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 305–358. FAO, GTZ, BMZ. (in press).

Schäfer, C. & Valle Zárate, A. 2006. Gene flow of sheep. In A. Valle Zárate, K. Musavaya & C. Schäfer, eds. *Gene flow in animal genetic resources: a study on status, impact and trends*, pp. 189–228. FAO, GTZ, BMZ. (in press).

Shrestha, J.N.B. 2005. Conserving domestic animal diversity among composite populations. *Small Ruminant Research*, 56: 3–20.

Thibier, M. & Wagner, H.G. 2002. World statistics for artificial insemination in cattle. *Livestock Production Science*, 74: 203–212.

Valle Zárate, A., Musavaya, K. & Schäfer, C. 2006. *Gene flow in animal genetic resources: a study on status, impact and trends*. FAO, GTZ, BMZ. (in press).

Willis, M. 1998. *Dalton's introduction to practical animal breeding*. 4th edition. Oxford, UK. Blackwell Science.

SECTION D: USES AND VALUES OF ANIMAL GENETIC RESOURCES

1 Introduction

This section presents an overview of the importance of AnGR to world agriculture, their contribution to the livelihoods of farmers and herders, and their broader social and cultural importance. The first chapter outlines the significance of livestock production in the various regions of the world in terms of economic output, land use and employment. Regional differences in the importance of livestock (overall and by species) are explored by presenting data on patterns of livestock distribution or “density”. This is followed by a discussion of the production of food, fibre, hides and skins. Other uses of livestock such as the supply of inputs to crop production, transport, social and cultural roles, and the provision of environmental services are then considered – these descriptions draw largely on the information provided in the Country Reports. Finally, the particular significance of livestock in the livelihoods of the poor is discussed.

2 Contribution to national economies

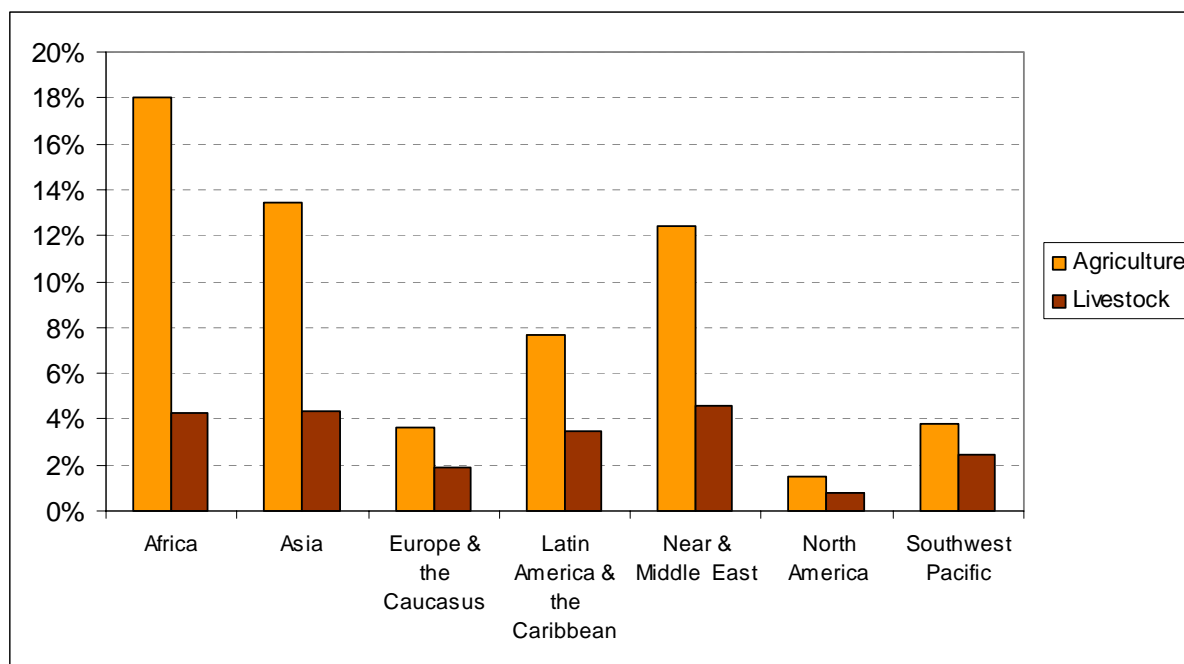
In all regions, livestock contribute significantly to food production and economic output. The relative importance of agriculture in total GDP is greatest in developing regions, with the highest proportion being in Africa (Figure 29). Within the agricultural sector, the contribution of livestock also varies from region to region, with rather higher proportions being found in the developed regions (and the Southwest Pacific region where figures are dominated by Australia and New Zealand). It is, however, interesting to note the historical trends with regard to the contribution of livestock to agricultural GDP. As shown in Figure 28, the trend for the developed regions has been slightly downwards over the past 30 years. Conversely, in most developing regions (Asia, Latin America and the Caribbean, and the Near and Middle East) there has been a rise in the importance of livestock. The exception is the Africa region, where the contribution of livestock production declined after having reached a peak in the 1980s.

The raw figures for livestock production’s contribution to the economy do not provide a complete picture of the socio-economic significance of livestock keeping. In many parts of the world it is an important element in the livelihoods of very large numbers of people, and contributes more than the marketable products that are considered in economic statistics. Data on the total numbers of livestock keepers are not available at global or regional levels. Figures are available at community, district or country levels, but at a larger scale, gaps in the data mean that accurate estimations are difficult to make – see Thornton *et al.* (2002) for a discussion of mapping livestock and poverty in the developing world. The proportion of the population employed in agriculture, as presented in Table 24, is a means of indicating the relative importance of farming as a livelihood activity in the different regions of the world. In both Africa and Asia, the majority of the population continues to make a living from agriculture. The livelihoods of a majority of these people will depend to a greater or lesser extent on livestock. In India for example it has been estimated that at least 70 percent of the rural population keep livestock of some kind (Arya *et al.*, 2002), and in the state of Assam, the figure is put at almost 90 percent (Sarkar, 2001).

The farming system and the types of livestock kept are inevitably influenced by the amount of agricultural land available relative to the size of the agricultural workforce – the latter being strongly influenced by the degree of industrialization and economic development. As Table 24 shows, there is considerable variation between regions in terms of the amount of land per person working in agriculture – with Asia being the region where land is most scarce in this respect. The most striking contrast to the figures for Asia is presented by Australia – an industrialized country where climatic conditions lead to a low rural population density. This country, along with the less extreme case of New Zealand, makes the Southwest Pacific the region with the largest amount of land per agricultural

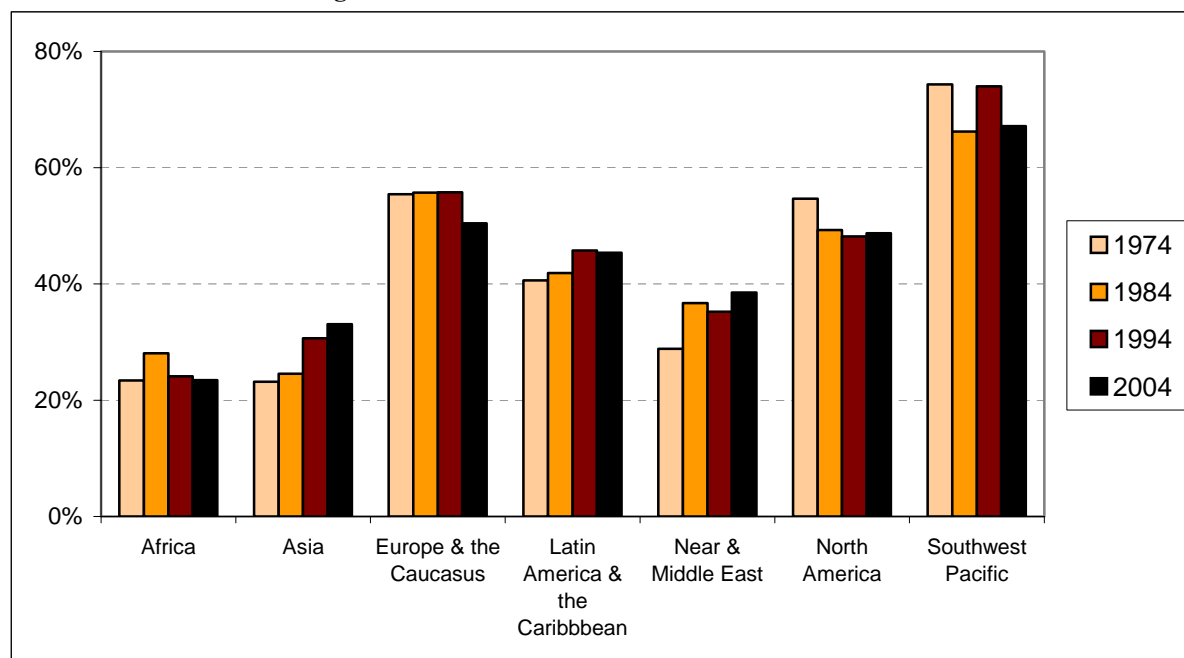
worker. The second region in this respect is North America, where the concentration process that has taken place in agriculture in recent decades has resulted in very low levels of employment in farming.

Figure 28
Contribution of agriculture and livestock to total GDP by region



Source: World Bank, figures for 2001, proportional contribution of agriculture and livestock based on current international dollar (Int.\$)⁴

Figure 29
Contribution of livestock to agricultural GDP



Source: FAOSTAT

⁴ International dollar (Int.\$) is a value which corrects for disparities in purchasing power between national economies. The conversion factors to achieve purchasing power parity (PPP) take into account differences in the relative prices of goods and services – particularly non-tradables – and therefore provide a better overall measure of the real value of output produced by an economy compared to other economies.

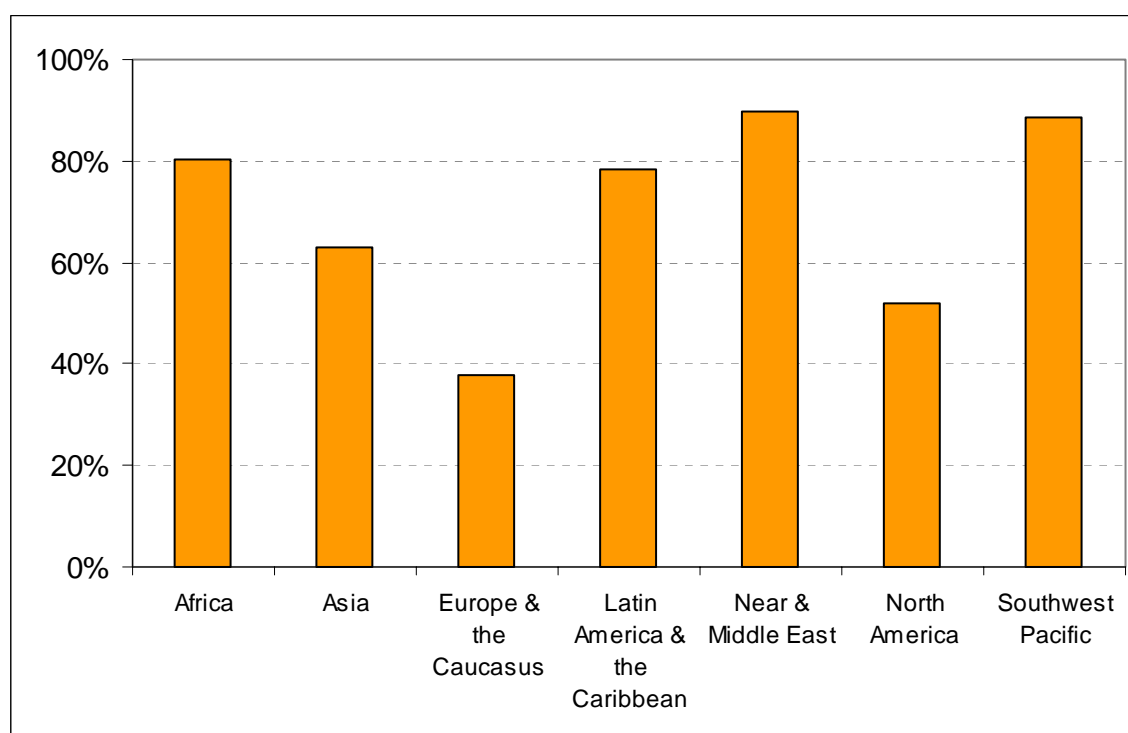
Besides its socio-economic importance, livestock production also plays a very significant role in terms of land use. Vast areas of land in all regions of the world are used for raising animals, particularly where natural conditions do not allow crop cultivation. This is illustrated by the fact that in all regions except Europe and the Caucasus, more than 50 percent of agricultural land is permanent pasture (Figure 30).

Table 24
Workforce employed in agriculture and land area per agricultural worker

| | Proportion of workforce employed in agriculture (%) | Agricultural land area per economically active person in agriculture (ha) |
|---|---|---|
| Africa | 59 | 5.1 |
| Asia | 56 | 1.4 |
| Europe & the Caucasus | 11 | 11.8 |
| Latin American & the Caribbean | 19 | 18.0 |
| Near & Middle East | 30 | 16.2 |
| North America | 2 | 143.4 |
| Southwest Pacific | 8 | 456.2 |
| - Southwest Pacific excl. Australia & New Zealand | 44 | 2.6 |
| - Australia and New Zealand | 5 | 761.0 |
| World | 42 | 3.8 |

Source: FAOSTAT – figures for 2002

Figure 30
Percentage of permanent pasture in total agricultural land



Source: FAOSTAT figures for 2002 (The following countries were excluded due to a lack of figures for pasture area: American Samoa, Aruba, Bermuda, Taiwan Province of China, Cook Islands, Egypt, Faeroe Islands, Kiribati, Malta, Netherlands Antilles, Saint Pierre and Miquelon, San Marino, Seychelles, Singapore, Turks and Caicos Islands, Wallis and Futuna Islands)

3 Patterns of livestock distribution

In this chapter the distribution of livestock biomass in tropical livestock units (TLU), and the number of livestock by species are considered in relation to the human populations that they support and the land area that is available. This provides a rough proxy for regional variation in the socio-economic significance of livestock and in their potential impact on natural resources. A fuller picture of the socio-economic importance of livestock could be provided if more complete data were available on patterns of livestock ownership, and the relative significance of different livestock species to the livelihoods of different sections of the population.

Overall, the global map (Figure 31) shows that the two American regions and the Southwest Pacific have large numbers of livestock units per person. Conversely, the figures are low in the Near and Middle East. The situation in the other regions is more varied. In Europe and the Caucasus, it is generally the more western countries that have the highest figures. African and Asian countries also show a great deal of variation, with large numbers of animals per person being found in some countries such as the Central African Republic, Chad, Mali, Mauritania, the Sudan and Mongolia.

Figure 31
Livestock density in relation to human population



Source: FAOSTAT – figures for 2004

The overall numbers of livestock units per hectare to a large extent mirror patterns of land use and the productivity of grazing land, but at the national level are also influenced by the growth of intensive and landless production systems and the import of feed. Most regions show large variation from country to country. In the Asia region, Japan, most of South Asia and several countries in Southeast Asia, have high livestock densities compared to Central Asia and China. Africa and the countries of the Near and Middle East generally have low densities, but Egypt is an exception. In Europe and the Caucasus, the western countries generally have high densities, but the figures are low for eastern parts of the region, particularly the Russian Federation. The Latin America and the Caribbean region also shows considerable variation from country to country. The map does not, of course, reveal the great diversity which also exists within countries in the distribution of livestock. Livestock density varies by agro-ecological zone, for example; and in many countries there is an increasing tendency for livestock populations to be concentrated close to urban centres. High livestock densities often present major challenges to the environment and the natural resource base (see Part 2 for a further discussion).

Figure 32
Livestock density per square kilometre of agricultural land



Source: FAOSTAT – figures for 2004

The importance of the various livestock species is far from even across the regions of the world – being affected by a range of agro-ecological, socio-economic and religious/cultural factors. Some species are largely restricted to a single region, while others are found throughout the world (see Section B: 3 for a discussion of species diversity).

Sheep and cattle are widely kept in all regions of the world, but the Southwest Pacific far outstrips other regions in terms of the number of animals per person (Table 25). The figures for the region are dominated by Australia and New Zealand, with their large areas of grazing land and low human population density. In the case of goats, Table 25 indicates their importance in the Near and Middle East region. The species is generally of greater importance in developing regions – the number of goats per person is particularly low in North America. The ass is another species that is of greatest significance to the inhabitants of the less-developed regions; the highest numbers per person are, again, found in the Near and Middle East, with Africa, and Latin America and the Caribbean also having relatively high numbers. The pattern is somewhat different for horses. North America, the Southwest Pacific, and Europe and the Caucasus have more horses per person than do most developing regions – horses in the developed world are now largely used for leisure activities. However, by far the highest figures are in Latin America and the Caribbean. In the case of pigs, the developed regions of North America, and Europe and the Caucasus (where monogastric production is dominated by landless systems) have the highest densities per inhabitant. Among the developing regions, Asia has the highest figures. Other mammalian species such as buffaloes and camelids have narrower distributions and are largely restricted to a few regions. The largest number of chickens per inhabitant is found in North America, followed by Latin America and the Caribbean, and the Southwest Pacific.

From the perspective of the number of animals per hectare of agricultural land (Table 26), a rather different pattern of species distribution can be discerned. In the case of cattle, for example, the Southwest Pacific has the lowest numbers per hectare – contrasting with its position as the region with the highest numbers of cattle per person. The arid and semi-arid rangelands of Australia are vast, but support a low livestock density. Europe and the Caucasus is the region with the highest sheep density, while in the case of goats, chickens and pigs, Asia supports the largest number of animals per hectare of agricultural land. For monogastric species, landless production is increasingly significant in many parts of Asia. The highest densities of cattle and horses are found in Latin America and the Caribbean.

Table 25
Number of animals by species/1000 human population

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific |
|-----------|--------|-------|-----------------------|-------------------------------|--------------------|---------------|-------------------|
| Asses | 14 | 4 | 2 | 14 | 23 | 0 | 0 |
| Buffaloes | 0 | 46 | 1 | 2 | 18 | 0 | 0 |
| Camels | 7 | 1 | 0 | 0 | 22 | 0 | 0 |
| Cattle | 251 | 116 | 181 | 693 | 228 | 330 | 1 409 |
| Chickens | 1 597 | 2 115 | 2 591 | 4 653 | 2 425 | 6 430 | 4 488 |
| Ducks | 9 | 260 | 82 | 29 | 46 | 24 | 32 |
| Geese | 4 | 72 | 23 | 1 | 46 | 1 | 3 |
| Goats | 231 | 128 | 32 | 60 | 308 | 4 | 32 |
| Horses | 5 | 4 | 8 | 44 | 1 | 17 | 14 |
| Mules | 1 | 1 | 0 | 12 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 12 | 0 | 0 | 0 |
| Camelids | | | | | | | |
| Other | 0 | 0 | 0 | 30 | 0 | 0 | 0 |
| Rodents | | | | | | | |
| Pigs | 28 | 159 | 235 | 140 | 0 | 226 | 143 |
| Rabbits | 4 | 105 | 148 | 9 | 47 | 0 | 0 |
| Sheep | 250 | 98 | 210 | 145 | 456 | 21 | 5 195 |
| Turkeys | 9 | 1 | 144 | 92 | 11 | 282 | 59 |

Source: FAOSTAT – figures for 2004

Table 26
Number of animals by species/1000 ha agricultural land

| Species | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific |
|-----------|--------|-------|-----------------------|-------------------------------|--------------------|---------------|-------------------|
| Asses | 11 | 11 | 2 | 10 | 13 | 0 | 0 |
| Buffaloes | 0 | 121 | 1 | 2 | 10 | 0 | 0 |
| Camels | 5 | 2 | 0 | 0 | 12 | 0 | 0 |
| Cattle | 205 | 307 | 276 | 483 | 126 | 229 | 78 |
| Chickens | 1 301 | 5 597 | 3 954 | 3 242 | 1 342 | 4 464 | 250 |
| Ducks | 7 | 688 | 126 | 20 | 26 | 17 | 2 |
| Geese | 3 | 191 | 35 | 0 | 25 | 1 | 0 |
| Goats | 188 | 339 | 49 | 42 | 170 | 3 | 2 |
| Horses | 4 | 10 | 13 | 31 | 0 | 12 | 1 |
| Mules | 1 | 3 | 1 | 8 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 8 | 0 | 0 | 0 |
| Camelids | | | | | | | |
| Other | 0 | 0 | 0 | 21 | 0 | 0 | 0 |
| Rodents | | | | | | | |
| Pigs | 23 | 420 | 359 | 98 | 0 | 157 | 8 |
| Rabbits | 3 | 277 | 226 | 6 | 26 | 0 | 0 |
| Sheep | 204 | 260 | 320 | 101 | 252 | 15 | 289 |
| Turkeys | 7 | 3 | 221 | 64 | 6 | 196 | 3 |

Source: FAOSTAT – production figures for 2004, land use figures for 2002

4 Food production

In terms of the overall economic value of food production from livestock, Asia is the leading region, reflecting its large livestock population. However, when considering the importance of livestock to the economy and to the supply of food, it is useful to examine production levels relative to the human population of the region (Table 27). In terms of milk and meat per person, the Southwest Pacific region has the highest production figures. Thanks to the contributions of Australia and New Zealand, the region has very high production levels for sheep and cattle meat, and milk from cows. Outside the Southwest Pacific, the highest milk production per person is found in the developed countries of Europe and the Caucasus, and North America; Latin America and the Caribbean has considerably higher levels of production than the other developing regions. Buffaloes make a major contribution to milk production in the Asia region, and are also quite significant in the Near and Middle East. The latter region also has the highest levels of sheep and goat milk production per inhabitant. Camel milk production is significant on a regional scale only in the Near and Middle East. Even in this region, the production levels are quite low relative to production from other species. North America is second to the Southwest Pacific in terms of meat production, and is the leader in terms of pig and poultry meat. Latin America and the Caribbean is also a major producer of meat. The livestock sector in this region produces slightly more meat per person than does that of Europe and the Caucasus, although the situation is reversed in the case of small ruminant meat. North America, and Europe and the Caucasus are the leading regions in terms of the number of eggs produced per person, followed by Asia, and Latin America and the Caribbean.

Table 27
Production of food of animal origin (kg/person/year)

| Food products | Africa | Asia | Europe & the Caucasus | Latin America & the Caribbean | Near & Middle East | North America | Southwest Pacific |
|-----------------------|--------|------|-----------------------|-------------------------------|--------------------|---------------|-------------------|
| Meat, Total | 13 | 28 | 67 | 69 | 21 | 131 | 203 |
| Beef and Buffalo Meat | 5 | 4 | 15 | 28 | 5 | 38 | 107 |
| Sheep & Goat Meat | 2 | 2 | 2 | 1 | 4 | 0 | 42 |
| Pig Meat | 1 | 16 | 31 | 11 | 0 | 34 | 18 |
| Poultry Meat | 3 | 7 | 17 | 29 | 9 | 58 | 34 |
| Meat of Camels | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Milk, Total | 23 | 49 | 279 | 114 | 75 | 258 | 974 |
| Cow Milk | 21 | 27 | 271 | 113 | 45 | 258 | 974 |
| Buffalo Milk | 0 | 20 | 0 | 0 | 13 | 0 | 0 |
| Goat Milk | 1 | 2 | 3 | 1 | 8 | 0 | 0 |
| Sheep Milk | 1 | 0 | 5 | 0 | 7 | 0 | 0 |
| Camel Milk | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Eggs | 2 | 10 | 13 | 10 | 4 | 17 | 8 |

Source: FAOSTAT – figures for 2004

As well as providing for consumption at the national level, livestock products are important export commodities in many countries. Trade in livestock products is growing, but faces a number of constraints – particularly associated with animal health. The countries of the world can be distinguished according to whether they are net exporters or net importers of particular animal products. Figures 33, 34 and 35 show the export/import status of countries for meat, milk and eggs respectively.

Brazil and the southern countries of South America are net exporters of meat, as are the countries of North America; Australia and New Zealand; a number African countries (most notably Botswana and Namibia); China, India and several other Asian countries; as well as many European countries. In the case of milk, long-standing net exporters such as Argentina, Australia and New Zealand, have been

joined in recent years by new exporting countries such as Colombia, India and Kyrgyzstan. Net exporters of eggs can be found in all regions of the world. In Asia, for example, major net exporters include China, India, the Islamic Republic of Iran and Malaysia. The largest net exporter of eggs in the Africa region is South Africa, but there are a number of other such countries including Ethiopia, Zambia and Zimbabwe. In Latin America and the Caribbean, Colombia and Peru have in recent years become net exporters of eggs, as has Egypt in the Near and Middle East.

Figure 33
Net exports – meat



Source: FAOSTAT

Figure 34
Net exports – milk equivalent



Source: FAOSTAT

Figure 35
Net exports – eggs



Source: FAOSTAT

5 Production of fibre, skins, hides and pelts

Livestock fibres, hides, skins and pelts are also important products. Although the world's sheep industry has over recent years seen a shift in orientation away from wool production and towards meat, wool remains an important product in many countries. The Southwest Pacific is the region of the world that produces the most wool (Table 28). China, the Islamic Republic of Iran, the United Kingdom and other countries with large sheep populations are also major producers of wool, but it is often of secondary importance to meat or milk. Demand for wool in China remains high, and the country is the world's largest importer of wool (much of which is used for the production of textiles and garments for export). In a number of countries, wool has traditionally been the most important product of the sheep sector – examples include Lesotho and Uruguay. In the latter country, the wool industry has been a major source of employment, employing 14 percent of the labour force in manufacturing (CR Uruguay, 2003). Many sheep breeds have been developed for their wool. The fine-wool Merino breed from Spain has spread to all regions of the world; and in many countries there are indigenous breeds noted for the particular qualities of their wool. In India, for example, the Chokla and Pattanwadi sheep are known for producing good carpet wool, the Magra breed produces lustrous wool, and the Chanthangi breed is noted for fine wool (CR India, 2004).

Table 28
Production of fibres skins and hides (1000 mt/year)

| Products | Africa | Asia | Europe & the Caucasus | Latin American & the Caribbean | Near & Middle East | North America | South-west Pacific |
|-------------------------------|--------|--------|-----------------------|--------------------------------|--------------------|---------------|--------------------|
| Cattle Hides, Fresh | 515.5 | 2576.7 | 1377.8 | 1809.0 | 119.7 | 1157.7 | 304.1 |
| Goatskins, Fresh | 112.2 | 727.9 | 30.6 | 23.2 | 64.9 | 0.01 | 5.4 |
| Sheepskins, Fresh | 0.05 | 0.03 | 0.06 | 0.03 | 0.01 | <0.01 | <0.01 |
| Buffalo Hides, Fresh | | 796.7 | 0.7 | | 23.3 | | |
| Wool, Greasy | 137.5 | 663.7 | 325.8 | 151.9 | 118.6 | 18.6 | 726.5 |
| Coarse Goat Hair | 0 | 21.6 | 2.7 | 0 | 0 | | |
| Fine Goat Hair ¹ | 0 | 56.9 | 0.3 | 0 | 0 | | |
| Hair Fine Animal ² | 5.3 | 25.0 | 1.6 | 3.7 | 0.1 | | |
| Hair of Horses | | | | | 0 | | 0.1 |

Source: FAOSTAT – figures for 2004

¹Hair from cashmere, angora (mohair) and similar goats; ²mainly from alpacas, llamas, vicuñas, camels and angora rabbits

Goats are also important producers of fibre. Fine hair is provided by breeds such as the Cashmere and Angora. Coarse hair is also a significant by-product of goat keeping. The production of goat hair is concentrated in the Asia region, with significant production also in Europe and the Caucasus. Fibre from South American camelids is increasingly in demand in international markets because of its unique qualities, and also provides inputs to local craft production. Angora rabbits are another source of fine hair; China is by far the world's largest producer. Hair is also a by-product in camel production. The soft undercoat of Bactrian camels, in particular, is a source of fine fibre; China is again the main producer. Hair from the undercoat of yaks is of very high quality. It is used domestically and sold on a small scale by the herders; it has become an increasingly important by-product in China where the textile industry has started to utilize yak fibre (FAO, 2003a). The coarse outer hair of yaks is used for a variety of purposes such as rope making. Among avian species, feathers may be an important by-product – used industrially in the manufacture of bedding, or for small-scale handicrafts.

Cattle, sheep and goat skins are produced in all regions of the world, while other products such as buffalo skins are more regional. Asia is the region that has the largest production of cattle hides and goatskins, while Europe and the Caucasus produces most sheepskins (Table 28). Hides and skins provide raw materials to local leather and tanning industries, often at the artisanal scale. In a number of countries, they are also significant export products. At the subsistence level, skins are used in the production of clothing, rugs and other household items. In most cases, hides and skins are by-products of livestock production. An exemption is the Karakul sheep, from which lamb pelts are the major product. This breed is kept in many Asian countries, but has also spread to other parts of the world such as Australia, Botswana and the United States of America. Other breeds noted for the quality of their skins include the Jining Grey goat of China which is famous for the colour and pattern of its kid skins, the Chèvre Rousse de Maradi of Niger, the Mubende goat of Uganda and the Black Bengal goat of Bangladesh (CR Bangladesh, 2004; CR China, 2003; CR Niger, 2003; CR Uganda, 2004).

Other useable livestock by-products include horns, hooves and bones – used on a small scale for the production of various decorative items, tools and household goods, and in the production of glue and gelatine. Meat and bone meal was an important source of feed protein in livestock production before the rise of concerns over BSE.

6 Agricultural inputs, transport and fuel

Draught power provided by animals contributes greatly to crop production in the developing world. Animal traction has traditionally been particularly important in Asia (Table 29), and relatively unimportant in sub-Saharan Africa where its use has been restricted by heavy soils and the presence of tsetse flies. Nonetheless, animal traction is of great importance in parts of Africa. In the Gambia, for example, 73.4 percent of crop fields are cultivated using animal power (CR Gambia, 2003). In Latin

America and the Caribbean, and in the Near and Middle East region, animal power is, again, vital to livelihoods of many small-scale farmers.

Table 29
Trends in the use of animals for draught power

| Region | Year | Area cultivated by different power sources (%) | | |
|-------------------------------|---------|--|------|---------|
| | | Draught animal | Hand | Tractor |
| All developing countries | 1997/99 | 30 | 35 | 35 |
| | 2030 | 20 | 25 | 55 |
| Sub-Saharan Africa | 1997/99 | 25 | 65 | 10 |
| | 2030 | 30 | 45 | 25 |
| Near East/North Africa | 1997/99 | 20 | 20 | 60 |
| | 2030 | 15 | 10 | 75 |
| Latin America & the Caribbean | 1997/99 | 25 | 25 | 50 |
| | 2030 | 15 | 15 | 70 |
| South Asia | 1997/99 | 35 | 30 | 35 |
| | 2030 | 15 | 15 | 70 |
| East Asia | 1997/99 | 40 | 40 | 20 |
| | 2030 | 25 | 25 | 50 |

Source: FAO (2003b)

Note that the regional classifications used in this table do not correspond exactly to the classification used elsewhere in the report.

In many parts of the world, the use of animal traction is declining as a result of increased mechanization. The trend is most pronounced in Asia (Table 29). CR Malaysia (2003), for example, reports that the country's agriculture is now highly mechanized and that animal power is of little significance. The trend, however, is not universal. Some factors continue to favour livestock as a source of power. Where farmers find fuel prices unaffordable, the use of draught animals remains popular and may even increase. Table 29 shows that animal traction is increasing in importance in sub-Saharan Africa.

Animal power is used for many agricultural purposes. CR Ethiopia (2004), for example, notes that the uses of draught cattle, horses or donkeys include weeding, ploughing, threshing, and levelling fields before and after sowing. Among households that own draught animals, hiring them out is frequently a source of income. Conversely, households lacking draught animals (or mechanized power) tend to be at a marked disadvantage with regard to the efficient utilization of their land.

In addition to working in the fields, livestock are often used for transport purposes –pulling carts or serving as pack animals. Several Country Reports note that motorized vehicles are replacing animals as a means of transporting people and goods. However, in parts of the world where rural infrastructure is poor and the terrain is harsh, transport continues to be an important role of livestock. Ethiopia, for example, is a country with a large equine population. It is estimated that 75 percent of farms in the country are located more than a day and a half's walk from all-weather roads (ibid.), and animals are therefore vital for the transportation of farm produce to the market.

A range of livestock species are utilized for draught purposes. In the above-mentioned case of the Gambia, horses are the most significant species – being used to cultivate 36 percent of the cropland (CR Gambia, 2003). Cattle (33 percent), donkeys (30 percent) and mules (1 percent) are the other species used (ibid.). In contrast, CR United Republic of Tanzania (2004) indicates that 70 percent of the country's animal draught power comes from cattle and 30 percent from donkeys. Some livestock breeds are particularly noted for their suitability as draught animals. CR Chad (2003), for example, describes the calm and docile nature of the Zébu Arabe, which makes it easy to train for draught purposes. The results of a survey presented in CR Gambia (2003) indicate that 97 percent of farmers interviewed stated that they preferred N'Dama cattle to exotic breeds for draught purposes. The significance of donkeys as draught animals is reported to be on the increase in some African countries. CR Zimbabwe (2004), for example, notes that the use of the species for draught purposes has increased in the smallholder sector, particularly in the drier parts of the country.

Buffaloes are also important draught animals, mainly in Asia, and are particularly suited to working in swampy conditions. In semi-arid areas of Africa, Asia, and the Near and Middle East, camels are used for ploughing, drawing water and for transport. Yaks are important pack animals in the high mountain ranges of Asia, where sheep and goats are also sometimes used for this purpose. CR Nepal (2004), for example, mentions transport as a function of the Chyangra and Sinhal goat breeds, and also the Baruwal sheep, which can carry loads of up to 13 kg on its back. In China, local horse breeds such as the Yuta, Merak Saktenta and Boeta are noted for their ability to cross rough mountain tracks. It is, however, reported that an increasing popularity of mules has led to a decline among many indigenous Chinese horse breeds, which are also threatened by excessive cross-breeding with the exotic Haflinger breed (CR China, 2003).

In Latin America and the Caribbean, horses, donkeys, mules and cattle provide draught power for cultivation, and are used to transport agricultural products. Buffaloes also contribute draught power in some countries of the region (CR Brazil, 2003; CR Costa Rica, 2004; CR Cuba, 2003). CR Ecuador (2003) and CR Peru (2004) report the use of llamas for transport purposes at high altitudes. The merits of the Criollo horse for transport and draught functions at high altitudes are noted in CR Bolivarian Republic of Venezuela (2004). CR Peru (2004) reports that among Criollo cattle there are various “ecotypes” specialized for different roles – the Ancash type being noted as a draught animal. The important role of horses in extensive cattle production systems is noted in CR Bolivarian Republic of Venezuela (2004) and CR Brazil (2003).

In the eastern parts of the Europe and the Caucasus region, horses are still used for draught by some small-scale farmers. Indeed, in some places the number of draught horses has increased in recent years as a result of the fragmentation of land holdings (CR Romania, 2003). However, CR Latvia (2003) notes that the breeding of horses for draught has increasingly been replaced by breeding for meat. In these circumstances, there is little motivation to conserve draught-related genetic traits. CR Albania (2002) reports the risk of extinction faced by the local buffalo breed, formerly used for draught in bog-land areas, which has lost its role as a result of land reclamation measures. Horses and donkeys continue to serve as pack animals in parts of Europe and the Caucasus. The Bosnian Mountain horse, for example, is still used to transport fuelwood in the mountains (CR Bosnia and Herzegovina, 2003).

The supply of agricultural manure is another important function of livestock. With greater use of inorganic fertilizers, the importance of manure has tended to decline in many parts of the world. However, CR Sri Lanka (2003) reports a trend towards the greater use of livestock manure for fertilizer, and notes that the product is traded to supply vegetable farmers who lack their own animals. In parts of Africa, demographic pressure and subsequent effects on soil fertility is necessitating a greater integration between crop and animal production, including an increased use of manure, particularly where inorganic fertilizers are difficult to obtain (CR Burundi 2003; CR Rwanda 2004). In other places, crop and livestock production is integrated through the grazing of pastoralists’ livestock on crop farmers’ fields after the harvest – the cropland benefiting from the manure and the livestock feeding on the crop residues (CR Cameroon, 2003). In some peri-urban areas, manure from pig and poultry enterprises facilitates the development of market gardening (CR Côte d’Ivoire 2003; CR Democratic Republic of the Congo 2005). CR Malaysia (2003) mentions systems that integrate fish farming with the keeping of livestock such as cattle, buffaloes and ducks. The significance of manure as a source of fertilizer is not confined to developing regions – it continues to be an important input in Europe and the Caucasus (CR Belarus, 2003; CR Hungary, 2003; CR Romania, 2003; CR Serbia and Montenegro, 2003; CR Slovenia, 2003). It is a key element of the organic production systems which are becoming increasingly popular in developed countries.

Dried dung cakes are widely used for fuel in the developing regions of the world, particularly where fuelwood is in short supply (CR Ethiopia, 2004). Alternatively, manure can be used in the production of biogas (CR Barbados, 2005; CR Jamaica, 2005). Other uses of livestock dung include burning to ward off insects (CR Sudan, 2005) and as a building material (CR Ethiopia, 2004).

7 Other uses and values

If it is difficult to fully quantify the value of livestock as a source of agricultural inputs, this is even more clearly the case for intangible benefits related to asset, insurance, social and cultural functions, and for environmental services. These roles are, therefore, illustrated below using examples from different regions as provided in the Country Reports.

7.1 Savings and risk management

While livestock often provide their owners with a regular supply of products that can be consumed or sold to obtain cash income, for many livestock keepers functions such as savings, insurance and the management of risk are extremely important. In many parts of the developing world, and particularly for poorer people, the institutions which could otherwise provide these services are largely inaccessible. Conversely, these functions are of negligible importance in industrialized regions such as North America, and western parts of Europe and the Caucasus.

Savings and insurance functions are widely acknowledged in the Country Reports. Livestock keeping offers a means of livelihood diversification, enabling households to cope with fluctuations in income from wage labour or crop production, which may be affected by ill-health or unemployment, droughts, floods or pests. For many small-scale farmers and herders, production is largely for subsistence. However, the need for a source of cash to meet expenses arises from time to time. Livestock sales are frequently a means of meeting these requirements. The goods and services in question range from household items such as soap, salt and petrol, to school fees, building materials, agricultural inputs, health expenses, taxes, and meeting the costs of marriages, funerals and other cultural events and ceremonies (CR Madagascar, 2003; CR Mozambique, 2004; CR Niger, 2003; CR Sao Tome and Principe, 2003; CR Senegal, 2003; CR Togo, 2003). Local breeds are well adapted to being used as a form of savings because their hardy characteristics reduce the risk that they die from disease or lack of feed.

From another perspective, livestock can be regarded as a means of capital accumulation. CR Mali (2002) notes that larger herds are often the result of the capitalization of surplus from crop production. The use of livestock as a method of savings or investment is not, however, always limited to farmers and rural people. CR Congo (2003) mentions that traders and employees in the public and private sector often hold their savings in the form of livestock. These individuals are generally absentee owners whose animals are kept by paid herders, relatives or other rural connections.

Box 12**Linguistic links between cattle and wealth**

The significance of the role of livestock as a form of wealth is highlighted by the fact that in many unrelated languages there are etymological links between the words for cattle and the words for wealth, capital, money or savings:

Cho-Chiku (Japanese: saving money) consists of two characters, of which the first *Cho* means saving. The second word is also used for livestock though the character is (only partly) different, *Chiku*. The Chinese etymology is very similar.

Rājākāyā in Javanese literally means *rich king*, but it has the meaning of wealth and cattle.

Ente means cattle in Lunyomkole (a Bantu language from Uganda), and *sente* means money in the same language.

Mikne (Hebrew) means cows, goats, camels etc. It consists of the root word *kne* or *kana*, that means to buy, and an affix *mi* that makes the root into a noun.

Byoto (Polish) means cattle and originates from a Slavic root-word *byd_o* which relates to the meanings of “being, standing, living, the house, possession”. This root meaning still survives in Czech and Slovakian but it has disappeared in Polish. The change of meaning from possession to livestock is typical for many Slavic languages.

Da (Welsh) means wealth or goods; good or goodness; as well as cattle or livestock (*da byw*). In the same language, *cyfalaf* the word for capital, is related to the word *alaf* – meaning a herd of cattle.

Vee (Dutch), **Vieh** (German) meaning *livestock* are related to *fee* (English) and originate from *fehu* (Old Saksish) which means both livestock and wealth or money. Compare *fia* (Old Frisian), *faihu* (Gothic), *fe* (Norwegian) and *fä* (Swedish).

Cattle is related to *capital* via *caput* (Latin: head, number of *e.g.* animals); the word *chattel* seems to be an intermediate.

Ganado (Spanish: livestock) is related to *ganar* (Spanish: to earn, to win, to gain).

Pecunia (Latin: wealth, money) is linked with *pecu* (livestock) and also used in the Spanish word for animal husbandry (*pecuaria*).

Provided by Hans Schiere (see also Schiere, 1995)

7.2 Sociocultural roles

In addition to the economic importance of farm animals, most Country Reports, from all regions of the world, recognize the sociocultural roles of livestock. Cultural motivations influence the utilization of AnGR, and there are often strong links between communities and their local breeds. This has contributed to the development and maintenance of animal genetic diversity in many parts of the world. In some societies the slaughter or sale of livestock tends to be associated with social and cultural factors rather than to result from strictly commercial motivations. In the Southwest Pacific region, for example, the importance of pigs in social obligations and for consumption at the time of ceremonies and feasts is emphasized in the Country Reports (CR Palau, 2003; CR Samoa, 2003; CR Tonga, 2005; CR Tuvalu, 2004). CR the Cook Islands (2005) reports that more animals are slaughtered for cultural, religious, recreational or social functions than are marketed.

The roles of livestock in religious and cultural life are highly varied, and it is only possible here to give some indication of the diversity mentioned in the Country Reports. In Guinea-Bissau, for example, small ruminants are important for feeding guests at events such as funerals, baptisms, birthdays, marriages and religious festivals (CR Guinea-Bissau, 2002). Similarly, CR Burundi (2003) describes the importance of sheep in ceremonies to mark the birth of twins. CR Nigeria (2004) indicates that Muturu cattle and rams play a part in title-taking and chieftaincy festivals, while in the north of the country, camels serve as ceremonial animals carrying drums and other regalia at Sallah day processions. Animals with specific colours or other characteristics are often favoured for particular cultural roles. In Chad, for example, pure black or white chickens are preferred for religious

ceremonies (CR Chad, 2004). Similarly, in Zimbabwe, black Mashona and red and white Nguni cattle are preferred for ceremonial purposes (CR Zimbabwe, 2004).

CR Bangladesh (2004) reports that large numbers of goats and cattle are sacrificed during the Eid-ul-Azha festival, while CR Sri Lanka (2003) mentions that cattle and buffaloes intended for slaughter are sometimes released as an appeasement to ensure the recovery of friends or relatives from illness. In parts of Bhutan, the first yak calf of the year is sacrificed, while in other parts of the country yak skulls are inscribed with Buddhist prayers; a yak may also be released into the wild as an appeasement to local deities (CR Bhutan, 2002). In parts of Indonesia it is a traditional practice to slaughter buffalo before work commences on the construction of a building (CR Indonesia, 2003). Specific breeds such as the Kalang and the Spotted buffalo are noted for their uses in traditional rituals (*ibid.*). In India, religious institutions such as Gaushalas contribute to the conservation of indigenous breeds (CR India, 2005).

In rural areas of Peru, cattle, horses and donkeys play a part in cultural festivals such as the Yawar Fiesta and the Jalapato (CR Peru, 2004). CR Vanuatu (2004) describes the traditional practice of breeding pigs in order to increase the incidence of pseudohermaphroditism or “Narave” in males. The intersex pigs were at one time extremely significant to the local culture, and breeding for this purpose is still practised on a very limited scale (*ibid.*).

Livestock by-products also have significance to cultural life. Skins and horns of sheep, goats and cattle as well as poultry feathers have diverse roles in religious ceremonies and as gifts (CR Togo, 2003). Similarly in Cameroon, the feathers of guinea fowl are used in the production of artistic and ceremonial objects (CR Cameroon, 2003).

In many societies, the exchange of livestock has traditionally played a role in the maintenance of social ties. CR Congo (2003) notes that loans and gifts of livestock, inheritance, and the transfer of animals at the time of marriage serve to maintain networks of obligation and dependence within family and social groups, and can also be a manifestation of hierarchical relationships between social strata. Similarly, CR Cameroon (2003) reports that several poultry species are important in the maintenance of social ties, and it is noted that cultural considerations are important factors influencing breed choice. CR Uganda (2004) mentions the role of Ankole and Zebu cattle breeds in traditional obligations associated with marriage. In parts of Malaysia, buffaloes are used as dowry (CR Malaysia, 2003). CR Philippines (2003) also reports the use of buffaloes as a “bride gift”.

Traditional healing practices also sometimes involve livestock. CR Uganda (2004) mentions the belief that goats’ milk is a cure for measles. In Zimbabwe, some communities feed donkey milk to children, as it is considered to have therapeutic benefits (CR Zimbabwe, 2004). Traditional ceremonies and healing practices have some influence on the choice of livestock breeds or varieties. CR Mozambique (2004), for example, describes a type of chicken, which has curled feathers and is popular with traditional healers. The birds therefore command a higher price than the regular chickens. In Uganda, black and white sheep are particularly prized by traditional healers (CR Uganda, 2004). In Peru, guinea pigs, particularly those with black coats, are used in traditional medicine (CR Peru, 2004). CR Republic of Korea (2004) reports that native goats and Yeonsan Ogol chickens, along with a number of other species such as deer, are kept to supply products for use in traditional medicine. Particular breeds of chickens are also valued for medicinal purposes in Viet Nam (Ac and Tre breeds) and in China (Silkies) (CR China, 2003; CR Viet Nam, 2005). CR Sri Lanka (2003) mentions that some animal products such as ghee, curd, whey, dung and urine are used in indigenous and ayurvedic treatments.

In many industrialized countries livestock and livestock products continue to have a significant cultural role. Numerous traditional religious events in Japan, for example, involve live farm animals (CR Japan, 2003), but there is no tendency to use indigenous rather than exotic breeds on these occasions (*ibid.*). In Latvia, white eggs are in demand at Easter time for egg dying activities, roasted geese are traditionally eaten at Martinmass and roasted cocks at Christmas (CR Latvia, 2003). Many rural people in Romania continue to fatten pigs for consumption at Christmas (CR Romania, 2003).

In many cases, however, rural customs, along with traditional crafts and farming practices, have lost their role in everyday life and are now regarded as “heritage” products to be marketed to the tourist or

day tripper. There is often a great need for new income-generating activities and livelihood diversification in rural areas, and the potential of traditional livestock breeds to appeal to the visitor is widely recognized. On the one hand, the rare or traditional breeds may be kept in specific attractions such as farm parks or rural museums; on the other, they may be an element of a “cultural landscape” which helps attract the tourist to a particular area. CR Japan (2003) mentions institutions such as the Cattle Museum in Maesawa, which contribute to raising awareness of the history of livestock keeping. CR Serbia and Montenegro (2002) notes the re-introduction of indigenous breeds in areas surrounding spas and monasteries in order to increase the attraction of the landscape to tourists. Such developments are not, however, limited to industrialized countries or more developed regions. CR Nepal (2004), for example, mentions the potential of eco-tourism and farm parks, and CR China (2003) notes the role of horses in the tourist industry. Similarly in South America, camelids are kept as attractions in parks and at tourist sites (CR Peru, 2004).

In many countries, the cultural roles of livestock are not merely valued for their potential role in income generation, but are regarded as an element of the “national heritage”. In the Republic of Korea, for example, the Jeju horse and the Yeonsan Ogol chicken (noted for the black colour of its beak, claws, skin and internal organs) have been designated national monuments (CR Republic of Korea, 2004). In Japan, several varieties of chicken along with Mishima cattle and the Misaki Horse have been designated “national treasures” and are included in special conservation efforts (CR Japan, 2003). Similar sentiments are expressed in several Country Reports from Europe and the Caucasus. CR Hungary (2003), for example, notes that the conservation of AnGR is related to the preservation of other aspects of the country’s culture – ranging from architecture and clothing to gastronomy and folk songs.

In all regions of the world, livestock are used in a variety of sports and entertainments. In the Near and Middle East region, for example, the horse is of great cultural importance and there is much enthusiasm for horse breeding and racing (CR Islamic Republic of Iran, 2004; CR Jordan, 2003; CR Kyrgyzstan, 2004). Horses are also used for leisure riding and feature in various shows, festivals, circuses and exhibitions (CR Islamic Republic of Iran, 2004; CR Tunisia, 2003). Horses are also widely used for sporting purposes in the Europe and the Caucasus region. CR Ireland (2003), for example, mentions activities such as point-to-point racing, show jumping and eventing. Harness racing and trotting are popular in parts of Europe (CR Norway, 2003; CR Slovenia, 2003). In some cases, sporting roles are recognized as a means of sustaining the use of threatened breeds. For example, CR Republic of Korea (2004) reports that a horse racing track has been built for the purpose of racing the protected Jeju breed.

Several other species are also kept for sporting purposes. On the island of Madura in Indonesia, for example, the local cattle breed is used for racing and dancing (CR Indonesia, 2003). The CRs from the Philippines (2003) and Malaysia (2003) mention buffalo racing. CR Sri Lanka (2003) notes that cattle are used in cart racing. The local breeds are admired for their running ability in these events (*ibid.*). Ducks are another species that is sometimes used for racing (CR Indonesia, 2003). In Bhutan, yak dancing is of great cultural importance (CR Bhutan, 2002). In Viet Nam, Ho and Choi (fighting) chickens are used for entertainment at religious festivals (CR Viet Nam, 2005). CR Indonesia (2003) also mentions cock fighting as a cultural activity, as well as the breeding of the Garut breed as a fighting sheep. Similarly, bullfighting is popular in a number of countries (CR Peru, 2004).

Livestock raising may, in itself, be a leisure activity. This function is most prominent in developed regions such as Europe and the Caucasus. According to CR Denmark (2003) “beef cattle, horses, sheep, goats, rabbits, ducks, geese, turkeys, ostriches and deer are mainly kept by part-time, leisure-time and hobby breeders.” As these livestock keepers are less influenced by commercial motivations, their contribution to the conservation of less-profitable breeds is important. In the United Kingdom, the conservation of horse and pony breeds is largely dependent on small-scale and part-time enthusiasts (CR United Kingdom, 2002). Small species such as rabbits, and particularly poultry, are often popular among “hobby” breeders. For example, CR Turkey (2004) notes that Denizli and Gerze, native poultry breeds, are popular with this group of livestock keepers. Similar motivations operate elsewhere in the world – CR Sri Lanka (2003) notes that ducks, turkeys and guinea fowl are kept for leisure purposes, and CR Pakistan (2003) mentions that peacocks and partridges are kept as pets.

In some places, long standing preferences for particular breeds also influence the actions of traditional small-scale farmers. CR Romania (2003), for example, reports that the preferences of the peasants have helped to conserve a number of sheep breeds and varieties such as the Tsurcana, the Blackhead Ruda and the Corkscrew Walachian.

Particular food products are also culturally important in many countries. Examples include the popularity of mutton from Dhamari sheep, and cheese from Taz Red goats in Yemen (CR Yemen, 2002). Meat from the Kampong chicken is considered by consumers in Malaysia to be better tasting than that from commercial breeds (CR Malaysia, 2003). Similarly, CR Philippines (2003) notes that native pig breeds are favoured, and command a high price, in the country's specialized roast pig or "lechon" market. Examples from Europe and the Caucasus include the preference of local consumers in Albania for traditionally produced meat and cheese from indigenous sheep and goat breeds such as the Dukati; demand for quality halloumi cheese, which has led to increased numbers of native and cross-bred goats in hilly areas of Cyprus; and the potential use of two endangered local Croatian pig breeds, the Black Slavonian and the Turopolje, in cross-breeding programmes aimed at producing high-quality traditional products such as paprika-flavoured sausage and ham (CR Albania, 2002; CR, Croatia, 2003; CR Cyprus, 2003).

Affluent consumers who are seeking quality and variety in their diets are increasingly a source of demand for "niche market" products. Sales to tourists are also an important part of the market for distinctive local food products. The potential importance of local breeds in meeting this demand is widely recognized, particularly in Europe and the Caucasus. However, in many countries, livestock breeds with the potential to meet the demands of niche markets still show declining populations. In Nepal, for example, the Bampudke pig, which is noted for its excellent meat is reported to be on the verge of extinction (CR Nepal, 2004). Similarly, yak cheese is reported to be very popular in Nepal, but yak populations continue to decline (*ibid.*).

7.3 Environmental services

Livestock can make a positive contribution to landscape and environmental management. This function is particularly recognized in developed regions such as Europe and the Caucasus. Grazing animals such as cattle, horses and small ruminants play a role in the maintenance and regeneration of pastures, heaths and moorlands. CR Serbia and Montenegro (2003), for example, notes that the biodiversity of pastures is endangered by the absence of grazing in depopulated mountain areas. CR Slovenia (2003) reports that small ruminants can serve to clear areas which have become overgrown with shrubs and, therefore prone to fires. Grazing donkeys can play a similar role in landscape management and fire prevention (CR Croatia, 2003). CR United Kingdom (2002) notes the role of the New Forest pony in scrub clearance.

Elsewhere in the world, mobile pastoralist production systems are an efficient means of producing food in a sustainable manner from land where grazing resources are meagre and fluctuating (CR Mali, 2002). CR Côte d'Ivoire (2003) notes that the use of livestock in crop production reduces the need for herbicides. Moreover, a consequence of the use of manure as a source of fertilizer is an increase in the diversity of soil microflora and microfauna (CR Mali, 2002). On tree-crop plantations, particularly in Asia, cattle have a role in controlling weeds and shrubs, and in facilitating the harvesting of coconuts. In Malaysia, for example, the Kedah-Kelantan cattle breed is noted for its suitability for use on tree-crop plantations (CR Malaysia, 2003). Although the breed shows slow growth, it is hardy and well-adapted to the challenging environment. Meeting the demand for this breed has proved to be a problem, and the gap has had to be filled by imports such as Brahman cattle from Australia (*ibid.*).

From the point of view of conserving rare or non-commercial breeds, livestock's role in environmental management potentially has positive implications. Two factors can be discerned. On the one hand, a desire for conservation of the environment may go together with a wish to preserve other cultural and historic aspects of rural life including traditional livestock. On the other hand, breeds adapted to the local environment may be particularly suitable for grazing on rough pastures. CR Germany (2004), for example, mentions sheep breeds such as the Heidschnucken, Skudden and Bergschaf, and also breeds of cattle such as Hinterwälder and Rotvieh Zuchtrichtung Höhenvieh, in this respect. However, there

is not necessarily a complete overlap between the two objectives in terms of breed choice. The best breeds for environmental management may not be indigenous to the country in question. In the Netherlands, for example, the animals used for landscape management are often Heck or Scottish Highland cattle, and Iceland or Konik ponies rather than local breeds (CR Netherlands, 2004).

Consumer disquiet regarding environmental impact is a factor that is increasingly motivating change in livestock production systems. Organic farming has expanded markedly in countries such as Sweden under strong promotion by government policy (CR Sweden, 2002), and its potential is recognized in a number of countries where livestock keeping is largely conducted under low external input conditions. The expansion of organic production potentially promotes the keeping of well-adapted local livestock breeds – particularly in the case of pigs and poultry kept under outdoor conditions.

A further characteristic of livestock is their capacity to convert “waste” (agro-industrial by-products, left-over food) into useful products. If such waste would otherwise require costly or environmentally damaging methods of disposal (e.g. burning or dumping in landfill sites), then this role is in itself a service additional to the other benefits (milk, meat etc.) that the animals supply. Livestock’s role as converters of waste may operate at the household level – in the disposal of kitchen wastes and crop residues; within a neighbourhood – for example, the collection of leftovers from markets or other businesses by small-scale pig keepers; or involve the large-scale, organized, use of by-products from food processing industries. The potential of livestock to utilize a range of “alternative” sources of feed is recognized in a number of Country Reports (CR Lao People’s Democratic Republic, 2005; CR Malaysia, 2003; CR Mauritius, 2004). These feedstuffs are diverse in their nature, and their efficient utilization tends to require a degree of diversity in the livestock population. CR Mauritius (2004) notes that the local AnGR are able to make better use of the by-products that are available in the country than are exotic breeds.

In the case of some by-products there are, of course, alternative uses (e.g. biofuels); and there may be obstacles to their utilization as livestock feed. For example, beyond the subsistence level, the recycling of waste food is greatly restricted by hygiene concerns. Other problems include the difficulty of transporting bulky materials, the costs of processing, and the seasonal nature of supplies (CR Malaysia, 2003). Nonetheless, with improved processing methods and better awareness of the nutritional value of such feeds, there is potential to enhance the contribution of livestock to the productive use of the by-products of other activities (*ibid.*).

Box 13**The history of Hungarian Grey cattle – changing uses over time**

The genetic origin of Hungarian Grey cattle has not been definitively elucidated. Ancestral animals may have come from Asia or from Mediterranean areas, and a genetic contribution from the wild aurochs has been suggested. The character of the breed developed slowly under the husbandry of the Hungarian breeders of the Carpathian Basin. Between the fourteenth and seventeenth centuries cattle were exported on a large scale, with herds covering several hundred kilometres on foot to Nürnberg, Strasburg or Venice. Demand emerged for a “trade-mark” appearance which guaranteed the quality of Hungarian beef. The long-horn animals with handsome conformation, hardy, healthy character, and excellent meat quality were greatly valued by contemporary buyers.

The early eighteenth century began a new period in the breed’s history, as urban populations expanded and required supplies of agricultural products. Since the demand was mainly for cereals, extensive animal husbandry declined. During this period, the function of the breed shifted to the production of working oxen. Czech sugar factories valued them for their fast movement, their simple dietary requirements, and their exceptional longevity. With the introduction of tractors after the First World War many farms disposed of their Hungarian Greys.

In 1931, the Hungarian Grey Cattle Breeders’ National Association was founded and breeding activity was stimulated. However the Second World War severely disrupted these endeavours and many herds were destroyed. During the post-war period, low levels of milk production meant that the breed’s numbers declined rapidly. Official policy favoured cross-breeding with Soviet Kostroma cattle. By the early 1960s the only remaining herds were found on three state farms, with a total stock of six bulls and about 160 cows. However, at about this time, the idea of preserving rare breeds took hold in Hungary, and the Directory of State Farms allowed two more herds to be established. Because of a certain patriotic attachment to the breed, and the provision of small but permanent subsidies by the state, the population started to increase. By 2002, the number of cows had reached 4 263.

Today, functions of the breed include conservation grazing in National Parks, hobby breeding and a role as a tourist attraction. With respect to meat production, the breeders and the Hungarian Grey Cattle Breeders’ Association aim to organize meat processing and develop high-value products such as speciality sausages.

For further information see: Hungarian Grey Workshop (2000); Bodó (2005)

8 Roles of livestock for the poor

As described in the preceding chapters, livestock have diverse roles and functions, and can contribute in many ways to the well-being of their keepers. Richer sections of the population tend to have access to alternative means of meeting these needs (financial services, motorized transport etc.). Goods and services of this kind are frequently unaffordable or inaccessible to the poor. Livestock, as multifunctional assets, are therefore often important to many aspects of poor people’s livelihood strategies. Moreover, they provide the poor with opportunities to benefit from resources that would otherwise be difficult to put to productive use, such as crop residues, waste food, and common grazing land. Accurate data on the numbers of poor livestock keepers in the world are hard to come by (and there are of course numerous ways in which “poverty” and “livestock keepers” could be defined). Recent approximations have put the figure at around 550 to 600 million (Thornton *et al.*, 2002; IFAD, 2004).

Subsistence consumption of home-produced milk, eggs or meat can make a very important contribution to the nutrition of poor households (providing essential vitamins and micronutrients, for example). Livestock manure and animal traction are vital inputs for many poor farmers in mixed farming systems, who would otherwise have to invest in more expensive alternatives. The savings and risk-management functions outlined above are also frequently of great significance to the poor, reducing their vulnerability to fluctuations in levels of income from other activities, and providing a ready source of cash to meet expenses. For those households that are able to look beyond mere subsistence, expanding their livestock keeping activities and engaging in more market-oriented production is a potential pathway to increased income and improved livelihoods. Moreover, accumulating capital in the form of livestock may, in time, provide the opportunity to embark on new livelihood activities. The three “strategies” have been termed “hanging in”, “stepping up”, and “stepping out” (Table 30) (Dorward *et al.*, 2004).

As well as their financial roles, and the physical inputs that they provide to the livelihoods of the poor, livestock also have important social functions. Ownership of livestock may enable participation in the social and cultural life of the community, and the exchange of animals through gifts and loans can be a means of reinforcing social networks that can be drawn upon in times of need (FAO, 2002; IFAD 2004; Riethmuller, 2003).

Table 30
Roles of livestock by livelihood strategy

| Livelihood strategy | Principle roles of livestock |
|---------------------|--|
| “Hanging in” | Subsistence Complementary production (inputs to cropping) Buffering (against income fluctuations) Insurance |
| “Stepping up” | Accumulation Complementary production (inputs to cropping) Market production/income |
| “Stepping out” | Accumulation |

Source: adapted from Dorward et al. (2004)

A number of Country Reports recognize the potential role of livestock in poverty reduction. It is noted that some classes of livestock tend to be more associated with the poor than others. CR Botswana (2003), for example, indicates that the distribution of goats is more equal than that of cattle among the country’s rural households. In some countries, however, cattle and buffaloes are also very important to the livelihoods of the poor – CR Bangladesh (2004) notes that 62.5 percent of the large ruminants in the country are kept by small farmers and the landless. Several Country Reports mention the strong potential of indigenous livestock breeds for improving the livelihoods of the poor. The CRs from the Lao People’s Democratic Republic (2005) and Indonesia (2003), for example, note the significance of indigenous poultry keeping as an activity for the poor, which should be supported through development programmes and further research. CR Ethiopia (2004) mentions a recent study, which revealed the strong potential of the scavenging Fayoumi chicken as a tool for poverty reduction. Similar findings related to scavenging chicken breeds are reported in CR Ghana (2003).

Conversely, other Country Reports describe the positive role of well-planned cross-breeding activities. CR Bangladesh (2004), for example, mentions semi-scavenging poultry production programmes supported by NGOs and the Department of Livestock Services, which provide a source of income to poor women and youths in rural areas. Exotic and cross-bred birds are kept and supported with supplementary feeding, improved management and healthcare (ibid.). Similarly, CR United Republic of Tanzania (2004) reports the contribution of imported goat breeds to a gradual increase in milk consumption among low-income groups.

The importance of home consumption of animal products to nutrition, particularly for children, pregnant women and nursing mothers is also recognized (CR Sri Lanka, 2003). CR Uganda (2004) notes that the milk of the Kigezi goat breed is used to provide milk to sick children in very poor households.

Women make up an estimated 70 percent of the world’s poor (UNDP, 1995). Development strategies that contribute to the livelihoods of women are, therefore, particularly important from the perspective of poverty reduction. A number of Country Reports identify particular classes of livestock, products or activities where women have particular roles or access to resources and decision-making. Women tend to be associated with smaller species such as poultry, goats or sheep (CR Botswana, 2003; CR Central African Republic, 2003; CR Comoros, 2005; CR Guinea, 2003; CR Ghana, 2003; CR Kenya, 2004; CR Nigeria 2004; CR United Republic of Tanzania, 2004). CR Mozambique (2004) reports that women generally keep poultry and pigs, while men keep cattle and small ruminants. Alternatively, women may be closely involved in the care of calves (CR Mali, 2002). In terms of breeds, CR Niger (2003) mentions the Chèvre Rousse de Maradi goat as being particularly associated with women. In some countries, women have particular roles in the processing and/or sale of milk (CR Guinea, 2003; CR Ghana, 2003; CR Mali, 2002; CR Nigeria, 2004). CR Mauritania (2005) mentions that selling hides and skins is an important source of income for women from the most deprived sections of

society. Gender roles are, however, not necessarily stable. CR Lesotho (2005) reports that pig rearing in the country was traditionally practised mainly by women, but an increased demand for pig meat has led to men involving themselves in keeping the species.

Despite the significant contribution of women to livestock production, as CR Niger (2003) notes, training and extension activities are often directed towards men. Policies advocated to promote the role of women in livestock keeping include the development of relevant technologies such as labour-saving devices for processing livestock products (CR Nigeria, 2004), training, organization and credit provision (CR Guinea, 2003; CR Mali, 2002). Low levels of literacy are, however, recognized as a constraint to the promotion of women's role in livestock keeping (CR Guinea, 2003).

9 Conclusions

The information provided in the Country Reports illustrates that the uses of AnGR are very diverse. This is particularly the case for the smallholder production systems of the developing world. Many farmers rely on animals to provide inputs to crop production, and insurance and asset functions are of great importance where modern financial services are unavailable or unstable. In urbanized societies, livestock functions tend to be reduced – focusing on market-oriented production of food, fibre, skins and hides. Nevertheless, some cultural functions remain important – including roles in sports and leisure (mainly horses) and the supply of food products for particular festivals. New roles are also emerging (often for traditional breeds) in the heritage/tourism industries and in the provision of environmental services. However, there remains a large knowledge gap regarding the current roles of specific breeds, and whether they have characteristics that make them especially suited to particular functions or production conditions. There is a need for more complete data to be collected and made available through existing information systems.

Multiple roles of livestock and multiple combinations of interdependent roles require diversity within the livestock population – including both specialized and multifunctional breeds. However, decision-making in the field of AnGR management is often characterized by a lack of attention to multiple functions, particularly non-marketed outputs and benefits that are difficult to quantify. In these circumstances there is a danger that the value of local multifunctional breeds is underestimated, and that only a partial picture of livestock's contribution to human well-being is obtained.

10 References

Arya, H.P.S., Yadav, M.P. & Tiwari, R. 2002. Livestock technologies for small farm systems. *In* P.S. BIRTHAL & P.P. Rao, *Technology options for sustainable livestock production in India*. Proceedings of the Workshop on Documentation, Adoption, and Impact of Livestock Technologies in India, 18–19 Jan 2001, ICRISAT-Patancheru, India, pp. 8–89. New Delhi/Patancheru, India. National Centre for Agricultural Economics and Policy Research/ International Crops Research Institute for the Semi-Arid Tropics.

Bodó, I. 2005. *From a bottle neck up to the commercial option*. Paper presented at the 4th World Italian Beef Cattle Congress, Gubbio, Italy, 29 April 29 – 1 May 1, 2005, (available at http://www.anabic.it/congresso2005/atti/lavori/023%20def_Bod%C3%B2_st.pdf).

CR (Country name). year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).

Dorward, A.R., Anderson, S., Paz, R., Pattison, J., Sanchez Vera, E., Nava, Y. & Rushton, J. 2004. *A guide to indicators and methods for assessing the contribution of livestock keeping to the livelihoods of the poor*. London. DFID. (also available at <http://www.ilri.cgiar.org/html/Guide16Dec.pdf>).

FAO. 2002. *Improved animal health and poverty reduction for rural livelihoods*. Animal Production and Health Paper, No. 153. Rome.

FAO. 2003a. *The yak*. second edition revised and enlarged by G. Wiener, H. Jianlin, & L. Ruijun. Bangkok. FAO Regional Office for Asia and the Pacific.

- FAO.** 2003b. *World agriculture towards 2015/2030. An FAO perspective*. Edited by J. Bruinsma. London. Earthscan.
- Hungarian Grey Workshop.** 2000. *The origins of the Hungarian Grey cattle*. Proceedings of a workshop held in Bugacpuszta, Hungary, 23–24 November 2000.
- IFAD.** 2004. *Livestock services and the poor. A global initiative. Collecting, coordinating and sharing information*. Rome. International Fund for Agricultural Development.
- Riethmuller, P.** 2003. The social impact of livestock: a developing country perspective. *Animal Science Journal*, 74(4): 245–253.
- Sarkar, A.B.** 2001. Strategies for development of animal husbandry in Assam. In B.C. Barah, ed. *Prioritisation of strategies for agricultural development in Northeastern India*. Proceedings 9, pp. 29–33. New Delhi. National Center for Agricultural Economics and Policy Research (ICAR).
- Schiere, J.B.** 1995. *Cattle, straw and system control*. Amsterdam. Koninklijk Institute voor de Tropen.
- Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, F., Odero, A.N. & Ndegwa, T.** 2002. *Mapping poverty and livestock in the developing world*. Nairobi. International Livestock Research Institute. (also available at <http://www.ilri.cgiar.org/InfoServ/Webpub/fulldocs/mappingPLDW/index.htm>).
- UNDP.** 1995. *The human development report 1995: gender and human development*. New York. United Nations Development Programme.

SECTION E: ANIMAL GENETIC RESOURCES AND RESISTANCE TO DISEASE

1 Introduction

Livestock diseases adversely affect animal production throughout the world. Livestock keepers and other stakeholders involved in promoting animal health can draw on a number of approaches to reducing these negative effects. Options at the herd level include chemotherapy, vaccination, the control of disease vectors, and appropriate management methods. However, there are often constraints to the sustainability of such disease control strategies. Problems include the environmental and food safety-related impacts of chemical treatments; the affordability and accessibility of treatments to poorer livestock keepers; and the evolution of parasite resistance to the treatments applied. Examples of the latter problem include widespread resistance of nematode parasites to anthelmintic drugs; bacterial resistance to antibiotics; resistance to antiprotozoal drugs such as those used in the treatment of trypanosomiasis; the evolution of virus resistance to vaccines for diseases such as Marek's disease; and acaricide resistance in ticks. In the case of antibiotics, there are also concerns regarding residues in the food chain, and the implications for human health of the emergence of antibiotic-resistant microorganisms (BOA, 1999).

For many livestock diseases, evidence has been found for genetic variation in the extent to which host animals are susceptible. Two distinct phenomena must be distinguished in relation to the genetic management of disease. On the one hand, "resistance" refers to the ability of the host to resist infection. On the other, "tolerance" refers to a situation where the host is infected by the pathogen, but suffers little adverse effect. The distinction can be important. For example, where the objective is to prevent the spread of the disease to other populations (as in the case of zoonotic diseases) disease resistance rather than tolerance is required.

Managing genetic resources in order to enhance the resistance or tolerance found in livestock populations offers an additional tool for disease control. A number of advantages of incorporating genetic elements in disease management strategies have been recognized (FAO, 1999) including:

- the permanence of genetic change once it is established;
- the consistency of the effect;
- the absence of the need for purchased inputs once the effect is established;
- the effectiveness of other methods is prolonged as there is less pressure for the emergence of resistance;
- the possibility of broad spectrum effects (increasing resistance to more than one disease);
- the possibility of having less impact on the evolution of macroparasites such as helminths, compared to other strategies such as chemotherapy or vaccination;
- adding to the diversity of disease management strategies.

A number of approaches to the genetic management of disease can be applied depending on the nature of the problem and the resources available. Strategies may include choosing the appropriate breed for the production environment; cross-breeding to introduce genes into breeds that are otherwise well adapted to the required purposes; and the selection for breeding purposes of individuals that have high levels of disease resistance or tolerance. The latter approach can be facilitated if molecular genetic markers associated with the desired traits have been identified.

The starting point for all these strategies is the genetic diversity of the livestock populations. If genetic resources are eroded, potentially important means of combating disease may be lost. Moreover, there is evidence, from simulation studies, to show that populations that are diverse in terms of the number of distinct genotypes conferring disease resistance are less susceptible to catastrophic disease

epidemics (Springbett *et al.*, 2003). The maintenance of diversity in terms of the genes underlying resistance provides an important resource for combating the effects of possible future pathogen evolution.

2 Disease resistant or tolerant breeds

There is much anecdotal evidence pointing to the greater disease resistance of livestock breeds indigenous to environments where they face a heavy disease challenge. When countries enter details of their livestock breeds in FAO's DAD-IS system, they have the opportunity to indicate whether the breeds have any particularly interesting or valuable characteristics – including disease resistance. In most of these cases the claims made for specific breeds have not been subject to scientific investigation. However, for many of the diseases in question, evidence is available in the scientific literature for differential disease resistance or tolerance among livestock breeds (see examples in Table 31). The following discussion highlights the information made available in DAD-IS regarding the resistance/tolerance of particular breeds, focusing on the diseases for which there is also scientific evidence that there is a genetic component to susceptibility. Table 32 presents an overview of the entries in DAD-IS that report disease resistance in mammalian breeds, and Tables 33 to 39 list the breeds reported as being resistant or tolerant to specific diseases or disease types.

Table 31
Selected studies indicating breed difference in resistance/tolerance to specific diseases

| Disease/ Parasite | Breed(s) showing greater resistance | Compared to which breed(s) | Experimental conditions | Results | Reference |
|--|--|-----------------------------------|---|---|-------------------------------|
| <i>Trypanosoma congolense</i> | Djallonke sheep | Djallonke × Sahelian cross-breeds | Artificial Infection | Lower parasitaemia level, a longer prepatent period and a higher antibody response than the cross-breeds, but the cross-breeds were still heavier and grew faster | Goosens <i>et al.</i> (1999) |
| Ticks (<i>Amblyomma variegatum</i> ; <i>Hyalomma spp.</i>) | N'Dama cattle | N'Dama × Zebu | Field conditions in the Gambia | Fewer ticks | Mattioli <i>et al.</i> (1993) |
| Ticks (various species) | N'Dama cattle | Zebu | Village herds in the Gambia | Fewer ticks | Claxton and Leperre (1991) |
| <i>Theileria annulata</i> | Sahiwal cattle | Holstein-Friesian | Artificial infection | Less severe clinical symptoms | Glass <i>et al.</i> (2005) |
| <i>Anaplasma marginale</i> ; ticks (various species) | N'Dama cattle | Gobra Zebu | Field conditions in the Gambia | Lower serological prevalence of <i>A. marginale</i> ; fewer ticks. | Mattioli <i>et al.</i> (1995) |
| <i>Haemonchus contortus</i> | N'Dama cattle | Zebu | Village herds in the Gambia | Fewer abomasal worms, lower FEC*. | Claxton and Leperre (1991) |
| <i>Haemonchus contortus</i> | Red Masaai sheep | Dorper | Lambs kept under field conditions in subhumid coastal Kenya | Lambs showed lower faecal egg count for <i>H. contortus</i> , higher PCV**, lower mortality than Dorper lambs. Estimated to be 2 to 3 times as | Baker (1998) |

| Disease/ Parasite | Breed(s) showing greater resistance | Compared to which breed(s) | Experimental conditions | Results | Reference |
|--|---|--|--|---|-------------------------------|
| <i>Haemonchus contortus</i> | Small East African goats | Galla | | productive as Dorper flocks under these conditions. Kids showed lower faecal egg count for <i>H. contortus</i> , higher PCV, lower mortality than Galla kids. Estimated to be 2 to 3 times as productive as Galla flocks under these conditions. | Baker (1998) |
| <i>Haemonchus contortus</i> | Santa Ines sheep | Ile de France, Suffolk | Lambs grazed on pastures in São Paulo State SE Brazil | Lower FEC, higher PCV, lower worm counts | Amarante <i>et al.</i> (2004) |
| <i>Fasciola gigantica</i> | Indonesian Thin Tailed sheep | Merino | Artificial Infection | Lower number of flukes recovered from liver; differences in immune response | Hansen <i>et al.</i> (1999) |
| <i>Fasciola gigantica</i> | Indonesian Thin Tailed sheep | St Croix | Artificial infection | Fewer parasites recovered from liver | Roberts <i>et al.</i> (1997) |
| <i>Sarcocystis miescheriana</i> | Meishan pigs | Piértrain | Artificial Infection | Less severely affected in terms of clinical, serological, haematological and parasitological indicators. | Reiner <i>et al.</i> (2002) |
| <i>Ascaridia galli</i> | Lohman Brown chickens | Danish Landrace | Artificial Infection | Lower worm burdens and egg excretion | Permin and Ranvig (2001) |
| Foot rot | East Friesian × Awassi cross-bred sheep | Pure-bred Awassi | Natural outbreak in Israel | Lower prevalence. | Shimshony (1989) |
| Foot rot | Romney Marsh, Dorset Horn, Border Leicester sheep | Peppin Merino, Saxon Merino | Natural transmission on irrigated pasture in Australia | Less serious lesions, faster recovery | Emery <i>et al.</i> (1984) |
| Newcastle Disease virus, Infectious Bursal Disease | Mandarrah chickens | Gimmazah, Sinah, Dandrawi (native Egyptian breeds) | Artificial Infection | Lower mortality rate than the other breeds | Hassan <i>et al.</i> (2004) |

* FEC = faecal egg count; **PCV = packed cell volume

Table 32
Mammalian breeds reported to DAD-IS as having resistance/tolerance to specific diseases or parasites

| Disease | Buffalo | Cattle | Goats | Sheep | Pig | Horse | Deer |
|---|---------|--------|-------|-------|-----|-------|------|
| Trypanosomiasis | | 17 | 4 | 4 | | | |
| Tick infestation/burden | 1 | 17 | | 1 | | | 1 |
| Tick-borne diseases (unspecified) | | 4 | | | | | |
| Anaplasmosis | | 2 | | | | | |
| Piroplasmosis/Babesiosis | | 4 | | | | 1 | |
| Heartwater/Cowdriosis | | 1 | | 1 | | | |
| Internal parasites/worms | 1 | 2 | 1 | 9 | 1 | 2 | 1 |
| Fascioliasis | 2 | | | 1 | | | |
| Bovine leukosis | | 9 | | | | | |
| Foot rot (<i>Bacteroides nodulosus</i>) | | 1 | | 14 | | | |
| Total* | 4 | 59 | 6 | 33 | 3 | 5 | 2 |

*Total number of entries related to disease resistance (some breeds are reported to show resistance to more than one disease)

2.1 Trypanosomiasis

Trypanosomiasis transmitted by tsetse flies is one of the most important animal health problems in Africa – occurring mainly in West and Central Africa, and in parts of East Africa. Other types of trypanosomiasis are significant problems both in Africa and in other regions. Parasite resistance associated with control based on trypanocidal drugs, and sustainability problems involved in the implementation of tsetse control programmes, have increased interest in the use of integrated control methods including the utilization of disease tolerant breeds of livestock (FAO, 2005). The most trypanotolerant breeds include N'Dama and West African Shorthorn cattle, as well as Djallonke sheep and goats. Despite smaller size, studies have shown that these breeds are more productive than susceptible animals under moderate to high tsetse challenge (Agyemang *et al.*, 1997). Table 33 shows the breeds reported in DAD-IS as being resistant/tolerant to trypanosomiasis.

Table 33
Breeds reported to DAD-IS as showing resistance/tolerance to trypanosomiasis

| Species/Subregion | Number of breeds | Most common name of breed |
|---------------------|------------------|--|
| Cattle | | |
| North & West Africa | 15 | N'dama (20), Baoulé (4), Lagune (Lagoon) (6), Bourgou (2), Mutura (2), Dahomey (Daomé) (2), Somba, Namchi, Kapsiki, Kuri, Toupouri, Ghana Shorthorn, Keteku, Somba |
| East Africa | 2 | Sheko, Jiddu |
| Sheep | | |
| North & West Africa | 4 | Vogan (2), West African Dwarf (4), Djallonké (10), Kirdimi |
| Goats | | |
| North & West Africa | 4 | West African Dwarf (16), Djallonké (2), Kirdimi, Diougry |

Figures in parenthesis = number of countries reporting if more than one

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

2.2 Ticks and tick-borne diseases

Ticks are a widespread problem for livestock producers, particularly in the tropics. Ticks themselves weaken animals by the withdrawal of blood, cause tick paralysis through the injection of toxins secreted in their saliva, damage hides, and provide sites for secondary infections. Moreover, they also spread a number of serious diseases, the most notable being anaplasmosis, babesiosis, theileriosis and cowdriosis (heartwater). The presence of specific tick species varies with agro-ecological conditions, some being more widely distributed than others. Resistance or tolerance to ticks and to a lesser extent to tick-borne diseases is well documented. For example, a number of studies indicate that N'Dama

cattle show a higher resistance than Zebu animals to ticks (Claxton and Leperre 1991; Mattioli *et al.*, 1993; Mattioli *et al.*, 1995). Another example is provided by a study in Australia which found that pure-bred *Bos indicus* cattle were less susceptible to babesiosis than were cross-bred *Bos indicus* × *Bos taurus* animals (Bock *et al.*, 1999). In the case of theileriosis caused by *Theileria annulata*, Sahiwal calves, a breed indigenous to India, were found to be less adversely affected than Holstein-Friesian calves when infected with the disease (Glass *et al.*, 2005). Tables 34 and 35, respectively, show the breeds reported in DAD-IS as showing resistance/tolerance to ticks and tick-borne diseases.

Table 34
Breeds reported to DAD-IS as showing resistance/tolerance to tick-burden

| Species/Subregion | Number of breeds | Most common name of breed |
|-----------------------|------------------|---|
| Cattle | | |
| Southern Africa | 8 | Nguni (2), Angoni, Sul Do Save, Pedi, Bonsmara, Shangaan, Kashibi, Tswana |
| Southeast Asia | 4 | Pesisir, Limousin, Javanese Zebu, Thai |
| Europe & the Caucasus | 1 | Zebu of Azerbaijan |
| South America | 1 | Romosinuano |
| Southwest Pacific | 3 | Australian Friesian Sahiwal, Australian Milking Zebu, Australian Sahiwal |
| Sheep | | |
| Southern Africa | 2 | Nguni (3), Landim |
| Buffalo | | |
| Southeast Asia | 1 | Thai |
| Deer | | |
| Southeast Asia | 1 | Sambar |

Figures in parenthesis = number of countries reporting if more than one

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

Table 35
Breeds reported to DAD-IS as showing resistance/tolerance to tick-borne diseases

| Species/Subregion | Disease | Number of breeds | Most common name of breed |
|------------------------|-----------------------------------|------------------|-------------------------------|
| Cattle | | | |
| North & West Africa | Tick-borne diseases (unspecified) | 2 | Baoulé, Ghana Shorthorn |
| Southern Africa | Tick-borne diseases (unspecified) | 1 | Angoni (2) |
| Europe & the Caucasus | Anaplasmosis | 2 | Cinisara, Modicana, |
| North & West Africa | Piroplasmosis | 2 | N'dama, Noire Pie de Mknès |
| Europe & the Caucasus | Piroplasmosis | 1 | Modicana |
| Europe & the Caucasus* | Heartwater (Cowdriosis) | 1 | Creole (also dermatophilosis) |
| Sheep | | | |
| Southern Africa | Heartwater (Cowdriosis) | 1 | Damara (2) |
| Horses | | | |
| Europe & the Caucasus | Piroplasmosis | 1 | Pottok |

Figures in parenthesis = number of countries reporting if more than one

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

*Guadeloupe, Martinique

2.3 Internal parasites

Helminthosis has been recognized as one of the most serious animal health constraints affecting poor livestock keepers (Perry *et al.*, 2002). Resistance/tolerance to *Haemonchus contortus*, an ubiquitous

nematode worm that infests the stomachs of ruminant animals, has been subject to many studies (see examples in Table 31). The Red Maasai sheep breed, for example, is noted for its resistance to gastrointestinal worms. A study conducted under field conditions in subhumid coastal areas of Kenya found that lambs of the Red Maasai breed showed lower faecal egg counts (FEC) for *Haemonchus contortus*, and lower mortality than Dorper lambs (another breed widely kept in Kenya). The Red Maasai flocks were estimated to be two to three times as productive as the Dorper animals under these subhumid conditions favourable to the parasites (Baker, 1998). Similarly, greater resistance and higher productivity was found in Small East African goats compared to goats of the Galla breed under the same conditions (ibid.). There is also some scientific evidence for resistance/tolerance to the liver fluke *Fasciola gigantica*, which is a widespread parasite. For example, Indonesian Thin Tailed sheep have been found to show greater resistance than sheep of the St. Croix and Merino breeds (Roberts *et al.*, 1997). One sheep breed and two buffalo breeds are reported in DAD-IS as showing some resistance/tolerance to fascioliasis (Table 36).

Table 36
Breeds reported to DAD-IS as showing resistance/tolerance to internal parasites/worms

| Species/Subregion | Number of breeds | Most common name of breed |
|-------------------------------|------------------|---|
| Cattle | | |
| Southern Africa | 1 | Madagascar Zebu |
| Southeast Asia | 1 | Javanese Zebu |
| Goats | | |
| Near & Middle East | 1 | Yei goat |
| Sheep | | |
| Southern Africa | 2 | Madagascar, Kumumawa |
| Southeast Asia | 3 | Garut, Malin, Priangan |
| Europe & the Caucasus | 1* | Churra Lebrijana (fascioliasis) |
| Latin America & the Caribbean | 3 | Criollo (8), Criollo Mora, Morada Nova |
| Near & Middle East | 1 | Rahmani |
| Buffalo | | |
| Southeast Asia | 3* | Papua New Guinea Buffalo, Kerbau-Kalang (fascioliasis), Kerbau Indonesia (fascioliasis) |
| Pigs | | |
| Southeast Asia | 1 | South China |
| Deer | | |
| Southeast Asia | 1 | Sambar |
| Horses | | |
| Southeast Asia | 2 | Kuda Padi , Bajau |

Figures in parenthesis = number of countries reporting if more than one

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

**Figures include breeds reported to be resistant to fascioliasis*

2.4 Foot rot

Foot rot is a contagious bacterial disease of hoofed animals which causes severe lameness. It is a serious economic problem, particularly for sheep producers. It occurs more often in temperate zones. There is evidence that some breeds are more resistant to foot rot than others. A study conducted in Australia revealed that when exposed to natural infection on irrigated pastures, the British breeds Romney Marsh, Dorset Horn and Border Leicester showed less susceptibility to foot rot (manifested by relatively benign lesions and a more rapid resolution) than did Peppin and Saxon Merinos (Emery *et al.*, 1984).

Table 37
Breeds reported to DAD-IS as showing resistance/tolerance to foot rot

| Species/Regions | Number of breeds | Most common name of breed |
|---------------------------------|------------------|---|
| Cattle Europe & the Caucasus | 1 | Sayaguesa |
| Sheep North & West Africa | 1 | Beni Ahsen |
| East Asia | 2 | Large Tailed Han, Small Tailed Han |
| Europe & the Caucasus | 10 | Kamieniecka, Leine, Swiniarka, Polskie Owce Długowelniste, Churra Lebrijana, Lacha, Bündner Oberländerschaf, Engadiner Fuchsschaf, Rauhwolliges Pommersches Landschaf, Soay |
| Southwest Pacific | 1 | Broomfield Corriedale |

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

Similarly, Shimshony (1989) reports that East Friesian × Awassi cross-bred sheep showed lower prevalence of the disease than pure-bred Awassi during an outbreak of the disease in Israel. It appears that breeds originating from wetter areas where the disease is more common are less susceptible. Breeds reported in DAD-IS as showing resistance/tolerance to foot rot are shown in Table 37.

2.5 Bovine leukosis

Bovine leukosis is a blood-borne disease caused by the bovine leukosis virus (BLV). The disease causes considerable economic losses as a result of trade restrictions, mortality and lost production, and condemnation of carcasses at the slaughterhouse. There appears to be a genetic component to susceptibility to the disease. Petukhov *et al.* (2002), for example, report differences between breeds, families, and bulls' daughters in terms of the frequency of BLV infection among cattle in West Siberia. Table 38 shows the breeds reported in DAD-IS as showing resistance/tolerance to bovine leukosis.

Table 38
Cattle breeds reported to DAD-IS as showing resistance/tolerance to leukosis

| Subregion | Number of breeds | Most common name of breed |
|-----------------------|------------------|--|
| Central Asia | 1 | Bestuzhevskaya |
| Europe & the Caucasus | 7 | Krasnaya gorbatovskaya, Istobenskaya, Kholmogorskaya, Suksunskaya skot, Yakutskii Skot, Yaroslavskaya, Yurinskaya, Sura de stepa |

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

2.6 Diseases of poultry

Outbreaks of Newcastle disease and gumboro (infectious bursal disease) frequently devastate village chicken flocks. Both diseases have a worldwide prevalence. Outbreaks of Newcastle disease have been reported for at least a century. Four panzootic waves occurred during the twentieth century. Gumboro was first described in 1962 and epidemic outbreaks have been reported since the 1970s.

Table 39
Breeds reported to DAD-IS as showing resistance/tolerance to avian diseases

| Species/Subregion | Disease | Number of breeds | Most common name of breed |
|-----------------------|-------------------|------------------|---|
| Chicken | | | |
| North & West Africa | Newcastle disease | 1 | Poule De Benna |
| Southern Africa | Newcastle disease | 1 | Nkhuku |
| Southeast Asia | Newcastle disease | 1 | Red Jungle Fowl |
| Central America | Newcastle disease | 1 | Gallina criolla o de rancho |
| Southeast Asia | Marek's disease | 1 | Ayam Kampong |
| Europe & the Caucasus | Marek's disease | 4 | Borky 117, Scots Dumpy, Hrvatica, Bohemian Fowl |
| Duck (domestic) | | | |
| North & West Africa | Newcastle disease | 2 | Local Duck of Moulkou and Bongor, Local Duck of Gredaya and Massakory |
| Guinea fowl | | | |
| North & West Africa | Newcastle disease | 2 | Numida Meleagris Galeata Pallas, Djaoulés (peulh) |
| Muscovy duck | | | |
| North & West Africa | Newcastle disease | 1 | Local Muscovy Duck of Karal and Massakory |
| Turkey | | | |
| North & West Africa | Newcastle disease | 1 | Moroccoan Beldi |

Note that there may be other breeds for which there is evidence of disease resistance/tolerance but for which this has not been reported to DAD-IS

A study comparing the effects of infection with Newcastle disease and infectious bursal disease virus on four Egyptian chicken breeds found that Mandarrah chickens (a dual purpose breed developed through cross-breeding) showed less susceptibility than the other breeds to both diseases – indicated by significantly lower mortality rates following artificial infection (Hassan *et al.*, 2004). Similarly, there is evidence for genetic resistance to Marek's disease. Lakshmanan *et al.* (1996), for example, report that a study of Fayoumi and White Leghorn chickens revealed the former to show greater resistance to the development of tumours (see below for a further discussion of breeding for resistance to Marek's disease). Table 39 shows the avian breeds reported in DAD-IS as showing resistance/tolerance to specific avian diseases.

3 Opportunities for within-breed selection for disease resistance

Selective breeding to take advantage of within-breed variation in disease resistance is an important strategy in the control of a number of diseases. For endemic diseases, which are a continuously present in the relevant production systems (e.g. mastitis, helminthosis) selection based on phenotypic response to disease challenge is possible. In the case of mastitis, somatic cell count in milk (an indicator of bacterial infection) or clinical cases of the disease can be used as phenotypic indicators of susceptibility. These indicators are routinely recorded in dairy herds, and their variation has been found to have a large genetic component (Rupp and Boichard, 2003). The existence of an antagonistic relationship between genetic merit for production traits and susceptibility to the disease has promoted interest in selection for resistance. Many dairy cattle breeding programmes, therefore, include increasing resistance to mastitis as an objective.

Parasite resistance to anthelmintic drugs is as a major problem for the livestock sector in many parts of the world, particularly in the case of small ruminant production. Control strategies based almost entirely on the frequent use of dewormers are increasingly regarded as unsustainable given the emergence of multiple drug resistant parasites (Kaplan, 2004). The need for alternative methods of control is highlighted by the fact that no major new class of anthelmintic drug has been launched for around 25 years, and there appears to be little immediate prospect for the emergence of new

candidates (*ibid.*). Interest is growing in integrated parasite management (IPM) programmes, of which breeding for genetic resistance is a component. Selective breeding of sheep on the basis of FEC has been shown to be an effective means of reducing the need for treatment with anthelmintics and of reducing the contamination of pastures with the eggs of nematode parasites (Woolaston, 1992; Morris *et al.*, 2000; Woolaston and Windon, 2001; Bishop *et al.*, 2004).

For epidemic diseases, alternative approaches have to be adopted. It is necessary to develop techniques for selection based on marker alleles associated with enhanced disease resistance (Bishop and Woolliams, 2004). In the case of Marek's disease (a viral disease of chickens), vaccine use has apparently increased the virulence of the disease. As such, breeding for resistance to the disease will become increasingly important in poultry production systems. Selection for resistance based on specific B alleles within the major histocompatibility complex (MHC) (Bacon, 1987) has been used for many years to assist in the management of the Marek's disease. More recently, researchers have also identified a number of quantitative trait loci (QTL) associated with resistance to the disease (Vallejo *et al.*, 1998; Yonash *et al.*, 1999; Cheng, 2005). Other diseases for which markers for disease resistance have been identified include dermatophilosis in cattle (Maillard *et al.*, 2003), diarrhoea caused by *E. coli* in pigs (Edfors and Wallgren, 2000) and scrapie in sheep (Hunter *et al.*, 1996).

Box 14 **Genetic resistance to African swine fever**

African swine fever (ASF) poses a serious threat to the global pork industry. ASF is a highly contagious disease causing rapid haemorrhagic death of domestic pigs. No effective vaccine is available and the only effective control strategies are strict regulation of movement of animals and their products and rapid identification, slaughter and disposal of infected animals. Alternative approaches are critically needed.

In contrast to the severe disease observed in domestic pigs, African swine fever virus (ASFV) infection causes no clinical effects in wild native African pigs, the common warthog (*Phacochoerus africanus*) and bushpig species (*Potamochoerus spp.*). Such naturally occurring species-specific genetic resistance is valuable to the study of molecular mechanisms integral to the pathogenesis of this disease.

Breeding for genetic resistance to ASF has been attempted by cross-breeding domestic pigs with resistant species. Despite anecdotal evidence to suggest that this may be possible, interbreeding has had limited success. Alternatively, it may be possible to breed for ASFV resistance by breeding domestic pigs that have survived natural ASFV challenge. Approximately 5–10 percent of domestic pigs survive ASFV infection. Unfortunately, survivors usually succumb to eradication measures following an outbreak. Such an approach would allow for study of the nature of genetic resistance and could provide founder animals for resource families that could be used to confirm and quantify genetic variation in resistance or tolerance to ASFV and for identification of associated genetic markers or QTL (quantitative trait loci).

Molecular and genomics-based studies have identified key cellular targets of ASFV proteins that are essential for virus replication or contribute to virus evasion of immune defence mechanisms. Comparative analysis of DNA sequences of these genes from pig species with varying susceptibilities may reveal mutations (single nucleotide polymorphisms or SNPs) that are associated with genetic variation in resistance. Transcriptome analysis of ASFV-infected macrophages using microarrays will provide new candidate genes that are differentially regulated during infection. Such candidate genes could be used for development of DNA marker tests for selection of animals with reduced susceptibility to disease.

Conservation of resistant breeds is critical for progress in genetic resistance to ASFV. Animals, tissues and DNA are vital resources for researchers.

Although breeding for increased resistance to ASFV may be possible, there are several factors to be considered before embarking on such a programme. One consideration is that resistant pigs that are unable to be infected by ASFV will be difficult to achieve. It is more likely that pigs will express a phenotype that is "tolerant" to the clinical effects of ASFV. While tolerant pigs may not express clinical disease, they may become infected and could shed ASFV into the environment. As such, these pigs could pose a risk to susceptible pigs in the area or undermine control strategies.

Provided by Dr Marnie Mellencamp

4 Conclusions

It is clear that there is a strong case for the inclusion of genetic elements within disease control strategies, particularly in the light of constraints to the sustainability of many other methods. There is well-documented evidence for variation within and between breeds in terms of susceptibility to many important diseases, and in a number of cases this element has been incorporated within breeding programmes. However, research into the genetics of resistance and tolerance to livestock disease is rather limited in terms of the diseases, breeds and species investigated. If breeds become extinct before their disease resistance qualities have been identified, genetic resources which could greatly contribute to improving animal health and productivity are lost for ever.

5 References

- Agyemang, K., Dwinger, R.H., Little, D.A. & Rowlands, G.J.** 1997. *Village N'Dama cattle production in West Africa: six years of research in the Gambia*. Nairobi. International Livestock Research Institute and Banjul, International Trypanotolerance Centre.
- Amarante, A.F.T., Bricarello, P.A., Rocha, R.A. & Gennari, S.M.** 2004. Resistance of Santa Ines, Suffolk and Ile de France sheep to naturally acquired gastrointestinal nematode infections. *Veterinary Parasitology*, 120(1–2): 91–106.
- Bacon, L.D.** 1987. Influence of the major histocompatibility complex on disease resistance and productivity. *Poultry Science*, 66(5): 802–811.
- Baker, R.L.** 1998. Genetic resistance to endoparasites in sheep and goats. A review of genetic resistance to gastrointestinal nematode parasites in sheep and goats in the tropics and evidence for resistance in some sheep and goat breeds in sub-humid coastal Kenya. *Animal Genetic Resources Information*, 24: 13–30.
- Bishop, S.C., Jackson, F., Coop, R.L. & Stear, M.J.** 2004. Genetic parameters for resistance to nematode infections in Texel lambs. *Animal Science*, 78(2): 185–194.
- Bishop, S.C. & Woolliams, J.A.** 2004. Genetic approaches and technologies for improving the sustainability of livestock production. *Journal of the Science of Food and Agriculture*, 84(9): 911–919.
- BOA.** 1999. *The use of drugs in food animals: benefits and risks*. Washington DC. Board on Agriculture, National Academies Press.
- Bock, R.E., Kingston, T.G. & de Vos, A.J.** 1999. Effect of breed of cattle on transmission rate and innate resistance to infection with *Babesia bovis* and *B. bigemina* transmitted by *Boophilus microplus*. *Australian Veterinary Journal*, 77(7): 461–464.
- Cheng, H.H.** 2005 Integrated genomic approaches to understanding resistance to Marek's Disease. In S.J. Lamont, M.F. Rothschild & D.L. Harris, eds. *Proceedings of the third International Symposium on Genetics of Animal Health*, Iowa State University, Ames, Iowa, USA. July 13–15, 2005.
- Claxton, J. & Leperre, P.** 1991. Parasite burdens and host susceptibility of Zebu and N'Dama cattle in village herds in the Gambia. *Veterinary Parasitology*, 40(3–4): 293–304.
- Edfors, L.I. & Wallgren, P.** 2000. *Escherichia coli* and *Salmonella* diarrhoea in pigs. In R.F.E. Axford, S.C. Bishop, J.B. Owen & F.W. Nicholas, eds. *Breeding for resistance in Farm Animals*, pp. 253–267. Wallingford, UK. CABI Publishing.
- Emery, D.L., Stewart, D.J. & Clark, B.L.** 1984. The susceptibility of five breeds of sheep to foot rot. *Australian Veterinary Journal*, 61(3): 85–88.
- FAO.** 1999. *Opportunities for incorporating genetic elements into the management of farm animal diseases: policy issues*. by S. Bishop, M. de Jong & D. Gray. Background Study Paper Number 18. Commission on Genetic Resources for Food and Agriculture. Rome.
- FAO.** 2005. *Trypanotolerant livestock in the context of trypanosomiasis intervention strategies*. by K. Agyemang. PAAT Technical and Scientific Series No. 7. Rome.
- FAOSTAT.** (available at <http://faostat.fao.org/site/291/default.aspx>).

- Glass, E.J., Preston, P.M., Springbett, A., Craigmile, S., Kirvar, E., Wilkie, G. & Brown, C.G.D.** 2005. *Bos taurus* and *Bos indicus* (Sahiwal) calves respond differently to infection with *Theileria annulata* and produce markedly different levels of acute phase proteins. *International Journal for Parasitology*, 35(3): 337–347.
- Goosens, B., Osaer, S., Ndao, M., Van Wingham, J. & Geerts, S.** 1999. The susceptibility of Djallonké and Djallonké-Sahelian crossbred sheep to *Trypanosoma congolense* and helminth infection under different diet levels. *Veterinary Parasitology*, 85(1): 25–41.
- Hansen, D.S., Clery, D.G., Estuningsih, S.E., Widjajanti, S., Partoutomo, S. & Spithill, T.W.** 1999. Immune responses in Indonesian thin tailed sheep during primary infection with *Fasciola gigantica*: lack of a species IgG₂ antibody response is associated with increased resistance to infection in Indonesian sheep. *International Journal for Parasitology*, 29(7): 1027–1035.
- Hassan, M.K., Afify, M.A. & Aly, M.M.** 2004. Genetic resistance of Egyptian chickens to infectious bursal disease and Newcastle disease. *Tropical Animal Health and Production*, 36(1): 1–9.
- Hunter, N., Foster, J.D., Goldmann, W., Stear, M.J., Hope, J. & Bostock, C.** 1996. Natural scrapie in closed flock of Cheviot sheep occurs only in specific PrP genotypes. *Archives of Virology*, 141(5): 809–824.
- Kaplan, R.M.** 2004. Drug resistance in nematodes of veterinary importance: a status report. *Trends in Parasitology*, 20(10): 477–481.
- Lakshmanan, N., Kaiser, M.G. & Lamont, S.J.** 1996. Marek's disease resistance in MHC-congenic lines from Leghorn and Fayoumi breeds. In Current research on Marek's disease, *Proceedings of the 5th International Symposium*, East Lansing, Michigan, 7–11 September 1996, pp. 57–62. Kennet Sque, Pennsylvania, USA. American Association of Avian Pathologists.
- Maillard, J.C., Berthier, D., Chantal, I., Thevenon, S., Sidibe, I., Stachurski, F., Belemsaga, D., Razafindraibe, H. & Elsen, J.M.** 2003. Selection assisted by a BoLA-DR/DQ haplotype against susceptibility to bovine dermatophilosis. *Genetics Selection Evolution*, 35(Suppl. 1): S193–S200.
- Mattioli, R.C., Bah, M., Faye, J., Kora, S. & Cassama, M.** 1993. A comparison of field tick infestation on N'Dama, Zebu and N'Dama × Zebu crossbred cattle. *Veterinary Parasitology*, 47(1–2): 139–148.
- Mattioli, R.C., Bah, M., Kora, S., Cassama, M. & Clifford, D.J.** 1995. Susceptibility to different tick genera in Gambian N'Dama and Gobra zebu cattle exposed to naturally occurring tick infection. *Tropical Animal Health and Production*, 27(2): 995–1005.
- Morris, C.A., Vlassoff, A., Bisset, S.A., Baker, R.L., Watson, T.G., West, C.J. & Wheeler, M.** 2000. Continued selection of Romney sheep for resistance or susceptibility to nematode infection: estimates of direct and correlated responses. *Animal Science*, 70(1): 17–27.
- Permin, A. & Ranvig, H.** 2001. Genetic resistance to *Ascaridia galli* infections in chickens. *Veterinary Parasitology*, 102(2): 101–111.
- Perry, B.D., McDermott, J.J., Randolph, T.F., Sones, K.R. & Thornton, P.K.** 2002. *Investing in animal health research to alleviate poverty*. Nairobi. International Livestock Research Institute.
- Petukhov, V.L., Kochnev, N.N., Karyagin, A.D., Korotkevich, O.S., Petukhov, I.V., Marenkov, V.G., Nezavitin, A.G. & Korotkova, G.N.** 2002. Genetic resistance to BLV. In *Proceedings of the 7th World Congress on Genetics Applied to Livestock Production*, Montpellier, France, August, 2002, Session 13, pp 1–4. Montpellier, France. Institut National de la Recherche Agronomique (INRA).
- Reiner, G., Eckert, J., Peischl, T., Bochert, S., Jäkel, T., Mackenstedt, U., Joachim, A., Daugschie, A. & Geldermann, H.** 2002. Variation in clinical and parasitological traits in Pietran and Meishan pigs infected with *Sarcocystis miescheriana*. *Veterinary Parasitology*, 106(2): 99–113.
- Roberts, J.A., Estuningsih, E., Widjayanti, S., Wiedosari, E., Partoutomo, S. & Spithill, T.W.** 1997. Resistance of Indonesian thin tail sheep against *Fasciola gigantica* and *F. hepatica*. *Veterinary Parasitology*, 68(1–2): 69–78.
- Rupp, R. & Boichard, D.** 2003. Genetics of resistance to mastitis in dairy cattle. *Veterinary Research*, 34(5): 671–688.

- Shimshony, A.** 1989. Footrot in Awassis and the crosses with East Friesian sheep. *New Zealand Veterinary Journal*, 37(1): 44.
- Springbett, A.J., MacKenzie, K., Woolliams, J.A. & Bishop, S.C.** 2003. The contribution of genetic diversity to the spread of infectious diseases in livestock populations. *Genetics*, 165(3): 1465–1474.
- Vallejo, R.L., Bacon, L.D., Liu, H.C., Witter, R.L., Groenen, M.A.M., Hillel, J. & Cheng, H.H.** 1998. Genetic mapping of quantitative trait loci affecting susceptibility to Marek's disease induced tumours in F2 intercross chickens. *Genetics*, 148(1): 349–360.
- Woolaston, R.R.** 1992. Selection of Merino sheep for increased and decreased resistance to *Haemonchus contortus*: peri-parturient effects on faecal egg counts. *International Journal for Parasitology*, 22(7): 947–953.
- Woolaston, R.R. & Windon, R.G.** 2001. Selection of sheep for response to *Trichostrongylus colubriformis* larvae: genetic parameters. *Animal Science*, 73(1): 41–48.
- Yonash, N., Bacon, L.D., Witter, R.L. & Cheng, H.H.** 1999. High resolution mapping and identification of new quantitative trait loci (QTL) affecting susceptibility to Marek's disease. *Animal Genetics*, 30(2):126–135.

SECTION F: THREATS TO LIVESTOCK GENETIC DIVERSITY

1 Introduction

Genetic diversity is potentially threatened by a variety of factors, whose effects may be felt in a number of ways – undermining the production systems of which AnGR form a part; physically destroying livestock populations; or provoking responses that are in themselves a threat. Driving forces of genetic erosion are also diverse in terms of the extent to which they are amenable to influence by policy interventions or, if they cannot be prevented, with respect to whether measures can be put in place to lessen their effects on AnGR diversity. In the literature, there is broad agreement regarding the general trends and factors threatening AnGR. For example, Rege and Gibson (2003) identify the use of exotic germplasm, changes in production systems, changes in producer preference because of socio-economic factors, and a range of disasters (drought, famine, disease epidemics, civil strife/war) as the major causes of genetic erosion. Tisdell (2003) mentions development interventions, specialization (emphasis on a single productive trait), genetic introgression, the development of technology and biotechnology, political instability and natural disasters. Analyses of the specific threats faced by particular livestock breeds, and of the reasons for past breed extinctions are, however, quite rare. For at-risk cattle breeds in Africa, Rege (1999) lists replacement by other breeds, cross-breeding with exotic breeds or with other indigenous breeds, conflict, loss of habitat, disease, neglect and lack of sustained breeding programmes among the threats. Similarly, Iñiguez (2005) identifies displacement by other breeds, and indiscriminate cross-breeding as threats to small ruminant breeds in West Asia and North Africa. These examples illustrate that there are a number of ways in which threats to genetic resources can potentially be classified, but for the purposes of the following discussion, three broad categories are distinguished: trends in the livestock sector; disasters and emergencies; and animal disease epidemics and control measures.

Driven by economic, social, demographic and political factors, the livestock sector is undergoing many changes. Trends include quantitative and qualitative changes in demand for livestock products and services; changes in the availability of natural resources, external inputs or labour; changes affecting livestock trade at national and international levels; and shifts in the policy environment which, directly or indirectly, affect the nature of livestock production systems (see Part 2 for a further discussion of trends in livestock production systems). In addition to threats associated with these general trends affecting the sector as a whole, inappropriate policies and methods within the more specific field of AnGR management can have severe consequences for genetic diversity.

Disasters and emergencies are distinguished from the more “gradual” trends on the basis of several factors. First, disasters and emergencies involve a distinct precipitating event or set of events. The occurrence of such events is relatively unpredictable, at least in terms of the intensity of their impact, and the specific locations that are affected. Hence, foreseeing their effects on AnGR presents a rather different (arguably more difficult) challenge. Second, disasters and emergencies are by their nature undesirable events, which give rise to responses aimed at alleviating their humanitarian, economic and social impacts. These responses are often hastily organized, have short-term objectives, and are unlikely to be particularly focused on AnGR. Third, in the context of disasters and emergencies, the possibility of valuable AnGR populations being wiped out in a very short period of time has to be taken into account. Disasters and emergencies potentially affecting AnGR include both the natural (e.g. hurricanes or tsunamis), and the human-induced (e.g. wars) (Goe and Stranzinger, 2002).

Livestock disease epidemics share with disasters and emergencies the characteristics of being relatively unpredictable, having the potential to devastate livestock populations in a short period of time, and provoking “emergency-type” responses (the specific nature and focus of the responses are, however, distinct from those that are implemented for other types of emergency). Eradication campaigns for endemic diseases fit less well into the pattern, being driven by a variety of factors – technological developments, marketing and trade-related issues, human health concerns etc. rather

than arising as a rapid response to an emergency. Nonetheless, in some cases (e.g. scrapie) rigorous efforts to eliminate such diseases are a potential threat to AnGR diversity.

A classification framework of this kind inevitably involves some simplification of a complex situation. Different driving forces will interact with each other. For example, a breed population may only be vulnerable to an acute disaster because its numbers and range have declined as the result of gradual changes to the production systems in which it is kept. Inappropriate policies and management approaches may exist under “normal” conditions, but may be particularly prevalent or damaging in the aftermath of an emergency. Similarly, disasters and emergencies may destroy the infrastructure and human and technical resources required to implement or develop appropriate management approaches. Moreover, the boundary between chronic emergencies on the one hand, and the negative effects of ongoing or diffuse trends on the other, is not always clear cut. Similarly, there may be “higher level” driving forces which operate through more than one of the mechanisms outlined above. A notable example is climate change, which has the potential both to increase the frequency of weather-related disasters, and gradually to affect the distribution and characteristics of production systems (FAO, 2006a).

Given the unpredictability and complexity of many of the forces threatening livestock genetic diversity, assessing their relative significance, and hence identifying priorities for their alleviation, presents a great challenge. Impacts are likely to be affected by the spatial scale of the threat; the speed with which the threat arises; for periodic threats, the frequency with which they occur; the intensity with which the threat strikes the affected populations; and by whether in the future threat is likely to increase or decrease in magnitude. Additionally, the significance which should be attached to a threat relates to the characteristics of the livestock affected. Concern should be greater if the populations affected contribute greatly to the world’s genetic diversity, are particularly well adapted to local conditions, or include breeds that are rare or have unique characteristics. Finally, the significance of a threat is affected by the state of existing capacity to respond – either by removing or alleviating the threat, or by putting measures in place to protect the threatened genetic resources.

2 Livestock sector trends: economic, social and policy factors

The outlook for a breed depends to a great extent on its present and future role in livestock systems. The decline of certain livestock functions as alternatives become available is often a substantial threat. Perhaps the most obvious example is that throughout much of the world, specialized draught breeds are threatened by the expansion of mechanization in agriculture (FAO, 1996); see also CR India (2004) and CR Malaysia (2003). Similarly, breeds developed for wool and fibre production may be threatened by the availability of alternative materials. Availability of alternative sources of fertilizer or financial services also shift the objectives of livestock keepers and may affect their choices regarding breeds.

The increased demand for livestock products in many parts of the developing world drives efforts to increase the output of meat, eggs and milk for the market (Delgado *et al.*, 1999). Replacing local breeds by a narrow range of high-yielding breeds is a very widespread consequence of efforts to increase output (in fact, there is also a narrowing of within-breed diversity in many popular international transboundary breeds). The rapid expansion of industrialized pig and poultry production systems in a region such as East Asia, which has a great diversity of indigenous pig and chicken breeds, is a concern. Cross-breeding with exotic animals is also widely practised as a means of increasing production levels. If, as is often the case, this takes place in an indiscriminate manner, it can be a major threat to local breeds. Stricter requirements for product uniformity and food hygiene limit the range of marketable livestock products and restrict the production conditions under which livestock are kept (FAO, 2006b). CR Zimbabwe (2004) for example, notes that the current carcass grading system discriminates against small animals, and therefore discourages the production of some indigenous cattle breeds. Other trends in consumer demand can threaten breeds that do not supply products with the desired characteristics. For example, consumer preference for leaner meat has led to the decline of pig breeds that have carcasses with a higher fat content (Tisdell, 2003).

Production systems can be affected not only by demands in local markets, but also by trends at the international level (FAO, 2005a). Greater economic globalization may contribute in several ways to genetic erosion: it encourages regional specialization and, hence, within a given region, may lead to the decline of specialized breeds associated with an unfavoured type of production; it promotes trends towards specialization in a single product at the farm level and, hence, may threaten multipurpose breeds; it promotes capacities to control the production environment and, hence, to utilize a narrower range of breeds; and it facilitates the transfer of genetic material across international boundaries (Tisdell, 2003). The latter factor also promotes the operation of the so-called “Swanson dominance-effect”. This term describes a situation in which choices made in the earliest-developing societies strongly affect later patterns of development elsewhere. In the face of a need to rapidly increase production, the choice of transboundary breeds which have already been subjected to many years of intense genetic improvement, and from which genetic material is readily available, is liable to prove attractive to livestock producers and policy-makers in developing countries, even if the development of local breeds might in the longer term provide better adapted animals (*ibid.*). Indeed, a similar process can operate to reduce within-breed diversity in high-output transboundary breeds – an example being the very widespread use of North American genetic stock in European Holstein-Friesian cattle.

In the context of increased international trade, the nature of livestock production and the choice of breeds may also be influenced by factors such as market trends in importing countries, increased competition from imported products, fluctuations in the prices of imported inputs, and trade restrictions associated with zoosanitary measures. Small-scale livestock keepers will often be poorly placed to respond to the challenges and opportunities posed by these developments, and may, therefore, lose out in competition with industrial producers (FAO, 2006). Legal frameworks affecting international trade in livestock and livestock products are discussed in greater detail in Part 3 – Section E.

The significance of demand-driven threats to livestock genetic diversity varies with location, being most significant where access to markets is easier. Here, increased demand and competition are highly important drivers of the transformation or marginalization/decline of traditional production systems. More remote (inaccessible) locations may be less affected by threats related to market demands. However production systems in these areas, which are often the home of specifically adapted genetic resources, face other threats. Degradation of the natural resource base, exacerbated by increasing pressure of population and the absence of suitable methods and strategies for managing grazing or soil fertility, can threaten sustainability (FAO, 1996). Lack of access rights to grazing land and water sources are increasingly threatening the livestock-keeping strategies of pastoralists (Köhler-Rollefson, 2005). Climate change is also a potential contributing factor. A decline in rainfall predicted to affect the main semi-arid zones of Africa has the potential to adversely affect the livelihoods of pastoralists in these areas (Hiemstra *et al.*, 2006). Apart from natural resource-related problems, constraints related to production (e.g. endemic diseases), marketing, the availability of external inputs, and a lack of the necessary infrastructure and services for breed improvement, can all decrease the economic viability of these production systems. Migration to urban areas in search of employment may result in the loss of the labour force and traditional knowledge associated with livestock keeping (Daniel, 2000; Farooquee *et al.*, 2004). The effects of such constraints on AnGR tend to be two-edged: while they may hinder economic sustainability, they normally promote the retention of indigenous breeds as they are the only ones that can flourish in the difficult production conditions.

Box 15**Mongolian reindeer under threat**

For millennia, reindeer have been the basis of the livelihoods and culture of nomadic peoples in the taiga and tundras of Eurasia. The Tsataan, or Dukha, people of Mongolia, for example, rely on their animals for transport – reindeer are ridden and used as pack animals, and food – largely in the form of milk. When a reindeer is culled, meat, hides and virtually every part of its body is utilized. As with many nomadic societies, a range of factors threaten the Dhuka's traditional way of life – including a fall in reindeer numbers that has occurred during recent decades.

Several threats to the herds have been identified. The region's wildlife population is declining due to commercial hunting. In the absence of wild game to hunt, the herders are forced to slaughter their animals at an unsustainable rate. Other economic developments such as mining are a further threat, as grazing areas are destroyed or migration patterns are disrupted. Reduced mobility as herders stay close to towns to take advantage of education services and access to consumer goods may negatively affect the reindeers' nutrition, as they are unable to access remote lichen-rich grazing areas. Traditional knowledge regarding breeding and husbandry may have been lost during the collectivized period, meaning that the new private herders are less adept at reindeer management than were their predecessors. At the same time, problems related to the health of the reindeer are exacerbated by the decline of government veterinary services and predator control measures.

There have also been suggestions that inbreeding is contributing to the reindeer's decline by increasing vulnerability to diseases such as brucellosis. In 1962, and again in the late 1980s, the Mongolian government brought reindeer from Siberia to replenish the herds. Since the end of the Soviet era, no such inflows have occurred. Proposals that there should be renewed import of reindeer or reindeer semen, from Siberia or from more distant places such as Scandinavia or Canada, have provoked some debate. Arguments have been put forward that cross-breeding has the potential to restore beneficial traits that have declined over time, including disease resistance, high milk production, and large body and antler size. Conversely, others argue that to introduce exotic genetic material may be inappropriate, as local reindeer have been selected for local requirements, in particular for riding and transporting goods. Molecular studies have indicated that the Dhuka's herds are no more inbred than many other reindeer populations. Further research is being undertaken by various NGOs, scientists, and Mongolian government authorities to explore in greater depth the best approaches to managing the reindeer genetic resources. Efforts are also being made to assess the animal health needs of the Dhuka and to provide improved veterinary care.

Advice on the preparation of this text box was provided by Brian Donahoe, Morgan Keay, Kirk Olson and Dan Plumley. For further information see: Donahoe and Plumley (2001 and 2003); Haag (2004); Owen (2004); Matalon (2004)

It should also be noted that apparently minor and innocuous changes to production practices can lead to the decline of breeds or strains adapted to specific systems. Dýrmundsson (2002) reports that in Iceland, increased hay and silage production during the mid-twentieth century led to a decline in the population of the unique "leadersheep" strain, which played an important role during winter grazing.

The above discussion has indicated that increased demand and greater globalization have tended to favour the industrialization of production systems and the use of a narrow range of genetic resources that are highly productive under these conditions. While this process is a threat to the diversity of AnGR, it has also contributed greatly to increasing the supply of food of animal origin in the face of rapidly growing demand. It might, therefore, be argued that a decline in AnGR diversity seems to be no great problem. Clearly, this perspective gives little weight to potential future benefits that may be foregone if a broader range of genetic diversity is not maintained. However, even from a short-term perspective, it is possible to identify a number of factors which may distort breed choice in favour of exotic high-producing breeds. These factors include: information deficits – a lack of knowledge regarding the relative performance of an exotic vs. a local breed leads to an inappropriate choice of the exotic; market failures – the presence of external costs or benefits associated with the keeping of a particular breed or the practising of a particular form of livestock production (e.g. environmental damage associated with industrial production systems); and policy distortions which promote inefficient resource allocation in the livestock sector (FAO, 2002).

Overt or hidden governmental subsidies have often promoted the development of industrial systems at the expense of the small-scale producer. In some countries, livestock sector policy decisions are strongly motivated by a desire to increase the export of animal products (see Box 16). These subsidies can take a variety of forms including grants and loans for capital investments, subsidization of inputs

such as imported feed, provision of free or subsidized livestock services (such as AI), and support prices for animal products (Drucker *et al.*, 2006).

Box 16

Policy distortions influencing the erosion of pig genetic resources in Viet Nam

There are around 25 breeds of pig in Viet Nam – 15 local and 10 exotic breeds. The latter are imported to “improve” the performance of the local breeds through cross-breeding. Of the estimated 21.5 million pigs in Viet Nam, about 28 percent are local breeds, 16 percent are imported breeds, and 56 percent are various crosses. Among the local breeds, three are considered technically extinct, four are classified as critical–declining, two as endangered–declining and four as vulnerable–declining (CR Viet Nam, 2003). In 1994, local breeds comprised around 72 percent of the sow population in north Viet Nam. By 1997, this level had decreased to 45 percent. The decline of local breeds stems from both market forces and government policies that distort the relative profitability of production using local or exotic breeds.

The government recognizes the importance of maintaining local breeds in order to conserve genetic diversity and provide material for cross-breeding programmes. Support and credit are provided to breeding stations, organizations, and individuals that keep local breeds (ACI/ASPS, 2002). However, the level of support for local breeds is low compared to the incentives aimed at the export-oriented keepers of exotic breeds.

The livestock breeding programme of the Ministry of Agriculture and Rural Development (MARD) is geared towards ensuring the supply of good quality breeds for domestic production as well as for export. Towards this end, two state-run breeding farms are subsidized to provide exotic breeds and crosses for sale to commercial pig producers (Drucker *et al.*, 2006). A number of decrees that have been issued by MARD also favour export-oriented pig farming. These measures have included preferential investment incentives from the Export Support Fund; loans from the Development Assistance Fund of up to 90 percent of the value of investment capital for projects involving the development of pig production for export; and incentives of VND (Viet Nam Dong) 280 (US\$0.02) per US\$1 export value of suckling pigs, and VND900 (US\$0.06) per US\$1 export value of pig meat (ACI, ASPS, 2002a,b).

A recent study (Drucker *et al.*, 2006) based on a case study in Son La province and interviews with key-informants at the national and local government levels assessed the significance of government subsidies for “high-quality” pig breeds. The total subsidy level was estimated to be around US\$31/sow/year (VND460 000/sow/year). Eleven types of subsidy were identified: more than half of the total (54 percent) came from the direct subsidies for the rearing of breeding stock. Other significant sources included direct subsidies of the purchase price of breeding stock (from national and provincial government grants) (17 percent); subsidized loans for the purchase of pigs and farm infrastructure (16 percent); and subsidized AI services (9 percent). It was estimated that the subsidy/sow/year would constitute between 19 percent and 70 percent of gross margin.

Provided by Achilles Costales, AGAL (PPLPI) FAO

For further information see: ACI/ASPS. (2002); Drucker et al. (2006)

More broadly, awareness of the significance of conservation and sustainable use of AnGR is often limited at the policy level (see Part 3 – Section A). This weakness contributes to the current lack adequate characterization of local breeds, and to a lack of consideration of AnGR in all policy decisions. Moreover, public sector investment in AnGR development is declining. There is an increased emphasis on biotechnology, and less attention is paid to more holistic breed improvement activities involving the design of breeding programmes, establishment and support of animal recording schemes, testing of alternative AnGR, and the involvement of local farmers and traditional breeds (FAO, 2004c). The result is that AnGR development is left to the commercial sector, with its focus on the (primarily temperate) international transboundary breeds. There is also a concern that if public sector research is focused heavily on expensive biotechnologies, this may reduce the availability of resources for research into broader aspects of AnGR management.

At the international scale, regulatory frameworks for AnGR covering exchange, and access and benefit sharing (ABS) have been slow to emerge relative to developments in the plant sector (see Part 3 – Section E:1 for a discussion of the main international legal frameworks affecting AnGR). Policy options are, however, increasingly being discussed (Hiemstra *et al.*, 2006). Clearly there is potential for developments in this area to impact the utilization of particular genetic resources or to affect the sustainability of particular livestock production systems, but there is as yet little concrete evidence as to how changing regulatory frameworks might increase or diminish threats to AnGR diversity.

The above-mentioned threat posed by indiscriminate cross-breeding may also be exacerbated by policy measures. Food security at the national level is a strong motivating factor for livestock development policies in developing countries. The desire to achieve rapid progress has meant that the use of genetic material from high-producing exotic breeds has often been favoured. Policies promoting the use of AI increase the rate with which exotic germplasm can be disseminated. An exacerbating factor can be the promotion of exotic germplasm by breeding companies from developed countries; in some cases this is supported by development agencies seeking to promote use of their national products (Rege and Gibson, 2003). In the absence of measures to ensure that the use of exotic genetic material is well planned, the impacts on local breeds can be serious. Moreover, indiscriminate cross-breeding with animals not adapted to the local environment may not achieve the desired effect in terms of increased production, and may leave the small-scale producer in a more vulnerable position (for example with regard to animal health problems). The problem is succinctly described in CR Botswana (2003):

“The Animal Breeding Section of the DAHP [Department of Animal Health and Production] facilitates the importation of cattle semen for farmers that do AI. The semen is also subsidized to help farmers afford improve genetic materials of fast growing breeds. There is no monitoring in terms of how the progeny of AI bulls do in terms of their survival and growth rates in communal production system. The importation of semen and live bulls has resulted in uncontrolled cross breeding of beef cattle and as a result the indigenous Tswana cattle are under threat.”

As noted above, the livelihoods of pastoralist livestock keepers in semi-arid areas are increasingly disrupted, which in turn threatens pastoral livestock breeds. These problems are often exacerbated by policy measures. Access to grazing resources is a key issue. Crop production, wildlife parks, and mineral extraction often take precedence in policy decisions about land use (FAO, 2001a). Such developments often impede traditional grazing strategies, which enabled the pastoralists to make effective use of rangeland vegetation. Inappropriate water developments can also have adverse effects. The mobile nature of traditional pastoral livestock keeping does not make for easy relationships with the state; the focus of development efforts has often been on promoting sedentary livelihoods, and pastoralists are rarely well represented at policy level or well served by livestock services.

Another area of policy that can have a major impact on AnGR is the relief and rehabilitation measures that are implemented in response to disasters and emergencies. This aspect of policy is discussed in the following chapter.

Box 17**Which dairy breeds for tropical smallholders?**

Smallholder dairy development in Kenya promotes the use of exotic dairy cattle. A recent study shows that these animals are of higher milk potential than tropical climates and feed resources can support.

Models of nutrition and energy balance in Friesians and their Zebu cross-breeds in zero-grazing units showed that daily milk yields greater than 18 litres cannot be supported by the energy density of available feed. Improving feed quality would raise daily yields above 22 litres, but would generate more heat than the cow could dissipate, even in the cool highlands. The cow's appetite would, therefore, be depressed and she would draw on her energy reserves to support higher yields. In coastal areas, nutrition is worse and cows producing as little as 11 litres per day suffer continuous, moderate stress in the hot season. To avoid these adverse effects, daily yield should not exceed 20 litres in the highlands and 14 litres at the coast, giving annual maxima of 4 500 litres and 3 000 litres respectively.

The drawback to exceeding these ceilings was not apparent at the start of lactation, when a cow with a daily yield of, for example, 35 litres had the lowest direct cost per litre, and provided sufficient milk for sale, home consumption, and reimbursement of family labour. However, a steep decline in lactation revealed the energy deficit, which also caused infertility and extended the calving interval to 460 days. The outcome of poor reproduction was reduced cull sales and a failure to breed a heifer replacement during the cow's productive life, which was shortened to less than 4 years by stress and under nutrition. This resulted in a high total cost per litre and a decline in herd size. The energy deficit faced by high-yielding Friesians explains why their average annual milk yield in smallholder zero-grazing units is only 1 500 litres in the highlands and 1 000 litres at the coast, and the replacement rate is one heifer bred for every two cows leaving the herd.

The annual milk yields for these Friesian are no better than those of dairy Boran, Nandi and Jiddu cows under improved management 50 years ago, and their fecundity and longevity are considerably worse. The performance of indigenous cows was illustrated by a Zebu cross-bred in the study. Her annual milk yield of 1 570 litres from a maximum daily yield of 11 litres incurred high direct costs, but these were offset by the birth of two heifer calves at an interval of 317 days, to give the lowest total cost per litre. This example demonstrates that in a low-output system, cow productivity should be redefined as efficient use of low inputs, increased herd life and number of calves, with less emphasis on maximum daily yield.

Provided by John Michael King

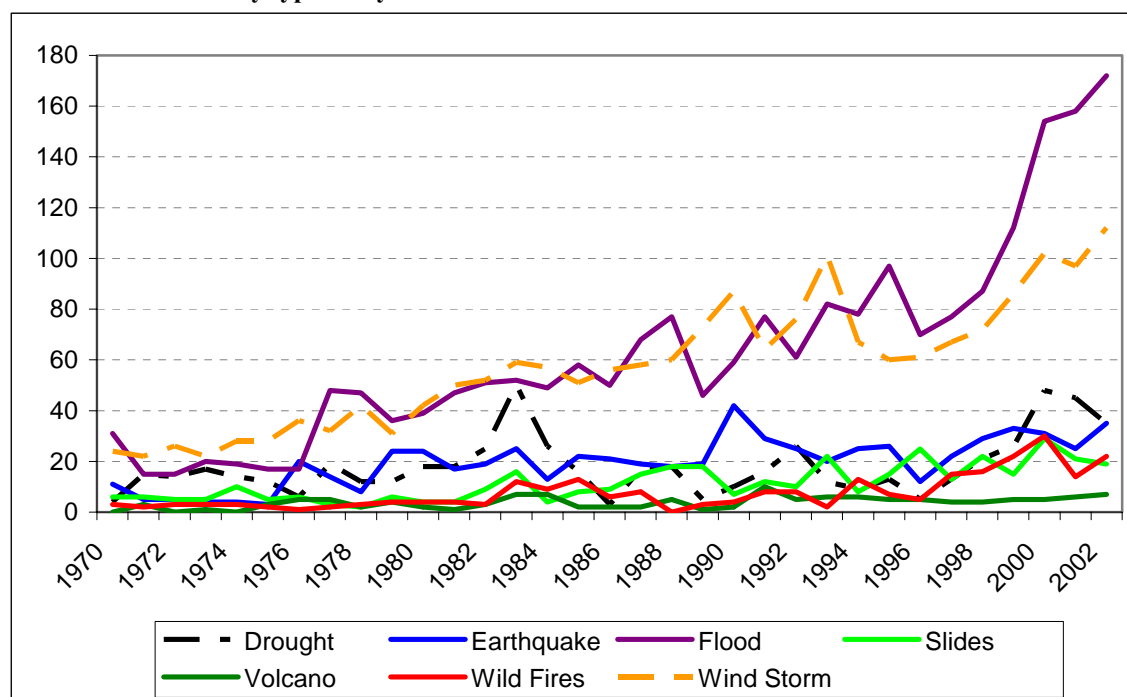
For further information see: King et al. (2006)

3 Disasters and emergencies⁵

Disasters such as droughts, floods, hurricanes, tsunamis, earthquakes, war and civil unrest have devastating impacts on lives and livelihoods around the world. Moreover, the frequency of many types of disaster is increasing. Hydrometeorological and geophysical disasters became, respectively, 68 percent and 62 percent more frequent over the decade between 1994 and 2003 (IFRCS, 2004). The numbers of people affected by disasters also shows an upward trend over this period, with an average of 213 million per year affected during the first five years of the decade and an average of 303 million per year during the second five years. During these ten years, drought and famine were the most deadly "natural" disasters accounting for at least 275 000 human deaths (ibid.). Subsequently, the Indian Ocean tsunami of December 2004 which killed over 100 000 people showed the massive destructive potential of geophysical disasters. Figure 36 illustrates the frequency of various classes of disaster over three decades.

⁵ For a more detailed discussion of the impact of disasters and emergencies on AnGR, see FAO (2006c).

Figure 36
Number of disasters by type and year



Source: EM-DAT: The OFDA/CRED International Disaster Database - <http://www.em-dat.net> - Université Catholique de Louvain - Brussels - Belgium. Criteria for the inclusion of a disaster in the EM-DAT database are ten or more people reported killed, 100 or more reported affected, a call for international assistance OR a declaration of a state of emergency.

Despite a vast output of literature on disasters, emergencies and recovery efforts, the impact of such events on the livestock sector has received relatively little attention. Accurate data are vital for identifying trends in disaster impacts, and for prioritizing risk reduction strategies (IFRCS, 2005). Useful disaster-related data are increasingly available, but coverage of the livestock sector remains quite limited. Publicly available sources of data include the Emergency Disasters Data Base (EM-DAT), maintained by the Brussels-based Centre for Research on the Epidemiology of Disasters (CRED) (<http://www.em-dat.net/index.htm>) and DesInventar, a database managed by a coalition of non-governmental actors, which covers 16 countries in Latin America and the Caribbean (<http://206.191.28.107/DesInventar/index.jsp>). Interestingly, the latter resource includes figures for the numbers of livestock dying in disasters. However, only a limited number of countries are covered, and the heavy dependence on media sources means that details of losses may not be completely reliable. Figures that break down livestock deaths by breed are even more difficult to obtain. It is, therefore, rarely possible to assess in detail the impacts of specific disasters on AnGR. Similarly, it is difficult to estimate the overall significance of disasters and emergencies as a threat to AnGR diversity on a global scale.

The literature on disasters and emergencies is filled with a variety of competing terms: natural disasters, geophysical hazards, climatic hazards, complex emergency, complex political emergency, crisis etc. (Oxfam, 1995; PAHO, 2000; Von Braun *et al.*, 2002; Shaluf *et al.*, 2003). There is, however, generally a distinction made between disasters and the consequent state of emergencies which they engender.

Historically, disasters have been categorized into two types: natural and human-made (ADB, 2005; Duffield, 1994). Within this typology, both forms of disasters were largely conceived as distinct and discreet events. In recent years, however, the division has been recognized as too rigid. Both natural and human-made events can have inter-related impacts. For example, severe drought in pastoralist rangelands often creates situations of social instability and unrest. Human-driven crises can be exacerbated by natural phenomenon. For example, civil unrest and the subsequent breakdown of disease control strategies can set up conditions for livestock epidemics. Moreover, primary events can

set up secondary hazards such as fires and pollution. A further important consideration is that disasters do not exist in isolation from the conditions under which they occur. For example, disaster impacts will frequently be more severe when they occur against a background of severe poverty, environmental degradation and/or weak institutional structures.

In contrast to “disasters” which are defined by the inciting event, the term “emergencies” is used to describe societal impacts, and in relation to the need for external intervention. Given this definition, it is clear that an assessment of the effects of emergencies on AnGR has to consider not only the immediate physical impact on livestock populations, but also how social changes induced by the emergency may affect livestock production, and importantly, the effects of the interventions which take place in response to the emergency. In particular, responses that involve the provision of livestock to a household or community by external agents – a process referred to as “restocking” (Heffernan *et al.*, 2004) have to be carefully assessed. In this context, it is useful to draw a distinction between “acute” and “chronic” emergencies. In the following discussion, the importance of the distinction relates to the intensity of impacts. For example, following an acute emergency, restocking activities tend to be large-scale and, in terms of population dynamics, the influx of new genetic material into the livestock population can be viewed as a single, discreet event, occurring over a limited time period. Restocking activities after the Balkan wars of the 1990s were largely concentrated during a three-year period (Box 18). Similarly, after the super-cyclone which hit coastal Orissa, India in 1999, large-scale restocking activities were generally completed within a few years. As such, the short-term impacts of these acute events on AnGR are high. Longer-term effects are largely dependent on how well the introduced animals survive in their new environment and on the breeding strategies farmers pursue (whether the restocked animals are preferentially selected for breeding).

Conversely, the response to chronic emergencies (such as the effect of HIV/AIDS or intermittent, low-level drought) tends to be much more sporadic, small-scale, and takes place over a longer duration. For example, restocking activities among subsistence farmers are often designed to “pass on the gift” i.e. transferring young stock to new beneficiaries (Heffernan *et al.*, 2004). Some projects of this nature have been up to a decade or more in length. Hence, the initial impact on AnGR under such conditions may be lower than in an acute emergency simply because of the smaller numbers of animal involved. However, the long-term effects should not be underestimated. The introduction of relatively small numbers of exotic animals can have a large effect on the genetic composition of the population over the longer term, particularly if they are favoured by the livestock keepers. Further, secondary impacts of chronic emergencies such as changes to the livestock sector labour force also have implications for AnGR and therefore, must be taken into account. HIV/AIDS, for example, can lead to the loss of family labour. The nature and extent of the impact of the disease on livestock management and breeding practices in countries with high incidence rates is, however, still not well understood (Goe, 2005; Goe and Mack, 2005).

The first question to consider with respect to impacts on AnGR, is the extent to which livestock populations are affected by the various types of disasters and emergencies. Within the wider agricultural sector, there is a notion that geological natural disasters are of lesser importance than those created by adverse climatic events (ECLAC 2000). However, in the case of livestock it is important not to dismiss the potential of geological events such as earthquakes, volcanic eruptions and tsunamis to kill large numbers of animals.

A further issue is whether raw figures for livestock mortality can be differentiated in any way that is useful with respect to assessing potential impacts on AnGR diversity. There is little evidence for differential impacts on different breeds or types of animal. Quantitative data for disaster impacts at the breed level are, perhaps unsurprisingly, very hard to come by. It is possible to speculate that different management practices could differentially expose animals to risks (FAO, 2006a; RamaKumar, 2000), or that for some types of emergencies animals with specific adaptations could have greater survival capacities, but drawing any conclusions regarding the significance of such effects is difficult. Aside from any such potential differences in terms of susceptibility, the size and the distribution of breed populations is a factor to be considered. Small populations, and particularly those concentrated within a limited geographical area, would seem to be the most threatened. Further, if the small populations happen to be located in disaster-prone areas, the risk will be greater. FAO (2006a), for example, notes

that Yucatan, Mexico where many backyard pigs were lost as a result of Hurricane Isodara in 2001, is home to the endangered Box Keken pig. While in the case of disease epidemics, there is some evidence of adverse impacts on small breed populations, it is difficult to find comparable accounts for other types of disaster. Given that for much of the world, information on the geographical distribution of livestock breeds is limited, assessing the extent of such risks, and taking any measures to alleviate them is problematic.

Where emergency response interventions are concerned, safeguarding AnGR will rarely be a high priority. Nonetheless, it is likely that informed decisions on the part of the livestock practitioners involved in such actions could greatly obviate negative effects on AnGR without disrupting humanitarian objectives. It is, therefore, important that the potential impacts of such actions with respect to breed diversity are explored.

Actions to alleviate the effects of disasters generally consist of a number of phases. Prior to an emergency, preparedness and risk-management strategies may be implemented. During and immediately after the event, the focus is on providing relief to the victims and assessing levels of damage and/or loss of life. At a later stage, efforts are made to restore and rebuild damaged infrastructure and economies. Historically, preparedness and risk-management activities were often created for the wider agricultural sector, but with few specific recommendations for livestock. In recent years, there have been efforts to redress this deficiency by a variety of international agencies (FAO, 2004b; Oxfam, 2005). However, the influence of this work on policy is not yet clear. Further, emergency response activities in developing countries are generally geared toward saving human lives, while animal medical emergency teams are restricted to wealthier countries. Conversely, rehabilitation activities generally do include livestock-related activities – mainly restocking. Historically, therefore, this has been the phase with the greatest potential impact with respect to AnGR.

Without external interventions, recovery of the livestock sector is a slow process, with the restoration of herds taking place over many years. Where restocking is undertaken by external agents such as donors and NGOs, recovery of the livestock economy is rapidly accelerated. While farmers generally cannot obtain animals from outside the locality, external agents can and do. Local livestock economies destroyed by the catastrophe can, thus, be rapidly jump-started. However, the unintentional consequence may be large-scale and irreversible changes to the genetic make-up of local livestock populations.

The question of AnGR diversity is not widely discussed in the literature on restocking. However, it is often argued that effects are minimal with regard to the overall size of the local livestock population, as animals used for restocking are purchased locally (Kelly, 1993; Oxby, 1994; Toulmin, 1994). If animals are sourced locally, then impacts on the genetic constitution of the livestock population will also be small. However, it is far from clear that this is always the case. Restocking projects require large numbers of breeding-age females, which are often unavailable in a post-disaster situation (Heffernan and Rushton, 1998). For example, Hogg (1985) describing a restocking project in northern Kenya notes that there was an inability to fulfil project quotas using only local sources. Livestock traders from nearby districts were required. In other cases, livestock may be imported from neighbouring countries or from further afield. Restocking projects carried out in the countries of former-Yugoslavia following the wars of the 1990s relied heavily on Simmental and other exotic cattle breeds imported from other parts of Europe (Box 18). Similarly, Hanks (1998) describes the use of cattle from Zimbabwe for restocking projects in Mozambique.

The next question that has to be considered, is whether the introduction of exotic animals through restocking projects has an important impact on the genetic composition of the local population. Using a simple population model tracing the progeny of the restocked animals, it can be shown that even a relatively small initial population of restocked animals can have a considerable impact on the indigenous gene pool, with the proportion of pure-bred indigenous animals in the local population declining markedly within a relatively short period of time (FAO, 2006c). The extent of the effect is heavily dependent on the breeding strategies adopted following the restocking, being greater if the restocked animals are favoured by the livestock keepers involved (*ibid.*).

Aside from potential impacts on AnGR diversity, there can be other reasons why choosing exotic animals for restocking projects may not be appropriate. In the case of the above-mentioned restocking projects in Mozambique, efforts were seriously disrupted by high mortality rates among the imported animals (Hanks, 1998). Longer-term socio-economic outcomes may also not be desirable. As Köhler-Rollefson (2000) notes:

“There are many cases where the substitution of native breeds through high-input-dependent exotic breeds or their dilution through cross-breeding has rendered communities dependent upon outside supplies and subsidies, as well as vulnerable to ecological calamities. Once the inputs stop or the economic scenario changes, keeping ‘improved’ animals is no longer technically feasible and economically viable.”

If the introduced animals are unable to survive or are immediately unpopular with the local livestock keepers, this may reduce the impacts of the restocking projects in genetic terms. However, there is a danger that such problems may not be immediately evident, and that indigenous breeds well adapted to the needs of the local population may be lost (*ibid.*). As such, inappropriate decisions regarding the breeds used for restocking can have negative impacts both in terms of genetic diversity and on the well-being of the human populations affected.

The importance of well-designed measures for the management of AnGR in the context of disasters and emergencies is therefore clear. As the previous discussion illustrates, activities are required in three phases: preparedness (prior to the emergency); salvage operations during the emergency; and rehabilitation (in the recovery phases).

Disaster preparedness activities can focus on several areas. First, an appropriate legislative environment for saving threatened AnGR under disaster conditions should be fostered. This can be particularly valuable in the case of disasters that unfold over an extended period of time such as drought or epidemic diseases (see following chapter) and where there is sufficient time to implement conservation measures during the emergency. Second, a variety of risk mitigation strategies can be undertaken such as the creation and support of fodder banks in areas affected by climatic hazards such as drought or severe winter snows – see, for example, CR Mongolia (2004). A further key activity is the characterization of the genetic resources in potentially affected areas. In many countries rare or priority AnGR have not been sufficiently identified – making informed choices during the emergency and during any subsequent restocking activities difficult. Finally, pre-emptive measures can be undertaken to establish *ex situ* conservation programmes, thereby seeking to ensure that some genetic material from the local breeds is maintained outside the areas affected by the emergency.

During an emergency, genetic salvage operations may be appropriate if rare AnGR are affected and there is a continuing threat to the animals that have survived the initial catastrophe. Operations of this kind are, however, likely to be logistically almost impossible in many countries. The most feasible approach is probably the collection of genetic material for cryoconservation. Effective action at this stage is only possible if accurate information is available regarding the characteristics of the affected animals and the extent of the threat faced. In the absence of such information it may still be feasible to collect genetic material for conservation, but measures will be less well targeted, and can be regarded as a last-resort attempt to reduce the impact of the emergency on AnGR.

The task of repopulating herds post-disaster is likely to require a commitment of several years on the part of the donor agency to establish a viable support programme for the intended beneficiaries. A first step for decision-makers is to consider the role of livestock within the production system in question. In the wake of an acute emergency it is generally not advisable to initiate a restocking project that changes the production orientation of the livestock keepers involved. For example, introducing dairy breeds in a post-disaster situation among households not previously involved in dairying is not likely to be successful. Many of the inputs required to support such a change are usually unavailable in a post-disaster situation. Thus, the objective of restocking in an acute emergency should, generally, be to restore previous production levels, rather than dramatically to alter the production system or livelihoods of the affected households. This should be done using breeds that are suitable for the local environment and existing levels of management. A failure to match the restocked animals to the prevailing production conditions is likely to present many of the restocked households with considerable problems (Etienne, 2004).

Conversely, in a chronic emergency there is more leeway for a change in the role of livestock. Indeed, there have been many cases of restocking projects that have introduced dairying to support local livelihoods with much success (HPI, 2002). Nevertheless, insufficient labour and access to inputs can remain important limitations. Hence, decisions regarding the appropriate genetic resources for such projects require careful consideration of the constraints and potentials of the local production environment. Additionally, an understanding of farmer perceptions regarding the breed and/or species to be utilized is required. This is an important consideration not only for the success of the project in livelihood terms, but also with respect to the impact of restocking on AnGR, as the latter will be affected by the breeding strategies that farmers pursue (FAO, 2006c).

An additional issue in an acute emergency is the quantification of livestock losses. Estimations of losses after disasters are often extrapolated from limited field surveys, and the reliability of the figures is often uncertain. An accurate estimation of livestock losses enables the scope of the required restocking to be determined. Further, the extent of the losses will determine whether animals can be sourced locally, or whether regional, national or even international populations have to be tapped. Also important is the identification of a population base-line against which future changes in the livestock population can be measured. Consequently, within the potential project area, the existing breeds should be catalogued and any at-risk breeds identified prior to restocking. These arguments, however, have to be balanced against the pressing demands on time and resources that prevail in an acute emergency situation. Information will never be completely accurate, and less formal methods of assessing losses will at times be the most appropriate.

Box 18

War and rehabilitation in Bosnia and Herzegovina

During the 1992–1995 war in Bosnia and Herzegovina the livestock sector was seriously affected. Cattle numbers are thought to have declined by 60 percent, sheep by 75 percent, pigs by 90 percent, poultry by 68 percent and horses by 65 percent. A nucleus herd of pure-bred Busa cattle near Sarajevo was destroyed along with the herd book and other documentation. The breeding and conservation programme for the Bosnian Mountain Horse was also severely disrupted. Additionally, a number of flocks of pure-bred Sjenicka sheep were completely eradicated.

In 1996, a three-year programme for the rehabilitation of the animal production sector was adopted. It envisaged the import of 60 000 high-quality cows, 100 000 sheep and 20 000 goats. During the first year of the programme (1997) around 10 000 heifers were imported, 6 500 of which were financed by the International Fund for Agricultural Development (IFAD) and coordinated by the Project Implementation Unit of the Federal Ministry of Agriculture. The remaining numbers were made up of donations from various governments and humanitarian organizations. Heifers were imported from Hungary, Austria, Germany and the Netherlands. Seventy-five percent were Simmental, 10 percent Holstein-Friesian, 10 percent Montafona (Alpine Brown) and 5 percent Oberinntal (Grey Tyrolean). Semen was also imported. Farmers who had lost over 50 percent of their farms' production assets and who had sufficient land to keep animals, could obtain soft loans from the government. In general, the policy was to supply one cow per family, but later more commercially oriented units with three to five cows were preferred. While the imported breeds clearly have the potential to increase milk and meat production, insufficient feed resources, poor management practices and a lack of animal health and milk collection services have in some cases limited the success of the restocking projects.

Numerous organizations have been involved in the distribution of animals in Bosnia and Herzegovina during the years following the war, and imports by the private sector have also sought to meet demand. The full extent of these imports and the breeds involved is not well recorded. Nonetheless, it is clear that the war and the subsequent rehabilitation efforts have led to considerable changes in to the composition of the livestock population over recent years. The population of Busa cattle, for example, estimated to be above 80 000 in 1991, fell to below 100 by 2003.

For further information see: CR Bosnia and Herzegovina (2003); FAO (2006c); SVABH. (2003).

4 Epidemics and disease control measures

Throughout the world, and in all production systems, livestock diseases lead to mortality and reduced productivity in farm animals, necessitate expenditures for prevention and control, constrain the objectives of livestock keepers, limit economic development, and threaten human public health.

Animal health constraints greatly influence decision-making with respect to livestock keeping and the utilization of genetic resources. Some disease epidemics have a devastating impact in terms of livestock deaths in the affected locations. Diseases posing a severe threat to the livestock economy provoke concerted control efforts, which may include large-scale slaughter programmes, in addition to other measures such as surveillance, vaccination and controls on the movement of animals. The diseases in question are, in many cases, transboundary diseases, outbreaks of which have severe consequences for international trade. Serious threats to human health from zoonotic diseases, particularly on an international scale, also motivate strong disease control measures. In recent years, numerous economically disastrous livestock disease epidemics, and particularly the emergence of highly pathogenic avian influenza (HPAI), have focused attention on the need for better control and prevention of transboundary diseases (FAO/OIE, 2004).

Epidemics potentially threaten AnGR as a result of livestock deaths from disease or slaughter policies. Alternatively, the effects of diseases may be less direct. Livestock breeds are often adapted to providing a particular set of products or services within a particular production environment. If conditions change – for example because of emerging animal health problems or the burdens imposed by disease control measures – existing livestock keeping practices may be adapted, replaced or abandoned, and the associated livestock breeds may be placed at risk. Additional costs or restrictions related to disease control may arise as a result of trade or food hygiene-related requirements, in addition to the immediate effects of disease on livestock productivity. Although the discussion here focuses on the threat of genetic erosion as a result of livestock diseases, it should be recognized that in many circumstances, the presence of diseases inhibits the introduction of susceptible exotic animals, and thereby necessitates the continued utilization of locally adapted breeds.

Recent years have seen a number of serious epidemics, which have led to the death or preventive slaughter of millions of animals. The HPAI outbreak in 2003–2004 in Thailand resulted in the loss of around 30 million birds (Ministry of Agriculture and Cooperatives, 2005). Between January and June 2004, 18 million native chickens were slaughtered in an effort to control the disease, a figure which amounted to approximately 29 percent of the country's native chicken population (*ibid.*). Approximately 43 million birds were destroyed in Viet Nam in 2003–2004, and 16 million in Indonesia – roughly equivalent to 17 percent and 6 percent of the respective national populations (Rushton *et al.*, 2005).

An outbreak of classical swine fever (CSF) in the Netherlands in 1997 resulted in the slaughter of almost 7 million pigs (OIE, 2005). The 2001 foot-and-mouth disease (FMD) epidemic in the United Kingdom resulted in the slaughter of around 6.5 million sheep, cattle and pigs (Anderson, 2002). The 1997 outbreak of African swine fever (ASF) in Benin resulted in the deaths of 376 000 pigs, with a further 19 000 slaughtered for disease control purposes (OIE, 2005) – this in a country where the total pig population at the time was only around 470 000 (FAOSTAT). Other recent epidemics causing high levels of mortality have included an outbreak of contagious bovine pleuropneumonia (CBPP) in Angola in 1997; outbreaks of CSF in the Dominican Republic in 1998 and in Cuba in 2001/2002; ASF epidemics in a number of African countries, such as Madagascar in 1998 and Togo in 2001; and FMD outbreaks in Ireland and the Netherlands in 2001, and in the Republic of Korea in 2002 (OIE, 2005). Table 40 shows the impacts, in terms of deaths and culls, of recent major disease epidemics. Unfortunately, the effects on genetic resources are often difficult to assess, as breed-specific information is unavailable. Other things being equal, impacts are likely to be high where a large proportion of the animal population dies. To give some indication of the relative impact of different epidemics in this respect, Table 40 presents the figures for deaths and culls as a proportion of national animal population figures for the species and year in question in addition to the raw mortality figures. The most serious recent outbreaks in terms of number of deaths relative to national population sizes for the affected species are shown.

Table 40
Impact of recent disease epidemics

| Disease | Year | Country | Number of animals [1000s] | | Proportion of the total population [%] | |
|-----------------------|--------|-----------------------|------------------------------|--------|---|--------|
| | | | Culls | Deaths | Culls | Deaths |
| African Swine Fever | 1997 | Benin | 18.9 | 375.9 | 4 | 80 |
| African Swine Fever | 1998 | Madagascar | 0 | 107.3 | 0 | 7 |
| African Swine Fever | 2001 | Togo | 2.2 | 15 | 1 | 5 |
| African Swine Fever | 2000 | Togo | 10 | 0 | 3 | 0 |
| Avian Influenza | 2003 | Netherlands | 30569 | 76.2 | 30 | 0 |
| Avian Influenza | 2003/4 | Viet Nam | 43000* | - | 17 | - |
| Avian Influenza | 2003/4 | Thailand | 29000** | | 15** | |
| Avian Influenza | 2003/4 | Indonesia | 16000* | - | 6 | - |
| Avian Influenza | 2000 | Italy | 11000 | 0 | 9 | 0 |
| Avian Influenza | 2004 | Canada | 13700 | 0 | 8 | 0 |
| CBPP (cattle) | 1997 | Angola | 435.2 | 0.2 | 12 | 0 |
| Classical Swine Fever | 2002 | Luxembourg | 16.2 | 0.04 | 20 | 0 |
| Classical Swine Fever | 1997 | Netherlands | 681.8 | 0 | 4 | 0 |
| Classical Swine Fever | 2002 | Cuba | 65.5 | 0.7 | 4 | 0 |
| Classical Swine Fever | 2001 | Cuba | 45.8 | 1.5 | 4 | 0 |
| Classical Swine Fever | 1998 | Dominican Republic | 8.7 | 13.7 | 1 | 1 |
| FMD (cattle) | 2001 | United Kingdom | 758*** | 0 | 7 | 0 |
| FMD (pigs) | 2001 | United Kingdom | 449*** | 0 | 8 | 0 |
| FMD (sheep) | 2001 | United Kingdom | 5249*** | 0 | 14 | 0 |
| FMD (sheep) | 2001 | Netherlands | 32.6 | 0 | 3 | 0 |
| FMD (cattle) | 2002 | Republic of Korea | 158.7 | 0 | 8 | 0 |

Sources: OIE (2005) for mortality figures; FAOSTAT for population figures.

*Rushton et al (2005) – number of culls only, no figures for deaths from the disease; ** FAO (2005b) – figure includes both culls and deaths from the disease; ***Anderson (2002) – figures exclude newborn lambs and calves slaughtered along with the mother, for which accurate figures are not available (ibid.) so actual number of culls would have been higher.

The impact on genetic resources cannot be quantified simply in terms of the numbers of dead animals. The risk of erosion is likely to be greatest where rare breeds are confined to areas severely affected by a disease outbreak, or where a disease disproportionately affects production systems where rare genetic resources or those with specific adaptations are to be found. The extent to which epidemics have an impact on genetic resources is also likely to be influenced by the nature of the restocking policies implemented in the wake of the outbreak (see previous section).

The extent to which diseases have affected AnGR is often difficult to assess fully because of a lack of data differentiating or characterizing the animals affected. For example, in Ngamiland, Botswana more than 340 000 uncharacterized cattle were slaughtered in 1995 because of an outbreak of CBPP (CR Botswana, 2003). However, there are some cases where there is evidence that disease mortality, slaughter programmes and/or subsequent restocking programmes have had a marked adverse impact on specific genetic resources.

CR Japan (2003) mentions that in 2000 approximately two-thirds of the population of the rare Kuchinoshima cattle breed on Kuchinoshima Island died as the result of a disease epidemic. Cattle populations in Zambia, particularly the indigenous Tonga breed, are reported to have been badly affected by corridor disease (a tick-borne disease) during the last ten years, with the number of cattle in Southern Province reduced by 30 percent (Lungu, 2003). Details of the impact of disease on genetic resources tend to be best recorded in countries such as the United Kingdom where there are well-established NGOs active in the conservation of rare breeds. The slaughter programmes enacted at the

time of the FMD epidemic in the United Kingdom in 2001, threatened breed populations that were largely confined to the affected areas. Affected populations included endangered breeds such as the Whitefaced Woodland sheep and Whitebred Shorthorn cattle (see Table 41). Similarly, during the FMD outbreak in the Netherlands, flocks of rare breeds such as the Schoonebeker sheep were culled in the Veluwe National Park (CR Netherlands, 2002).

Table 41
Examples of breeds affected by the FMD outbreak in the United Kingdom in 2001

| Breed | Total number of breeding females in 2002 | Estimated reduction of breeding females in 2001 [%] |
|-------------------------|--|---|
| Cattle | | |
| Belted Galloway | 1 400 | approx. 30 |
| Galloway | 3 500 | 25 |
| Whitebred Shorthorn | 120 | 21 |
| Sheep | | |
| British Milksheep | 1 232 | < 40 |
| Cheviot (South Country) | 43 000 | 39 |
| Herdwick | 45 000 | 35 |
| Hill Radnor | 1 893 | 23 |
| Rough Fell | 12 000 | 31 |
| Swaledale | 750 000 | 30 |
| Whitefaced Woodland | 656 | 23 |

Source: Roper, 2005

An extreme example is presented by the case of the Haitian Creole pig. During the late 1970s there were outbreaks of ASF in several Caribbean countries (FAO, 2001b). In Haiti, slaughter programmes to eradicate the disease, implemented between 1979 and 1982, led to the elimination of the local Creole pigs. The country was first restocked with Yorkshire, Hampshire and Duroc breeds brought in from the United States of America. Attempts to establish large peri-urban piggeries proved unsustainable, and the breeds were not suited to the management conditions found in local small-scale production. Later, Gascon × Chinese × Guadeloupe Creole pigs, more appropriate to the local conditions, were introduced (CR Haiti, 2004).

With respect to the potential for disease epidemics to have differential impacts on production systems where indigenous breeds are kept, the case of the HPAI emergency in Southeast Asia may offer an example. Village or backyard poultry flocks are generally comprised of indigenous breeds, in contrast to the commercial hybrid birds found in large-scale poultry units. Efforts to control the disease could lead to the establishment of “poultry free zones” around large-scale production units (FAO, 2004a). The sustainability of backyard poultry production may also be constrained by changes to management practices and cultural activities enforced with the aim of minimizing the threat of HPAI. For example, the raising of multiple species, such as keeping ducks or geese alongside chickens has been prohibited in some countries in the wake of HPAI outbreaks. Cultural and social events involving the mixing of birds (for example cock fighting or the exhibition of songbirds) may be banned. Traditional mobile duck keeping on rice paddies, which involve the movement of flocks over considerable distances, is also being discouraged. In short, the ongoing threat of HPAI is likely to result in a future Southeast Asian poultry sector which has “fewer backyard producers ... [and] no more ranging, herded [duck] flocks” (FAO, 2005b). Small-scale commercial poultry producers also face great difficulties in responding to the threat of HPAI, and their future may also be in doubt. However, these producers largely keep imported breeds.

In the case of ASF, CR Madagascar (2003) indicates that the appearance of the disease in the country in 1998, and subsequent regulations imposed on pig keeping, has accelerated a trend towards more intensive pig production and the disappearance of scavenging systems based on indigenous breeds. Similarly, CR Sri Lanka (2002) mentions that scavenging pig production may be threatened because of concerns about outbreaks of Japanese encephalitis in humans. A contrasting example of how the threat of disease may influence the nature of production systems, and hence the utilization of genetic resources, is an increase in the population of general-purpose sheep breeds in the United Kingdom, as

a result of an increased number of self-contained flocks following the 2001 FMD epidemic (CR United Kingdom, 2002).

Genetic resources may also be threatened by efforts undertaken to eradicate diseases that have a genetic dimension to their causation. For example, the EU's regulations (EU, 2003a) related to the elimination of scrapie have raised concerns regarding rare breeds that lack or have low frequency of the resistant genotypes. Having been present in European flocks for at least 250 years, scrapie is a rather different case to the acute epidemics described elsewhere in this chapter. However, because of concerns about human health, there is a strong motivation to act rapidly to introduce rigorous control measures. Participation in breeding schemes will be compulsory for all flocks of "high genetic merit". In the United Kingdom, for example, the regulations will apply to "all purebred breeding flocks and, in addition, any other flock that produces and sells homebred rams for breeding." (DEFRA, 2005). Slaughter or castration of rams and ram lambs found to be carrying the scrapie-susceptible VRQ allele will be compulsory. The immediate removal of these genotypes would be likely to present problems for the conservation of a number of rare British sheep breeds (Townsend *et al.*, 2005).

Although the picture is far from complete, the evidence indicates that in many cases it is the control measures rather than the disease itself which pose the greatest threat to AnGR diversity. Following recent severe disease epidemics, the need to address potential conflicts between veterinary and conservation objectives has begun to be recognized. For example the EU's 2003 FMD Directive provides for exemptions to the regulations requiring the immediate slaughter of infected animals, at sites such as laboratories, zoos, wildlife parks or other fenced areas, which have been identified in advance as the location of a breeding nucleus indispensable to the survival of a breed (EU, 2003b). During the 2001 epidemic in the United Kingdom measures were introduced to allow the owners of flocks of rare sheep or goats to apply for exemption to the slaughter programmes affecting animals on farms within 3 km of a site of infection, provided strict biosecurity measures were observed (MAFF, 2001). With regard to the avian influenza situation in Asia, the protection of valuable genetic material is regarded as a possible justification for pre-emptive vaccination of poultry populations against HPAI (FAO, 2004a). In the case of scrapie control programmes, further research is being undertaken to assess the probable impacts on specific rare breeds, in order to devise appropriate conservation strategies in the context of efforts to eradicate the disease (Townsend *et al.*, 2005).

A number of precautionary measures aimed at minimizing the risks to valuable livestock genetic resources in the event of disease epidemics have been advocated. For example, the prospect of rare breed populations being wiped out by an epidemic can be seen as a justification for cryoconservation programmes. Further preventive actions could include ensuring that sites conserving important genetic resources are established in more than one location and preferably in regions with low livestock density; in the case of farms keeping multiple breeds, ensuring the isolation of rare breeds from other livestock; and maintaining up-to-date lists of sites keeping rare breeds (CR Germany, 2003).

It is important to note that all such measures are to a very large extent dependent on the availability of accurate information regarding the characteristics, and risk status of the threatened breeds and, importantly, of their distribution by geographical location and/or production system within the affected countries. This, again, underlines the need for effective characterization of AnGR if conservation goals are to be achieved. A further point to highlight is the need for advanced planning of any conservation actions to be implemented in the event of livestock disease epidemics. Trying to formulate and implement responses once an outbreak has started is far more difficult.

5 Conclusions

Many of the underlying factors threatening AnGR cannot easily be influenced. Change is an inevitable feature of livestock production systems, and "catastrophic" events will never be fully preventable or even predictable. Moreover, it is neither possible nor desirable that the conservation of AnGR *per se* should take precedence over other objectives such as food security, humanitarian response to disasters, or the control of serious animal diseases. Nonetheless, there are a number of measures that could be put in place to alleviate the effects of these threatening forces. Too often, however, threats to AnGR, as well as the potential contribution of local breeds to wider development objectives are overlooked at

the policy level. This tends to translate into policies that promote the increased use of a limited range of AnGR, and that fail to put measures in place to protect threatened breeds.

In many cases, a fundamental problem is a lack of sufficient knowledge regarding the characteristics of AnGR; their distribution geographically and by production system; their roles in the livelihoods of their keepers; and the ways in which their utilization is affected by changing management practices and broader trends in the livestock sector. This often means that emerging threats are not identified or that their significance is not appreciated.

It is generally difficult to quantify the impact of disease epidemics on AnGR diversity – mortality data are rarely broken down by breed. However, it is clear that large numbers of animals can be lost, and that it is often the culling measures rather than the disease itself that accounts for the largest number of deaths. It is only recently that threats to AnGR have been given any consideration in the planning of disease control measures, and they continue to be largely ignored. The FMD epidemics of 2001 showed that even in European countries with a strong tradition of breed conservation activities, steps to protect AnGR had to be taken on an ad hoc basis, and that several rare breeds were quite seriously threatened by the culling campaign. Disease control often operates within legal frameworks that reduce the scope for flexibility in emergency response measures to account for threats to AnGR. Limited steps to address this issue have been taken in Europe (see Part 3 – Section E: 3), but the potential for conflict between animal health and breed conservation objectives remains considerable. Advanced planning is essential if rare breeds are to be protected. Drawing up effective plans is, however, again hampered by a lack of relevant information regarding what breeds to prioritize and how to target them.

The impact of disasters and emergencies on AnGR is also not well documented. In the initial aftermath of a disaster collecting data on losses and protecting local AnGR will never be of high priority. Nevertheless, experience shows that post-disaster restocking activities need to be carefully considered if they are not to have an adverse effect on AnGR diversity, and to ensure that the breeds used are appropriate to the needs of the intended beneficiaries.

To conclude, it is clear that the management of threats to AnGR, needs to be better integrated into many aspects of livestock sector development. Concrete steps towards meeting this objective include:

- better characterization of AnGR and their locations;
- providing tools for the *ex-ante* assessment of the genetic impact of development interventions, including post-emergency restocking measures; and
- the elaboration, in advance, of plans to protect unique AnGR in the event of disease outbreaks or other acute threats (including where necessary a re-examination of relevant legislation).

It is likely that in many cases such measures would not only help to reduce the risk of genetic erosion, but would also promote efficient utilization of existing AnGR, and hence would be complementary to wider livestock development objectives.

6 References

- ACI/ASPS.** 2002. *Commercialization of livestock production in Viet Nam*. Policy Brief for Viet Nam. Agriculture Sector Programme Support (ASPS); Hanoi. Agrifood Consulting International (ACI).
- ADB.** 2005. *Country Environmental Analysis: Mongolia*. Mandaluyong City, the Philippines. Asian Development Bank.
- Anderson, I.** 2002. *Foot and mouth disease 2001: lessons to be learned inquiry report*. Presented to the Prime Minister and the Secretary of State for Environment, Food and Rural Affairs, and the devolved administrations in Scotland and Wales. London. The Stationery Office.
- CR (Country name).** year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).
- Daniel, V.A.S.** 2000. *Strategies for effective community based biodiversity programs interlocking development and biodiversity mandates*. Paper presented at the Global Biodiversity Forum, held 12–14

- May 2000, Nairobi, Kenya. (available at http://www.gbf.ch/Session_Administration/upload/paper_daniel.pdf#search=%22loss%20migration%20urban%20livestock%20%22loss%20of%20traditional%20knowledge%22%22).
- DEFRA.** 2005. *NSP Update*, Issue 7. National Scrapie Plan, Worcester, UK. Department for Environment Food and Rural Affairs.
- Delgado, C., Rosegrant, M., Steinfeld, H., Ehui S. & Courbois, C.** 1999. *Livestock to 2020: the next food revolution*. Food Agriculture and the Environment Discussion Paper 28. IFPRI/FAO/ILRI.
- Donahoe, B. & Plumley, D.** 2001 Requiem or Recovery: The 21st-Century Fate of the Reindeer-Herding Peoples of Inner Asia. *Cultural Survival Quarterly*, 25(2): 75–77. (also available at <http://209.200.101.189/publications/csq/csq-article.cfm?id=570>).
- Donahoe, B. & Plumley, D. (eds.)**. 2003. The troubled taiga: survival on the move for the last nomadic reindeer herders of South Siberia, Mongolia, and China. Special Issue of *Cultural Survival Quarterly*, 27(1)..
- Drucker, A., Bergeron, E., Lemke, U., Thuy, L.T. & Valle Zárate, A.** 2006. Identification and quantification of subsidies relevant to the production of local and imported pig breeds in Vietnam. *Tropical Animal Health and Production*, 38(4): 305–322.
- Duffield, M.** 1994. Complex emergencies and the crisis of developmentalism. In *Linking Relief and Development*, IDS Bulletin. Vol. 25(4): 37–45.
- Dýrmundsson, Ó.R.** 2002. Leadersheep. the unique strain of Iceland sheep. *Animal Genetic Resources Information*, 32: 45–48.
- ECLAC.** 2000. *Handbook for estimating the socio-economic and environmental effects of disasters*. Santiago, Chile, Economic Commission for Latin American and the Caribbean.
- Etienne, C.** 2004. From a chaotic emergency aid-to a sustainable self-help programme. *BeraterInnen News*, 2: 25–28.
- EU.** 2003a. Council Directive 2003/85/EC of 29 September 2003 on Community measures for the control of foot-and-mouth disease repealing Directive 85/511/EEC and Decisions 89/531/EEC and 91/665/EEC and amending Directive 92/46/EEC. *Official Journal of the European Union*, 22.11.2003
- EU.** 2003b. Commission Decision of 13 February 2003 laying down minimum requirements for the establishment of breeding programmes for resistance to transmissible spongiform encephalopathies in sheep. *Official Journal of the European Union*, 14.02.2003.
- FAO.** 1996. *Livestock - environment interactions. Issues and options*. by H. Steinfeld, C. de Haan & H. Blackburn, Rome.
- FAO.** 2001a. *Pastoralism in the new millennium*. Animal Production and Health Paper 150. Rome.
- FAO.** 2001b. *Manual on the preparation of African swine fever contingency plans*. Animal Production and Health Paper 11. Rome.
- FAO.** 2002. *Valuing animal genetic resources: some basic issues*, by H. Steinfeld. Unpublished Report. Rome.
- FAO.** 2004a. *FAO recommendations on the prevention, control and eradication of highly pathogenic avian influenza (HPAI) in Asia, September 2004*. Rome.
- FAO.** 2004b. A step forward in the preparation of the first report. *Animal Genetic Resources Information*, 34: 1.
- FAO.** 2004c. *Conservation strategies for animal genetic resources*, by D.R. Notter, Background Study Paper No. 22 Commission on Genetic Resources for Food and Agriculture. Rome.
- FAO.** 2005a. *The globalizing livestock sector: impact of changing markets*. Committee on Agriculture, Nineteenth Session, Provisional Agenda Item 6. Rome.
- FAO.** 2005b. *Economic and social impacts of avian influenza*. by A. McLeod, N. Morgan, A. Prakash & J. Hinrichs, FAO Emergency Centre for Transboundary Animal Disease Operations (ECTAD). Rome.
- FAO.** 2006a. *A review of environmental effects on animal genetic resources*, by S. Anderson. Rome.

- FAO.** 2006b. Underneath the livestock revolution, by A. Costales, P. Gerber & H. Steinfeld. In *Livestock report 2006*, pp. 15–27. Rome.
- FAO** 2006c. *The impact of disasters and emergencies on animal genetic resources: a scoping document*, by C. Heffernan & M. Goe. Rome.
- FAO/OIE.** 2004. *The global framework for the progressive control of transboundary animal diseases*. FAO/OIE. Paris/Rome.
- FAOSTAT.** (available at <http://faostat.fao.org/site/291/default.aspx>).
- Farooquee, N.A., Majila, B.S. & Kala, C.P.** 2004. Indigenous knowledge systems and sustainable management of natural resources in a high altitude society in Kamaun Himalaya, India. *Journal of Human Ecology*, 16(1): 33–42.
- Goe, M.R.** 2005. *Livestock production and HIV/AIDS in East and Southern Africa*. Working Paper. Animal Production and Health. Rome. FAO.
- Goe, M.R. & Mack, S.** 2005. *Linkages between HIV/AIDS and the livestock sector in East and Southern Africa*. Technical Workshop, Addis Ababa, Ethiopia, 8-10 March 2005. Animal Production and Health Proceedings No. 8. Rome. FAO.
- Goe, M.R. & Stranzinger, G.** 2002. *Developing appropriate strategies for the prevention and mitigation of natural and human-induced disasters on livestock production*. Internal Working Document. Breeding Biology Group, Institute of Animal Sciences, Swiss Federal Institute of Technology, Zurich.
- Haag, A.L.** 2004. *Future of ancient culture rides on herd's little hoofbeats*, New York Times, December 21, 2004 (also available at <http://query.nytimes.com/gst/abstract.html?res=F10B11FE38540C728EDDAB0994DC404482>).
- Hanks, J.** 1998. *The development of a decision support system for restocking in Mozambique*. Field Report. Reading, UK. Veterinary Epidemiology and Economics Research Unit, University of Reading.
- Heffernan, C., Nielsen, L. & Misturelli, F.** 2004. *Restocking pastoralists: a manual of best practice and decision-support tools*. Rugby, UK. ITDG.
- Heffernan, C. & Rushton, J.** 1998. Restocking: a critical evaluation. *Nomadic Peoples* 4(1).
- Hiemstra, S.J., Drucker, A.G., Tvedt, M.W., Louwaars, N., Oldenbroek, J.K., Awgichew, K., Bhat, P.N. & da Silva Mariante, A.** 2006. *Exchange, use and conservation of farm animal genetic resources. identification of policy and regulatory options*. Wageningen, the Netherlands. Centre for Genetic Resources, the Netherlands (CGN), Wageningen University and Research Centre.
- Hogg, R.** 1985. *Restocking pastoralists in Kenya: a strategy for relief and rehabilitation*. ODI Pastoral Development Network Paper 19c. London, Overseas Development Institute.
- HPI.** 2002. *Project Profiles: Helping people around the world fight hunger and become self-reliant*. Little Rock, Arkansas. Heifer Project International.
- IFRC.** 2004. *World disasters report 2004*. Geneva. International Federation of Red Cross and Red Crescent Societies.
- IFRC.** 2005. *World disasters report 2005*. Geneva. International Federation of Red Cross and Red Crescent Societies.
- Iñiguez, L.** 2005. Sheep and goats in West Asia and North Africa: an Overview, *In* L. Iñiguez, ed. *Characterization of small ruminant breeds in West Asia and North Africa*, Aleppo, Syria. International Center for Agricultural Research in Dry Areas (ICARDA).
- Kelly, K.** 1993. *Taking stock: Oxfam's experience of restocking in Kenya*. Report for Oxfam. Nairobi.
- King, J.M., Parsons, D.J., Turnpenny, J.R., Nyangaga, J., Bakari, P. & Wathes, C.M.** 2006. Modelling energy metabolism of Friesians in Kenya smallholdings shows how heat stress and energy deficit constrain milk yield and cow replacement rate. *Animal Science*, 82(5): 705–716.
- Köhler-Rollefson, I.** 2000. *Management of animal genetic diversity at community level*. Eschborn, Germany. GTZ.

- Köhler-Rollefson, I.** 2005. *Building an international legal framework on animal genetic resources: can it help the drylands and food insecure countries*. Bonn, Germany. League for Pastoral Peoples, German NGO Forum on Environment and Development.
- Lungu, J.C.N.** 2003. *Animal Genetic Resources Policy Issues in Zambia*. Paper presented at a Workshop Meeting to Strengthen Capacity for Developing Policies Affecting Genetic Resources, 5–7 September, 2003, Rome, Italy.
- MAFF.** 2001. *Exemptions for rare breeds and hefted sheep from contiguous cull*. MAFF News Release, 4 May 2001. London. United Kingdom Ministry of Agriculture Fisheries and Food.
- Matalon, L.** 2004. Reindeer decline threatens Mongolian nomads, *National Geographic News*, October 12, 2004. (also available at http://news.nationalgeographic.com/news/2004/10/1012_041012_mongolia_reindeer.html).
- Ministry of Agriculture and Cooperatives.** 2005. *Socio-economic impact assessment for the avian influenza crisis: gaps and links between poultry and poverty in smallholders*. Department of Livestock Development, Ministry of Agriculture and Cooperatives, The Kingdom of Thailand. (FAO/TCP/RAS/3010e).
- OIE.** 2005. *Handistatus II*. (available at <http://www.oie.int>).
- Owen, J.** 2004. "Reindeer people" resort to eating their herds. *National Geographic News*, November 4, 2004. (also available at http://news.nationalgeographic.com/news/2004/11/1104_041104_reindeer_people.html).
- Oxby, C.** 1994. *Restocking: a guide*. Midlothian, UK. VETAID.
- Oxfam.** 1995. *The Oxfam handbook of development and relief*. Oxford, UK. Oxfam.
- Oxfam.** 2005. *Predictable funding for humanitarian emergencies: a challenge to donors*. Oxfam Briefing Note October 24, 2005. Oxfam International. (available at http://www.oxfam.org.uk/what_we_do/issues/conflict_disasters/downloads/bn_cerf.pdf).
- PAHO.** 2000. *Natural disasters: protecting the public's health*. Scientific Publication No. 575. Washington D.C. Pan American Health Organisation, WHO.
- RamaKumar, V.** 2000. *Role of livestock and other animals in disaster management*. (available at <http://www.vethelpineindia.com/ProfRamKumar-article.doc>).
- Rege, J.E.O.** 1999. The state of African cattle genetic resources I. classification framework and identification of threatened and extinct breeds. *Animal Genetic Resources Information*, 25: 1–25.
- Rege, J.E.O. & Gibson, J.P.** 2003. Animal genetic resources and economic development: issues in relation to economic valuation. *Ecological Economics*, 45(3): 319–330.
- Roper, M.** 2005. *Effects of disease on diversity*. Paper presented at the International Conference on Options and strategies for the conservation of farm animal genetic resources, Agropolis, Montpellier, 7–10 November 2005. (also available at <http://www.ipgri.cgiar.org/AnimalGR/Papers.asp>).
- Rushton, J., Viscarra, R., Guerne-Bleiche, E. & McLeod, A.** 2005. Impact of avian influenza outbreaks in the poultry sectors of five South East Asian countries (Cambodia, Indonesia, Lao PDR, Thailand, Viet Nam) outbreak costs, responses and potential long term control. *Proceedings of the Nutrition Society*, 61(3): 491–514.
- Shaluf, I., Ahmadu, F. & Said, A.** 2003. A review of disaster and crisis. *Disaster Prevention and Management*, 12(1): 24–32.
- SVABH.** 2003. *Animal genetic resources in Bosnia and Herzegovina*. Sarajevo. State Veterinary Administration of Bosnia and Herzegovina.
- Tisdell, C.** 2003. Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. *Ecological Economics*, 45(3): 365–376.
- Toulmin, C.** 1994. Tracking through drought: Options for destocking and restocking. In I. Scoones, ed. *Living with uncertainty*, pp. 95–115. London. Intermediate Technology Publications.
- Townsend, S.J., Warner, R. & Dawson, M.** 2005. PrP genotypes of rare sheep breeds in Great Britain. *Veterinary Record*, 156(5): 131–134.

Von Braun, J., Vlek, P. & Wimmer, A. 2002. *Disasters, conflicts and natural resources degradation: multi-disciplinary perspectives on complex emergencies*. Annual Report (2001–2002). Bonn, Germany. ZEF Bonn Centre for Development Research, University of Bonn.

Part 2

Livestock Sector Trends

Introduction

In the context of pre-industrial agriculture, livestock breeds had to be adapted to local environments, and fulfilled multiple functions, they were thus very diverse. However, driven by a growing demand for animal products, the livestock sector is rapidly moving towards intensive and specialized systems, in which the production environment is controlled and productivity traits are central criteria for the selection of species and breeds. The industrialized sector's demands for animal genetic resources (AnGR) have been met by a limited number of high-output breeds, and this has tended to narrow genetic diversity between and within breeds.

Despite the economic importance and rapid growth of intensive production systems, the world's livestock sector continues to be characterized by a high degree of diversity. Intensive and industrialized production systems contribute to meeting most of the growing demand for livestock-derived food. However, livestock keeping is also an important element in the livelihoods of many small-scale producers. Enabling poorer livestock keepers to improve their livelihoods remains an important objective. Achieving these food security and livelihood-related goals while also preserving natural resources, such as water, soil fertility and biodiversity, and addressing problems such as the emission of greenhouse gases, is a major challenge. This challenge demands a critical review of the current choice and use of AnGR, which may not always be optimal for the production conditions, and in which information deficits hinder the emergence of rational management strategies.

This section reviews drivers of change in the livestock sector and corresponding trends in production systems. It also introduces some of the most significant interactions between livestock keeping and the environment. Finally it highlights implications for the use of AnGR.

Box 19

The concept of productivity

When discussing the relative merits of particular breeds or production systems, the use of the term "productivity" can be misleading if it is not carefully defined. A distinction must be drawn between high productivity and high levels of production or output. Strictly speaking, "productivity" or "efficiency" is a measure of the output obtained per unit of input. For example, it can be defined in terms of the ratio of the output of a product such as milk relative to costs in monetary terms. Animals fed on crop residues like straws produce little, but as they do so at little cost, their productivity, so defined, is not necessarily low.

A broader view of the costs of production can yield very different results in terms of productivity estimates. For example, if environmental costs are counted, then the productivity of high-yielding animals kept under industrial production systems may not be as impressive as it otherwise appears.

A more comprehensive consideration of the outputs of livestock production is also relevant. Frequently overlooked functions of livestock include their role in the provision of financing and insurance. This is particularly important to livestock keepers who are unable to access these services from other sources. Several attempts have been made to quantify the value of financing and insurance functions and include them in calculations of the net benefits of livestock production. For example, studies have indicated that these functions account for 81 percent of net benefits from meat goat production in southwestern Nigeria (Bosman *et al.*, 1997), 23 percent in the case of cattle production in upland mixed farming systems Indonesia (Ifar, 1996), and 11 percent in smallholder dairy goat production in the Eastern Highlands of Ethiopia (Ayalew *et al.*, 2002). Manure is another important product in mixed farming systems which is often not accounted for in calculations of the total benefits derived from livestock. The Ethiopia study showed that manure production accounted for 39 percent of gross benefits derived from goat keeping in this system (*ibid.*). The significance of manure production is also highlighted by the findings of Abegaz (2005) which show that in mixed farming communities in the Northern Highlands of Ethiopia animal manure and draught power are the major production targets, and account for the high livestock densities observed.

It is important to emphasize that it is not only in tropical and/or poorer societies that livestock have multiple values and costs. The arguments about productivity are also valid in wealthier societies (Van De Ven, 1996; Schiere *et al.*, 2006a). The fact that they are overlooked is the very reason for the environmental problems often encountered. This again underlines the need to assess the value of biodiversity in broader terms and not only with respect to potential milk or meat yield.

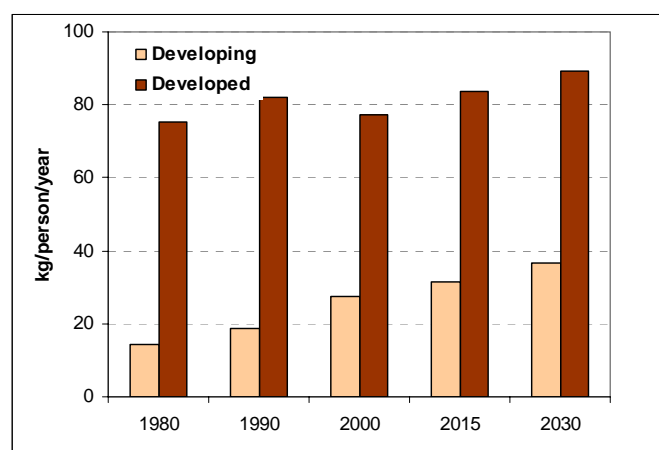
SECTION A: DRIVERS OF CHANGE IN THE LIVESTOCK SECTOR

1 Changes in demand

Consumption of meat and milk worldwide has been rapidly growing since the early 1980s. Developing countries have accounted for a large share of this increase (Figure 37); growth in poultry and pork consumption in developing countries has been particularly striking. Between the early 1980s and the late 1990s, total meat and milk consumption in the developing world grew at 6 and 4 percent *per annum*, respectively¹.

Figure 37

Changes in the meat consumption of developing and developed countries



Sources: 1980, 1990 and 2000 figures from FAOSTAT; 2015 and 2030 figures from FAO (2002a)

In 1980, the human population of developing countries made up three-quarters of the world's population, and consumed one-third of the world's meat and milk (Tables 42 and 43). It is estimated that by 2030, developing countries may account for 85 percent of the world's population, and two-thirds of direct consumption of meat and milk. Increasing demand strongly stimulates production. For the 1999-2001 to 2030 period, FAO (2006a) estimates that production growth rates of meat and milk will be 2.4 percent *per annum* and 2.5 percent *per annum*, respectively, in developing countries; while the growth rates for the whole world will be 1.7 percent for meat and 1.4 percent for milk. Growth of per capita consumption is, however, predicted to be weaker, especially in sub-Saharan Africa, the Near and Middle East and North Africa, and in places where consumption is already high, such as developed countries or Latin America (particularly for meat). Except for Africa, consumption per capita is projected to grow at a lower pace after 2030, with consumers achieving better-balanced diets. This, in turn, may reduce production growth: over the 2030 to 2050 period, meat and milk production in developing countries are expected to develop at 1.3 percent *per annum* and 1.4 percent *per annum* respectively.

In developing countries, 70 percent of the additional meat consumption is of pork and poultry; in developed countries, the comparable figure is 81 percent. Poultry consumption in developing countries is projected to grow at 3.4 percent *per annum* to 2030, followed by beef at 2.2 percent and ovine meat at 2.1 percent. In the world as a whole, poultry consumption is projected to grow at 2.5 percent *per annum* to 2030, with other meats growing at 1.7 percent or less. Growth rates have been particularly high in China, India and Brazil, and the sheer size and vigour of these countries will mean that they will continue to increase their dominance of world markets for livestock products. High growth in consumption is spread throughout the developing world, but it is important to consider regional and between-country differences in the extent of the "livestock revolution". For example, consumption

¹ Compound annual growth rates were estimated between 1983 and 1997

levels for meat, milk and eggs in sub-Saharan Africa have remained static over the last decade (FAO, 2006f). Furthermore, trends in demand for individual commodities will vary widely in different parts of the developing world, with China leading the way in meat, with a near doubling of the total quantity consumed – the increase being primarily in poultry and pork consumption. India and the other countries of South Asia will drive a large increase in total milk consumption.

Table 42
Projected trends in meat consumption from 2000 to 2050

| Region | Production | | | Consumption per capita | | |
|---------------------------------|------------------------|---|--|------------------------|---|--|
| | 1999/2001 [1000 mt] | Growth rate 1999/2001 to 2030 [% p.a.] | Growth rate 2030 to 2050 [% p.a.] | 1999/2001 [kg] | Growth rate 1999/2001 to 2030 [% p.a.] | Growth rate 2030 to 2050 [% p.a.] |
| Sub-Saharan Africa | 5 564 | 3.3 | 2.8 | 9.5 | 1.2 | 1.4 |
| Near East / North Africa | 7 382 | 3.3 | 2.1 | 21.9 | 1.6 | 1.1 |
| Latin America and the Caribbean | 31 608 | 2.2 | 1.1 | 59.5 | 0.9 | 0.7 |
| South Asia | 7 662 | 3.9 | 2.5 | 5.5 | 2.7 | 1.9 |
| East Asia | 73 251 | 2.1 | 0.9 | 39.8 | 1.5 | 0.9 |
| Developing world | 125 466 | 2.4 | 1.3 | 26.7 | 1.2 | 0.7 |
| World | 229 713 | 1.7 | 1.0 | 37.6 | 0.7 | 0.5 |

Source: FAO (2006a)

The rationale on the basis of which people select their food is complex: it is multi-objective, and decisions are influenced by individual and societal capacity and preferences. Food preference is also changing rapidly. The pace of dietary change, both qualitative and quantitative, accelerates as countries become richer and populations become more urbanized.

Table 43
Projected trends in milk consumption from 2000 to 2050

| Region | Production | | | Consumption per capita | | |
|---------------------------------|------------------------|---|--|------------------------|---|--|
| | 1999/2001 [1000 mt] | Growth rate 1999/2001 to 2030 [% p.a.] | Growth rate 2030 to 2050 [% p.a.] | 1999/2001 [kg] | Growth rate 1999/2001 to 2030 [% p.a.] | Growth rate 2030 to 2050 [% p.a.] |
| Sub-Saharan Africa | 16 722 | 2.6 | 2.1 | 30.6 | 0.5 | 0.6 |
| Near East / North Africa | 29 278 | 2.3 | 1.5 | 88.5 | 0.6 | 0.6 |
| Latin America and the Caribbean | 58 203 | 1.9 | 1 | 122.4 | 0.7 | 0.5 |
| South Asia | 109 533 | 2.8 | 1.5 | 82.3 | 1.5 | 0.9 |
| East Asia | 17 652 | 3.0 | 0.6 | 13.1 | 2.1 | 0.7 |
| Developing world | 231 385 | 2.5 | 1.4 | 53.1 | 1.3 | 0.7 |
| World | 577 494 | 1.4 | 0.9 | 94.2 | 0.4 | 0.4 |

Source: FAO (2006a)

1.1 Purchasing power

Among the various drivers of change in animal production, the literature concurs in identifying purchasing power as the most influential (Delgado *et al.*, 1999; Zhou *et al.*, 2003). Animal product consumption rises with purchasing power. However, the effect of increased income on diets is greatest among lower and middle-income populations (Delgado *et al.* 2002). This observation is true at individual level as well as at national level (Devine, 2003). Per capita consumption of animal-derived foods is, therefore, generally greatest among high-income groups, and most dynamic among lower and middle-income groups under conditions of strong economic growth. It goes without saying, that these groups are not evenly distributed across the globe – the former are concentrated in OECD countries, while the latter are mostly found in locations that have rapidly growing economies, such as Southeast Asia, costal provinces of China, the states of Kerala and Gujarat in India, and São Paulo State in Brazil. The two groups coincide in the urban centres of rapidly growing economies.

1.2 Urbanization

Urbanization is recognized to be the second main factor influencing per capita consumption of animal products (Rae, 1998; Delgado *et al.*, 1999). Urbanization is accompanied by changes in habitual food consumption patterns and dramatic lifestyle changes – including a marked reduction in levels of physical activity. In developing countries that are urbanizing, quantitative changes in dietary intake have been accompanied by qualitative changes in the diet. Changes include shifts from cereal-based diets to energy-dense diets with high animal protein and fat contents, as well as increased consumption of sugars and sugar-based products. Explanation for this trend may lie in the wider food choices and dietary influences found in urban centres, as well as a preference for convenience and taste (Delgado *et al.*, 1999). The organization of food markets and the opportunity cost of the time of the main food preparers in the household both point to the consumption of more processed and pre-prepared foods, including street foods. Pre-packaged, pre-seasoned cooked meats, for example, tend to be appealing to urban consumers (King *et al.*, 2000).

Rae (1998) shows that in China, for a given level of expenditure, urbanization has a positive effect on per capita consumption levels, and also on the magnitude of the consumption response to a marginal increase in expenditure. Urbanization and income-increase effects coincide in the urban centres of rapidly growing economies, creating hotspots of demand for animal products.

1.3 Consumer taste and preference

If purchasing power and urbanization are the most important factors contributing to patterns of per capita consumption, other factors are significant and can have great influence locally. For example, Brazil has a slightly higher income per capita than Thailand, and Thailand has a higher level of urbanization than Brazil, but animal product consumption in Brazil is roughly twice as high as it is in Thailand. Conversely, countries with contrasting per capita incomes can have similar levels of animal-derived food consumption (e.g. the Russian Federation and Japan).

A number of factors are at play, including natural endowment. Access to marine resources on the one hand, and to natural resources for livestock production on the other, have drawn consumption trends in opposite directions. Lactose-intolerance, found particularly in East Asia, has limited milk consumption. Cultural reasons, including religion, have further influenced consumption habits (Harris, 1985). This is, for example the case in South Asia, where meat consumption per capita is lower than income alone would predict. This influence is also seen in preferences for certain species and types of product. Examples include the exclusion of pork by Muslims, and the high preference for red meat among the Maasai. These various factors have given rise to a rich pattern of consumer preference, and also influence the way consumers assess the quality of animal products (Krystallis and Arvanitoyannis, 2006).

More recently, other institutional factors have influenced consumption trends. An example is the emergence of the “concerned consumer” (Harrington, 1994) in OECD countries. The consumption

patterns of these consumers are influenced not only by market and taste factors, but by concerns about health, environmental, ethical, animal welfare and development issues. These consumers tend to reduce or even stop their consumption of particular animal products or to opt for certified products, such a free range or organic meat, milk or eggs (Krystallis and Arvanitoyannis, 2006). Government promotion campaigns are also identified as potential drivers of change in consumption patterns (Morrison *et al.*, 2003).

Box 20

Sustainable utilization of the Iberian pig in Spain – a success story

The Iberian pig was once the most widely kept pig breed in Spain. The breed's hardiness, foraging abilities, capacity to endure periods without much food, and its tolerance of extreme temperatures, make it ideal for extensive production under local conditions. Traditional pig keeping contributes to the maintenance of the *dehesa*, a wooded pastureland ecosystem recognized as a Natural Habitat of Community Interest by the EU, part of which has been declared a Biosphere Reserve by UNESCO. Keeping the Iberian pig has long been of great economic and social importance in these areas.



Photo credit: Vicente Rodríguez Estévez

However, from the 1960s onwards, the large-scale introduction of exotic breeds contributed to the decline of many Spanish livestock breeds including the Iberian pig. Traditional pig production systems declined as a result of low levels of yield, and problems related to disease control. By 1982, the number of sows of the Iberian breed had fallen to around 66 000.

Since that time, a very successful marketing infrastructure has been developed, focusing on the quality of meat from pigs fattened under the traditional system where the animals are free to forage for grass and acorns without any additional feeding. The resulting products are high in unsaturated fatty acids and are of excellent eating quality. The meat is in great demand: pigs fattened under the

traditional system fetch prices up to 160 percent higher than conventionally raised animals, and dry cured hams fetch between 350 and 500 percent higher. Indeed, the main constraint to further increasing the output of these products is not lack of demand, but the limited range of the breed's traditional habitat.

Technological innovations have also been introduced to the traditional production systems – improvements to the quality of the pasture, and the more efficient use of crop residues. Many studies have been undertaken to increase knowledge of the breed's nutrition, handling, behaviour, morphology, genetic characteristics and meat quality.

By 2002 the number of sows had reached approximately 193 000. Most of this population increase has taken place under more intensive production conditions outside the breed's traditional home areas. However, 16.3 percent of the population is still being raised under the extensive system.

Provided by Manuel Luque Cuesta and Vicente Rodríguez Estévez

2 Trade and retailing

Increasing international trade as well as the rise of large retailers and integrated food chains are other important drivers of change in the livestock sector. More precisely, they influence the relative competitiveness of producers and production systems in supplying the rising demand for animal-derived foods.

2.1 Flows of livestock and their products

Livestock production traded across international borders has increased from 4 percent in the early 1980s to approximately 10 percent at the present time. A number of developing countries are among the top 20 exporters and importers in value terms (FAOSTAT). The main developing-country export products are live animals and the meat of cattle, sheep, goats, pigs, horses, chickens and ducks, fresh and condensed cow milk, as well as pig and cattle feed. Products imported in large quantities include

the meat of cattle, sheep, chickens and ducks, fresh and dried cow milk, ghee, animal feeds, and live cattle, goats, sheep, buffaloes and chickens.

Four structural developments in livestock markets can be discerned (FAO, 2005b):

- International market chains: supplying livestock products from one country to retailers and consumers in another country. These chains are either controlled by large retailers, such as supermarkets, or by importing firms dealing with particular commodities.
- Chains created by foreign direct investment: vertically integrated market chains supplying a domestic, mainly urban market. Typically, they are controlled by large retailers such as international or national supermarkets or fast food companies.
- Domestic markets affected by globalization: effects of globalization on consumer demand and behaviour have led to responses in domestic market chains other than vertically integrated chains. For example, dairy processors, fast food chains and restaurants have developed and increased the diversity of products on the market, but are not part of vertically integrated chains.
- Increasing local markets: geographical concentration and intracountry specialization (see below) on the one hand, and urbanization on the other, lead to increasing livestock product (and feed resource) transfers at national level.

With globalization, international and domestic markets can become connected. Within poultry markets, for example, not all cuts are exported; those not required for export are sold in the domestic market. Pig producers in some Southeast Asian countries switch from national to regional markets depending on relative prices at different times of year. Although these markets are not identical, there are some common features in their requirements and their impacts.

Increased and long-distance trade requires standards and regulation to ensure safety and reduce transaction costs. Food control and certification systems must be of a high standard. In addition to the health and safety standards and regulations agreed by international bodies (such as OIE and Codex Alimentarius), technical requirements may be imposed by retailers. These may include demands for particular meat cuts, carcass size and weight, leanness of meat, fat levels in milk, egg colour, or labelling with particular information or in specified languages. There may be demands for organic production or high animal welfare standards. In interconnected markets, the standards of the higher-value market may be adopted by the lower-value market, although in general they will be less strictly monitored.

Globalized markets have the potential to increase national income and create employment. For producers and traders, developing domestic markets can offer flexibility and a greater diversity of livelihood options. However, globalized markets are exclusive. Only some producers meet the requirements necessary to access them, and small producers can find it hard to acquire knowledge of these requirements or make the necessary investments. For example, many African-produced food products fail to meet international food safety and quality standards. This hampers the continent's efforts to increase agricultural trade both intraregionally and internationally, and locks many farmers out of a chance to improve their economic well-being (De Haen, 2005).

Box 21**Overcoming constraints to the development of small-scale market oriented dairying**

Demand for milk in developing countries is expected to increase by 25 percent by 2025 (Delgado *et al.*, 1999). Mobilizing the small-scale dairy sector to increase production has the potential to provide benefits such as increased incomes and food security for small-scale producers. Lack of regular income is a major problem for poor households. Both crop farming and meat production yield only periodic returns. Conversely, dairying, even on a very small scale, can provide modest but regular income.

One challenge to small-scale dairy development is posed by competition from rapidly increasing dairy imports to developing countries, which grew by 43 percent between 1998 and 2001, and is predicted to continue rising. However, there are some market developments that favour local producers. The National Dairy Development Board of India recently reported an increase of production in response to market demand for indigenous fermented milk products from 26 623 metric tonnes in 1999/2000 to 65 118 metric tonnes in 2003/2004, and a rise in the production of paneer from 2008 metric tonnes in 1999/2000 to 4496 metric tonnes in 2003/2004 (NDDB, 2005).

The entry of small-scale producers into the dairy sector is often constrained by a lack of capital to invest in animals, feed and equipment; a lack of water and power; a lack of knowledge regarding dairy husbandry and the requirements of the market; a lack of access to support services (health and AI); and a lack of access to production and processing technologies. Clearly, there are instances when the costs of milk production and the poor state of infrastructure render dairying uncompetitive for the small producer. However, a number of factors that enhance the prospects for successful small-scale dairy development can be identified.

The Market Oriented Dairy Enterprise (MODE) approach has been suggested as a template for development. Milk or producer groups are the essential entry point, and developments should be risk based, and move progressively to a market orientation, as group members become empowered to make well-informed decisions. The MODE approach consists of three steps: 1) groups are set up and operational; 2) a low level of activities is recorded with limited returns; and 3) a market-oriented approach is adopted. Other important considerations include the significance of local markets, which are often overlooked while export potential is overemphasized; the need for appropriate institutional development to ensure that milk collection, processing and marketing systems do not exclude the small producer; and a facilitative policy environment linking dairy development to national livestock development policy.

Provided by Tony Bennett

For further information on the MODE approach, see FAO (2006e)

2.2 The rise of large retailers and vertical coordination along the food chain

The rapid expansion in supermarket penetration in developing countries is a fairly recent phenomenon. It has become significant only over the last five to ten years, and has proceeded at different rates in the various regions of the developing world. Reardon and Timmer (2005) describe the diffusion of supermarkets in developing countries as having occurred in three successive waves. The first, in the early 1990s, covered much of Latin America and East Asia (except China), north-central Europe, and South Africa, with supermarkets accounting for only 5 to 10 percent of agrifood retail sales on average these areas at that time. The second wave of supermarket diffusion took place in the mid-1990s, covering parts of Central America and Mexico, Southeast Asia, and south-central Europe, with the share of supermarkets in total food retail reaching about 30 to 50 percent by the early 2000s. The take-off of supermarkets in the third wave of diffusion started only in the late 1990s. Countries affected included China, India, the Russian Federation, and some countries in Central and South America, Southeast Asia and Africa. By the mid-2000s, supermarkets' share of food retail had already reached 10 to 20 percent in the countries included in the third wave.

The entry of transnationals into the agrifood chain in developing countries, particularly in the retail and processing sectors, has transformed the manner in which agrifood products are purchased from suppliers, processed into differentiated products, and distributed to consumers. As these large new distribution and retail units have to compete for market share, between themselves, and even with traditional suppliers and wholesalers in the domestic market, they must offer competitive prices. They can only maintain or expand market share by cutting costs. At the same time, they must compete in delivering the consistent product quality that is demanded by their main market. The concept of

“quality” from the producers’ perspective is complex, and its attributes evolve over time. Its definition varies according to retailers’ strategies on the one hand, and to cultural influences on the other. It includes food safety, nutrition, and attributes related to the commercial differentiation of the products (Farina *et al.*, 2005); as well as characteristics related to the mode of production (e.g. niche products). Large retailers require a reliable supply of agricultural products from their suppliers (producers) with consistency in volume and in quality.

In vertically integrated chains controlled by large retailers, procurement processes tend to shift towards centralized procurement systems, including the use of wholesalers specialized in a product category or dedicated to the market chain. Large supermarket chains may use preferred-supplier systems to select producers who meet quality and safety standards, and to reduce transaction costs.

Table 44
Standards in the livestock market and implications for small-scale producers

| | Positive factors | Negative factors |
|--|--|--|
| Process standards UHT treatment of milk, government requirement. Hazard Analysis Critical Control Point in abattoir, required by importers and supermarkets. Organic produce, standards set by certifying bodies. | Clearly specified process. Clearly specified process. Premium price. Can be carried out on a small scale. Favours labour- intensive systems. | Administration costs of inspection. Investment in equipment and training may exclude smallholders. Probably neutral for small producers. Certifying bodies, harder to establish in developing countries. High costs of certification. Difficult to achieve by unorganized smallholders. |
| Performance standards Salmonella levels in meat, with financial penalty for poor performance. | | Standards usually set to stringent developed-country consumer requirements. No guaranteed method to meet required standards. Cost of tests may be prohibitive unless subsidized. |
| Combined standards Contract farming requirements for timing of activities and quality of product. | Premium price. Support with investment and cash flow. May be assisted to overcome risk, e.g. restocking after HPAI outbreaks. Technical support. | Risk of total market loss if there is failure to produce the required quality. Not all producers meet requirements. Social stigma if there is failure to “make the grade”. |

Source: adapted from FAO (2006d)

Producers who become part of an integrated chain may face a change in contractual arrangements (e.g. becoming dedicated contract farmers) with increased levels of assistance and higher prices for quality products, but with increased risk if contracts are not met or the retailer closes down. This applies particularly where the farmer must specialize to satisfy volume, safety and quality requirements (Table 44). Typically, smallholders use enterprise diversity to hedge against risk, and make relatively small investments in several enterprises. This becomes harder if they are required to invest more heavily in one enterprise to meet the needs of a retailer. Globalized markets, with higher safety and quality requirements, are typically riskier, as the entire market can close down with the outbreak of a disease or the discovery of a quality problem. Smallholder producers and small traders have limited scope and ability to insure themselves against loss.

3 Changing natural environment

The Millennium Ecosystem Assessment² concludes that the degradation of ecosystems could become significantly worse during the first half of this century, and be a barrier to achieving the Millennium

² <http://www.maweb.org/en/index.aspx>

Development Goals. Recent changes in climate, especially warmer regional temperatures, have already affected biodiversity and ecosystems, particularly in dryland environments such as the African Sahel. Global climate change is likely to have significant impact on the world's environment. In general, the faster the changes, the greater will be the risk of damage. Mean sea level is expected to rise by 9 to 88 cm by the year 2100, causing flooding of low-lying areas, and other damage. Climatic zones could shift towards the poles, and vertically – affecting forests, deserts, rangelands and other ecosystems. Many habitats will decline or become fragmented, and individual species could become extinct (IPCC, 2001). Climate change is taking place against the background of a natural environment that is already stressed by resource degradation – often exacerbated by existing agricultural practices.

Societies will face new risks and pressures. Food security is unlikely to be threatened at the global level, but some regions are likely to experience food shortages and hunger. Water resources will be affected as precipitation and evaporation patterns change around the world. Physical infrastructure will be damaged, particularly by rising sea levels and by extreme weather events. There will be many direct and indirect effects on economic activities, human settlements and human health. The poor and disadvantaged are the most vulnerable to the negative consequences of climate change.

A warming of more than 2.5 °C could reduce global food supplies and contribute to higher food prices. Some agricultural regions will be threatened by climate change, while others may benefit. The impact on crop yields and productivity will vary considerably. The livestock sector will also be affected. Livestock products will become costlier if agricultural disruption leads to higher grain prices. In general, it seems that intensively managed livestock systems will more easily adapt to climate change than crop systems. This may not be the case for pastoral systems, however, where livestock depend to a greater extent on the productivity and quality of the rangelands – which are predicted to decline and become more erratic. Extensive systems are also more susceptible to changes in the severity and distribution of livestock diseases and parasites. Negative effects of climate change on extensive systems in the drylands are therefore predicted to be substantial.

The effectiveness of adaptation to climate change will depend critically on regional resource endowments (IPCC, 2001). This has significant implications for the distribution of impacts within developing countries, as well as between more and less-developed countries. Developed countries will probably be more effective in adapting to climate change than developing countries and countries in transition, especially in the tropics and subtropics. Climate change is likely to have its greatest adverse effects on areas where resource endowments are poorest and the ability of farmers to respond and adapt is most limited (*ibid.*).

4 Advances in technology

Technological developments are another driver of change. Advances in transport and communication have promoted the expansion of global markets, and have facilitated the spread of production systems in which livestock are kept at a distance from sources of feed. Technological advances have also enabled increasing levels of control over the production environments in which animals are kept. Examples include improvements in building technology and cooling systems, but progress in breeding and nutrition have played the most critical roles.

Feed

Advances in feed technology allowing the preparation of “near ideal” rations to match the nutritional demands of pigs, poultry and dairy cows at different stages in their lives/production cycles, have had an important effect on livestock production. In addition to technological developments, declining grain prices, a trend that has prevailed since the 1950s, has been one of the factors driving changes in livestock feeding practices. Despite growing demand over this period, supply has not lagged behind. The total supply of cereals increased by 46 percent over the 24 years from 1980 to 2004. In real terms (constant US\$) international prices for grains have halved since 1961. Expanding supply at declining prices has been brought about predominantly by intensification of the existing cropped area, and to a lesser extent by area expansion in some regions (globally, the areas of cereal harvested shrank by 5.2 percent over the same period).

Genetics and reproductive and biotechnologies

New biotechnologies in combination with increased computing capacity enable rapid genetic advances, especially in the commercial pig and poultry sectors where AnGR are tailored to achieve high efficiency of feed conversion. Reproductive biotechnologies such as artificial insemination (AI) and embryo transfer (ET) greatly facilitate the dissemination of genetic material. These technologies are widely used in the developed world, and to a lesser extent in developing countries. Advances in molecular genetics have given rise to new techniques in animal breeding such as gene-based selection (mainly against diseases and genetic defects), and marker assisted selection and introgression of genes. Newer biotechnologies including cloning, transgenesis and transfer of somatic material may have significant impacts in the future (see Part 4 – Sections D and F). With regard to the application of biotechnologies, the scientific, political, economic and institutional basis to provide adequate safeguards and to ensure that potential benefits are realized is not yet in place in most countries. The main question to be addressed is not what is technically possible, but where and how life sciences and biotechnology can contribute to achieving a more sustainable agriculture.

5 Policy environment

Public policies can be seen as forces that add to the drivers described above, and influence changes in the sector with the aim of achieving a particular set of societal objectives. Policies are designed and adjusted, taking into account the state of markets, available technologies and natural resources (the drivers previously described), and the current status of the sector. Experience in both developed and developing countries confirms that a *laissez-faire* approach, simply standing back and allowing market forces to play out, is not a viable option³. In the absence of effective policies, many of the hidden costs of expanding livestock production – environmental degradation, disruption of the livelihoods of poor traditional livestock keepers, and threats to veterinary and human public health, are eventually borne by governments and the public. It is important that the attention of policy-makers is not exclusively focused on the role large-scale production. Some systems remain little affected by trends towards industrialization. These systems do not account for the bulk of production growth. They do, however, affect the livelihoods of many people, and involve a wide range economic objectives and production practices. They are mostly oriented towards household consumption, local markets, niche markets or the delivery of environmental services.

Public policies are both drivers of and responses to changes in the livestock sector. At any point in time, policies that are in existence and enforced are drivers of change, while policies in preparations are part of the public response to changes. This subchapter summarizes the broad policies that have affected the livestock sector.

Policies for institutional and technological change are initiated at both national and local levels, and not only by national governments. Other stakeholders, including farmer associations, development agencies and non-governmental organizations have often played an important role in strengthening institutions and promoting technologies that increase productivity, compliance with standards or market access for small producers.

Policy-makers have generally utilized three main instruments to influence change in the sector: prices, institutions and promotion of technological change. Environmental objectives may be pursued using a combination of measures such as regulations, public support to extension and research, incentives or taxation, so as to make prices reflect real costs and encourage compliance with standards. In the absence of policy interventions and other measures, inputs such as land and water are often underpriced and the prices of livestock products often fail to reflect the cost of environmental damage.

³ The following paragraphs of this section draw on the FAO Livestock Policy Brief “Responding to the livestock revolution – the case for livestock public policies” – http://www.fao.org/ag/againfo/resources/en/pubs_sap.html

The main regulatory and policy frameworks that have influenced the sector include:

- market regulation, regulation of foreign direct investment, regulation of property rights (including intellectual property), and regulations on credit that shape the “investment climate” in a country;
- institutional and regulatory frameworks affecting ownership and access to land and water resources;
- labour policy, including regulations affecting the cost of labour, the employment of migrant labourers, and working conditions;
- mobility, security and migration policies, which particularly affect mobile forms of livestock production such as pastoralism;
- incentive frameworks, which shape relative competitiveness and production levels and practices – farm subsidies in OECD countries (US\$257 billion in 2003) have, for example, substantially contributed to increased production levels;
- sanitary standards and trade policies, which have direct impacts on competitiveness and access to national and international markets; and
- environmental policies, which have affected farm practices and, to a limited extent, increased the relative competitiveness of production in countries where environmental regulations are less stringent or not enforced.

Box 22**Facts and trends in the emerging world food economy**

Slowdown in population growth: The growth rate of 1.35 percent *per annum* in the second half of the 1990s is expected to decline to 1.1 percent in 2010–2015 and to 0.5 percent by 2045–2050 (UN Habitat, 2001).

Income growth and reductions in poverty*: Per capita income growth in developing countries is predicted to increase from 2.4 percent *per annum* for the period from 2001 to 2005 to 3.5 percent for the period between 2006 and 2015. The incidence of poverty is predicted to fall from 23.2 percent in 1999 to 13.3 percent in 2015.

Average food intake will increase but hunger will remain high: Daily per capita calorific intake in developing countries will increase from an average of 2 681 kcal in 1997/1999 to 2 850 in 2015. Under “business as usual”, undernourishment will decline from 20 percent in 1992 to 11 percent in 2015, but reductions in absolute numbers of undernourished people will be modest – from 776 million in 1990/1992 to 610 million in 2015 – far from meeting the World Food Summit target.

Slower rate of agricultural production growth: Growth of demand for agricultural products, and therefore of production, will slow as a result of slower population growth and reduced scope for consumption increases in places where food consumption is already high. For developing countries, production growth will decline from an average of 3.9 percent *per annum* between 1989 and 1999 to 2.0 percent *per annum* between 1997–1999 and 2015 (FAO, 2002a).

Changes in product composition: Between 1997 and 2015, wheat and rice production in developing countries will grow modestly (by 28 and 21 percent respectively). However, significant increases are expected in coarse grains (45 percent), vegetable oils and oilseeds (61 percent), beef and veal (47 percent), mutton and lamb (51 percent), pig meat (41 percent), poultry meat (88 percent), and milk and dairy production (58 percent) (FAO, 2002a).

Production growth based mostly on yield growth: Yield improvements will account for about 70 percent of production growth, land expansion for 20 percent, and increased cropping intensity for the rest. Nevertheless, FAO projections show that the arable area in developing countries will increase by almost 13 percent (120 million ha) and water withdrawals for irrigation by 14 percent by 2030. One in five developing countries will face water shortages (FAO 2002a).

Growing agricultural trade deficits: Agricultural trade surpluses in developing countries are shrinking and by 2030 will have become a deficit of about US\$31 billion, with a rapid rise in imports of cereals and livestock products, and a decline in surpluses in vegetable oils and sugar.

Urbanization: Virtually all of the world's anticipated population growth between 2000 and 2030 will be concentrated in urban areas (UN Habitat, 2001). At the present rate of urbanization, the urban population will equal the rural population as early as 2007 and will exceed it from that point on.

Diet transitions: The pace of dietary change, both qualitative and quantitative, accelerates as countries become richer and populations become increasingly urbanized, with a shift in diet structure towards a higher energy density diet in developing countries, and a dramatic increase in the contribution to food calories from livestock products (meat, milk and eggs), vegetable oils, and, to a lesser extent, sugar. Average developing-country per capita meat consumption increased from 11 kg *per annum* in the mid-1970s to around 26 kg in 2003, and oil-crop products from 5.3 kg to 9.9 kg. Increases in saturated fat intake from animal sources, a greater amount of added sugar in foods, reduced intakes of complex carbohydrates and fibre, and reduced fruit and vegetable intakes have been shown to be responsible for an increased incidence of non-communicable diseases (e.g. cardiovascular diseases and diabetes).

Market structures: Agrifood systems are evolving from an industry dominated by family based farms and small-scale, relatively independent firms, to one of larger firms that are more tightly aligned across the production and distribution chain. Food retailing is increasingly customer responsive, more service focused and more global in ownership; in parallel, the input supply and product processing sectors are becoming more consolidated, more concentrated, and more integrated. Tangible evidence of this is the rise of supermarkets and changing patterns of food procurement in urban areas in many parts of the world, especially in Latin America (see Reardon and Berdegue, 2002).

Source: FAO (2005c)

* These figures are for developing countries as a whole. It should be acknowledged that reductions in the incidence of poverty will be geographically uneven with the greatest progress being made in East Asia and the least progress in sub-Saharan Africa (FAO, 2002b).

SECTION B: LIVESTOCK SECTOR'S RESPONSE

The livestock sector is responding to the above-described drivers by undergoing a series of changes, which are described below, production system by production system. While there is a broad trend towards industrialization of the sector, the importance of the driving forces and the pace of particular developments differ between countries and regions. Furthermore, the development pathway of a given production system is influenced by the interaction of many factors, both external and internal to the system.

There are five broad farm or farm-household strategies that livestock producers may adopt in response to changing conditions:

- expansion of farm or herd size;
- diversification of production or processing;
- intensification of existing production patterns;
- increasing the proportion of off-farm income, both agricultural and non-agricultural; or
- exit from the agricultural sector within a particular farming system (FAO, 2001a).

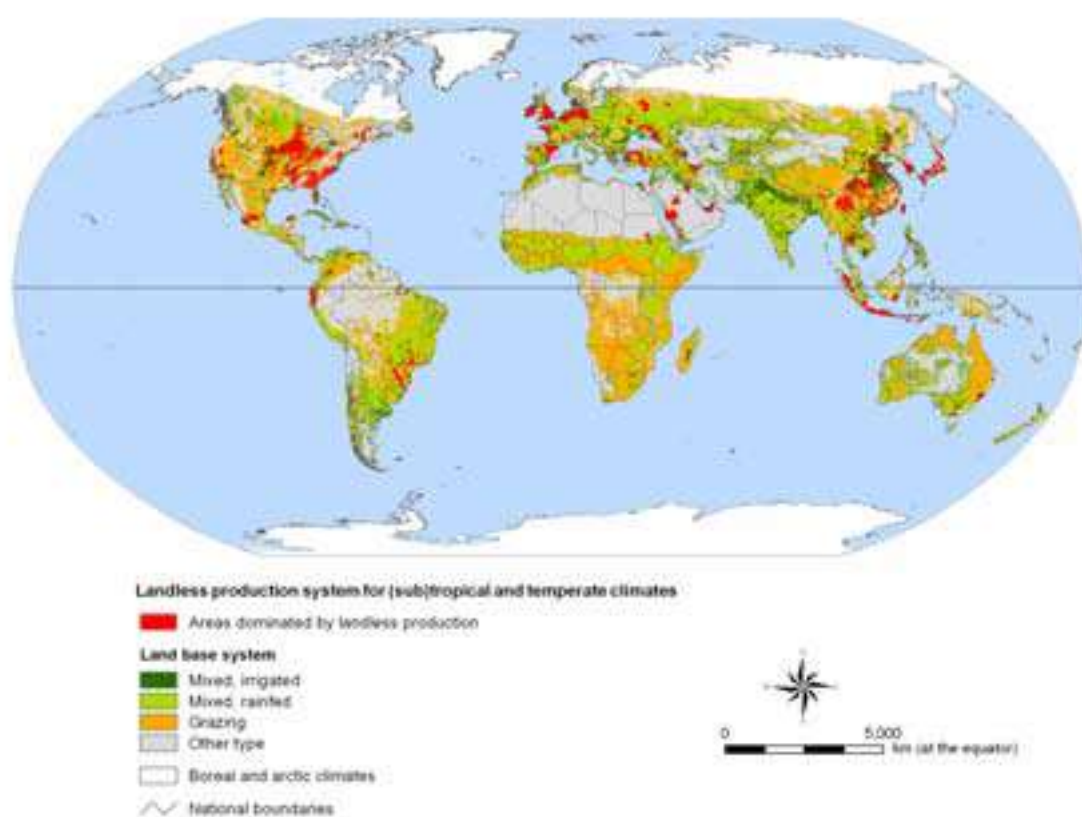
Which strategy or combination of strategies livestock producers have taken in the past or will take in the future depends on the circumstances in which they seek to make a living. These circumstances vary in terms of agro-ecological environment, socio-economic conditions, the state of infrastructure and services, cultural and religious practices, political and institutional environment, and development policies. Even where external circumstances are similar, the development options of individual farms/households differ depending on the assets and capacities that they have at their disposal, and on the motivations of the individuals involved regarding their future lives. It is beyond the scope of this section to consider all these factors and how they influence specific development strategies. A generalized discussion of responses to the driving factors is, therefore, presented at the level of livestock production systems.

The grouping of livestock production units on the basis of shared characteristics is a means of understanding common elements within the overall variety. Approaches to classifying livestock production systems vary according to the purpose of the classification, the scale, and the availability of relevant data. An important criterion is the dependence on, and linkage to, the natural resource base. This criterion leads to an initial distinction between land-based and landless systems (Ruthenberg, 1980; Jahnke, 1982; FAO, 1996a). The latter term describes situations where livestock feed is obtained neither from within the farm nor from grazing pastures, but is purchased or otherwise obtained from external sources. Land-based systems are often further distinguished based on land use, into grassland-based and crop-based systems. This distinction is also closely linked to the relative economic importance of livestock within the system. Within these categories, further distinctions may be drawn on the basis of characteristics such as agro-ecological zone, scale of production, mobility, location in relation to markets, or subsistence versus commercial orientation. Classification systems may vary considerably depending on the purpose and the angle of perception of the originator. For example, the more economically oriented classification developed by Doppler (1991) distinguishes systems first by market versus subsistence orientation, and at the next level on the basis of the scarcity of production factors (Doppler, 1991). Schiere and De Wit (1995) proposed a classification of farming systems on the basis of a two dimensional matrix. One dimension relates to the relative importance of livestock and crops, and distinguishes predominately livestock, mixed, and predominately crop-based systems. The second dimension is defined by the mode of farming, and distinguishes between expansion of the farm area, LEIA (low external input agriculture), new conservation (organic farming etc.) and HEIA (high external input agriculture). This classification eventually evolved into a more elaborate understanding of the interaction between drivers and people's preferences in the emergence of mixed (= diverse) production systems (Schiere *et al.*, 2006a).

The livestock production system classification developed by Seré and Steinfeld (FAO, 1996a), which is largely followed in this section, initially distinguishes two broad categories: solely livestock systems

and mixed farming systems. Solely livestock systems are differentiated from mixed farming systems in that more than 90 percent of the total value of production comes from livestock farming activities and that less than 10 percent of the dry matter fed to animals is obtained from crop residues or stubbles. Within the solely livestock systems, landless livestock production systems are distinguished from grassland-based systems on the basis of having a stocking rate above ten livestock units (LU) per hectare of agricultural land and obtaining less than 10 percent of the dry matter fed to animals from within the farm. The mixed system is further differentiated into mixed rainfed and mixed irrigated systems. In mixed irrigated systems more than 10 percent of the value of non-livestock farm production comes from irrigated land. The land-based systems (the grassland-based and mixed systems) are further defined on the basis of agro-ecological zone (arid/semi-arid, humid/subhumid and temperate/tropical highland). Figure 38 illustrates the spatial distribution of the three major land-based systems and indicates areas that have a high concentration of landless systems.

Figure 38
Distribution of livestock production systems



Source: Steinfeld et al. (2006)

The following chapters describe the three main livestock production systems categories – landless, grassland-based and mixed farming, focusing on their characteristics, trends and their requirements for AnGR. Within landless systems, industrialized production systems, and small-scale peri-urban/urban and rural landless systems are distinguished⁴. Within mixed farming systems special characteristics of mixed irrigated systems are described in a separate chapter. Where relevant, differences between the three agro-ecological zones as defined above are highlighted for land-based systems. Environmental impacts of the different systems are presented, with a view to understanding potential implications for longer-term sustainability. Negative environmental impacts can be considered as longer-term internal drivers as they reinforce or counteract the dynamics in the systems.

⁴ This distinction is not in line with the FAO (1996a) classification, in which landless monogastric and ruminant systems are differentiated within landless livestock production systems. It should also be noted that some small scale peri-urban and urban livestock keepers are actually mixed farmers as they also cultivate crops and more than 10 percent of the total value of their production comes from non-livestock farming activities.

1 Landless industrialized production systems

1.1 Overview and trends

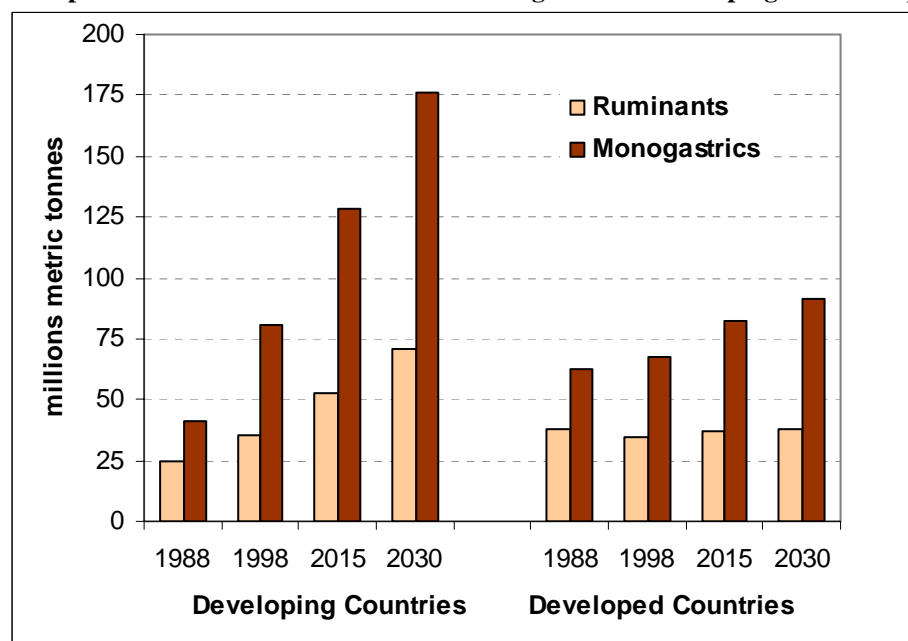
A description of industrialized production systems inevitably involves a discussion of the strong trend towards this type of livestock production. Industrialization of the livestock sector in response to the growing demands for animal products – the so-called “livestock revolution” – has received great public and scientific attention and is, in economic terms, the most important development within the livestock sector and within agriculture as a whole. The industrialization of farming has been ongoing in developed countries since the 1960s. In the mid-1980s, the trend started to affect developing countries, and it has accelerated in the last decade (Table 45). The trend has been particularly significant in monogastric meat production (Figure 39).

Table 45
Trends in production of meat and milk in developing and developed countries

| Production | Developing countries | | | | | Developed countries | | | | |
|--|----------------------|------|------|------|------|---------------------|------|------|------|------|
| | 1970 | 1980 | 1990 | 2000 | 2002 | 1970 | 1980 | 1990 | 2000 | 2002 |
| Annual per capita meat production (kg) | 12 | 14 | 19 | 27 | 28 | 28 | 40 | 60 | 99 | 105 |
| Annual per capita milk production (kg) | 31 | 34 | 40 | 49 | 51 | 65 | 77 | 83 | 80 | 82 |
| Total meat production (million mt) | 31 | 47 | 75 | 130 | 139 | 70 | 90 | 105 | 105 | 108 |
| Total milk production (million mt) | 80 | 112 | 160 | 232 | 249 | 311 | 353 | 383 | 346 | 353 |
| Shares of meat production | 31 | 34 | 42 | 55 | 56 | 69 | 66 | 58 | 45 | 44 |
| Shares of milk production | 21 | 24 | 29 | 40 | 41 | 79 | 76 | 71 | 60 | 59 |

Source: FAOSTAT

Figure 39
Meat production from ruminants versus monogastrics in developing and developed countries



Source: FAO (2002a)

Note: Ruminant meat = bovine and ovine meat production; monogastric meat = pig and poultry meat production

On a global scale, industrial production systems now account for an estimated 67 percent of poultry meat production, 42 percent of pig meat production, 50 percent of egg production, 7 percent of beef and veal production, and 1 percent of sheep and goat meat production (Table 46).

Table 46**Livestock numbers and production of the world's livestock production systems – averages for 2001-2003**

| | Livestock production system | | | | Total |
|--|-----------------------------|---------------|-----------------|------------|--------|
| | grazing | rainfed mixed | irrigated mixed | industrial | |
| Livestock numbers (10 ⁶ head) | | | | | |
| cattle | 406.0 | 618.0 | 305.4 | 29.1 | 1358.5 |
| dairy cows | 53.2 | 118.7 | 59.7 | - | 231.6 |
| buffaloes | 0 | 22.7 | 144.4 | - | 167.1 |
| sheep and goats | 589.5 | 631.6 | 546 | 9.2 | 1776.3 |
| Production (10 ⁶ mt) | | | | | 0 |
| total beef and veal | 14.6 | 29 | 10.1 | 3.9 | 57.6 |
| total sheep and goat meat | 3.8 | 4.0 | 4.0 | 0.09 | 11.8 |
| total pork | 0.9 | 12.5 | 42.1 | 39.8 | 95.3 |
| total poultry meat | 1.2 | 8.1 | 14.9 | 49.7 | 73.9 |
| total eggs | 0.5 | 5.6 | 23.3 | 29.5 | 58.9 |
| total milk | 71.6 | 319.2 | 203.7 | - | 594.5 |

Source: FAO (1996a) updated by FAO (2004)

In countries undergoing rapid economic development and demographic changes, new markets for animal products emerge. Supplying vertically integrated food chains and large retailers requires meeting certain food quality and safety standards. The demands of these emerging markets favour industrial production, which can take full advantage of economies of scale and technological advances in animal husbandry, food processing and transport. The development of poultry production, in particular, is “discontinuous”, i.e. there is typically no “organic” growth through which small poultry farmers gradually expand and intensify their production. Rather, as soon as urban markets, transport infrastructure and services develop, investors, often having no previous association with livestock production, step in and establish large-scale industrial-type units, integrated with modern processing and marketing methods (FAO, 2006f).

The emergence of industrial livestock production is dependent on the availability of a ready market for animal products, and the availability of the required inputs, in particular feed, at relatively low cost. A favourable policy environment, including for example, public investment in the livestock sector, trade liberalization, and the imposition of higher food safety standards, contributes to the speed of this development. China, India and Brazil – three very large developing countries which play a leading role of in their respective regions, but which have different economic structures and livestock sectors, are the largest contributors to the trend towards industrialization. These three countries now account for almost two-thirds of the total meat production in developing countries and more than half of the milk (Table 47). They also account for almost three-quarters of the production growth in developing countries for both commodity groups (FAO, 2006f). Landless industrialized systems in these countries mainly contribute to the production of meat from poultry and pigs, while beef, mutton and milk production are mainly concentrated in grassland-based and mixed systems.

Table 47**The developing countries with the highest meat and milk production (2004)**

| Country Group/ Country | Meat [million mt] | Milk | Meat [%] | Milk [%] |
|---------------------------|----------------------|-------|-------------|-------------|
| Developing Countries | 148.2 | 262.7 | 100 | 100 |
| China | 70.8 | 22.5 | 47.8 | 8.6 |
| India | 6.0 | 90.4 | 4.0 | 34.4 |
| Brazil | 19.9 | 23.5 | 13.4 | 8.9 |
| “Big three” | 96.7 | 136.4 | 65.2 | 51.9 |

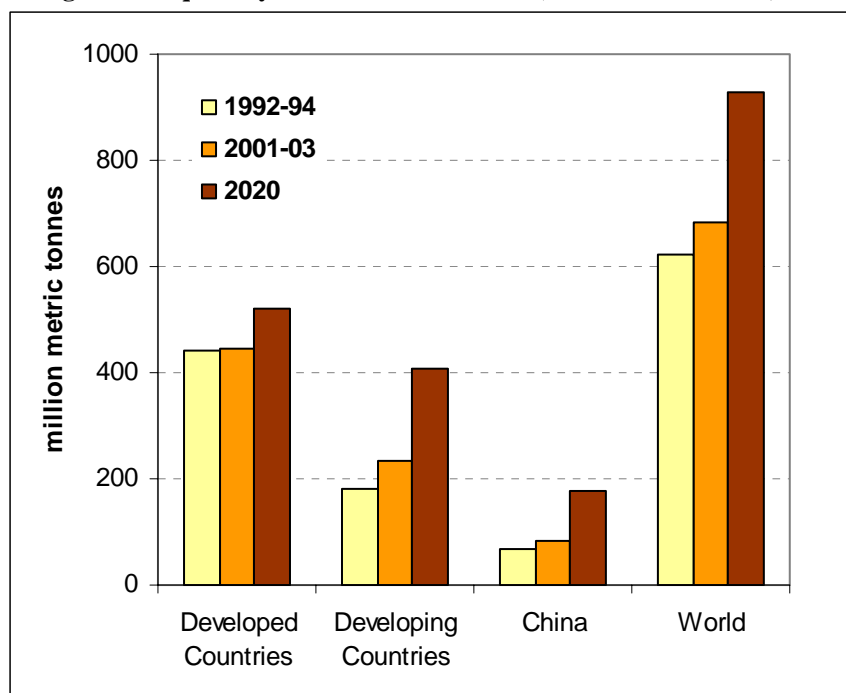
Source: FAO (2006f)

The process of industrialization can be characterized as a combination of three major trends: intensification, scaling up, and regional concentration.

Intensification

Intensification of livestock production is taking place with respect to most inputs. In particular, feed efficiency has been greatly improved over recent decades. Traditional fibrous and energy-rich feed stuffs are in relative decline, and protein-rich feeds and sophisticated additives which enhance feed conversion are on the rise. As livestock production intensifies, it depends less and less on locally available feed resources, such as local fodder, crop residues and unconsumed household food. Concentrate feeds, which are traded both domestically and internationally, are increasingly important. In 2004, a total of 690 million tons of cereals were fed to livestock (34 percent of the global cereal harvest) and another 18 million tons of oilseeds (mainly soya). These figures are projected to increase further (see Figure 40 for cereals). In addition, 295 million tons of protein-rich agricultural or food processing by-products were used as feed (mainly bran, oilcakes and fishmeal). Pigs and poultry make the most efficient use of these concentrate feeds. The most favourable feed conversion rates have been achieved in the poultry sector. Ruminants are only fed with concentrates in countries with low grain/meat price ratios. Where these ratios are high, typically in grain or cereal-deficit developing countries, feeding grain to ruminants is not profitable.

Figure 40
Changes in the quantity of cereals used as feed (1992-1994 and 2020)



Sources: FAOSTAT for the 1992-1994 and 2001-2003 figures; and FAO (2002a) for the 2020 figures

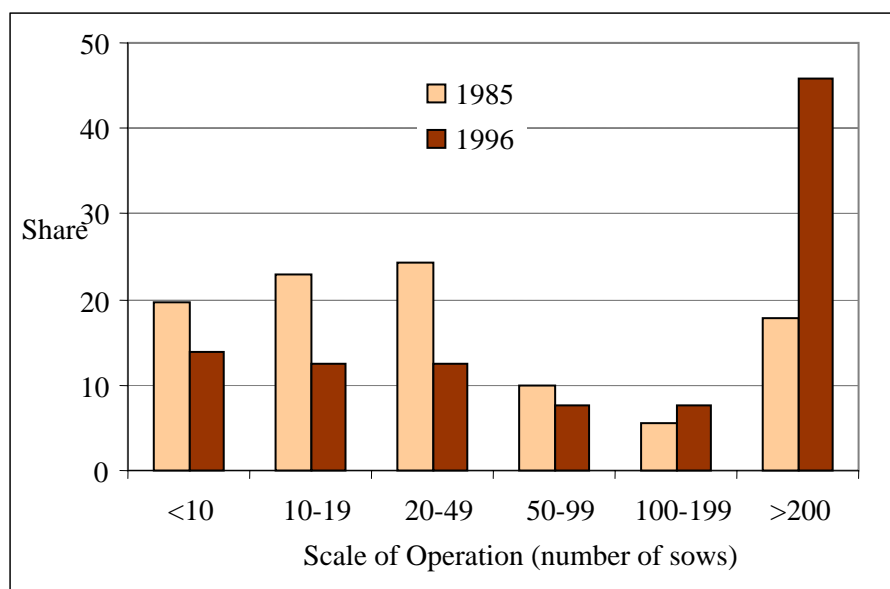
Intensification also draws on technical improvements in other fields, such as genetics, animal health and farm management. The use of high levels of external inputs to alter the production environment, including the control of pathogens, feed quantity and quality, temperature, humidity, light, and the amount of space available, creates conditions where the genetic potential of high-output livestock breeds can be fully realized. A narrow range of breeds are used, and the focus is on maximizing the production of a single product. Technical advances are being diffused as a result of increasing support from external service providers and the specialization of production. This is accompanied by a substantial shift from backyard and mixed systems to commercial, single-product operations. As a result, natural resource-use efficiency and output per animal has been increased substantially. Over the 24 years between 1980 and 2004, offtake of pig meat, chicken meat and milk per unit of stock increased by 61 percent, 32 percent and 21 percent respectively (FAO, 2006d).

Intensification of production may, however, make use of the full set of available technologies for improvement without necessarily leading to industrialization. It can also be an effective strategy for smallholders to improve their livelihoods if supported by favourable policies and infrastructure. For example, milk production in India continues to be largely smallholder based. Cooperative movements, supported by the National Dairy Development Board have successfully linked smallholders to the growing urban markets, and have supplied the feed and animal health inputs, and basic knowledge needed for intensification (FAO, 2006f). These developments can be contrasted to the situation in Brazil, for example, where the number of small-scale dairy producers has decreased as national production has increased (FAO, 2006e).

Scaling up

Besides intensification, the industrialization process is accompanied by a scaling up of production. Economies of scale – cost reductions realized through expanding the scale of operations – at various stages of the production process trigger the creation of large production units. As a result, the number of producers rapidly diminishes even though the sector as a whole may expand. In many fast-growing economies, the average size of operations is rapidly increasing and the number of livestock producers is in sharp decline. For example, Figure 41 shows that in Brazil, between 1985 and 1996, there was a large increase in the proportion of pig farms keeping more than 200 sows.

Figure 41
Changes in the distribution of the size of pig farms in Brazil (1985 to 1996)



Source: De Camargo Barros *et al.* (2003)

Where alternative employment opportunities are limited, the opportunity cost of family labour is low, and livestock keeping is likely to remain an economically attractive option for poorer households. However, where employment opportunities in other sectors improve, the opportunity cost of labour rises, and small family farm operations become increasingly unprofitable. Tenant farmers and landless livestock keepers will gradually find other employment, often in urban areas. Small landowners will, likewise, find it more profitable to sell or lease their holdings rather than to cultivate them.

Different commodities and different stages in the production process show different potential for economies of scale. They tend to be high in post-harvest sectors (e.g. slaughterhouse, dairy plants). Poultry production is the most easily mechanized sector, and shows a trend towards industrial forms even in the least-developed countries. In the case of pig production in Asia, the potentials for economies of scale are greater in finished-pig production than in piglet production (Poapongsakorn *et al.*, 2003). Dairy production continues to be dominated by family-based production because of high labour requirements, usually met by the use of family labour below the level of minimum wages.

However, the expansion of smallholder production beyond a semi-subsistence level is constrained by a number of barriers, lack of competitiveness and risk factors.

Geographical concentration

The geographical distribution of livestock production shows a common pattern in most developing countries. Traditionally, livestock production is based on locally available feed resources, particularly those of limited or no other value, such as natural pasture and crop residues. The distribution of ruminant livestock can be explained by the availability of such resources, while the distribution of pigs and poultry follows closely that of humans, because of their role as converters of waste.

When urbanization and economic growth give rise to “bulk” demand for animal food products, large-scale operators emerge which, at the initial stage, are located close to towns and cities. Livestock products are highly perishable, and their preservation without chilling and processing poses serious problems. In order to reduce transport costs, animals are therefore raised close to centres of demand. Livestock production is, thus, physically separated from the production of the feed resources. In a subsequent phase, infrastructure and technology develop sufficiently to make it possible to keep livestock further away from the markets where the products are sold. Livestock production moves away from urban centres, driven by a series of factors such as lower land and labour prices, easier access to feed, lower environmental standards, tax incentives and fewer disease problems.

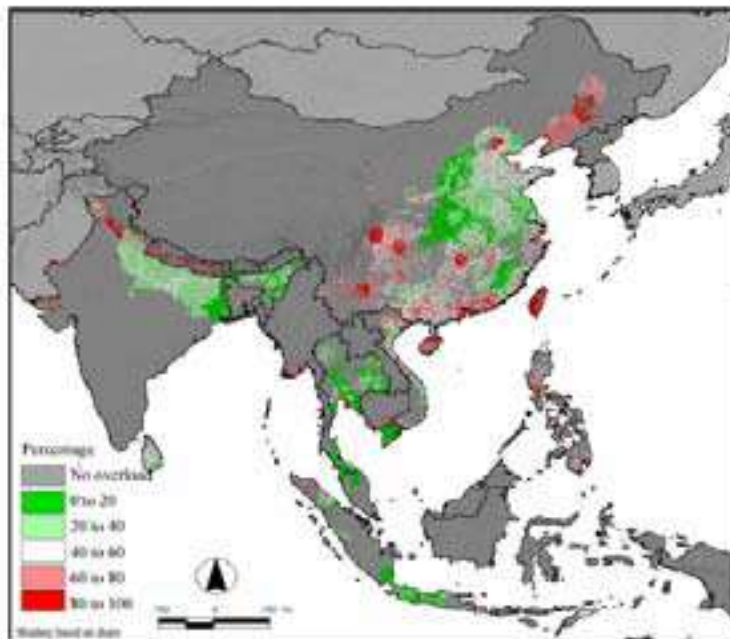
1.2 Environmental issues

In many respects, large-scale industrial systems are the main focus of concerns with regard to the environmental impacts of livestock production. This is particularly the case where development occurs very rapidly, without an appropriate regulatory framework. Although, as the following discussion will outline, there are numerous problems with this type of farming, industrial production can have certain advantages from the environmental perspective. Intensive production methods are at a particular advantage with regards to the efficiency of feed conversion (FAO, 2005a). Commercial livestock producers will tend to favour efficient use of priced resources. However, the potential of this motivation to promote more environmentally friendly intensive production is hampered by inadequate pricing of natural resources.

The decoupling of crop and livestock production through the geographical concentration of livestock in areas with little or no agricultural land leads to high levels of environmental impact – mainly related to manure and waste-water mismanagement (Naylor *et al.*, 2005). Nutrient overloads can arise from several sources amongst which are over-fertilization of crops, over-feeding of fish ponds, and improper waste disposal of agricultural or industrial wastes. In the case of livestock production, nutrient overloads mainly occur when the nutrients present in manure are not properly removed or recycled, which is often the case close to urban centres (Figure 42).

Figure 42

Estimated contribution of livestock to total phosphate supply on agricultural land in areas presenting a phosphate mass balance of more than 10 kg per hectare in selected Asian countries (1998 to 2000)



Source: Gerber et al. (2005), p. 275

Heavy application of manure to fields can result in nitrates and phosphates leaching into waterways. Excessive nutrient loading of waterways leads to the phenomenon known as eutrophication – the build up of algal growths which deny oxygen to other forms of aquatic life. In parts of the world, fragile ecosystems, important reservoirs of biodiversity, such as wetlands, mangrove swamps and coral reefs are threatened. In the South China Sea, pollution from livestock production has been identified as a major cause of massive algal “blooms”, including one in 1998 which killed more than 80 percent of the fish in a 100 km² area of coastal water (FAO, 2005a). Industrial production systems often necessitate the storing of manure. At this stage, nitrogen loss is mainly in the form of ammonia emitted from the surface of the manure (FAO, 1996b). The volatilization of ammonia can lead to the acidification and eutrophication of the local environment and damage fragile ecosystems such as forests. Nitrous oxide, a particularly active greenhouse, gas is also produced from livestock manure (17 percent of global emissions are estimated to come from livestock including manure applied to farmland) (Table 48). Another problem associated with the spreading of manure derived from industrial livestock production is the contamination of pastures and cropland with heavy metals, which can cause health problems if they enter the food chain. Copper and zinc are nutrients that are added to concentrate feed, while cadmium enters livestock feed as a contaminant. Inappropriate management of manure can also lead to the pollution of soil and water resources with pathogens (ibid).

Another way in which industrial livestock production contributes to the production of greenhouse gases (in this case carbon dioxide) is through the associated transportation of feed over long distances, which requires the use of fossil fuels. In the case of methane, however, emissions arising from ruminant digestion are greater where the feed energy supplied to the animals takes the form of low-quality forages. As such, industrial production, with its greater use of concentrate feed, and breeds that are more efficient converters of feed, has advantages with respect to the amount of methane produced relative to the output of livestock products.

Table 48
Agriculture's contribution to global greenhouse gas and other emissions

| Gas | Carbon dioxide | Methane | Nitrous oxide | Nitric oxides | Ammonia |
|---|---|---|---|--|---|
| Main effects | Climate change | Climate change | Climate change | Acidification | Acidification and eutrophication |
| Agricultural source (estimated % contribution to total global emissions) | Land use change, especially deforestation | Ruminants (15) Rice production (11) Biomass burning (7) | Livestock (including manure applied to farmland) (17) Mineral fertilizers (8) Biomass burning (3) | Biomass burning (13) Manure and Mineral fertilizers (2) | Livestock (including manure applied to farmland) (44) Mineral fertilizers (17) Biomass burning (11) |
| Agricultural emissions as % of total anthropogenic sources | 15 | 49 | 66 | 27 | 93 |
| Expected changes in agricultural emissions to 2030 | Stable or declining | From rice: stable or declining From livestock: rising by 60% | 35–60% increase | | From livestock: rising by 60% |

Source: FAO (2002a)

The environmental effects of feed production also need to be considered. Thirty-three percent of arable land is used for the production of animal feeds, mostly concentrates (FAO, 2006c). Much of this production takes place under conditions of high pesticide and fertilizer use. Expansion of the land area used for crop production can threaten biodiversity. In parts of Latin America, for example, large areas of rainforest are being destroyed as land is given over to the production of livestock feed (particularly soybeans). Increased demand has driven increased exports of feed from countries such as Brazil for use in intensive livestock production in countries where land is scarcer (FAO, 2006g).

A further feature of industrial production units is the concentration of large numbers of animals within confined spaces. Crowded conditions provide an environment in which disease can easily spread unless preventive measures are taken. Industrial units, therefore tend to be heavy users of livestock drugs, which if not used appropriately can enter the food chain and have adverse effects on human health. Similarly, hygiene requirements in large livestock units demand the heavy use of chemical cleaning agents, and other inputs such as fungicides, which if not carefully managed are a further potential source of pollution in neighbouring environments.

2 Small-scale landless systems

2.1 Overview

In economic terms, the contribution to food production of small-scale landless systems is nowhere near as significant as that of the industrialized systems. In fact, their contribution has never been evaluated at a global scale. However, small-scale peri-urban/urban livestock keeping is now being (re)discovered by officials, and research and development workers in many poor and wealthy countries. Surveys in some African, Asian and Latin American cities have revealed surprisingly large number of urban livestock keepers, even including some better-off citizens (Waters-Bayer, 1996; FAO 2001b). Overall, neither the scale of economic benefits which urban livestock provide for their keepers nor their contribution to wider food security is well known. This lack of knowledge is even greater in the case of rural landless livestock production.

Small-scale landless livestock keepers are characterized by having no croplands of their own, and no access to large communal grazing areas. Often poor, these livestock keepers are found both in urban and peri-urban zones, and in rural areas dominated by mixed farming systems, particularly where population density is high or the distribution of land ownership is unequal.

Rural landless livestock keepers are often highly dependent on off-farm employment, frequently in the form of casual labour. Feed for the livestock is obtained from a variety of sources including scavenging, grazing on marginal lands, utilization of waste food and by-products, cutting and carrying, and purchasing. Compared to their land-owning neighbours, rural landless livestock keepers face particular constraints in relation to feeding. Their production objectives for livestock may also differ, given their reduced ability to make immediate use of some products such as manure and draught power. In general, small-scale rural landless farmers keep the local breeds or cross-breeds common in the area. However, if they engage in more commercial activities, higher-output breeds may be kept.

The most distinctive feature of urban production systems is the close vicinity of large numbers of consumers, which reduces the necessity of transporting perishable products over long distances. To benefit from this advantage, livestock keeping in and around towns and cities has been practised since ancient times. Reasons for engaging in urban livestock keeping are diverse and include, gaining income through sales; the pleasure of keeping livestock and the opportunity to continue practising a traditional livelihood activity; the accumulation of capital embodied in livestock as a form of insurance or to finance future projects; dietary supplementation with home-produced milk, eggs or meat; and the opportunity to make use of available resources such as waste food. Animals can also provide inputs such as manure and draught power for urban crop production. However, the urban environment presents livestock keepers with a number of constraints. Particularly if larger animals are involved, limited space can be a problem, as can obtaining sufficient feed at a cost that is not prohibitive. Urban production systems often have multiple connections to the surrounding rural areas,

whether in the form of feed provision, the supply of animals, or the flow of traditions and knowledge related to livestock keeping. Relatives or paid herders in rural areas may take care of part of the herd owned by urban residents. Animals such as dairy cows or buffaloes may be transferred to rural areas during unproductive phases of their production cycle in order to take advantage of cheaper feed (Schiere *et al.*, 2006b). The type of livestock breeds kept in these systems depends on the species, the marketed product, and the strength of rural-urban linkages.

2.2 Environmental issues

Small-scale livestock production in peri-urban/urban areas faces some of the same basic environmental problems as industrialized systems (e.g. problems of waste disposal and contamination of water sources). The scale of the problems may be as significant as for large-scale operations if a large number of small production units are concentrated within a limited area. In addition, the operation of environmental control regulations may be weak, and infrastructure for waste management poorly developed. Another feature of these systems tends to be that humans and animals live in close vicinity to each other. This poses hazards related to the spread of zoonoses such as avian influenza. Problems are often exacerbated by poor standards of animal health control and the absence of management skills adapted to the urban environment. Livestock can also cause nuisance problems such as noise, dirt, clogged sewage systems, traffic congestion and damage to property. The problems of urban livestock keeping tend to be greatest close to the centre of the city, as concentrations of animals and people are high, possibilities to use wasteland for grazing are low, and the distance to surrounding croplands or pastures is high (Schiere *et al.*, 2006b).

As in urban environments, some rural landless livestock keepers may also face health problems arising from the need to keep the animals close to (or in) human dwellings, and limited access to veterinary inputs. Given the proximity of cropland the disposal of manure is likely to be less of a problem. Indeed, manure may be a product that can be sold. Increasing livestock numbers may put pressure on the marginal grazing areas utilized by landless livestock keepers and contribute to the degradation of these resources, although the areas involved are, by definition, limited in scale.

2.3 Trends

In general, small-scale landless production offers relatively limited options for development. However, the numbers of urban poor are still expanding as result of ongoing rural–urban migration in search of work. As employment opportunities are often limited and insecure, the potential numbers engaging in small-scale urban livestock keeping or agriculture will tend to increase. Close rural–urban linkages are important to overcome constraints of feed scarcity, and to use the comparative advantages of each location. Poor urban livestock keepers are generally not well served by veterinary and other services, and in many towns and cities livestock keeping activities run into conflict with the law. Access to formal markets may be limited by quality or hygiene-related issues. There is, however, an increasing recognition of the significance of small-scale urban production and the need to develop appropriate policies to minimize adverse effects and to support the livestock keepers' livelihoods.

The growing demand for animal products seems to offer opportunities for some smaller-scale urban or peri-urban livestock keepers to intensify their production. India, for example, has been successful in integrating small-scale landless buffalo and cattle keepers into milk collection schemes around urban centres. Other instances of intensification outside the large-scale industrial system are found in poultry production. For example, in Burkina Faso, Laos, Myanmar and Cambodia, poultry meat production increased by 169 percent, 84 percent, 1530 percent and 106 percent, respectively, over the period from 1984 to 2004; this corresponded to 17, 8, 153 and 17 thousand metric tons, respectively (FAOSTAT). The growth took place in small-scale intensified systems in peri-urban settings utilizing improved feed, genetics and management practices. It is, however, probable that intensification of this kind is transitory. As soon as the volume of demand is sufficiently large and concentrated to allow for substantial economies of scale, scaling-up occurs with the arrival of large companies. The latter trend is now observed, for example, in Cambodia.

In the already densely populated rural areas of Asia, the population continues to increase while the land area used for agriculture cannot be further expanded. Where there are limited alternative livelihood options outside agriculture, livestock keeping is likely to remain an important activity for the landless rural poor. Where markets are accessible, there may be some opportunity for engaging in more commercially oriented activities such as dairying. This has happened in the case of the dairy cooperative movements in India, where a considerable proportion of the milk delivered to dairy plants is produced by rural landless buffalo or cattle keepers who often participate in related genetic improvement programmes. However, landless livestock keepers face severe constraints to expanding the output of their herds or flocks, particularly with regard to the supply of feed.

3 Grassland-based systems

3.1 Overview

Grassland-based or grazing production systems are largely found in locations that are unsuitable or marginal for growing crops, as a result of low rainfall, cold, or rough terrain, or where degraded cropland has been converted into pasture. Grazing systems are found in temperate, subhumid and humid climatic zones, but are particularly abundant in arid and semi-arid locations. Livestock breeds kept under grazing systems have to be well adapted to the environment and the objectives and management practices of the livestock keepers. Harsh environments mean that livelihoods are often precarious, and livestock management practices have to be adapted to cope with climatic extremes, and limited or erratic availability of feed resources.

One-third of the world's small ruminants, nearly one-third of the cattle population and 22 percent of the dairy cows are found in grassland-based systems (Table 46). These animals produce 25 percent of global beef and veal, 12 percent of total milk production, and 32 percent of sheep and goat meat. While small ruminant production is proportional to the numbers, the figures for cattle are lower than in the other systems.

Grazing systems found in arid and semi-arid zones include both the pastoralist systems of sub-Saharan Africa, North Africa, the Near and Middle East, and South Asia (Table 49), and the ranch-type systems found in the drier parts of Australia, the United States of America, and in parts of Southern Africa. Ranching is characterized by private ownership of rangeland (individual, commercial organization or in some cases group ranches). Production is market-oriented – usually of cattle, which are sold for fattening in other systems. Sheep and goats are kept for fibres or pelts in subtropical zones. In contrast, traditional pastoralism is largely a subsistence-oriented activity based on the keeping of cattle, camels and/or small ruminants. One objective is to ensure a year-round production of milk for consumption. Another objective is the production of live animals for sale. This is probably becoming more important as a result of growing demand for livestock products. The mobility of pastoral herds and flocks allows for efficient use of feed resources, the availability of which is dependent on unpredictable rainfall patterns. Traditionally, indigenous institutions have regulated access to common grazing and water resources.

Table 49
Estimated number of pastoralists in different geographic regions

| Region | Number of Pastoralists [million] | Proportion of Rural Population [%] | Proportion of Total Population [%] |
|--------------------------|----------------------------------|------------------------------------|------------------------------------|
| Sub-Saharan Africa | 50 | 12 | 8 |
| West Asia & North Africa | 31 | 18 | 8 |
| Central-East Asia | 20 | 3 | 2 |
| Newly Independent States | 5 | 12 | 7 |
| South Asia | 10 | 1 | 0.7 |
| Central & South America | 5 | 4 | 1 |
| Total | 120 | | |

Source: Rass (2006), calculations based on Thornton *et al.* (2002)

Grazing systems are also found in some subhumid or humid zones, mostly in South America, but also in Australia and to a limited extent in Africa. Extensive cattle production mostly for beef is the most frequent activity, but buffalo ranching occurs in very humid areas, and wool sheep are kept in subtropical areas of South America, Australia and South Africa (FAO, 1996a). The system tends to be concentrated in locations where crop production is restricted because of biophysical reasons or lack of market access.

In the grazing systems of temperate zones, highly selected animals are utilized along with a range of technologies to maximize production. Breeds from temperate countries are also suited to many tropical highland locations. However, where more subsistence-oriented production is practised, or at very high altitudes, locally adapted breeds and species are important. In the Andes of South America, for example, camelid species adapted to the high altitudes are important. Similarly, in the mountains of Asia the yak is of great significance to the livelihoods of local people.

3.2 Environmental issues

Grazing livestock often have a poor reputation with respect to environmental impacts. As in all production systems, the ruminants kept under grazing systems are a source of methane, and hence contribute to global warming. Indeed, the low-quality forage resources on which the livestock in these systems often rely, means that the animals produce large quantities of methane relative to the levels of production obtained. However, it is probably the issues of overgrazing and the destruction of tropical rainforests to make way for cattle ranching that have raised the greatest concerns in grazing systems.

It is certainly the case that prolonged heavy grazing can lead to changes in the composition of vegetation, with palatable species becoming less common. The removal of plant cover through heavy grazing and trampling can lead to erosion and the loss of fertile soils. Recent years have, however, seen something of a change in the way in which grazing systems in arid zones are understood. Arid rangelands have come to be viewed as non-equilibrium systems in which abiotic factors (most notably rainfall), rather than livestock density, are the driving forces influencing patterns of vegetation cover (Behnke *et al.*, 1993). Livestock numbers in turn respond to the availability of grazing. As such, traditional mobile opportunistic systems are often considered to be the most appropriate form of livestock management from the point of view of efficiently utilizing grazing resources under arid conditions. In less arid areas, the availability of grazing is less variable, population density is higher, and cropping is more widespread. Livestock keeping tends to be more sedentary. Grazing pressure is more likely to be the factor influencing the extent of vegetation cover. In these circumstances, overgrazing, along with cropping in fragile areas and excessive collection of fuelwood, can lead to serious problems of soil erosion and loss of biodiversity (FAO, 1996b).

Problems are increasingly exacerbated by trends that restrict the mobility of pastoralists (see next subchapter). Inappropriate water developments or the availability of subsidized grains for feeding

animals can also lead to situations in which livestock are retained for too long in a particular area, thereby preventing the normal regeneration of the pasture. Another factor is the breakdown of traditional arrangements for the management of access to common grazing lands. This can lead to a situation in which the contradiction between private ownership of livestock and open access to grazing land means that individual livestock keepers will be motivated to graze extra animals even though the combined outcome of their actions is the degradation of the pastures (FAO, 1996a).

Particularly in Latin America, the expansion of cattle ranching on planted pastures in humid areas has been an important driver of the destruction of rainforests, the most biodiverse ecosystems on earth. In addition to the sheer scale of habitat loss, the fragmentation of the remaining forested areas also has serious consequences for biodiversity. Clearing and burning rainforests also releases billions of tonnes of carbon dioxide into the atmosphere each year.

The problem has often been exacerbated by policies including: inappropriate road building schemes in forest areas; tax policies and subsidies designed to promote beef production and exports; migration and colonization projects that shift poor populations to areas with low population density; and land titling schemes that lead to the spread of livestock grazing as a cheap and easy means of establishing ownership rights (*ibid.*). In many countries, subsidies promoting the expansion of ranching have now been discontinued, but livestock production continues to be an important driver of deforestation. It is estimated that 24 million hectares of land in Central America and tropical South America that was forest in 2000 will be used for grazing by 2010 – meaning that two-thirds of land deforested in these areas is expected to be converted to pasture (*ibid.*). Further policy measures are required to slow the expansion of the agricultural frontier and to promote more sustainable use of land that is already being grazed. Packages of technologies (combining improved grazing management, genetics, animal health etc.) need to be developed and promoted in order to enable livestock keepers to make productive use of their existing grazing land. There is a growing interest in silvopastoral production systems, and in schemes that provide farmers with payments for the provision of ecosystem services such as carbon sequestration, biodiversity conservation and watershed management (FAO, 2006b).

The effects of inappropriate grazing can also be a concern in temperate countries – for example in dwarf shrub and woodland habitats. However, managed grazing is increasingly viewed as an important tool for conservation. In the United Kingdom, for example, grazing is utilized to promote the biodiversity of species-rich grassland, heath and wetland habitats (Harris, 2002). Some plant species thrive under grazing pressure, others are unable to survive in grazed habitats, while others are able to thrive if grazing is avoided during growing periods. As such, it is possible to use managed grazing to control the distribution of plants in accordance with conservation objectives. Patterns of livestock trampling and dunging also affect the vegetation, and have to be considered for conservation management. Unfortunately, the plants that the conservation manager wishes to control are not always the most palatable to livestock. This problem can to some extent be overcome by utilizing the differential feeding habits of different species and breeds. It is in this context that there is potentially an important role for breeds that are not economically viable in conventional production. These breeds are often well adapted to grazing and browsing poor quality vegetation, and are able to thrive under harsh environmental conditions and with low levels of management intervention. Conservation sites are diverse, and are often managed to provide a mosaic of habitats for wildlife. Grazing requirements can, therefore, be very specific and benefits can be maximized if breed characteristics are closely matched to these requirements. An interesting development in this respect is the Grazing Animals Project⁵ in the United Kingdom, which provides breed-specific information on grazing preferences along with other breed characteristics relevant to conservation grazing such as hardiness, husbandry requirements, interactions with the public, and marketability.

3.3 Trends

As discussed in the previous subchapter, the sustainability of many grazing systems is threatened by pressure on natural resources, and the disruption or abandonment of well-adapted traditional management practices. At the same time, large populations traditionally reliant on subsistence-

⁵ <http://www.grazinganimalsproject.info/pilot1024.php?detect=true>

oriented livestock production, continue to seek a livelihood from the rangelands. In general, pastureland productivity has lagged far behind that of cultivated areas, although detailed estimates are difficult to make. A number of factors contribute to this trend. First, intensification of pastures is often technically difficult and unprofitable. Constraints commonly relate, to climatic conditions, topography, shallow soils, acidity and disease pressure. The difficult conditions that characterize pasturelands are exemplified by the pastoralist and agro-pastoralist systems of the arid and semi-arid lands of sub-Saharan Africa. These constraints could only be overcome by massive investments on various fronts; piecemeal interventions will have no effect. Additionally, in much of Africa and Asia, most pastures are under common ownership, which further complicates their intensification. Without firm institutional arrangements, private investments in these areas are difficult to organize as returns accrue to individuals, in proportion to the number of animals they keep on the communal land. Lack of infrastructure in these remote areas further contributes to the difficulty of improving productivity through individual investments. Globally, these limitations are reflected in the slow growth of meat production from grassland systems compared, particularly, to industrial systems (FAO, 1996a).

Though often remote, pastoralist production systems are not unaffected by macroscale economic, political and social changes, and by technological and infrastructural developments. The increasing globalization of trade, for example, may mean that the marketing of products from pastoral systems is affected by competition from imported meat, or by increasingly stringent hygiene requirements (FAO, 2001c). Modern armed conflict, endemic in many pastoral zones, disrupts herding activities and displaces populations. Motorized transport enables those with the necessary resources to rapidly move animals in search of grazing or to the market, a situation which is increasingly common in the Near and Middle East region for example (FAO, 1996b). As well as potentially disrupting traditional regimes for grazing management, this development can affect demands for genetic resources, reducing the desirability of traits such as walking ability, and promoting more market-oriented production objectives. Motorization also means that the role of pack animals such as camels or donkeys declines in importance. The introduction of modern veterinary medicines can promote the enlargement of herd sizes (FAO, 2001c), and may facilitate the introduction of exotic genetic resources less adapted to local disease challenges.

A number of factors threaten the sustainability of mobile pastoralist systems. The expansion of crop production into former grazing lands is one threat – often driven by population growth in crop-producing systems (FAO, 1996b). Particularly disruptive is the spread of cropping into dry-season grazing areas, which form a key element of mobile pastoralists' grazing strategies. In places, the development of irrigation schemes also promotes the expansion of the cropped area (FAO, 2001c). Moreover, among some pastoralist communities the uptake of crop production is increasingly common, as a response to the growing insecurity of livestock-based livelihoods, and as a by-product of sedentarization (Morris, 1988).

There is, thus, a general shift away from pastoralism towards agropastoralism (a rather ill-defined term describing production systems in semi-arid environments that combine crop and livestock production, but where livestock are highly dependent on rangeland grazing). In sub-Saharan Africa, for example, Thornton *et al.* (2002) predict a substantial shift from pastoral to agropastoral systems over the next 50 years. The long-term sustainability of crop production in the most marginal areas is, however, questionable, particularly where inappropriate water developments have been implemented (FAO, 2001c). In mountainous areas of Asia, transhumant migration routes are also increasingly disrupted by the expansion of cropping (FAO, 2003). The fencing of traditional grazing areas is also a problem for livestock keepers in parts of the Andes (see Box 102 in Part 4 – Section: F: 6).

Policies promoting sedentarization, the regularization of stocking rates or the development of individual ranch-type farms also play a role (FAO, 1996b). Particularly in Africa, the establishment of wildlife reserves, motivated both by conservation objectives and by the potential economic benefits from tourism, can exclude pastoralists from their traditional grazing lands (FAO, 2001c). School attendance and alternative employment (e.g. involving migration to urban areas) may restrict the availability of labour for herding and increase the trend towards sedentarization (*ibid.*).

While the significance of different driving forces varies from place to place, the broad trend is towards greater numbers of people seeking to make a living from more restricted and often less well-managed grazing land. Under severe pressure, herders may be forced to abandon pastoral livelihoods. Less dramatically, there may be shifts in breed or species utilization, as livestock keepers adapt to difficult circumstances. For example, as pasture resources are depleted, herders may adapt, by abandoning cattle in favour of small ruminants or camels. Trends towards social differentiation are also widespread – promoted by differential capacity to respond to the disruption of pastoral systems, and to take advantage of policy and technological developments. Large-scale, often absentee livestock owners on the one hand, and destitute populations increasingly sedentarized around urban settlements, on the other, may no longer be able or willing to continue traditional pastoral livelihoods. Given that the livestock breeds of pastoral zones are not only adapted to the natural environment, but have been developed to meet the needs and preferences of the local livestock keepers, such changes may have substantial effects on the utilization of AnGR.

Having outlined trends towards the disappearance of traditional mobile livestock production systems, some countervailing factors must be noted. It is increasingly recognized that “pastoralists remain a resource, a system of producing meat and milk cheaply in land that is otherwise hard to exploit” (FAO, 2001c). It is also recognized that appropriate development policies for the rangelands are required if such systems are to survive or flourish (*ibid.*). Similarly, in many remote locations prospects for the emergence of alternative sources of income are limited, and seeking to scrape a living from livestock keeping is likely to remain one of the few livelihood options available to local populations (FAO, 2003). As noted above, the expansion of crop production may not always be sustainable in the long term, and a swing back towards pastoral livestock keeping cannot be ruled out in some places (FAO, 2001c). One part of the world which has seen some recent return to more traditional grazing systems has been Central Asia, following the decline of collectivized farming and the infrastructure established during the Soviet era (*ibid.*).

The extensive ranching systems of the Latin America and the Caribbean region are also facing changes. The subsidies which promoted the expansion of livestock ranching (often at the expense of rainforests) have largely been discontinued (FAO, 2006b). Urban demand for crop staples and an improved road infrastructure promotes the expansion of mixed farming into grazing areas (FAO, 1996a). At the same time, increasing numbers of incentive measures are being put in place to promote the conservation of natural resources and the provision of environmental services (FAO, 2006b). One reflection of these developments is a growing interest in silvopastoral systems (*ibid.*).

Over the coming decades, grazing systems are also likely to be affected by changing temperature and rainfall patterns associated with global climate change. It is, of course, difficult to predict with great accuracy the impacts of climate change on livestock production. However, changes to the length of growing period are expected to shift the boundaries of zones suitable for cropping. In sub-Saharan Africa, Thornton *et al.* (2002) predict that current mixed farming areas that will be more suitable for pastoral production by 2050 include zones stretching in bands across the Sahel and the Sudan, and across southern Angola and central Zimbabwe, as well as transition zones to lower elevations in Ethiopia. Conversely, some pastoral lands, mainly in Kenya, the United Republic of Tanzania and Ethiopia, are predicted to become suitable for mixed farming. Taken as a whole, however, the area of land in sub-Saharan African with a climate suitable for crop production is predicted to decline (*ibid.*). Central parts of Asia and North America, both areas where grazing systems are of major importance, are also predicted to be seriously affected by climate change (Phillips, 2002). Increased frequency and severity of droughts is also predicted to exacerbate pressures on dryland production systems (FAO, 2001c).

In the temperate zones of developed countries, the functions of grazing systems are also changing. Demands placed on the system increasingly relate to the provision of environmental services, and the relative significance of animal production *per se* is often in decline (FAO, 1996a). Policy concerns also relate to the provision of employment in remote, often relatively poor, rural areas. While in some cases locally adapted livestock breeds may be threatened by the poor profitability of livestock production in remote areas, lower-output breeds are often well suited to alternative roles such as

conservation grazing, the production of speciality products, or forming part of an appealing rural landscape to attract the tourist.

4 Mixed farming systems

4.1 Overview

Crop–livestock production systems dominate smallholder production throughout the developing world. The system is particularly dominant in the subhumid and humid tropics, but mixed farming is also widespread in semi-arid, highland and temperate areas. The use of land for mixed farming depends on the feasibility of rainfed crop production (Table 50) or, where quantity and distribution of rainfall does not allow rainfed production, on the possibility of irrigation.

Table 50
Land with rainfed crop production potential

| | Land surface | | Land suitable for rainfed production | |
|---------------------------------|-----------------------|--|--------------------------------------|---|
| | Total [million ha] | Proportion suitable for rainfed production [%] | Total [million ha] | Proportion marginally suitable [%] |
| Developing countries | 7302 | 38 | 2782 | 10 |
| Sub-Saharan Africa | 2287 | 45 | 1031 | 10 |
| Near East/North Africa | 1158 | 9 | 99 | 32 |
| Latin America and the Caribbean | 2035 | 52 | 1066 | 8 |
| South Asia | 421 | 52 | 220 | 5 |
| East Asia | 1401 | 26 | 366 | 13 |
| Industrial countries | 3248 | 27 | 874 | 20 |
| Transition countries | 2305 | 22 | 497 | 18 |
| World | 13400 | 31 | 4188 | 13 |

Source: adapted from FAO (2002a)

The majority of the world's ruminants are kept within crop–livestock systems: 68 percent of the world's cattle population, 66 percent of the sheep and goat population, and 100 percent of the buffalo population. This translates into 68 percent of beef and veal production, 100 percent of buffalo meat production, 67 percent of sheep and goat meat production, and 88 percent of milk production. Mixed systems also produce 57 percent of pig meat production, 31 percent of poultry meat production, and 49 percent of egg production (Table 46).

Many crop–livestock farming systems in developing countries are characterized by relatively low levels of external inputs, with the products of one component of the system being used as inputs for the other (Table 51). Crop residues provide a source of feed for the animals, while the use of livestock manure helps to maintain soil fertility (Savadogo, 2000), and draught animals often provide a source of power. Livestock offer a means of intensifying crop production systems based on limited additional requirements for labour or expensive inputs. The cycling of nutrients and limited use of non-renewable resources results in a relatively benign impact on the environment.

The traditional mixed farming systems of developing countries are home to many of the world's poor (Thornton *et al.* 2002). For poor households, livestock provide a means of diversifying livelihood activities, are an asset to be sold to raise cash in times of need, and provide a range of products for home consumption, as well as the above-mentioned contributions to crop production. Purchased inputs in terms of veterinary care, feed or housing are limited.

Table 51
Main crop–animal interactions in crop-based livestock systems

| Crop Production | Animal Production |
|--|--|
| Crops provide a range of residues and by-products that can be utilized by ruminants and non-ruminants. | Large ruminants provide power for operations such as land preparation and for soil conservation practices. |
| Cropland left fallow or improved fallows (ley) and cover-crops growing under perennial tree crops can provide grazing for ruminants. | Both ruminants and non-ruminants provide manure for the maintenance and improvement of soil fertility. In many farming systems it is the only source of nutrients for cropping. Manure can be applied to the land or, as in Southeast Asia, to the water which is applied to vegetables whose residues are used by non-ruminants. |
| Cropping systems such as alley-cropping can provide tree forage for ruminants. | The sale of animal products and the hiring out of draught animals can provide cash for the purchase of fertilizers and pesticides used in crop production. Animals grazing vegetation under tree crops can control weeds and reduce the use of herbicides in farming systems. Animals provide entry-points for the introduction of improved forages into cropping systems as part of soil conservation strategies. Herbaceous forages can be undersown in annual and perennial crops, and shrubs or trees established as hedgerows in agroforestry-based cropping systems. |

Source: adapted from Devendra *et al.* (1997)

There is, however, great diversity in the world's mixed farming systems. In the temperate zones of developed countries more intensive production practices involving greater use of external inputs and high-output livestock breeds have emerged. Production objectives largely focus on a single product. Feeding livestock during the cold months of the year presents a challenge, and given high levels of demand for livestock products and the availability of high-yielding animals, cropland is often devoted to the production of specialized forage crops which are conserved for winter feeding (FAO, 1996a). Conversely, in the mixed systems of the tropical highlands, livestock tend to have multiple functions, with the provision of support services to cropping being very significant (Abegaz, 2005).

The humid and subhumid zones of the tropics are demanding environments for livestock production. In addition to high temperatures and humidity, the challenge presented by livestock disease is often severe. In these environments, the dominant function of livestock is, again, often the provision of inputs to crop production. In drier environments, crop production becomes increasingly difficult and risk-prone. Livestock acquire a more significant role relative to cropping in the provision of products for sale or home consumption, and offer a means of diversifying livelihoods against the risk of crop failure. Limited availability of crop residues means that grazing land becomes more important as a source of feed. Animal traction is again common, and livestock contribute to enhancing the productivity of cropland by transferring nutrients from rangelands in the form of manure. Fuel in the form of dung cakes is an important livestock product, particularly in locations where fuelwood is scarce as a result of deforestation. Under these conditions, agropastoralist systems, which may involve migration with the livestock away from croplands for parts of the year, are prevalent (Devendra *et al.*, 2005). In some places agropastoral production is a long-standing traditional system. In other cases, however, agropastoralism has emerged as pastoralists or settled farmers adapt their livelihood activities in the face of changing circumstances (*ibid.*).

4.2 Environmental issues

Mixed farming systems, if they are well managed, are generally regarded as relatively benign in environmental terms. The use of draught animals rather than mechanized cultivation, and limited use

of external inputs reduces the need for the use of fossil fuels. The waste products of crop and animal production are recycled through the other components of the system. The fertility of cropland is maintained, and nutrients do not escape into ecosystems where they can act as pollutants. In terms of biodiversity, smallholder mixed farming systems often support a greater diversity of trees and birds than are found in grazing systems. The addition of manure to the soil also increases the diversity of soil microflora and fauna. On the other hand, heavy grazing pressure on areas adjacent to cropland can reduce biodiversity. The development of cultivation can also lead to the fragmentation of wildlife habitats and, hence, have an adverse effect on biodiversity.

Sustainable mixed farming systems are, however, often under threat – leading to greater environmental concerns. The system is affected both by changes in demand, and by interactions with the natural resource base on which livestock production depends. The key issue is often one of nutrient balance (FAO, 1996b). At one end of the spectrum, high levels of demand for livestock products can outstrip the productive capacity of traditional mixed agriculture, and lead to a shift towards specialized production. Artificial fertilizers come to replace manure, tractors replace animal power, and high-yielding crop varieties produce less residue with which to feed livestock. Livestock and crop production become increasingly separated. In such circumstances, the cycling of nutrients between crops and animals becomes problematic, and excess nutrients may escape into neighbouring ecosystems.

In contrast, in more isolated areas, mixed farming systems can enter a downwards spiral of fertility decline. As population density increases, the ratio of grazing to cropland decreases, thereby decreasing the availability of nutrients transferred from pastureland. Crop yields tend to decline, leading to further expansion of cropping and greater competition for land. The use of draught animals may facilitate the expansion of cropping, thus exacerbating the problems. Larger numbers of livestock grazing a more restricted area of pastureland leads to further losses of fertility and soil erosion. In the absence of income sources to support conservation practices and maintain soil fertility, a negative cycle can ensue – a situation referred to as the “involution” of the farming system (FAO, 1998).

4.3 Trends

Among the factors which influence the development of mixed farming systems are demand for livestock products and the availability and costs of inputs. Economic growth in developed countries has led to high levels of demand for meat and dairy products and has made available a range of inputs which increase yields from livestock production. This has resulted in a trend in the temperate mixed farming systems, particularly of Europe and North America, towards larger-scale more mechanized agriculture with greater use of purchased feed, veterinary inputs and housing. Livestock production tends increasingly to be specialized in a single product such as meat or milk. Moreover, there is a trend towards separation of crop production and animal production, with monogastric animals in particular increasingly concentrated in landless systems. In this context, traditional livestock breeds, adapted to harsh conditions or to multiple purposes, decline in popularity and may become threatened with extinction. There are, however, some factors that indicate the continued relevance of crop–livestock farming in resource-rich conditions. In the Netherlands, for example, mixed farming is being “rediscovered” as a way to better recycle nutrients (Bos, 2002; Van Keulen and Schiere, 2005). In other areas, such as in the central plains of the United States of America, keeping livestock within the cropping system is typically a means to mitigate risk (Schiere *et al.*, 2004).

As described above, many parts of the developing world are experiencing very rapid increases in demand for livestock products. Pressure to meet this demand leads to the growth of landless systems at the expense of traditional mixed farming. In areas of rapid economic growth, the creation of alternative employment opportunities may also contribute to a departure from traditional labour-intensive forms of agriculture. Rising demand for milk products in many developing countries has led to the development of a commercially oriented smallholder dairy sector focused on urban markets. These systems tend to require higher levels of external inputs than traditional mixed farming systems, and often involve the use of exotic breeds or cross-bred animals.

However, in locations where access to expanding markets is limited, notably in parts of sub-Saharan Africa, impacts associated with the “livestock revolution” are far less marked. As well as an absence of market demand for livestock products, remote areas often face limited access to inputs and services. Moreover, requirements for multiple livestock functions remain strong, and restrict the development of more commercialized production.

In addition to shifts in demand, changes in mixed farming systems are brought about by pressures on resources. This pressure can result in changes to feed management practices and the relationship between animal and crop production. Population growth in areas where alternative employment opportunities are few tends to lead to the expansion of croplands and a restriction in the amount of communal pastureland available for grazing animals. Restrictions on the availability of grazing often mean increased dependence on on-farm crop residues as livestock feed. As landholdings decrease in size, livestock are increasingly confined, and there is greater use of external sources of feed such as cut-and-carried fodder. Combined with the increased levels of demand described above, these developments can lead to increasing reliance on purchased feed inputs including concentrates in the form of grains or agro-industrial by-products. In these circumstances the mixed system evolves towards landless production.

Increasing availability of alternatives to replace the traditional functions of livestock within mixed farming systems has significant implications for AnGR diversity. Mechanized power is expanding and in many places is leading to a decline in the importance of draught animals. This development tends to affect the choice of cattle breeds, and reduces the role of species kept largely for draught purposes such as horses and donkeys. The trend is mediated by factors such as fuel prices, and the decline in the role of draught animals is far from universal. Animal traction is increasing in importance in parts of Africa where it has been previously restricted by heavy soils and the presence of tsetse flies. Increasing use of inorganic fertilizer also reduces the importance of livestock as a source of manure. Other livestock functions such as savings and transport also decline in significance where alternatives such as financial services and motorized vehicles become widely available.

As noted in the discussion of trends in grazing systems, climate change is likely to result in some shifts in the distribution of mixed farming systems. Climate change along with associated changes in the distribution of pests and disease may also lead to changes within mixed production systems, associated with shifts in the types of crops grown or livestock kept.

5 Issues in mixed irrigated systems

Although the immediate impact of irrigation is on the crop component of the system, the conditions for livestock production also tend to be different in a number of respects from those in rainfed areas. Irrigation reduces the variation in the output obtained from crop farming, and extends the cropping season in areas where the growing period is otherwise limited by a lack of rainfall. Both land use and the economics of crop production are affected. In turn, the inputs (particularly feed) available for animal production, as well as the roles of livestock within the production system are affected, and this has a knock-on effect on all aspects of production including the management of AnGR.

Irrigated mixed farming systems are not widespread in temperate zones or in the tropical highlands, but are found in Mediterranean countries and in some temperate zones in East Asia (FAO, 1996a). Irrigated rice production is widespread in the densely populated mixed farming areas of humid/subhumid Asia. Draught power is of particular importance in these systems as there is a need to rapidly prepare land for the next cropping cycle. In Southeast and East Asia, the swamp buffalo (*Bubalus bubalus carabanesis*) has traditionally been the main draught animal, but its role is increasingly threatened by mechanization. Limited opportunities for grazing on crop stubble means that buffaloes and cattle are normally fed on cut-and-carried fodder, particularly straw. The contribution of crop residues as a source of fodder may, however, be threatened by the use of crops that emphasize grain production over straw, such as the high-yielding rice varieties widely used in these systems. Pigs and poultry are often kept under scavenging conditions with some supplementary feeding (FAO, 2001a), and provide a means of utilizing waste food and agricultural by-products. Free

ranging ducks may be kept on paddy fields where they feed on left-over rice, insects and other invertebrates.

The availability of irrigation makes year-round cropping possible in arid/semi-arid zones. In some dry areas (in Israel for example) very high levels of output are obtained from dairy cows kept under intensive management in mixed irrigated systems (FAO, 1996a). Elsewhere, notably in India, mixed irrigated systems (often in semi-arid zones) support large numbers of commercially oriented dairy smallholders, often keeping buffaloes or cross-bred cows. Nutritional demands are high in these systems and there is often a shortage of quality feed. Irrigated fodder production has, therefore, become increasingly significant. For the small-scale farmer, the less variable crop production made possible by irrigation may reduce the significance of livestock's role as a buffer against crop failure (Shah, 2005). Areas dominated by large-scale irrigated production of cash crops (e.g. in parts of the Near and Middle East) also often support substantial populations of cattle, buffaloes and small ruminants (FAO, 2001a).

Mixed irrigated systems have some specific environmental problems – related, for example, to waterlogging or salinization of soils, the effects of dam building, and problems associated with the disposal of surplus water which may be contaminated with excess nutrients or pesticides (FAO, 1997). Paddy fields are also a source of methane emissions (FAO, 1996a). However, these problems are not specifically related to the livestock components of the system.

At present in developing countries, irrigated agriculture, which takes up about a fifth of all arable land, accounts for 40 percent of all crop production and almost 60 percent of cereal production (Table 52). Projections for crop production in the period up to 2030 suggest an increasing importance for irrigated agriculture. It is predicted that it will account for a third of the total projected increase in arable land, and for over 70 percent of the projected increase in cereal production.

In the densely populated rice systems of Asia, there is little scope for expansion of the area used for irrigated cultivation. Farm sizes are becoming smaller, and even intensified rice production is often insufficient to ensure a livelihood from the land (FAO, 2001a). In these circumstances, diversification into activities such as fish farming or intensive livestock production may be the only alternatives to greater reliance on off-farm employment or migration to urban areas (*ibid.*). Integrated systems such as the rice/vegetables/pigs/ducks/fish systems of Thailand (Devendra *et al.*, 2005) may offer scope for intensification.

Table 52
Shares of irrigated production in total crop production of developing countries

| Shares (percentage) | All crops | | | Cereals | |
|--------------------------------------|-------------|----------------|------------|----------------|------------|
| | Arable land | Harvested land | Production | Harvested land | Production |
| Share in 1997/1999 | 21 | 29 | 40 | 39 | 59 |
| Share in 2030 | 22 | 32 | 47 | 44 | 64 |
| Share in increment 1997-1999–2030 | 33 | 47 | 57 | 75 | 73 |

Source: FAO (2002a)

Note: Apart from some major crops in some countries, there are only very limited data on irrigated land by crops and the results presented in the table are almost entirely based on expert judgment

In some other parts of the world, there are greater opportunities for the expansion of irrigation. However, the sustainability of expanded irrigation may be threatened by inappropriate use of water resources. As described above, there can be adverse environmental effects if irrigation is not carefully managed. Moreover, water use has been growing at more than twice the rate of population increase during the past century, and chronic water shortages affect many parts of the world including much of the Near and Middle East, Mexico, Pakistan and large parts of India and China (UN Water, 2006). Irrigated agriculture is usually the first sector to be affected by water shortages. It is increasingly recognized that the large-scale “mining” of ground water which occurs in many countries is not sustainable in the long term (*ibid.*). Conflicts over access to water can arise both at the local level, and between countries, for example where rivers flow across international borders.

SECTION C: IMPLICATIONS OF THE CHANGES IN THE LIVESTOCK SECTOR FOR GENETIC DIVERSITY

In land-based livestock production systems livestock species and breeds have been selected for a wide range of criteria including adaptive traits related to a variety of environmental challenges. By removing environmental stresses industrial systems allow a focus on a narrower range of selection criteria. Industrial systems are characterized by the standardization of production and by a high degree of control over production conditions. These systems are also highly specialized: they optimize production parameters with regard to a single or reduced number of outputs. The animal genetic requirements of industrial systems are thus characterized by:

- less demand for species/breeds adapted to local environments;
- less demand for disease resistance/tolerance as animals are raised in closed systems and farmers rely on intensive use of veterinary inputs;
- more demand for efficiency, and especially feed conversion ratio, to maximize benefit per animal place (in industrial systems, feed typically represents 60 to 80 percent of production costs); and
- more demand for quality traits due to consumer demand and technical requirements related to standardization, size, fat content, colour, flavour etc.

The industrialization of livestock production is most advanced in the pig and poultry sectors. Particularly in Europe, North America and Australia, pork production is highly industrialized, and a few transnational breeding companies dominate production chains. The poultry sector, in turn, is the most industrialized of all forms of livestock production, and large-scale production is now widespread in many developing countries. Dairy production is also increasingly reliant on a limited number of breeds. The trend is most advanced in developed countries. In most parts of the developing world, dairying is dominated by small-scale producers, but in peri-urban areas the use of exotic or cross-bred animals to supply expanding urban markets is increasing. As well as being driven by demand, such changes may also be promoted by improvements in the availability of animal health provision and other services and technologies, which allow the keeping of animals less adapted to local production conditions. Industrial systems and the associated private breeding companies have the resources to develop breeds that match their requirements. They have developed highly specialized breeds, which enable them to maximize productivity in the context of current consumer requirements and resource costs. As a consequence, substantial erosion of breeds has already occurred in developed countries, where livestock production has been industrialized for three or four decades (see Part I – Section B).

However, in the medium or long term, breed selection criteria in industrial systems may have to be revised. At present, industrial production takes place in a context that is characterized by low input prices (e.g. grain, energy and water); locally deficient environmental and public health policies; and in developing countries, a generally low level of public concern about the conditions in which animals are reared. As public policies are put in place to adjust the price of resources to reflect their social costs, and consumers become more interested in agro-ecological and welfare aspects of animal production, the economic context may change.

In parallel to the development of industrial systems, low to medium external input production systems persist, particularly where there is no strong economic growth, or where the resources and support services required for industrialization are lacking. These conditions are found in areas with harsher environmental conditions (e.g. drylands, mountains or cold areas), or in rural areas with poor connection to centres of demand. In these circumstances, production systems continue to deliver a wide range of outputs to local communities, and livestock usually have multiple purposes (see Part I – Section D). Livestock keeping is often intimately linked to traditional ways of life and culture, particularly in pastoral systems. As such, low to medium external input production systems have specific requirements for AnGR. They rely on native breeds, or in some cases, on cross-breeds or composite breeds that contain genetic material from local breeds.

Despite their adaptation to the production environment, the AnGR associated with grazing and mixed farming systems face substantial threats. Problems are often driven by inappropriate livestock development policies. Moreover, in a context of population growth and climate change, small-scale grassland-based and mixed production systems face increasing pressure on resources, which may threaten the associated AnGR. For example, shortages of feed resources may lead to a shift towards keeping sheep and goats rather than large ruminants, or to the use of donkeys rather than oxen for draught power. To make the systems sustainable, their efficiency needs to be improved, especially with regard to the use of land and water resources. Moreover, efforts are likely to be necessary to enhance the production of marketable livestock products as a source of income, which in turn may facilitate the investments needed to improve the productivity and sustainability of the systems (e.g. soil conservation measures).

If wider markets are to be accessed, meat and milk production from these systems will have to meet the quality standards required by the consumers. Achieving these objectives while improving productivity traits, and maintaining multifunctionality and adaptation to local environments, is a challenge. In this context, local livestock genetic diversity is likely to be a key resource to be drawn upon. The basis for evaluating individual animal performance should include criteria such as lifetime productivity (e.g. number of offspring per female), economic returns from the herd or flock (as opposed to individual performance), and biological efficiency (output/input). In essence, recommendations for breed development will be of little value if they do not take account of the specific environment in which the animals are expected to perform. The specific environment is a combination of climate, availability of feed resources, and disease challenge on the one hand, and the degree of management control of these conditions on the other. The resulting variety of situations gives rise to the need for a large range of breeds. Moreover, socio-economic and cultural factors also affect choices regarding species, breeds, products and product quality.

Even in developed countries, or developing countries with strong economic growth and a well developed infrastructure, traditional, extensive production continues to supply informal markets and niche markets, such as local food specialities, high-quality products and organic food. An example of the persistence of a local informal market can be found in Thailand, where it is estimated that 20 percent of poultry production will remain independent of large operators. Organic farms in Europe and other parts of the world are characterized by a high integration between crops and animals, the use of limited chemical inputs, and often by the use of typical native breeds. The production philosophy generally does not allow for scaling-up, which is also constrained by the low volumes – in 2003, organic milk and eggs represented only 1.5 percent and 1.3 percent respectively of overall production in the European Union.

In the case of grassland-based production systems the delivery of environmental services is increasingly becoming a focus of national policies in developed countries. In these circumstances, producers have to tailor practices to maximize service delivery rather than the output of conventional livestock products. Breed selection criteria may have to adapt to these new objectives. Selected traits in these circumstances would relate to the consumption of biomass from different sources (grass, shrubs, or trees) and its effects on functions such as landscape preservation, biodiversity conservation, carbon sequestration, soil conservation and nutrient cycling.

Breed development has always been highly dynamic and driven by strong interactions between specific environments and human needs. A large genetic diversity, relying more on differentiation within species (breed diversity) than on the domestication of additional species, has been created over a long period. Recently, the industrialization process has led to a narrowing of the genetic pool. However, it is genetic diversity which provides livestock keepers with the opportunity to match genetic resources to the specific requirements of production systems – now and in the future. In parallel, the existing diversity of production systems offers scope for keeping a high diversity of livestock genetic resources in use. A prerequisite for this is that the necessary breed-related information is made available and that access to and exchange of genetic material is ensured.

References

- Abegaz, A.Y.** 2005. Farm management in mixed crop-livestock systems in the Northern Highlands of Ethiopia. Wageningen University, the Netherlands. (PhD Thesis)
- Ayalew, W., King, J.M., Bruns, E. & Rischkowsky, B.** 2003. Economic evaluation of smallholder subsistence livestock production: Lessons from Ethiopian goat development program. *Ecological Economics*, 45:473–485.
- Behnke, R.H., Scoones, I. & Kerven, C.** 1993. *Range ecology at disequilibrium*. London. Overseas Development Institute/International Institute for Environment and Development Commonwealth Secretariat.
- Bos, J.** 2002. Comparing specialised and mixed farming systems in clay areas of the Netherlands under future policy scenarios: an optimisation approach. Wageningen University, the Netherlands. (PhD Thesis)
- Bosman, H.G., Moll, H.A.J. & Udo, H.M.J.** 1997. Measuring and interpreting the benefits of goat keeping in tropical farm systems. *Agricultural Systems*, 53:349–372.
- CR (Country name).** year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).
- De Camargo Barros, G.S.A., De Zen, S. Bacchi, M.R.P., de Miranda, S.H.G., Narrod, C. & Tiongo, M.** 2003. Policy, technical, and environmental determinants and implications of the scaling-up of swine, broiler, layer and milk production in Brazil. IFPRI-FAO AGAL LEAD Livestock Industrialization Project, 2003.
- Delgado, C., Rosegrant, M. & Meijer, S.** 2002. *Livestock to 2020: the revolution continues*. World Brahman Congress. Rockhampton.
- Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. & Courbois, C.** 1999. *Livestock to 2020: the next food revolution*. Washington DC. IFPRI/FAO/ILRI.
- Devine, R.** 2003. La consommation des produits carnés. *INRA Prod. Anim.*, 16(5): 325–327.
- De Haen, H.** 2005. cited in: Africans meet to improve food safety on the continent. Experts and officials from 50 countries work to establish safer food systems. 3 October 2005, FAO Newsroom Geneva/Rome. FAO/World Health Organization. (available at <http://www.fao.org/newsroom/en/news/2005/107908/index.html>).
- Devendra, C., Morton, J., Rischkowsky, B. & Thomas, D.** 2005 Livestock systems. In E. Owen, A. Kitalyi, N. Jayasuriya & T. Smith, eds. *Livestock and wealth creation: improving the husbandry of animals kept by resource-poor people in developing countries*, pp. 29–52. Nottingham, UK. Nottingham University Press.
- Devendra, C., Thomas, D., Jabbar, M.A. & Kudo, H.** 1997. *Improvement of livestock production in rainfed agro-ecological zones of South-East Asia*. Nairobi. International Livestock Research Institute.
- Doppler, W.** 1991. *Landwirtschaftliche Betriebssysteme in den Tropen und Subtropen*. Stuttgart, Germany. Ulmer.
- FAO.** 1996a. *World livestock production systems. Current status issues and trends*, by C. Seré & H. Steinfeld with J. Groenewold. Animal Production and Health Paper, No. 127. Rome.
- FAO.** 1996b. *Livestock and the environment: finding a balance*, by C. de Haan, H. Steinfeld & H. Blackburn. Rome.
- FAO.** 1997. *Small scale irrigation for arid zones: issues and options*, by D. Hillel. FAO Development Series, No. 2. Rome. (available at <http://www.fao.org/docrep/W3094E/W3094E00.htm>)
- FAO.** 1998. *A food security perspective to livestock and the environment*, by L. Fresco & H. Steinfeld. Rome. (available at <http://www.fao.org/WAIRDOCS/LEAD/X6131E/X6131E00.HTM>)
- FAO.** 2001a. *Farming systems and poverty – improving farmers' livelihoods in a changing world*, by J. Dixon, A. Gulliver & D. Gibbon (ed. M. Hall). Rome. (also available at <http://www.fao.org/DOCRP/Y1860E/y1860e00.htm>).
- FAO.** 2001b. *Livestock keeping in urban areas, a review of traditional technologies*, by J.B. Schiere, & R. Van Der Hoek. Animal Production and Health Paper, No. 151. Rome.
- FAO.** 2001c. *Pastoralism in the new millennium*. Animal Production and Health Paper, No. 150. Rome.
- FAO.** 2002a. *World agriculture: towards 2015/2030. An FAO perspective*, edited by J. Bruinsma, London. Earthscan Publications.

- FAO.** 2002b. The state of food insecurity in the world 2002. Rome.
- FAO.** 2003. *Transhumant grazing systems in temperate Asia*, edited by J.M. Suttie & S.G. Reynolds, Plant Production and Protection Series No. 31(Rev. 1). Rome.
- FAO.** 2004. Classification and characterization of world livestock production systems. Update of the 1994 livestock production systems dataset with recent data, by J. Groenewold. Unpublished Report. Rome.
- FAO.** 2005a. *Pollution from industrialized livestock production*. Livestock Policy Brief, No. 2. Rome.
- FAO.** 2005b. *The globalizing livestock sector: impact of changing markets*. Committee on Agriculture, Nineteenth Session, Item 6. Rome.
- FAO.** 2005c. *Agricultural and rural development in the 21st century: lessons from the past and policies for the future*. An International Dialogue 9–10 September 2005 Beijing China. Background paper. Rome. (available at [ftp://ftp.fao.org/docrep/fao/meeting/010/ae885e.pdf](http://ftp.fao.org/docrep/fao/meeting/010/ae885e.pdf)).
- FAO.** 2006a. World agriculture: towards 2030/2050. Interim report. Rome.
- FAO.** 2006b. Relevance and applicability of the Latin American experience for the development of benefit sharing mechanisms for payment of environmental services at the forest-pasture interface in Southeast and East Asia, by M. Vinqvist & M. Rosales, LEAD Electronic Newsletter V3N2, February 2006. Rome.
(also available at http://www.virtualcentre.org/en/enl/A3/download/enl08_A3_Policy_paper.doc).
- FAO.** 2006c. *Livestock's long shadow – environmental issues and options*, by H. Steinfeld, P. Gerber, T. Wassenaar, V. Castel, M. Rosales & C. de Haan. Rome.
- FAO.** 2006d. Underneath the livestock revolution, by A. Costales, P. Gerber & H. Steinfeld, In *Livestock Report 2006*, pp. 15–27. Rome.
- FAO.** 2006e. The future of small-scale dairying, by A. Bennet, F. Lhoste, J. Crook, & J. Phelan. In *Livestock Report 2006*, pp. 45–55. Rome.
- FAO.** 2006f. Old players, new players, by H. Steinfeld, & P. Chilonda. In *Livestock Report 2006*, pp. 3–14. Rome.
- FAO.** 2006g. *Cattle ranching and deforestation*. Livestock Policy Brief No. 3. Rome.
- FAO.** 2006h. Policies and strategies to address the vulnerability of pastoralists in sub-Saharan Africa, by N. Rass. PPLPI (Pro-Poor Livestock Policy Initiative) Working Paper 37. Rome.
- FAOSTAT** (available at <http://faostat.fao.org/site/291/default.aspx>).
- Farina, E.M.M.Q., Gutman, G.E., Lavarello, P.J., Nunes, R. & Reardon, T.** 2005. Private and public milk standards in Argentina and Brazil. *Food Policy*, 30(3): 302–315.
- Gerber, P., Chilonda, P., Franceschini, G. & Menzi, H.** 2005. Geographical determinants and environmental implications of livestock production intensification in Asia. *Bioresource Technology*, 96: 263–276.
- Harrington, G.** 1994. Consumer demands: major problems facing industry in a consumer-driven society. *Meat Science*, 36: 5–18.
- Harris, M.E.** 1985. *Good to eat: riddles of food and culture*. New York, USA. Simon and Schuster.
- Harris, R.A.** 2002. Suitability of grazing and mowing as management tools in Western Europe. Experiences in Scotland and the United Kingdom. In J. Bokdam, A. van Braeckel, C. Werpachowski & M. Znaniecka, eds. *Grazing as a conservation management tool in peatland*. Report of a Workshop held 22–26 April 2002 in Goniadz Poland. Wageningen, the Netherlands. University of Wageningen/Biebrza National Park/WWF.
- Ifar, S.** 1996. *Relevance of ruminants in upland mixed farming systems in East Java, Indonesia*. PhD Thesis, Wageningen Agricultural University, the Netherlands. (PhD Thesis)
- IPCC.** 2001 *Climate Change 2001*. Cambridge, United Kingdom. Cambridge University Press.
- Jahnke, H.E.** 1982. *Livestock production systems and livestock development in tropical Africa*. Kiel, Germany. Wissenschaftsverlag Vauk.
- King, B.S., Tietjen J.L. & Vickner, S.S.** 2000. *Consumer trends and opportunities*. Lexington KY. University of Kentucky.
- Krystallis, A. & Arvanitoyannis, I.S.** 2006. Investigating the concept of meat quality from the consumers perspective: the case of Greece. *Meat Science*, 72: 164–176.
- Morris, J.R.** 1988. *Interventions for African pastoral development under adverse production trends*. African Livestock Policy Analysis Network Paper, No. 16. Addis Ababa. International Livestock Centre for Africa (ILCA).

- Morrison, J.A., Balcombe, K., Bailey, A., Klonaris, S. & Rapsomanikis, G.** 2003. Expenditure on different categories of meat in Greece: the influence of changing tastes. *Agricultural Economics*, 28: 139–150.
- Naylor, R., Steinfeld, H., Falcon, W., Galloway, J., Smil, V., Bradford, E., Alder, J. & Mooney, H. 2005. Losing the links between livestock and land. *Science*, 310: 1621–1622.
- NDDDB.** 2005. *Annual Report 2004/2005*. Anand, India. National Dairy Development Board.
- Phillips, C.** 2002. Future trends in the management of livestock production. *Outlook on Agriculture*, 31(1): 7–11.
- Poapongsakorn, N., NaRanong, V., Delgado, C., Narrod, C., Siriprapanukul, P., Srianant, N., Goolchai, P., Ruangchan, S., Methrsurarak, S., Jittreekhun, T., Chalermphao, N., Tiongco, M. & Suwankiri, B. 2003. *Policy, technical, and environmental determinants and implications of the scaling-up of swine, broiler, layer and milk production in Thailand*. Washington DC. IFPRI-FAO. AGAL LEAD Livestock Industrialization Project.
- Rae, A.** 1998. The effects of expenditure growth and urbanisation on food consumption in East Asia: a note on animal products. *Agricultural Economics*, 18(3): 291–299.
- Reardon, T. & Berdegue, J.A.** 2002. The rapid rise of supermarkets in Latin America: challenges and opportunities for development. *Development Policy Review*, 20(4): 371–388.
- Reardon, T. & Timmer, C.P.** 2005. Transformation of markets for agricultural output in developing countries since 1950: how has thinking changed? In R.E. Evenson, P. Pingali & T.P. Schultz eds. *Handbook of agricultural economics: agricultural development: farmers, farm production and farm markets*. Volume 3. Amsterdam. North-Holland Publ.
- Ruthenburg, H.** 1980. *Farming systems in the tropics*. 3rd edition. Oxford, UK. Clarendon Press.
- Savado, M.** 2000: Crop residue management in relation to sustainable land use. A case study in Burkina Faso. Wageningen University, the Netherlands. (PhD Thesis).
- Schiere J.B., Baumhardt A.L., Van Keulen H., Whitbread A.M., Bruinsma A.S., Goodchild A.V., Gregorini P., Slingerland, M.A. & Wiedemann-Hartwell B. 2006a. Mixed crop-livestock systems in semi-arid regions. In G.A. Peterson, P.W. Unger & W.A. Payne eds. *Dryland agriculture*, 2nd ed. Agronomy. Monograph. No. 23, pp. 227–291. Madison, Wisconsin, USA. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America, Inc.
- Schiere, J.B., Joshi, A.L., Seetharam, A., Oosting, S.J., Goodchild, A.V., Deinum, B. and Van Keulen, H.** 2004. **Grain** and straw for whole crop value: implications for crop management and genetic improvement strategies, a review paper. *Experimental Agriculture*, 40: 277– 94.
- Schiere, J.B., Thys, E., Matthys, F., Rischkowsky, B. & Schiere, J.J.** 2006b. Chapter 12: Livestock keeping in urbanised areas, does history repeat itself? In R. Van Veenhuizen, ed. *Cities farming for the future: urban agriculture for green and productive cities*, pp. 349–379. Leusden, the Netherlands. RUAF (Resource Center on Urban Agriculture and Forestry).
- Schiere, J.B. & De Wit, J.** 1995. Livestock and farming systems research II: development and classifications, pp. 39– 6. In J.B. Schiere, ed. *Cattle, straw and systems control*. Amsterdam, the Netherlands. Royal Tropical Institute.
- Shah, A.** 2005. *Changing interface between agriculture and livestock: a study of livelihood options under dry land farming systems in Gujarat*. Ahmedabad, Gujarat. Institute of Development Research. (also available at <ftp://ftp.fao.org/docrep/nonfao/lead/ae752e/ae752e00.pdf>).
- Steinfeld, H., Wassenaar, T. & Jutzi, S.** 2006. Livestock production systems in developing countries: status, drivers, trends. *Rev. Sci. Rech. Off. Int. Epiz.*, 25(2): 505–516.
- Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S, Atieno, F., Odero, A.N. & Ndegwa, T.** 2002. *Mapping poverty and livestock in the developing world*. Nairobi. International Livestock Research Institute.
- UN Habitat.** 2001. The state of the world's cities 2001 Revision. New York, USA.
- UN Water.** 2006. *Coping with water scarcity: a strategic issue and priority for system-wide action*. (available at <ftp://ftp.fao.org/agl/aglw/docs/waterscarcity.pdf>).
- Van De Ven, G.W.J.** 1996. A mathematical approach to comparing environmental and economic goals in dairy farming on sandy soils in The Netherlands. Wageningen Agricultural University, the Netherlands. (PhD thesis)
- Van Keulen, H. and Schiere, J.B.,** 2004. Crop-Livestock systems: old wine in new bottles? In R.A. Fischer, N. Turner, J. Angus, L. McIntire, M. Robertson, A. Borrel & D. Lloyd eds. *New directions for*

a diverse planet. Proceedings for the 4th International Crop Science Congress, Brisbane, Australia, 26 September – 1 October 2004.

Waters-Bayer, A. 1996. Animal farming in African cities. *African Urban Quarterly*, 11: 218–226.

Zhou, Z.Y., Wu, Y.R. & Tian, W.M. 2003. *Food consumption in rural China: Preliminary results from household survey data*. Proceedings of the 15th annual conference of the Association from Chinese Economics Studies, Australia.

Part 3

The state of capacities in animal genetic resource management

Introduction

This part of the Report analyses countries' capacities in the management of animal genetic resources for food and agriculture (AnGR), based on the information provided in the Country Reports. The analysis highlights regional differences, and identifies specific weaknesses; thus informing the identification of strategic priorities for action. The analytical approach varies from section to section according to the nature and the depth of the information provided in the Country Reports. It is important to recognize that the analysis presented here is based on Country Reports that were received by FAO between 2002 and 2005 (the majority being submitted in 2003 and 2004) and may, therefore not present a full picture of the state of capacity in 2007.

The first section presents an analysis the state of human and institutional capacity for AnGR management. This is followed by sections describing the state of structured breeding programmes, conservation programmes, and the use of reproductive and molecular biotechnologies. The final section covers the regulatory framework affecting AnGR. Legal frameworks at the country level need to be considered in the context of international and regional frameworks. Thus, the analysis of legislation and policy measures at the national level is preceded by an overview of relevant international legal instruments; and a discussion of regional-level legislation (mainly focusing on the European Union). Because of the increasing attention given to patenting in the discussion of policies for AnGR management this issue is introduced separately.

SECTION A: INSTITUTIONS AND STAKEHOLDERS

1 Introduction

The implementation of measures to enhance the conservation and sustainable use of AnGR is highly dependent on the existence of a sound institutional framework. Strong human capacity is also essential. A prerequisite for institutional development and capacity building in the field of AnGR management is, however, recognition of the importance of the issue. A further challenge is posed by the fact that the diverse stakeholders involved in the field have many different backgrounds and motivations, and may have conflicting interests.

Institutional roles and capacities have to be considered in the context of the driving forces that influence their development. In broad terms, the institutions involved in the management of AnGR are shaped by the evolving requirements of the livestock sector and changing policy concerns. In addition to these general trends, a number of specific influences have affected the development of institutional capacity over the last decade. These include the Convention on Biological Diversity (CBD), which provides the main international legal framework for the management of biodiversity. The significance of the World Trade Organization (WTO) agreements was also mentioned in many Country Reports. Furthermore, the State of the World's Animal Genetic Resources for Food and Agriculture (SoW-AnGR) reporting process has affected institutional development at the country level through the preparation of Country Reports and the identification and empowering of National Coordinators (NCs) and National Consultative Committees (NCCs) for AnGR. The preparatory meetings which took place as part of the SoW-AnGR process also provided a forum for discussion among stakeholders at the regional level.

The following chapters summarize the state of capacities, institutions and institutional networks in the field of AnGR. The analysis is primarily based on countries' own assessments of the situation as provided in the Country Reports. A brief description of the methodology used to analyse the Country Reports and the other sources used is first presented. Assessments of various aspects of institutional capacity to manage AnGR are then set out. The section ends with a discussion of the main potentials and constraints identified.

2 Analytical framework

The aim of the analysis was to provide an inventory and assessment of human and institutional capacities for the management of AnGR at the national, subregional, regional and international levels.

At the country level, the following factors were considered:

- Stakeholders' involvement in the preparation of the Country Report, along with their involvement in the field of AnGR, their background/history and their group membership. The following categories were used to classify group membership: governmental organization; farmer/herder association; interest organization (conservation); commerce/private company; research/science; development organization; donors; breeding association; extension service; insemination organization/association; international organization (governmental); international organization (non-governmental).
- Institutional assessment – including the following thematic areas: infrastructure/capacities for the management of AnGR; participation of stakeholders at local level; research capacities; (indigenous) knowledge of AnGR; level of awareness of AnGR management; existing or proposed laws and programmes; and the degree of implementation of development policy for AnGR.

At the subregional, regional and international levels, organizations and networks were identified.

2.1 Stakeholders' involvement and background at country level

For the purposes of the analysis, stakeholder participation in the SoW-AnGR process at the country level was taken as a proxy for the existence of established relationships between stakeholders and the officially appointed national institutions for AnGR management. Besides the information given in the Country Reports (e.g. on NCC membership and composition, and on actors involved in the preparation of the Country Report or in activities related to AnGR), additional information on stakeholders and their backgrounds was obtained from FAO's DAD-IS information system and through additional Web-based research.

2.2 Assessment of institutional capacities at country level

The institutional assessment was entirely based on the information provided in the Country Reports. The Guidelines for the Development of Country Reports suggested that one chapter should provide information on "Country capacity to manage AnGR". This section was intended to include institutional infrastructures and human resources. To facilitate consistent reporting, a number of predefined tables were provided:

- Table 4.6 – detailing the role of stakeholders (national government, regional/local government, breeders' organizations, private companies, research organizations, NGOs) in the implementation of tools for the development of AnGR (setting breeding goals, individual animal identification, recording, artificial insemination (AI), genetic evaluation);
- Table 4.7 – detailing the involvement of the various stakeholders in thematic areas related to the development of AnGR (legislation, breeding/genetic improvement, infrastructure, human resources and producers' organizations);
- Table 4.8 – detailing the preferences of the various stakeholders with respect to different types of AnGR (locally adapted breeds, breeds imported from within the region, imported exotic breeds);
- Table 4.9 – detailing priority needs (knowledge, training, financial resources, breeding organizations) for the use of technologies (recording, genetic evaluation, AI/embryo transfer (ET), molecular techniques).

Where available, the information provided in these tables was used for the analysis presented here. However, only 38 percent of countries utilized the tables. For this reason, an analytical framework which also drew on other sections of the Country Reports was developed. The variation in the level of detail presented in the reports was high, and placed some limitation on the scope for quantitative analysis. The sections of the Country Reports that were used as sources of information for each thematic area assessed are shown in Table 53.

Table 53
Sources of information (Country Report sections) for the national level assessments

| Thematic area | Part VI: How the Country Report was prepared | Part I: Overview | Part II : Changing demands, policies, strategies, programmes | Part III: State of national capacities, assessing future capacity building requirements | Part IV: Identifying national priorities | Part V: International cooperation | Annex: Predefined tables prepared for stakeholder involvement, priorities, etc. |
|--|---|---------------------|---|--|---|---|---|
| Infrastructure/ capacities | ● | ● | ● | ● | | ● | ● |
| Participation of stakeholders at local/regional level | ● | ● | | ● | | | ● |
| Research | ● | | | ● | | ● | |
| Knowledge | ● | | | ● | | ● | |
| Awareness for topic | ● | ● | ● | ● | ● | | |
| Laws, political programmes | | ● | ● | | ● | ● | ● |
| Degree of implementation | | | ● | | ● | ● | ● |

(See the Annex to this section for explanation)

For each thematic area in the institutional assessment, a score was awarded according to the level of activity/capacity in the country in question. Countries were scored 0 (nothing), + (little), ++ (medium) or +++ (high). Scores for each thematic area were assigned subjectively taking into account criteria such as Country Report descriptions of the state of capacity, tabulated information (if available), and reported priority needs (see details in the Notes to Annex Table 53). The proportion of countries scoring at 0, +, and ++/+++ in the institutional assessments is presented for each subregion.

The individual country scores in each thematic area of the institutional assessment were aggregated to characterize the subregional/regional situation. The maximum score (achieved if all the countries in a subregion or region scored “+++” for the category in question) is equal 1 (or 100 percent) and the minimum score (if all the countries in a subregion or region scored “0” for the category in question) is equal 0. The average scores the regions achieved in the institutional assessments are shown in Figure 43 (the scores for the subregions are shown in the tables in the Annex to this section). The different thematic areas were arranged on a scale ranging from basic/organizational capacities to strategic capacities for AnGR management. For example, low scores in the assessment of infrastructure indicate a need for action at a basic/organizational level, while a high score for implementation of laws and political programmes indicates existing activities at a strategic level. This aggregation allows the identification of specific weaknesses of subregions/regions with respect to their institutional capacities. Comparison with the country assessments allows the identification of countries with the potential to play a leading role in the subregions.

2.3 Organizations and networks with a potential role in regional and international collaboration

In most Country Reports, some information on cooperation was presented. Additional Web-based research was used to obtain further information on stakeholders and their backgrounds at subregional, regional and international levels. Further sources of information used for the analysis of institutional structures, and the identification of stakeholders and networks at these levels, were reports from international (governmental and non-governmental) organizations received as part of the SoW-AnGR process, and information from the regional/subregional e-mail consultations organized by FAO in late 2005.

3 Stakeholders, institutions, capacities and structures

3.1 Stakeholder involvement in the State of the World process at country level

The results presented in this subchapter are intended to indicate the extent to which established relationships exist between the officially appointed country-level institutions for AnGR management and the various stakeholders involved in the field. Stakeholder participation in the SoW-AnGR process is used as a proxy measure of such involvement. For the preparation of the Country Reports, countries were encouraged to involve all stakeholders – governmental and non-governmental (e.g. breeders' associations), as well as the commercial sector. In addition to the nomination of an NC, the establishment of a supporting structure, such as a National Consultative Committee (NCC) representing all stakeholders was recommended, and was implemented in most countries.

The pattern of participation by various stakeholder groups in the process varied little from country to country. Individuals from governmental and scientific backgrounds were the most often involved. Institutions of the National Agricultural Research Systems (NARS) played a leading role in the process, and were actively involved in nearly all NCCs and Country Report preparation processes. In 44 percent of countries, the host institution of the NC was a national research institute. However, many Country Reports note with regret that these institutes are rarely involved in AnGR-related studies, and interest in this topic is often limited to isolated departments which lack adequate financial resources. Moreover, where research institutions do pay more attention to AnGR, the work is usually rather narrow in focus, concentrating on high-output breeds or advanced technical matters.

In 37 percent of countries NGOs (mostly breeders' associations) participated in the NCC. The involvement of NGOs was more prominent in South America and western Europe. This is in accordance with the high number of such organizations existing in these parts of the world. In other regions and countries, conditions for the involvement of these stakeholders were less favourable. In some cases, individual farmers or herders were members of the NCC, but information on their organizational backgrounds is not available.

The commercial sector was rarely included. It is noted in the Country Reports that commercial operators are highly active in the use of AnGR, and are often well organized even at the international level – most notably in the poultry and pig sectors. However, many Country Reports from all regions indicate that the involvement of these stakeholders in national programmes for the conservation of AnGR is difficult, as their interest is limited to breeding programmes relevant to the breeds used in commercial production. Central Asia and the eastern part of the Europe and the Caucasus region were exceptions to this pattern. Here, stakeholders from the commercial sector were more often involved in the NCCs. This may be because of the transitional state of many countries in this part of the world – recent privatization means that stronger links remain between governmental and quasi-commercial stakeholders.

3.2 Assessment of institutional capacities at country and regional level

Participation, infrastructure and capacities

As the utilization and *in situ* conservation of AnGR usually takes place at the local level, considerable participation by non-governmental stakeholders, such as breeding organizations or the private sector in general, in policy processes relating to AnGR might be expected. However, this is not borne out by the majority of the Country Reports analysed. Such organizations have the potential to compensate for weak state structures (such as exist, for example, in many countries in Africa and the former Soviet Union), and to take over key roles in activities such as inventory and *in situ* conservation. CR Czech Republic (2003), CR Spain (2004) and CR Germany (2003), for example, refer to the role of so-called “neo-rurales” or “hobby farmers” in AnGR management.

A strong local-level capacity (e.g. clearly defined and well monitored responsibilities for local stakeholders, and the integration of local organizations in the national policy arena) could be identified mostly in western and northern Europe and, to a lesser extent, in Central and South America. Reports from transition countries emphasize a need for stronger integration of the private sector in order to take advantage of the above-mentioned potential to compensate for the weakness of the state sector in the fields of inventory and monitoring. However, in many regions and subregions an established infrastructure exists in the shape of governmental structures such as extension services, which extend down to the local level. This infrastructure and capacity may offer opportunities for better inventory and monitoring, and for further integration and support of AnGR-related activities at the local level. Some Country Reports remark that infrastructure at a high technical level exists, but is not used because of a shortage of human resources/capacities, financial difficulties or political crises – see for example the Country Reports from the countries of the former Soviet Union, southeastern Europe, and CR Cuba (2003).

Table 54 shows the state of country-level infrastructure and participation based on the Country Report analysis. Particularly in the North and West Africa subregion, in the Southwest Pacific, and in Central Asia, the Country Reports indicate that the present state of infrastructure and capacities is very low or non-existent (+ or 0). For example, 33 percent of countries in Central Asia scored 0 for the state of infrastructure and capacities. However, countries with more favourable conditions (++/+++), such as Australia in the Southwest Pacific, can be identified. These countries have the potential to take on a facilitating role in their respective regions.

Table 54
Institutional assessment – infrastructure and capacities and participation

| Region | Infrastructure/Capacities [% of countries] | | | | Participation of local/regional level [% of countries] | | |
|--|---|-----|----|--------|--|----|--------|
| | n* | 0** | + | ++/+++ | 0 | + | ++/+++ |
| AFRICA | | | | | | | |
| North and West Africa | 24 | 29 | 63 | 8 | 71 | 25 | 4 |
| East Africa | 7 | 14 | 57 | 29 | 29 | 71 | 0 |
| Southern Africa | 11 | 18 | 64 | 18 | 46 | 36 | 18 |
| ASIA | | | | | | | |
| Central Asia | 6 | 33 | 67 | 0 | 83 | 17 | 0 |
| East Asia | 4 | 0 | 50 | 50 | 25 | 25 | 50 |
| South Asia | 7 | 0 | 43 | 57 | 14 | 57 | 29 |
| Southeast Asia | 8 | 13 | 63 | 25 | 38 | 63 | 0 |
| SOUTHWEST PACIFIC | 11 | 27 | 64 | 9 | 73 | 18 | 9 |
| EUROPE & THE CAUCASUS | 39 | 10 | 21 | 69 | 13 | 18 | 69 |
| LATIN AMERICA & THE CARIBBEAN | | | | | | | |
| Caribbean | 3 | 0 | 33 | 67 | 0 | 67 | 33 |
| Central America | 9 | 11 | 67 | 22 | 44 | 33 | 22 |
| South America | 10 | 0 | 30 | 70 | 0 | 70 | 30 |
| NORTH AMERICA | 2 | 0 | 0 | 100 | 0 | 0 | 100 |
| NEAR AND MIDDLE EAST | 7 | 0 | 86 | 14 | 43 | 57 | 0 |

* n=number of Country Reports included in the analysis; ** 0= nothing, +=little, ++/+++ =middle/high

NGOs' limited integration in the policy arena and in the preparation of the Country Reports can be interpreted as a sign of limited organizational capacity at the country level (NGOs simply do not exist), or as a sign of a lack of mechanisms to involve NGOs in such processes. In nearly all countries (87 percent), no institutional structures apart from the NCC, exist for the comprehensive coordination of activities related to AnGR. The importance of the NCC is emphasized by the countries as well as by the Intergovernmental Technical Working Group on AnGR (ITWG–AnGR) and other stakeholders involved in policy processes. Nonetheless, the operation of the NCCs has not in all cases been sustainable. A survey in 2004 (FAO, 2004) found that 65 percent of NCCs were active at the time. The results of the FAO regional e-mail consultations held in late 2005 (and also the low level of participation in these activities) suggested that this figure had further decreased. In some countries, even the NC is no longer active. This is frequently the result of a lack of resources, which in turn often results from a lack of awareness of the subject.

Research and knowledge

In many countries, capacity is lacking not only in organizational terms, but also at technical and educational levels. Capacity building is prioritized in most Country Reports. In many countries, there are national research institutions for the livestock sector in general, but there is little specialization in the field of AnGR use and conservation. This is reflected by the fact that many of those working in the field were trained in other fields (e.g. as veterinarians) and had to go abroad for further education or specialization in AnGR. University livestock departments rarely offer specialized training in the management of AnGR.

Even where advanced technologies are available, research often remains isolated or remote from local needs and indigenous knowledge. It is also not well linked to the policy level, where further awareness building is required to generate higher levels of support to the field of AnGR management (including

in financial terms). The state and accessibility of knowledge regarding the value and utilization of AnGR is also often described as very weak.

Table 55 shows the state of research and knowledge in the countries analysed. Some countries have the potential to play an initiating or supporting role within a subregion or region (e.g. Japan and China in Asia). To realize these potential benefits, more cooperation among the NARS and other research institutions is necessary. The need for increased cooperation is particularly recognized in Country Reports from Latin American countries (e.g. CR Argentina 2003; CR Colombia, 2003; CR Costa Rica, 2004; CR El Salvador, 2003 and CR Uruguay, 2003) and many express a willingness to engage to a greater extent in coordinated activities.

Table 55
Institutional assessment – research and knowledge

| Region / Frequency 0 nothing, + little, ++/+++ middle/high | n* | Research [% of countries] | | | Knowledge [% of countries] | | |
|---|----|------------------------------|----|--------|-------------------------------|----|--------|
| | | 0** | + | ++/+++ | 0 | + | ++/+++ |
| AFRICA | | | | | | | |
| North and West Africa | 24 | 46 | 42 | 13 | 42 | 46 | 13 |
| East Africa | 7 | 29 | 43 | 29 | 29 | 57 | 14 |
| Southern Africa | 11 | 27 | 73 | 0 | 46 | 55 | 0 |
| ASIA | | | | | | | |
| Central Asia | 6 | 17 | 83 | 0 | 33 | 67 | 0 |
| East Asia | 4 | 0 | 25 | 75 | 0 | 25 | 75 |
| South Asia | 7 | 14 | 29 | 57 | 14 | 71 | 14 |
| Southeast Asia | 8 | 25 | 50 | 25 | 50 | 25 | 25 |
| SOUTHWEST PACIFIC | 11 | 36 | 55 | 9 | 55 | 36 | 9 |
| EUROPE & THE CAUCASUS | | | | | | | |
| | 39 | 5 | 31 | 64 | 5 | 28 | 67 |
| LATIN AMERICA & THE CARIBBEAN | | | | | | | |
| Caribbean | 3 | 33 | 0 | 67 | 0 | 33 | 67 |
| Central America | 9 | 0 | 78 | 22 | 22 | 56 | 22 |
| South America | 10 | 0 | 30 | 70 | 0 | 50 | 50 |
| NORTH AMERICA | 2 | 0 | 0 | 100 | 0 | 0 | 100 |
| NEAR AND MIDDLE EAST | | | | | | | |
| | 7 | 14 | 71 | 14 | 14 | 71 | 14 |

* n=number of Country Reports included in the analysis; ** 0= nothing, +=little, ++/+++ =middle/high

Developing countries in particular express an urgent need for technical assistance. This is most often expressed in the context of the need for an increase in livestock production by means such as the use of imported high-output breeds.

State of policy development: awareness, laws and political programmes and their degree of implementation

Awareness of the value of animal genetic diversity is essential to raising the political profile of the topic, and bringing about appropriate institutional change. In most countries, much remains to be done if these goals are to be achieved. The situation is illustrated in Table 56, which shows that many Country Reports describe the degree of awareness as very low. This is mirrored by the state of policies and programmes, and by their degree of implementation. Although awareness is growing among some stakeholders, this has rarely filtered through to the policy level, as can be seen from the very low numbers of policies that have been implemented to date. Most laws that have been implemented are in the field of animal health, and only a few are related to breeding programmes or policies for the conservation of AnGR.

Table 56
Institutional assessment – state of policy development

| Region / Frequency 0 nothing, + little, ++/+++ middle/high | Awareness for topic [% of countries] | | | | Laws, political programmes [% of countries] | | | Degree of imple- mentation [% of countries] | | |
|--|---|-----|----|--------|---|----|------------|---|----|--------|
| | n* | 0** | + | ++/+++ | 0 | + | ++/ +++ | 0 | + | ++/+++ |
| AFRICA | | | | | | | | | | |
| North and West Africa | 2 | 33 | 54 | 13 | 71 | 25 | 4 | 83 | 13 | 4 |
| East Africa | 4 | | | | | | | | | |
| East Africa | 7 | 14 | 57 | 29 | 71 | 14 | 14 | 100 | 0 | 0 |
| Southern Africa | 1 | 36 | 55 | 9 | 55 | 36 | 9 | 55 | 46 | 0 |
| | 1 | | | | | | | | | |
| ASIA | | | | | | | | | | |
| Central Asia | 6 | 33 | 67 | 0 | 50 | 50 | 0 | 83 | 17 | 0 |
| East Asia | 4 | 0 | 50 | 50 | 0 | 50 | 50 | 25 | 25 | 50 |
| South Asia | 7 | 14 | 29 | 57 | 14 | 57 | 29 | 43 | 43 | 14 |
| Southeast Asia | 8 | 50 | 25 | 25 | 50 | 25 | 25 | 50 | 25 | 25 |
| SOUTHWEST PACIFIC | 1 | 73 | 18 | 9 | 55 | 36 | 9 | 73 | 18 | 9 |
| | 1 | | | | | | | | | |
| EUROPE & THE CAUCASUS | 3 | 8 | 23 | 69 | 10 | 26 | 64 | 13 | 33 | 54 |
| | 9 | | | | | | | | | |
| LATIN AMERICA & THE CARIBBEAN | | | | | | | | | | |
| Caribbean | 3 | 0 | 33 | 67 | 33 | 33 | 33 | 67 | 0 | 33 |
| Central America | 9 | 22 | 56 | 22 | 33 | 44 | 22 | 67 | 11 | 22 |
| South America | 1 | 0 | 50 | 50 | 10 | 50 | 40 | 30 | 20 | 50 |
| | 0 | | | | | | | | | |
| NORTH AMERICA | 2 | 0 | 0 | 100 | 0 | 50 | 50 | 0 | 0 | 100 |
| | | | | | | | | | | |
| NEAR AND MIDDLE EAST | 7 | 14 | 71 | 14 | 14 | 86 | 0 | 29 | 71 | 0 |

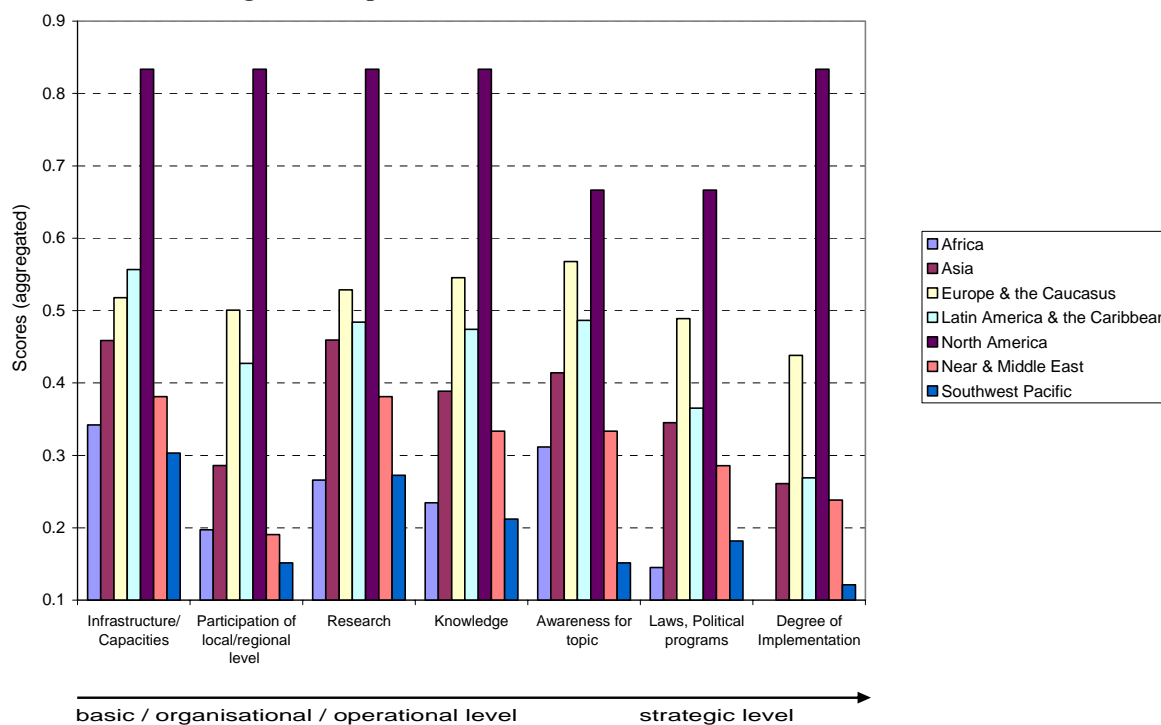
* n = number of Country Reports included in the analysis; ** 0 = nothing, + = little, ++/+++ = middle/high

As, in many regions, institutional and organizational structures remain poorly developed, further awareness building at national and regional levels will depend on the personal engagement and networking of individuals or isolated departments. Furthermore, to create more awareness of the subject at the policy level, a crucial challenge is to highlight the need for an appropriate balance between immediate demands for high-output breeds and the need to conserve genetic diversity. Many Country Reports, as well as the results of the regional e-mail consultations, indicate the difficulties that stakeholders face in overcoming their isolation and in communicating arguments in favour of conservation in the policy arena, as these arguments relate to a long-term perspective. The need for international assistance to overcome structural or financial obstacles at national level was often expressed.

Regional aggregation of institutional assessments

Figure 43 presents a regional comparison of the state of institutions related to the management of AnGR. The country scores are aggregated at regional (Figure 43) and subregional levels (Annex Figures 44 to 46) to identify regions and subregions with more or less favourable conditions. The figures also allow the identification of specific thematic areas where further support is needed in each region.

Figure 43
State of institutions – regional comparison



As the figure shows, only in North America, Europe and the Caucasus, and to some extent Latin America and the Caribbean, is there a sound base for strategic action. Particularly in North America and western Europe, much action has already been undertaken with regard to policy formulation and implementation (for more details of European Union (EU) legislation see Section E: 3.2). In contrast, in Africa, the Near and Middle East, and the Southwest Pacific weaknesses are evident not only at the strategic level, but also at the basic, operational and organizational levels. Awareness of the value of AnGR and biological diversity in general is expressed strongly in many reports from Latin America and the Caribbean, which also stress the regional character of these resources. However much remains to be done in these countries, as illustrated by the scores of 0.38 and 0.27 achieved by the region for the state of laws and programmes, and the state of their implementation, respectively.

Some differences within regions should also be noted. In Europe and the Caucasus, many countries from the eastern part of the region are relatively weak at the strategic level, and also with respect to the basic, organizational and operational levels. The subregions of Asia are also quite heterogeneous, with East Asia achieving higher scores in all thematic areas than the other Asian subregions. Country Reports from the East Africa subregion indicate that awareness of the topic is growing – which should provide a base for future action at the strategic level.

Comparing the status of individual countries (Annex Table 58) with the averages for the regions and subregions may help to identify countries with potential to play a facilitating role at regional or subregional level. Such suggestions on the basis of Country Reports written over a period of several years (the first being received by FAO in 2002) have to be considered with care, as circumstances may have changed and new opportunities or new constraints may have arisen. Nevertheless, it is evident that some countries are in a favourable position to play a facilitating role. For example, Australia offered, during the e-mail consultation, to support the implementation of regional cooperation networks. South Africa has offered laboratory capacity for the Southern Africa subregion, as has Malawi. Similarly, there may be potential for North African countries to assist with AnGR-related research in West African countries. Japan has played a leading role – financing a cooperative project in the subregions of Asia.

3.3 Organizations and networks with a potential role in subregional, regional and international collaboration

Subregional and regional organizations and networks

This subchapter gives an overview of networks/organizations at subregional and regional levels mentioned in the Country Reports and during the regional e-mail consultations (Table 57). The current state of networks for the management of AnGR is varied across the regions and subregions. In Europe and the Caucasus, networks at governmental and non-governmental level exist, but in other regions the situation is less favourable. In Central Asia, no networks are mentioned. This is explained in the Country Reports from this subregion by the breakdown of structures following the collapse of the Soviet Union (see for example CR Kyrgyzstan, 2003). Networks with a focus on AnGR exist in and between East and Southern Africa. However, no concrete networks are mentioned for North and West Africa, which is a heterogeneous subregion with a long history of conflicts. In South and Central America, there is a basic network structure which also involves Spain. The two North American countries report cooperation with Latin America and the Caribbean, but no specific networks are mentioned.

The basis of many networks is research – one element of which is research related to AnGR. This is reflected in the few concrete proposals for further international networking given in the Country Reports. Where such proposals are put forward, (e.g. CR Argentina, 2003; CR Uruguay, 2003; and CR Japan, 2003), they mainly relate to the establishment of subregional “centres of expertise” covering fields such as research or training on specific breeds or methodologies.

Networks that are exclusively built for AnGR management are rare. Moreover, there are only a limited number of networks and organizations that focus on the subject or that have related activities and programmes. Examples include the European Association for Animal Production (EAAP), the SAVE Foundation (Safeguard for Agricultural Varieties in Europe), the Inter-Governmental Authority on Development (IGAD), the Southern African Development Community (SADC) and the Southern African Centre for Cooperation in Agriculture and Natural Resources Research and Training (SACCAR). However, some other networks are mentioned in the Country Reports as being relevant to livestock development. Most frequently these are economic networks¹. Such organizations provide a platform for networking in the field of AnGR. It should be noted that there is a growing awareness of the value of AnGR arising from the globalization process, international trade in animals and animal products, and the world trade agreements (see for, example, CR Cuba, 2003; CR India 2004; CR Malaysia, 2003; CR Switzerland, 2002; CR Tonga, 2005 and CR Zambia, 2003). These developments, as the Country Reports indicate, have increased motivation to build networks related to animal production, but have not yet led to concrete action specifically for AnGR.

Another point to be stressed is the varying degree of activity of the few networks that do exist. The Country Reports do not give much indication of the actual role which the different organizations/networks play in AnGR management or of their concrete activities. Furthermore, other networks exist that are not mentioned in the Country Reports². Thus, the available information only provides a starting point for identifying organizations and networks that have potential for coordinating future actions.

¹ For example: the Southern Common Market (MERCOSUR) in Latin America; the Economic and Monetary Community of Central Africa (CEMAC) in Africa; the Caribbean Community and Common Market (CARICOM) in the Caribbean; D-8 as a body for development cooperation among Bangladesh, Egypt, Indonesia, the Islamic Republic of Iran, Malaysia, Nigeria, Pakistan and Turkey; and the Asia-Pacific Economic Cooperation (APEC) with its Agricultural Technical Cooperation Working Group (ATCWG).

² For example in Africa the two agricultural research and development networks: FARA (Forum for Agricultural Research in Africa) and CORAF/WECARD (Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricole/ West and Central African Council for Agricultural Research and Development), were not mentioned by any African Country Report. Another example of an institution not mentioned in the Country Reports is the Centre International de Hautes Etudes Agronomiques Méditerranéennes (CIHEAM), which conducted an advanced training course on conservation and management of AnGR in 2003.

Table 57
Organizations and networks that play or may play a role in animal genetic resources management at regional/subregional level

| Region | Networks/Organizations | |
|-----------------------|--|---|
| | Name | Description |
| AFRICA | ILRI (International Livestock Research Institute) | Research and training, CGIAR centre |
| North and West Africa | IRD (Institut de Recherche pour le Développement, ex-OSTROM) | Research projects and scientific programmes on relations between humans and environment in the tropics |
| | CIRDES (Centre International de Recherche-Développement sur l'Élevage en Zone Subhumide) | Regional research centre, focusing on epidemiological research and the application of new biotechnologies |
| | CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement) | French research institute for agricultural research in the service of developing countries and French overseas departments |
| | ICARDA (International Center for Agricultural Research in the Dry Areas) | Research and training, CGIAR centre |
| | ACSAD (The Arab Center for Studies of Arid Zones and Dry Lands) | Centre for agricultural research and development, within the frame of the League of Arab States |
| East Africa | ASARECA (The Association for Strengthening Agricultural Research in Eastern and Central Africa) | Agricultural research network |
| | IGAD (Intergovernmental Authority on Development) | Regional cooperation for overall development, was created as the Intergovernmental Authority on Drought and Development (IGADD) |
| Southern Africa | SADC (Southern African Development Community) | Development community, was a party to a UNDP/FAO project on AnGR management |
| | SACCAR (Southern African Center for Cooperation in Agricultural and Natural Resources Research and Training) | Agricultural research and training network, active at the policy level |
| ASIA | | |
| Central Asia | | |
| East Asia | | |
| South Asia | SAARC (South Asian Association for Regional Cooperation) | Subregional cooperation platform to enhance economic growth, social progress and cultural development |
| Southeast Asia | ASEAN (Association of Southeast Asian Nations) | Subregional cooperation platform to enhance economic growth, social progress and cultural development |
| | ARCBC (ASEAN Regional Center for Biodiversity Conservation) | Centre for exchange of knowledge, an intergovernmental organization of ASEAN |
| | ILRI | Research and training, CGIAR centre |
| EUROPE & THE CAUCASUS | EAAP (European Association for Animal Production) | Organization for animal production |
| | DAGENE (Danubian Alliance for Gene Conservation in Animal Species) | NGO active in AnGR conservation |
| | Nordic Genebank | Genebank |
| | SAVE (Safeguard for | Umbrella organization for NGOs working on |

| Networks/Organizations | | |
|--|---|---|
| Region | Name | Description |
| | Agricultural Varieties in Europe) | conservation of biodiversity in agriculture |
| LATIN AMERICA & THE CARIBBEAN | IICA (Inter-American Institute for Cooperation on Agriculture) | Regional cooperation for rural development |
| | ILRI, CIAT (International Center for Tropical Agriculture) | Research and training, CGIAR centres |
| | ALPA (Latin-American Association for Animal Production) | Professional organization |
| | FIRC (International Federation of Creole Breeds) or IberoAmerican Federation of Autochthonous and Creole Breeds | Ibero-American Federation of Criollo Breeds |
| | CYTED (Red XII-H: Ibero-American Network) | Network for AnGR, research and training |
| Caribbean | CARDI (Caribbean Agricultural Research and Development Institute) | Subregional agricultural research and development institute |
| South America | | |
| Central America | | |
| NEAR AND MIDDLE EAST | ACSAD (Arab Center for Studies of the Arid Zones and Dry Lands) | Centre for agricultural research and development, within the frame of the League of Arab States |
| | AOAD (Arab Organization for Agricultural Development) | Development, research, training and reporting in food and agriculture in Arab states |
| SOUTHWEST PACIFIC | ICARDA SPC (Secretariat of the Pacific Community) | Research and training, CGIAR centre Regional cooperation for development |
| ASIA/NORTH AMERICA/ SOUTHWEST PACIFIC | ATCWG (Agriculture Technical Cooperation Working Group) Part of APEC (Asia-Pacific Economic Cooperation) | Forum for exchange of information between technical and scientific experts, e.g. on biotechnology, conservation of genetic resources, pest management and sustainable agriculture |

Source: Country Reports and e-mail consultations

Cooperation should be a logical consequence of shared resources. The Country Reports often mention regional cooperation as a necessity and express a willingness to participate. However, there are few examples of concrete activities. A variety of historical factors probably contribute to the lack of cooperation in certain subregions. The Country Reports from some southeast European countries provide examples of the problems faced. International organizations and networks can play a facilitating or mediating role in cases where bilateral or regional cooperation is hindered by such factors.

Nearly all regions lack key stakeholders with the capacity to host a Regional Focal Point (RFP) for AnGR management. Currently, only the European Regional Focal Point is functioning. The former RFP in the Asia region is no longer active. A few potential host organizations are mentioned in the Country Reports or were mentioned during the regional e-mail consultations. For example, in the East Africa subregion, ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa) and IGAD (Inter-Governmental Authority on Development) are mentioned, while SADC (Southern African Development Community) and SACCAR (Southern African Centre for Cooperation in Agriculture and Natural Resources Research and Training) are mentioned in the Southern Africa subregion.

International organizations and networks

Besides FAO's global network of NCs and other stakeholders (along with the discussion forum DAD-Net³), no international networks specialized in AnGR management exist. However, some organizations dealing with livestock development have incorporated some aspects of AnGR management into their agendas. The World Association of Animal Production (WAAP) and its various member organizations is an example of an existing international network, although it has not yet achieved worldwide coverage. Organizations covering specific aspects of AnGR management (e.g. animal recording), such as the International Committee for Animal Recording (ICAR) or the International Bull Evaluation Service (INTERBULL) are also named as global players in the Country Reports. NGOs such as Rare Breeds International (RBI) and the League for Pastoral People (LPP) can play an important role in awareness building at local, national and international levels. However, their impact (including that of their training activities) is limited as a result of a lack of financial and human resources. As part of the SoW-AnGR process, intergovernmental and non-governmental organizations were asked to indicate their involvement in the field of AnGR. However, response to the invitation was limited. Reports were received from four international non-governmental organizations, three intergovernmental organizations, and two research organizations. A further three organizations stated that, as yet, they were not undertaking any activities related to AnGR. A summary table showing the responses received from these organizations is included in the Annex to this section (Table 61), and the reports are available in the Annex to the SoW-AnGR (attached CD-ROM). This low level of response may indicate that awareness of AnGR is lacking not only in national agendas, but also at the international level.

The institutions of the Consultative Group on International Agricultural Research (CGIAR) play a central role in research and training activities at the international level. The centres with programmes of research on AnGR are the International Livestock Research Institute (ILRI) and the International Center for Agricultural Research in the Dry Areas (ICARDA). The System-wide Genetic Resources Programme (SGRP), based at the International Plant Genetic Resources Institute (IPGRI), links the genetic resources programmes and activities of all the centres of the CGIAR – covering the crop, livestock, forest and aquatic sectors. Surprisingly, the CGIAR centres do not feature prominently in the Country Reports. They are mentioned as strategic players, but a lack of connection to national needs and structures is mentioned by some countries.

In nearly all Country Reports from developing countries or countries in transition, a strong demand for a genebank for *ex situ* conservation is expressed. The CGIAR centres, under the auspices of FAO, maintain the "International Network of *Ex situ* Collections" together with the CGIAR System-wide Information Network for Genetic Resources (SINGER), which has focused to date on plant genetic resources. It is mentioned in the report contributed by the CGIAR to the SoW-AnGR process that "ILRI in collaboration with relevant international and national agencies is developing an active programme aiming to conserve AnGR, with a focus on *in situ* conservation, but also looking into the role of other approaches to conservation, such as *ex situ in vivo* and *in vitro*." Advances in technology, reductions in costs and changing pressures on diversity mean that a reassessment is needed of the role of *in vitro* technology as a means of conserving AnGR.

It can be argued that even though the international research and development institutions are active in the field of AnGR, there is urgent need for further investment. This is underlined by a report prepared for the Science Council of the CGIAR:

"The needs for future CGIAR activities in FanGR [farm animal genetic resources] identified throughout this report focus more on filling particular urgent needs rather than obtaining a better balance of activities across the broad spectrum of characterisation, conservation and utilisation. Examples, ... include: a substantial commitment and clear role in development of policy and regulatory frameworks for management of farm animal genetic resources; a detailed assessment and possible active role in *in vitro* conservation of farm animal genetic resources; a clear and focused program on sustainable methods of genetic improvement of farm animal genetic resources" (Gibson and Pullin, 2005, p. 37).

³ DAD-Net@fao.org

Additionally, a strong demand for regional and international information networks and databases is expressed in the Country Reports. FAO's Domestic Animal Diversity Information System (DAD-IS) and ILRI's Domestic Animal Genetic Resource Information System (DAGRIS) are highlighted in nearly half of the Country Reports as useful tools for information management, even though they still need further improvement (cf. Australian contribution in regional e-mail consultation; CR Malaysia, 2003). For a system like DAD-IS, the interactivity of the database⁴ is of great importance, as it gives ownership to the data contributors. The significance of such interactive systems, therefore, relates not only to the management of data, but also to the process of motivation and awareness building. Efforts have been made to achieve harmonization between European and FAO-managed global databases (see Box 69). Another existing resource is the Agro Web, an Internet portal with more than 25 participating countries in Europe and the Caucasus. However, at the time of this analysis, not all member countries had updated their pages, and this portal is not mentioned in any Country Report.

4 Conclusions

The analysis, which was primarily based on the countries' own assessments, shows that in most parts of the world the institutional and structural situation at national, regional and international levels is not always supportive for the sustainable use and conservation of AnGR. AnGR are not a priority topic in most national, regional and international policy arenas. The relevance of AnGR to food security and poverty alleviation is not fully recognized, and this is reflected in the low level of awareness of the subject in many countries, and by its limited presence on international agendas and in the work of international organizations.

Opportunities to specialize in conservation or utilization of AnGR have been limited, and the prominence of the topic is only slowly increasing in the curricula of universities and research centres. This is reflected in the backgrounds of many of those working in the field. Adequate infrastructure and technical resources are also needed for effective management of AnGR, but are often lacking or not used. Research seems sporadic and isolated from policy processes.

Legal structures, policies and development programmes with a focus on AnGR are often lacking, as are basic institutions for characterization, inventory and monitoring, and structures for national and international cooperation. Even where networks for cooperation exist, there is frequently a need for further efforts to vitalize them or to establish new structures for cooperation.

The reasons for this situation are manifold. The Country Reports and the results of the regional e-mail consultations indicate that an emphasis on technical education, and the short-term perspective of livestock sector policies focused on the immediate need to increase output, are contributing factors. The benefits accruing from investment in AnGR conservation and utilization are often only to be achieved in the long term, and are associated with a degree of uncertainty. It is, therefore, difficult to communicate the need for investment in AnGR management in the policy arena. The commercial sector, which would often have the financial means to support conservation activities, is difficult to integrate into programmes for the management of AnGR. For example, few countries achieved the inclusion of commercial stakeholders in NCCs or in the preparation of the Country Reports. This does not seem to be a case of conflicting interests, but simply of a lack of shared interests. The objectives of commercial operators tend to be short-term profitability, and their interests centre on the limited range of livestock breeds that can achieve high levels of output in large-scale production units. If greater integration of the commercial sector is to be achieved, there is a need to demonstrate the relevance of publicly sponsored conservation activities in terms of enhancing profitability and providing insurance in the longer term. A potential area of cooperation could be for private-sector AI companies to share "low-value" cryoconserved genetic material that they have in their keeping with national programmes.

⁴ DAD-IS:3 is part of a global network of stand alone information systems. The network allows FAO's DAD-IS to be linked to regional databases – such as EFABIS (European Farm Animal Biodiversity Information System), successor to EAAP-AGDB (European Association of Animal Production – Animal Genetic Data Bank) at <http://efabis.tzv.fal.de/> – and in turn to national databases in individual countries. The global network enables the automatic propagation of public data to all databases in the network – enhancing communication and the availability of information at all levels. Individual countries have the option to establish their own national Web-based information systems, into which the country's AnGR related information can be entered. Alternatively, countries can make use of the global or regional systems.

In many countries there also seems to be a lack of national NGOs interested and active in AnGR management. Where such organizations exist, for example in India⁵, they were often not present in the NCCs or involved in the preparation of Country Reports, and are not involved in reporting on the state of AnGR diversity. Only in Europe, North America, South America and Australia is the involvement of NGOs more prominent. In some countries, national rare breed societies make an important contribution to conservation efforts. However, it is clear that further efforts need to be undertaken, both at the country level and by the international community, to strengthen stakeholder involvement in AnGR management.

Ex situ conservation is cost-intensive, and in most countries cannot be undertaken without international support. The central problem for *in situ* conservation is the heterogeneity of the users of AnGR and the fragile state of the production systems under which many threatened breeds are managed. For example, CR Czech Republic (2003)⁶ and CR Bulgaria (2004) report that local breeds considered to be of low productivity are increasingly kept only by older farmers. When the working lives of these farmers end, the keeping of these breeds will also end unless steps are taken to promote their continued use. In countries where cattle are largely kept by herders practising mobile husbandry, changing economic, ecological and political conditions threaten the herders' livelihoods and, thereby, restrict opportunities for the implementation of *in situ* conservation measures. Establishing an institutional environment able to respond to such problems is difficult even at the national level, and presents a greater challenge at international level. These arguments underline the need for international cooperation to overcome structural or financial obstacles at the national level. Consequently, there is an urgent need for functioning national and regional structures to support sustainable use and conservation of AnGR.

Box 23 **Suggestions for strengthening national structures**

Where possible, National Coordinators (NCs) should be made full-time professionals dedicated to the management of AnGR. They would, thus, be able to allocate sufficient time to the coordination of activities at the country level, and to close cooperation with relevant stakeholders. Adequate financial resources should be provided for the work of the NCs. Experience in some countries indicates that funding is improved when AnGR management is mainstreamed within the hosting institution's annual work plans and agendas. Other key stakeholders, such as breeding companies, research and training organizations, NGOs and representatives of community organizations, are also potential sources of funds. Such opportunities will, of course, differ from country to country.

As well as financial support, NCs need to be supported by well-organized national structures with clearly defined functions and roles. The necessary technical expertise to implement these functions needs to be in place. The regional and the global focal points may provide support in this respect, but training to strengthen human resources at the country level is frequently an important priority. Efforts should be made to increase awareness of the importance of AnGR at government level. The inclusion of priority actions for AnGR management within governments' action plans for poverty alleviation and food security is a means to facilitate closer cooperation between NCs and other ministries.

Source: extracted from S. Moyo (2004). Strengthening national structures for the management of farm animal genetic resources – (contributions from a National Coordinator). Working Document written for FAO.

The NCCs, which were established during the preparation process of Country Reports, are a means of supporting the work of the NCs. The committees should be maintained and/or further developed as a mechanism for the involvement of all stakeholders and the organization of coordinated action. The establishment of focal points in the regions and subregions is a further important step in coordinating cross-border activities. Strong regional and subregional networks supported by development partners are important to ensure ongoing improvements in capacities and institutions for AnGR management. However, such networks are still not well developed, and cooperation is hindered not only by a lack of awareness of the subject, but also by a lack of settled relations between some countries.

⁵ In India there are several NGOs such as ANTHRA (a trust of women veterinary scientists), LPPS (Lokhit Pashu PalakF Sansthan) and SEVA.

⁶ Following the development of the Country Report, the Czech Republic amended its Breeding Act to reflect AnGR issues particularly to implement a monitoring system and reaction mechanism which is based on a subsidy system.

In the field of research and knowledge, the NARS are key players at the country level. The Country Reports note a lack of links between the NARS and the CGIAR centres, which is a further important structural gap. Moreover, AnGR is still not prioritized in the activities of the NARS or the CGIAR, and further awareness building is needed. The same is true for the international donor community. As, particularly in developing countries, the infrastructure (e.g. for inventory and monitoring of AnGR) is weak, a further engagement of the donor community is needed.

The Country Reports and the regional e-mail consultations, however, indicate that the SoW-AnGR preparation process has given rise to developments in the field of AnGR management. Awareness, the key to policy and institutional change, is growing in most countries, and new networks are being created.

5 References

CR (Country name). year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).

FAO. 2004. Strengthening national structures for the management of farm animal genetic resources – results of a questionnaire survey. Commission on Genetic Resources for Food and Agriculture, Tenth session, Rome, 8–12 November 2004.

Gibson, J. & Pullin, R. 2005. *Conservation of Livestock and Fish Genetic Resources: joint report of two studies commissioned by the CGIAR Science Council*. Rome. CGIAR Science Council Secretariat. (available at <http://www.sciencecouncil.cgiar.org/activities/spps/pubs/AnFiGR%20study%20report.pdf>).

6 Annex

Notes to Table 53

List of criteria taken into account to assign scores to each thematic are:

Infrastructure and capacities

- State as described in the Country Reports.
- State as detailed in Table 4.7 of the Country Reports (see Section A: 2 for description of the contents of this table).

Participation of stakeholders at local/regional level

- State as described in the Country Reports.
- Existing mechanisms for participation and integration of stakeholders; participation in the preparation of the Country Reports, in the NCC or other structures (who has which role and what authority), degree of organization, and influence in policy setting.
- Existence of decentralized or centralized structures (as mentioned in the Country Reports).

Research

- State of research as described in the Country Reports (capacities, number of institutions, grade of specialization in AnGR, priorities, research focus in the country).
- Role/relevance of research related to varying aspects of AnGR as described in Tables 4.6 – 4.9 of the Country Reports (see Section A: 2 for description of the contents of these tables).
- Participation of research institutions in the NCC, in report writing, and in other existing national/international structures.

Knowledge

- State and efficiency of AnGR-related extension services as described in the Country Reports.
- State and accessibility of (indigenous) knowledge as described in the Country Reports.
- Priority needs as described in Table 4.9 of the Country Reports (see Section A: 2 for description of the contents of these tables).

Awareness

- State as described in the Country Reports (priorities, policy focus).
- Role of various stakeholders with respect to legislation (Table 4.7 of the Country Reports – see Section A: 2 for details of this table).

Laws and political programmes

- Number and state of laws, programmes as described in the Country Reports (chapter on legal situation, institutions and programmes).

Degree of implementation

- Degree of implementation of laws and programmes as described in the Country Reports (chapter on legal situation, institutions, and programmes).

Figure 44
State of institutions – subregional comparison within Africa

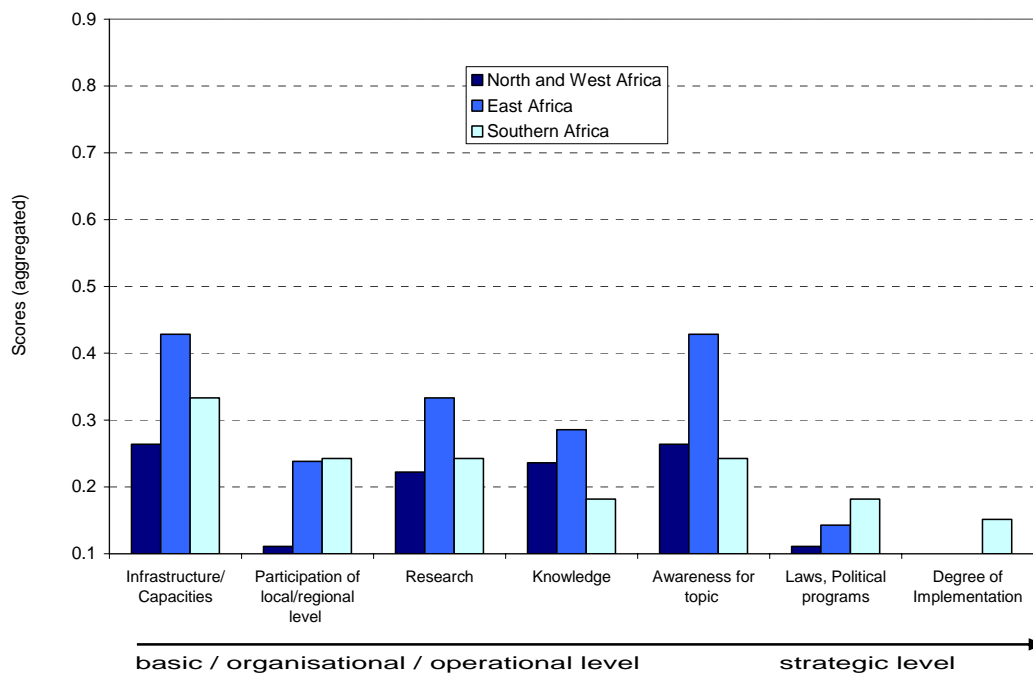


Figure 45
State of institutions – subregional comparison within Asia

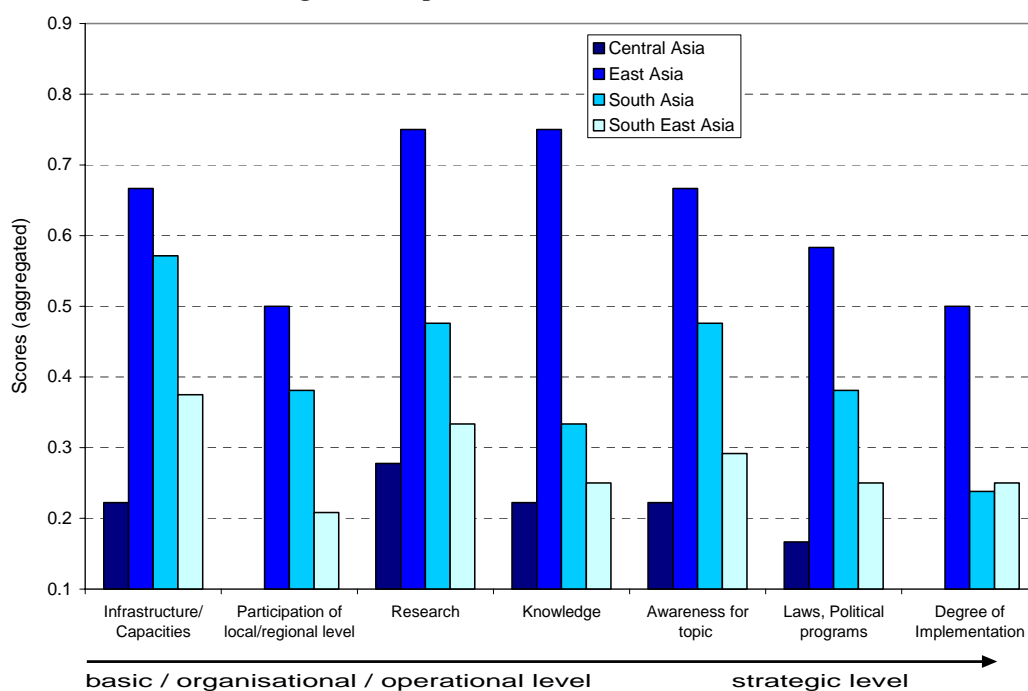


Figure 46
State of institutions – subregional comparisons within Latin America and the Caribbean

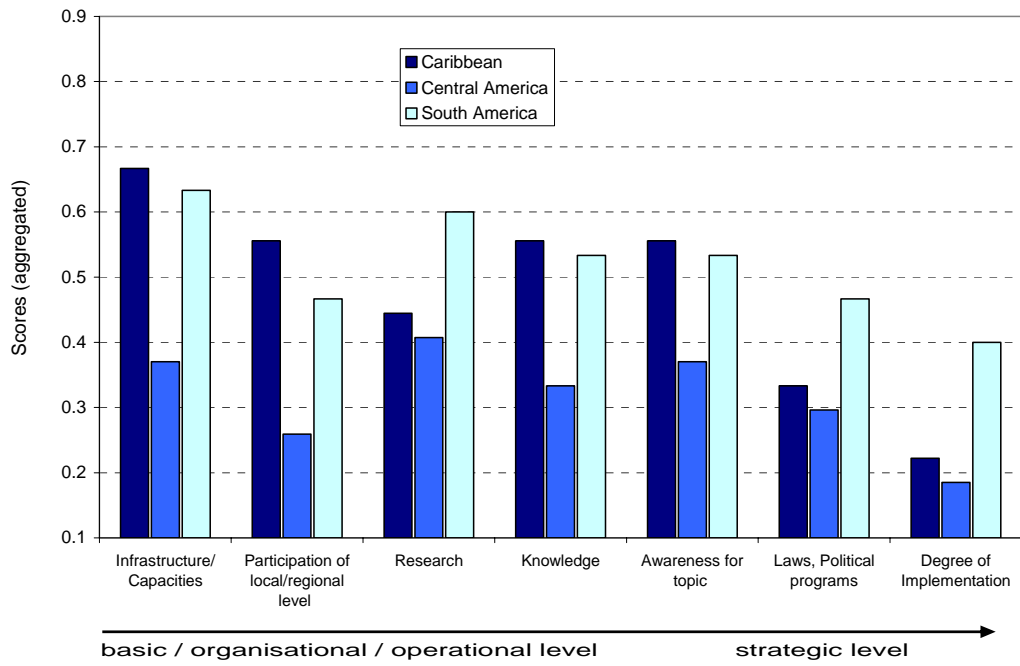


Table 58
Institutional assessment at country level

| Subregion/Country | Research | Knowledge | Awareness for topic | Infrastructure / Capacities | Participation of local / regional level | Laws, Political programmes | Degree of Implementation |
|----------------------------------|----------|-----------|---------------------|-----------------------------|---|----------------------------|--------------------------|
| North and West Africa | | | | | | | |
| Algeria | + | ++ | + | + | 0 | 0 | 0 |
| Benin | 0 | 0 | 0 | + | + | 0 | 0 |
| Burkina Faso | + | + | 0 | + | 0 | 0 | 0 |
| Cameroon | + | + | ++ | + | 0 | 0 | + |
| Cape Verde | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Central African Republic | 0 | 0 | + | + | + | + | 0 |
| Chad | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Congo | + | + | + | + | 0 | 0 | 0 |
| Côte d'Ivoire | + | + | ++ | + | + | ++ | ++ |
| Democratic Republic of the Congo | 0 | 0 | 0 | ++ | 0 | 0 | 0 |
| Equatorial Guinea | 0 | 0 | + | 0 | 0 | 0 | 0 |
| Gabon | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gambia | 0 | + | + | + | 0 | 0 | 0 |
| Ghana | + | + | + | + | ++ | + | 0 |
| Guinea | + | + | + | + | 0 | 0 | 0 |
| Guinea-Bissau | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mali | + | + | + | + | 0 | + | 0 |
| Mauritania | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Niger | ++ | ++ | ++ | ++ | + | + | + |
| Nigeria | ++ | + | + | + | 0 | + | + |
| Sao Tome and Principe | 0 | 0 | + | 0 | 0 | 0 | 0 |
| Senegal | + | + | + | + | + | + | 0 |
| Togo | + | + | + | + | + | 0 | 0 |
| Tunisia | ++ | ++ | + | + | 0 | 0 | 0 |

Table 58
Institutional assessment at country level (cont.)

| Subregion/Country | Research | Knowledge | Awareness for topic | Infrastructure / Capacities | Participation of local/regional level | Laws, Political programmes | Degree of Implementation |
|-----------------------------|----------|-----------|---------------------|-----------------------------|---------------------------------------|----------------------------|--------------------------|
| East Africa | | | | | | | |
| Burundi | 0* | 0* | + | 0* | 0* | 0* | 0 |
| Eritrea | 0 | + | 0 | + | + | 0 | 0 |
| Ethiopia | + | + | +++ | + | + | 0 | 0 |
| Kenya | ++ | ++ | + | +++ | + | + | 0 |
| Rwanda | + | 0 | + | + | 0 | 0 | 0 |
| Uganda | + | + | ++ | + | + | ++ | 0 |
| United Republic of Tanzania | ++ | + | + | ++ | + | 0 | 0 |
| Southern Africa | | | | | | | |
| Angola | + | 0 | 0 | + | 0 | 0 | 0 |
| Comoros | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Botswana | + | + | ++ | ++ | ++ | + | + |
| Lesotho | 0 | 0 | + | + | ++ | + | + |
| Madagascar | + | + | + | + | 0 | ++ | + |
| Malawi | + | + | + | + | + | + | + |
| Mauritius | + | 0 | 0 | + | + | + | + |
| Mozambique | + | + | + | + | + | 0 | 0 |
| Swaziland | + | + | + | ++ | + | 0 | 0 |
| Zambia | + | + | + | 0 | 0 | 0 | 0 |
| Zimbabwe | 0 | 0 | 0 | + | 0 | 0 | 0 |

**The figures presented in this table are based on analysis of the information presented in Country Reports received by FAO between 2002 and 2005. The situation in some countries may have changed subsequent to the submission of the Country Report. After countries were given the opportunity to review the first draft SoW-AnGR in December 2006/January 2007, Burundi indicated that the current situation in the country would be better represented if 0 were replaced by + in these columns.*

Table 58
Institutional assessment at country level (cont.)

| Subregion/Country | Research | Knowledge | Awareness for topic | Infrastructure / Capacities | Participation of local / regional level | Laws, Political programmes | Degree of Implementation |
|----------------------------------|----------|-----------|---------------------|-----------------------------|---|----------------------------|--------------------------|
| Central Asia | | | | | | | |
| Iran (Islamic Republic of) | + | + | + | 0 | 0 | + | 0 |
| Kazakhstan | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Kyrgyzstan | + | + | + | + | 0 | + | 0 |
| Tajikistan | + | + | + | + | + | 0 | 0 |
| Turkmenistan | + | 0 | + | + | 0 | 0 | 0 |
| Uzbekistan | + | + | 0 | + | 0 | + | + |
| East Asia | | | | | | | |
| China | +++ | +++ | +++ | +++ | 0 | +++ | +++ |
| Japan | +++ | +++ | +++ | +++ | +++ | ++ | ++ |
| Mongolia | ++ | ++ | + | + | ++ | + | + |
| Republic of Korea | + | + | + | + | + | + | 0 |
| South Asia | | | | | | | |
| Bangladesh | ++ | ++ | ++ | + | + | + | + |
| Bhutan | ++ | + | ++ | ++ | ++ | ++ | + |
| India | ++ | + | ++ | +++ | + | ++ | ++ |
| Maldives | 0 | 0 | 0 | + | 0 | 0 | 0 |
| Nepal | + | + | ++ | + | + | + | 0 |
| Pakistan | ++ | + | + | ++ | + | + | 0 |
| Southeast Asia | | | | | | | |
| Cambodia | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indonesia | + | + | + | + | + | + | + |
| Lao People's Democratic Republic | + | 0 | 0 | + | + | 0 | 0 |
| Malaysia | ++ | ++ | ++ | ++ | + | ++ | ++ |
| Myanmar | + | 0 | 0 | + | 0 | 0 | 0 |
| Papua New Guinea | 0 | 0 | 0 | + | 0 | 0 | 0 |
| Philippines | + | + | + | + | + | + | + |
| Viet Nam | ++ | ++ | +++ | ++ | + | ++ | ++ |

Table 58
Institutional assessment at country level (cont.)

| Region/Country | Research | Knowledge | Awareness for topic | Infrastructure / Capacities | Participation of local / regional level | Laws, Political programmes | Degree of Implementation |
|---|----------|-----------|---------------------|-----------------------------|---|----------------------------|--------------------------|
| Europe & the Caucasus | | | | | | | |
| Albania | + | + | + | + | 0 | + | + |
| Armenia | + | + | + | + | + | + | + |
| Azerbaijan | 0 | + | ++ | + | + | + | + |
| Bulgaria | ++ | ++ | ++ | ++ | + | ++ | + |
| Belgium | +++ | +++ | +++ | +++ | +++ | ++ | ++ |
| Belarus | + | ++ | ++ | ++ | ++ | ++ | ++ |
| Bosnia and Herzegovina | 0 | 0 | 0 | + | + | 0 | 0 |
| Croatia | ++ | ++ | +* | +* | +* | +* | + |
| Cyprus | + | + | 0 | 0 | 0 | 0 | 0 |
| Czech Republic | ++ | ++ | +++ | ++ | ++ | ++ | ++ |
| Denmark | ++ | ++ | +++ | +++ | ++ | ++ | ++ |
| Estonia | ++ | ++ | + | ++ | ++ | ++ | + |
| Finland | +++ | +++ | +++ | +++ | +++ | +++ | ++ |
| France | +++ | +++ | +++ | +++ | +++ | +++ | ++ |
| Georgia | + | + | 0 | 0 | 0 | 0 | 0 |
| Germany | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| Greece | ++ | + | ++ | ++ | ++ | ++ | ++ |
| Hungary | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Iceland | + | + | ++ | ++ | ++ | ++ | + |
| Ireland | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Latvia | + | + | ++ | ++ | ++ | + | + |
| Lithuania | ++ | ++ | ++ | ++ | ++ | ++ | + |
| Moldova | + | 0 | + | 0 | 0 | + | 0 |
| Netherlands | +++ | +++ | +++ | ++ | +++ | +++ | +++ |
| Norway | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| Portugal | +++ | +++ | +++ | +++ | +++ | ++ | ++ |
| Poland | + | ++ | + | ++ | ++ | + | + |
| Romania | + | + | + | + | ++ | + | + |
| Russian Federation | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Serbia and Montenegro | + | + | + | + | + | + | + |
| Slovakia | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Slovenia | +++ | +++ | +++ | +++ | ++ | ++ | ++ |
| Spain | +++ | +++ | +++ | +++ | ++ | +++ | +++ |
| Sweden | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| Switzerland | +++ | +++ | +++ | +++ | +++ | +++ | +++ |
| The former Yugoslav Republic of Macedonia | + | + | + | 0 | 0 | 0 | 0 |
| Turkey | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Ukraine | ++ | ++ | ++ | + | + | + | + |
| United Kingdom | ++ | ++ | ++ | ++ | ++ | ++ | ++ |

**The figures presented in this table are based on analysis of the information presented in Country Reports received by FAO between 2002 and 2005. The situation in some countries may have changed subsequent to the submission of the Country Report. After countries were given the opportunity to review the first draft SoW-AnGR in December 2006/January 2007,*

Croatia indicated that the current situation in the country would be better represented if + were replaced by ++ in these columns

Table 58
Institutional assessment at country level (cont.)

| Subregion/Country | Research | Knowledge | Awareness for topic | Infrastructure / Capacities | Participation of local / regional level | Laws, Political programs | Degree of Implementation |
|------------------------------------|----------|-----------|---------------------|-----------------------------|---|--------------------------|--------------------------|
| | | | | | | | |
| Caribbean | | | | | | | |
| Barbados | 0 | + | + | + | + | + | 0 |
| Jamaica | ++ | ++ | ++ | +++ | +++ | ++ | ++ |
| Trinidad and Tobago | ++ | ++ | ++ | ++ | + | 0 | 0 |
| Central America | | | | | | | |
| Costa Rica | ++ | ++ | ++ | ++ | ++ | + | ++ |
| Cuba | + | + | + | + | + | ++ | + |
| Dominican Republic | + | + | + | + | 0 | + | 0 |
| El Salvador | + | 0 | + | + | 0 | 0 | 0 |
| Guatemala | + | + | + | + | + | + | 0 |
| Haiti | + | 0 | 0 | 0 | 0 | 0 | 0 |
| Honduras | + | + | 0 | + | 0 | 0 | 0 |
| Mexico | ++ | ++ | +++ | ++ | ++ | ++ | ++ |
| Nicaragua | + | + | + | + | + | + | 0 |
| South America | | | | | | | |
| Argentina | ++ | + | + | ++ | + | + | + |
| Bolivia | + | + | + | + | + | 0 | 0 |
| Brazil | +++ | +++ | +++ | +++ | +++ | +++ | ++ |
| Chile | ++ | ++ | ++ | +++ | + | ++ | ++ |
| Peru | ++ | ++ | ++ | ++ | ++ | ++ | ++ |
| Colombia | ++ | ++ | + | ++ | + | + | ++ |
| Ecuador | + | + | + | + | ++ | + | 0 |
| Paraguay | + | + | + | + | + | + | 0 |
| Uruguay | ++ | ++ | ++ | ++ | + | ++ | ++ |
| Venezuela (Bolivarian Republic of) | ++ | + | ++ | ++ | + | + | + |

Table 58
Institutional assessment at country level (cont.)

| Region/Country | Research | Knowledge | Awareness for topic | Infrastructure / Capacities | Participation of local / regional level | Laws, Political programs | Degree of Implementation |
|--------------------------|----------|-----------|---------------------|-----------------------------|---|--------------------------|--------------------------|
| North America | | | | | | | |
| Canada | +++* | ++ | ++ | +++* | ++ | + | +++* |
| United States of America | +++ | +++ | ++ | +++ | +++ | +++ | +++ |
| Near & Middle East | | | | | | | |
| Egypt | +++ | ++ | ++ | ++ | + | + | + |
| Iraq | + | + | + | + | 0 | + | + |
| Jordan | + | + | + | + | + | + | + |
| Lebanon | | | | | | | |
| Libyan Arab Jamahiriya | | | | | | | |
| Oman | 0 | 0 | 0 | + | 0 | 0 | 0 |
| Sudan | + | + | + | + | 0 | + | 0 |
| Syrian Arab Republic | + | + | + | + | + | + | + |
| Southwest Pacific | | | | | | | |
| Australia | +++ | +++ | +++ | +++ | +++ | ++ | ++ |
| Cook Islands | + | + | 0 | + | 0 | + | 0 |
| Fiji | + | + | 0 | + | 0 | + | + |
| Kiribati | + | 0 | 0 | + | 0 | + | + |
| Northern Mariana Islands | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Palau | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Samoa | + | + | + | + | + | + | 0 |
| Solomon | + | + | 0 | + | + | 0 | 0 |
| Tuvalu | + | 0 | 0 | + | 0 | 0 | 0 |
| Tonga | 0 | 0 | + | 0 | 0 | 0 | 0 |
| Vanuatu | 0 | 0 | 0 | + | 0 | 0 | 0 |

*The figures presented in this table are based on analysis of the information presented in Country Reports received by FAO between 2002 and 2005. The situation in some countries may have changed subsequent to the submission of the Country Report. After countries were given the opportunity to review the first draft SoW-AnGR in December 2006/January 2007, Canada indicated that the current situation in the country would be better represented if ++ were replaced by +++ in these columns.

Table 59
List of international organizations and contributed reports on their activities

| Organizations | Type of response |
|---|---|
| International Society for Animal Genetics (ISAG)/FAO advisory group on animal genetic diversity | Report on activities, March 2005 |
| Safeguard for Agricultural Varieties in Europe (SAVE) Foundation | Brief Portrait, April 2004 |
| League for Pastoral Peoples | Report on Activities, November 2004 |
| The Mediterranean Agronomic Institute of Zaragoza (IAMZ) | Report on Training activities, January 2005 |
| World Organisation for Animal Health (OIE) | Presentation to the Commission on Genetic Resources for Food and Agriculture, 10th Session, November 2004 |
| European Association for Animal Production (EAAP) | Report of the Working Group on Animal Genetic Resources (EAAP-WG-AGR), February 2005 |
| D8 Countries | Report on Animal Genetic Resources in the D-8 Countries – Strategic Priorities for Action; and Reports on Seminars on Conservation of Farm Animal Genetic Resources |
| Arab Center for the Studies of Arid zones and Dry lands (ACSAD) | Report on Activities, December 2004 |
| Consultative Group on International Agricultural Research (CGIAR) Centres | Report, Section I: Description of the CGIAR Institutes and Programmes, May 2004 |
| World Intellectual Property Organization (WIPO) | indicated that they had some activities, but did not send a report |
| International Council for Game and Wildlife Conservation (CIC) | indicated that they had some activities, but did not send a report |
| Observatoire du Sahara et du Sahel (Sahara and Sahel Observatory, OSS) | responded that they had no activities in the field of AnGR management |
| Commonwealth Secretariat, Special Advisory Services Division | responded that they had no activities in the field of AnGR management |
| Institute for Environment and Sustainability (IES) of the European Commission's Joint Research Centre | responded that they had no activities in the field of AnGR management |

SECTION B: STRUCTURED BREEDING PROGRAMMES

1 Introduction

This section presents a review and analysis of breeding programmes based on the information provided in the Country Reports. Country priorities with respect to species and breeding objectives are first set out, followed by details of the organizational structures and tools used. Regional descriptions of the state of breeding programmes for the various species are then presented. The review ends with some general conclusions about the state of breeding programmes in the countries considered.

Breeding programmes are here defined as systematic and structured programmes to change the genetic composition of a population based on objective performance criteria. Pure-breeding is defined as breeding activities within a specified breed, and cross-breeding as the systematic or unsystematic combination of two or more breeds. Breeding activities conducted by individuals or small informal groups of breeders are not considered.

The analysis is based on the 148 Country Reports that were submitted by July 2005. For some countries, additional sources would have been available, but a common basis for the analysis was considered preferable, and only the information provided in the Country Reports was, therefore, utilized. Although most Country Reports have a common structure, the way in which breeding activities and breeding programmes are reported is very variable. The information is presented in different chapters, and is discussed in relation to different topics. Countries with active conservation programmes gave more emphasis to the reporting of breeding activities involving breeds under conservation programmes than to the main breeding programmes. The quality of the information and the degree of detail presented are, thus, very variable. Information about objectives and the scale of the active breeding population is not provided in many Country Reports, and in several cases it is difficult to conclude whether the reported breeding programmes are actually being implemented, are planned, or are historical events. Collecting more detailed information through further requests to the countries concerned was not considered feasible in the time available.

About 70 countries submitted information about breeding activities utilizing pre-defined tables. In the following discussion these countries are referred to as the “subsample countries” (see Annex Table 67). Note that no countries from Latin America and the Caribbean or the Southwest Pacific are included among the subsample countries. These countries provided data on the total number of breeds, and the number of breeds for which there are specified breeding goals and breeding strategies, and for which individual identification, performance recording, genetic evaluation procedures and AI are implemented. The data are analysed and reported on a regional basis. However, when interpreting the results, it is important to consider that the extent to which breeds are actually exposed to the reported tools/technologies may vary greatly across a region.

For the major species – cattle, buffaloes, sheep, goats, pigs and chickens – countries are classified according to whether they regard breeding programmes as a priority, and whether they actually have breeding programmes. The existence of breeding programmes was also recorded for horses, camels, rabbits, turkeys, ducks and geese. Countries are considered to regard breeding programmes for a given species as a priority if they are specifically mentioned as such in the Country Report, or if activities of breeding associations for the species are reported. The number of countries which consider breeding programmes as a priority is, thus, larger than those which have existing programmes. If the priority and existence of breeding programmes could not be clearly established from the Country Report it was classified as “not mentioned”. Information about breeding programmes is presented on the basis of the regions Africa, Asia, the Near and Middle East, Europe and the Caucasus, the Caribbean and Central America, South America, North America, and the Southwest Pacific.

For the classification of animals into breeds, this review follows the usage in the Country Reports. Where information is presented regarding the numbers of breeds in the different regions,

transboundary breeds are counted more than once – regional totals are therefore the sum of the number of breeds in each country

2 Species priorities and breeding objectives

Breeding objectives are influenced by a wide range of factors, and have to consider the needs and priorities of the animal owners or producers, the consumers of animal products, the food industry, and increasingly also the general public. The relative importance of the different factors varies depending on the species, and the priorities and development-stage of the country. It also changes over time. The more important functions and requirements of breeding programmes are to:

- increase production and product quality;
- increase productivity and cost efficiency;
- maintain genetic diversity;
- support the conservation and use of specific breeds; and
- consider animal welfare and sustainable systems.

Finding the right balance between the different demands is a continuous process, and requires anticipation of future conditions and careful planning of breeding programmes. In a multifactorial environment, and among increasingly heterogeneous consumers, it is a challenge to predict changes in consumption patterns and to arrange breeding programmes and livestock production activities accordingly. The priority attached to these processes by governments or public institutions also varies considerably between countries and regions, and between species.

2.1 Cattle

Breeding programmes for cattle have the highest priority and are implemented in the largest number of countries. Ninety-four countries (65 percent) of the 144 countries keeping cattle indicate that they see cattle breeding as a priority (Table 60), while 68 (47 percent) implement such programmes (Table 61). Countries from Africa, the Caribbean and Central America express the lowest priority for cattle breeding (excluding the Southwest Pacific). The greatest discrepancy between priority and actual implementation of breeding programmes is found in the countries of the Near and Middle East.

Table 60
Countries prioritizing breeding activities (by species)

| | Cattle | Buffalo | Sheep | Goats | Pigs | Chickens |
|-------------------------------|---------------------------|---------|-------|-------|------|----------|
| | [percentage of countries] | | | | | |
| Africa | 52 | 0 | 19 | 19 | 17 | 14 |
| Asia | 71 | 44 | 30 | 40 | 24 | 20 |
| Near & Middle East | 71 | 67 | 71 | 43 | 0 | 14 |
| Europe & the Caucasus | 90 | 18 | 67 | 54 | 69 | 23 |
| Latin America & the Caribbean | 55 | 14 | 23 | 9 | 9 | 14 |
| - Caribbean & Central America | 42 | 0 | 17 | 8 | 8 | 8 |
| - South America | 70 | 50 | 30 | 10 | 10 | 20 |
| North America | 100 | 0 | 50 | 50 | 100 | 50 |
| Southwest Pacific | 13 | 0 | 40 | 0 | 18 | 9 |
| World | 65 | 29 | 39 | 31 | 33 | 18 |

*Based on information in the Country Reports
Percentage of the countries that keep the respective species*

Table 61
Structured breeding activities for the main livestock species

| | Cattle | Buffalo | Sheep | Goats | Pigs | Chickens |
|-------------------------------|---------------------------|---------|-------|-------|------|----------|
| | [percentage of countries] | | | | | |
| Africa | 31 | 0 | 10 | 10 | 6 | 2 |
| Asia | 58 | 38 | 30 | 32 | 19 | 16 |
| Near & Middle East | 14 | 33 | 57 | 43 | 0 | 14 |
| Europe & the Caucasus | 74 | 9 | 59 | 54 | 62 | 23 |
| Latin America & the Caribbean | 36 | 14 | 23 | 9 | 9 | 14 |
| - Caribbean & Central America | 17 | 0 | 17 | 8 | 8 | 8 |
| - South America | 60 | 50 | 30 | 10 | 10 | 20 |
| North America | 100 | 0 | 50 | 50 | 100 | 50 |
| Southwest Pacific | 13 | 0 | 40 | 0 | 18 | 9 |
| World | 47 | 22 | 33 | 27 | 27 | 14 |

As mentioned in the Country Reports

Percentage of the countries that keep the respective species

Among the 70 subsample countries, breeding goals have been specified for 22 percent of cattle breeds, and definitive strategies are being implemented for 19 percent of breeds (Table 62). Breeding strategies are less clearly specified in the countries of the Near and Middle East, and Latin America. Improvement of quantitative traits and increased production are mentioned by a large number of countries as the main breeding objectives for both dairy and beef cattle. Improved milk quality, efficiency of production, fertility and conformation traits are gaining an increasing importance in breeding programmes in Europe and the Caucasus. In Scandinavian countries, breeding for health traits has a high priority, and is achieved with the help of extensive recording programmes. Increasing product uniformity and consistency is an important objective for dairy cattle in North America, but more recently functional traits have been integrated into the selection index.

Table 62
Strategies and tools used in cattle breeding

| | World | Africa | Asia | Near & Middle East | Europe & the Caucasus | LAC** | Southwest Pacific |
|-------------------------------------|-------|--------|------|--------------------|-----------------------|-------|-------------------|
| No. of countries | 67 | 24 | 8 | 3 | 21 | 10 | 1 |
| Total no. of breeds | | | | | | | |
| Local | 505 | 143 | 71 | 12 | 112 | 166 | 1 |
| Exotic | 476 | 143 | 34 | 10 | 159 | 125 | 5 |
| Breeds with | | | | | | | |
| Breeding Goal | 22% | 18% | 28% | 14% | 44% | 4% | 0% |
| Strategy Implemented | 19% | 13% | 24% | 9% | 44% | 1% | 0% |
| Individual Identification | 34% | 11% | 12% | 9% | 44% | 58% | 0% |
| Performance Recording | 31% | 12% | 16% | 9% | 42% | 45% | 0% |
| Artificial Insemination | 42% | 23% | 12% | 23% | 48% | 69% | 0% |
| Genetic Evaluation | 22% | 9% | 12% | 5% | 38% | 24% | 0% |
| Breeds with system of use specified | | | | | | | |
| Pure-breeding | 544 | 113 | 24 | 5 | 151 | 246 | 5 |
| Cross-breeding | 27% | 33% | 42% | 60% | 44% | 11% | 20% |
| Both | 25% | 36% | 17% | 20% | 16% | 26% | 0% |
| | 49% | 31% | 42% | 20% | 40% | 63% | 80% |

Regional averages calculated from information of the subsample countries Latin America and the Caribbean

2.2 Buffaloes

Only 41 Country Reports indicate that buffaloes are kept. Of these countries, 29 percent mention buffalo breeding as a priority (Table 60) and 22 percent have breeding programmes (Table 61). In Asia, the main buffalo rearing region, the figures are 44 percent and 38 percent, respectively. The main countries with breeding programmes for buffaloes are India, Pakistan, China, Egypt and Bulgaria, with milk yield being the main breeding objective.

2.3 Sheep and goats

Breeding programmes for sheep and goats are much less frequently seen as a priority than programmes for cattle. Breeding activities for sheep and goats are considered important by 39 percent and 31 percent, of countries respectively (Table 60). Thirty-three percent and 27 percent of countries actually have such programmes (Table 61). After Europe and the Caucasus, the largest number of countries with breeding programmes for small ruminants is found in Asia. The interest in breeding programmes for small ruminants in African countries is low, and only four countries have such programmes. Interest and implementation is also low in the countries of Latin America and the Caribbean. Information from the 70 subsample countries indicates that breeding goals and breeding strategies are developed for a larger proportion of sheep than goat breeds (see Annex Tables 68 and 69 for data from the different regions). Few countries report specific breeding objectives for small ruminants, but growth traits appear to have the greatest importance. Wool quality and production traits are decreasing in importance even in countries with sheep specialized for wool production. Improving dairy characters is the main breeding objective for goats in European countries.

2.4 Pigs

Pig breeding is considered a priority in 44 countries (33 percent, Table 60), but only 36 countries (27 percent) report the existence of structured breeding programmes (Table 61), and only 10 of these countries are outside Europe and the Caucasus or North America. The discrepancy between the expression of priority and the actual existence of breeding programmes is, thus, much smaller than for cattle but similar to that for small ruminants. Several Country Reports from Latin America and the Southwest Pacific indicate that genetic improvement of pig populations largely depends on the import of animals or semen. Systematic cross-breeding programmes, mainly involving three-breed crosses, have become the standard in nearly all countries with advanced pig production – 34 Country Reports indicate the existence of such systems. Among the 70 subsample countries, the number of pig breeds reported is much smaller than the number of cattle or small ruminant breeds (Annex Table 70). Breeding goals and breeding strategies have been specified for 35 percent and 30 percent of the breeds, respectively, but the proportion is more than twice as high in Europe and the Caucasus as in the other regions. The number of specific local breeds reported is much smaller than for ruminants, while a few international breeds such as Landrace, Large White, Duroc, Hampshire and Yorkshire have a very wide distribution. Important objectives of the reported breeding programmes include fertility, feed conversion rate, and proportion of lean meat production. According to many Country Reports, pigs of the lard type have largely lost their former importance.

2.5 Poultry

Of all the major livestock species, chickens have the lowest number of countries indicating that breeding programmes are a priority (Table 60), and the lowest number of countries having such programmes (Table 61). Chicken breeding activities, both for layer and broiler breeds, are largely carried out by a few transnational breeding companies, which market their products worldwide. Very few countries report structured breeding activities for other poultry species such as turkeys (five countries), ducks (eight countries) and geese (four countries). The low importance of chicken breeding programmes in most countries is reflected by a low proportion of breeds with a specific breeding goal (13 percent) and breeding strategy (11 percent). The proportion of breeds with breeding strategies is

larger in Europe and the Caucasus than in the other regions (Annex Table 71). The Country Reports provide no specific information about breeding objectives for poultry.

2.6 Other species

Systematic breeding programmes for horses are mentioned in 31 Country Reports (Annex Table 72). This may not reflect the full extent of planned breeding activities for horses, especially those that are maintained for sports and racing. Horse breeding is characterized by a significant international exchange of breeding material. In most European countries, the majority of horses are now bred for the leisure activities of amateur riders. Other reasons for keeping horses are meat production and work – especially cattle herding in South America which utilizes large numbers of horses. Among the 44 countries that report the keeping of camelids, two countries in Asia have breeding programmes for dromedaries, and Argentina has a programme for llamas. Among 108 countries that mention rabbit production in their Country Reports, 26 have significant production, but only five mention systematic breeding programmes. This figure does not include the large number of organized hobby breeders of rabbits, found particularly in Europe and the Caucasus.

It is reasonable to assume that the majority of countries that do not report the importance or existence of breeding programmes for a given species in their Country Reports do not have such programmes. Moreover, there are also many indications that the population involved in most existing breeding programmes in African and Asian countries is rather small. The results of the review, thus, indicate that except for cattle, the majority of countries do not have their own structured breeding programmes and do not yet consider them a priority.

3 Organizational structures

Structured breeding programmes require organization to enable systematic performance recording, planned mating and genetic evaluation. These activities are carried out through government and non-governmental structures or a combination of the two. Breeding programmes that are directly implemented by government institutions include those carried out on state breeding farms and at research institutes and universities. Non-governmental stakeholders that implement breeding programmes include breeding organizations and private companies.

The majority of systematic breeding activities for cattle and small ruminants in the countries of Africa, Asia, and the Near and Middle East are implemented by government institutions, while in western Europe, breeding organizations have the greatest importance (for details see Annex Tables 73 to 76). Most of the government breeding programmes in Africa, Asia, and the Near and Middle East are carried out through nucleus herds/flocks on state farms. The animals and semen produced are then distributed to the general population. There is, therefore, no active participation by the livestock keepers in the breeding process. These programmes are often implemented with no monitoring of the influence of the breeding activities on the general livestock population. Only a few countries in these regions have government breeding programmes that involve the direct participation of the breeders. Examples include buffalo breeding programmes in India and Pakistan, and sheep breeding programmes in Tunisia and Côte d'Ivoire.

Joint implementation of breeding programmes by the governmental and non-governmental sectors often indicates a transitional phase from government breeding programmes to an increased involvement of private breeders and breeding organizations. The Country Reports show that efforts to establish breeding organizations for cattle are considered important in many countries, but other species are given less priority (Table 63). Such developments are taking place in a few African and Asian countries, and particularly in the former centrally planned countries of eastern Europe. It seems likely that in countries whose reports do not indicate the organizational structures of their breeding programmes, governmental and non-governmental institutions have shared responsibilities. Direct involvement of government institutions in breeding programmes has been systematically reduced in most western European countries, and no longer exists in North America. Active participation of individual breeders is an important characteristic of the programmes in these regions. Private breeding

programmes (both through breeding organizations and companies) are highly developed for pigs. In poultry, a few transnational companies have a dominating role.

Table 63
Training, research and farmers' organizations in current policies

| | Africa | | Asia | | Near & Middle East | | Europe & the Caucasus | | Total | |
|--------------------------------|--------|------------|------|------------|--------------------|------------|-----------------------|------------|-------|------------|
| | n | Score | n | Score | n | Score | n | Score | n | Score |
| Training & Research | | | | | | | | | | |
| Cattle | 21 | 3.4 | 7 | 3.6 | 3 | 2.7 | 15 | 3.5 | 46 | 3.4 |
| Sheep | 21 | 3.2 | 7 | 2.3 | 4 | 2.8 | 16 | 3.3 | 48 | 3.1 |
| Goats | 20 | 3.1 | 7 | 2.4 | 4 | 2.3 | 16 | 2.5 | 47 | 2.7 |
| Pigs | 19 | 3.0 | 5 | 2.6 | | | 14 | 3.3 | 38 | 3.1 |
| Chickens | 21 | 3.2 | 7 | 2.7 | 5 | 2.4 | 15 | 3.0 | 48 | 3.0 |
| Organizing Farmers | | | | | | | | | | |
| Cattle | 21 | 3.1 | 7 | 3.4 | 3 | 2.3 | 15 | 3.2 | 46 | 3.1 |
| Sheep | 21 | 2.8 | 6 | 1.8 | 4 | 2.5 | 16 | 3.2 | 48 | 2.8 |
| Goats | 20 | 2.7 | 6 | 2.0 | 4 | 2.0 | 16 | 2.7 | 46 | 2.5 |
| Pigs | 19 | 3.0 | 4 | 2.8 | | | 14 | 3.1 | 37 | 3.0 |
| Chickens | 21 | 3.1 | 6 | 3.0 | 5 | 3.2 | 14 | 3.1 | 46 | 3.1 |

n: Number of countries reporting and average scores for regions.

Scores (1 = none, 2 = little, 3 = regular, 4 = more, 5 = high) indicate the importance given to the activity in current policies.

Highest scores for each region are shown in bold.

Breeding programmes in South America are largely implemented by breeding organizations, but are supported in several countries by government agencies or research institutes. In addition to breeding organizations that implement systematic breeding programmes, most South and Central American countries have a large number of breeders' organizations. These breeders' organizations, especially for cattle and horses, register pedigree information for animals of specific breeds, but systematic performance recording and genetic evaluation is rare.

The involvement of the different stakeholders (government, breeders and research) in breeding activities is an important indicator for the characterization of breeding programmes. Table 64 summarizes information provided by the 70 subsample countries (note that these include no countries from Latin America and the Caribbean, or the Southwest Pacific, as no countries from these regions utilized the relevant pre-defined tables). In all regions except western parts of Europe and the Caucasus, breeding goals are largely determined by research institutions and their staff, to a lesser extent by government institutions, and only marginally by the breeders themselves. Similar circumstances are reported for other aspects of breed development such as individual identification, recording and genetic evaluation (Table 64). In particular, breeders in the countries of Africa and the Near and Middle East appear to have a limited role in influencing breeding activities organized and implemented by government institutions. In combination with a lack of follow-up activities, this lack of participation by the livestock keepers means that there is considerable risk that breeding efforts will have limited success or even fail.

Table 64
Stakeholder involvement in the development of animal genetic resources

| | Total | Africa | Asia | Near & Middle East | Europe & the Caucasus |
|---------------------------|------------|------------|------------|--------------------|-----------------------|
| Breeding Goals | 48 | 21 | 7 | 4 | 16 |
| Governments | 3.0 | 3.1 | 3.1 | 3.0 | 2.8 |
| Breeders | 2.4 | 1.9 | 2.4 | 1.5 | 3.2 |
| Research | 3.4 | 3.3 | 3.4 | 3.0 | 3.6 |
| NGOs | 2.2 | 1.9 | 1.8 | 3.0 | 2.6 |
| Individual Identification | 45 | 19 | 6 | 4 | 16 |
| Governments | 2.7 | 2.2 | 3.0 | 1.8 | 3.4 |
| Breeders | 2.4 | 1.9 | 2.3 | 1.3 | 3.4 |
| Research | 2.8 | 3.1 | 3.0 | 1.8 | 2.8 |
| NGOs | 1.8 | 1.7 | 1.4 | 1.7 | 2.0 |
| Recording | 48 | 21 | 6 | 4 | 17 |
| Governments | 2.5 | 2.3 | 2.8 | 1.8 | 2.9 |
| Breeders | 2.6 | 2.0 | 2.8 | 1.5 | 3.5 |
| Research | 3.0 | 3.4 | 2.7 | 1.5 | 2.8 |
| NGOs | 2.0 | 2.1 | 1.6 | 2.3 | 2.0 |
| Genetic Evaluation | 45 | 17 | 7 | 4 | 17 |
| Governments | 2.1 | 1.8 | 2.6 | 1.3 | 2.4 |
| Breeders | 1.8 | 1.4 | 1.4 | 1.0 | 2.5 |
| Research | 3.1 | 2.7 | 3.1 | 2.0 | 3.8 |
| NGOs | 1.6 | 1.3 | 1.8 | 1.3 | 1.9 |

n: Number of countries reporting and average scores for regions

Scores (1 = none, 2 = little, 3 = regular, 4 = more, 5 = high) based on thorough analyses of data available, to indicate the role of involvement of each stakeholder on the implementation of tools that support the development of animal genetic resources. Highest scores for each region are shown in bold.

For all species, but most frequently for small ruminants and poultry, breeding activities are also implemented by national and international NGOs. These activities often consist of the distribution of small numbers of breeding stock, frequently of exotic breeds to “upgrade” the local population. No systematic information is provided in most County Reports about the impacts of these initiatives, but there are indications that they are not significant. Exceptions are probably the large-scale implementation of AI programmes for cattle and buffaloes by NGOs in the countries of South Asia.

In countries with active breeding programmes, international competition is leading to concentration in fewer, bigger schemes, with fewer breeding organizations. This process is most advanced for the poultry industry, but is also occurring in dairy cattle and pig breeding. To compete in the international market, Scandinavian countries have developed joint breeding activities, and Germany and Austria jointly implement the estimation of breeding values for dairy cattle. The standardization of international genetic evaluations for cattle through the International Bull Evaluation Service (INTERBULL) is also promoting the implementation of breeding programmes beyond national borders. Genetic improvement of pigs and Holstein-Friesian dairy cattle in South and Central America is largely achieved through imports of semen from North America, or Europe and the Caucasus. There are concerns expressed in the Country Reports that the increased internationalization of dairy cattle breeding may lead to negative effects with regard to the adaptation of the cattle population to the specific local conditions.

4 Tools and implementation

Collection of performance data, analysis of the data for the identification of superior animals, and use of these superior animals to produce the next generation, are the main components of structured breeding programmes. Among the countries with structured breeding programmes, and among the different species, the scale and use of these tools varies significantly. With the exception of a few Latin American countries (Argentina, Brazil, the Bolivarian Republic of Venezuela and Mexico) and India, the large-scale collection of performance data from individual livestock owners for breeding

purposes is largely restricted to Europe, North America and Australia.⁷ On a smaller scale, collection of performance data from individual small ruminant flocks is carried out in some North and West African countries.

Most Country Reports from Africa and Asia provide very limited information about the active breeding population. However, in addition to the small proportion of breeds included (Table 62, Annex Tables 68–71), the active breeding population is probably very small. The other extreme is represented by a country such as Norway, where more than 95 percent of all dairy cows are covered by a recording scheme.

While best linear unbiased prediction (BLUP) programmes for the estimation of breeding values are the standard for all countries with advanced breeding programmes, no information is provided in the Country Reports about selection methods used in the nucleus herds/flocks kept on governmental farms. Selection of animals by phenotypic characteristics probably still has an important role on these farms. Extensive datasets with BLUP “test day” models allow increasingly good prediction of breeding values in intensive dairy cattle breeding programmes.

Planned breeding requires controlled mating. As a large proportion of the grazing livestock in low and medium input production systems are kept under conditions of uncontrolled mating, planned breeding for these animals is difficult. Such systems are very common in African and Latin American countries. CR Ecuador (2003), for example, reports 49 percent uncontrolled mating for cattle, 81 percent for sheep, and 61 percent even for pigs. In addition to the use of improved males, AI is used in many countries as a tool for controlled mating. One-hundred and fourteen countries (77 percent) reported the use of AI in cattle, 18 percent in sheep, 7 percent in goats and 32 percent in pigs. Use of AI in cattle is common in all regions, for the other species it is more common in Europe and the Caucasus, and the Americas (Table 65). The greater importance of AI for cattle is also reflected by a higher proportion of breeds included in the programmes (Table 62, Annex Tables 68–71) and the number of inseminations performed. By all these criteria, AI for pigs has the second highest importance. Both locally produced and imported semen is used for AI. The high proportion of cattle breeds used in cross-breeding schemes (Table 62) may indicate that a considerable amount of the semen used in countries without advanced breeding programmes is imported or from exotic breeds. In Latin America, AI of pigs also relies largely on imported semen.

Table 65
Number of countries reporting the use of artificial insemination

| Regions | Cattle | Sheep | Goats | Pigs |
|-------------------------------|--------|-------|-------|------|
| Africa | 31 | 2 | 1 | 1 |
| Asia | 17 | 4 | 2 | 8 |
| Near & Middle East | 4 | 0 | 0 | 0 |
| Europe & the Caucasus | 38 | 16 | 8 | 23 |
| Latin America & the Caribbean | 21 | 8 | 8 | 13 |
| – Caribbean & Central America | 11 | 2 | 4 | 7 |
| – South America | 10 | 6 | 4 | 6 |
| North America | 2 | 0 | 1 | 1 |
| Southwest Pacific | 5 | 1 | 1 | 4 |
| World | 118 | 31 | 21 | 50 |

Locally adapted and exotic breeds are used in both pure-breeding and cross-breeding systems. The information in Table 62 and Annex Tables 68–71 shows the relative importance of these two breeding systems for the different species, based on the data provided by the 70 subsample countries. Pure-breeding is the most common breeding system in sheep only, while for the other species, cross-breeding or a combination of both are more frequent. The tables also show that exotic breeds play a

⁷ New Zealand, another country with an important livestock industry and breeding programmes, did not submit a Country Report and is, thus, not included in the analysis.

significant role in many countries. Systematic cross-breeding programmes are common in advanced production systems for pigs and for beef cattle. A very large proportion of cross-breeding activities for all species in African, Asian and South American countries are, however, undertaken without a systematic programme.

The information in Table 66, based on the data provided by the 70 subsample countries, indicates that current government policies favour the use of locally adapted breeds for cattle and small ruminants, but exotic breeds for pigs and poultry. This situation clearly reflects the efforts to intensify pig and poultry production and the need for breeds with higher productive capacity. Efforts to increase dairy production make exotic cattle more popular in Asian countries than in Africa. The information provided by the subsample countries also shows that exotic breeds of sheep and goats are not considered a priority by most countries (Table 68).

Table 66
Importance of species and locally adapted versus exotic breeds in current policies

| | Africa | | Asia | | Near & Middle East | | Europe & the Caucasus | | Total | |
|------------------------|--------|-------|------|-------|--------------------|-------|-----------------------|-------|-------|-------|
| | n | Score | n | Score | n | Score | n | Score | n | Score |
| Cattle | | | | | | | | | | |
| Locally adapted breeds | 21 | 3.9 | 7 | 3.1 | 3 | 2.0 | 14 | 3.5 | 45 | 3.5 |
| Exotic breeds | 21 | 3.1 | 7 | 3.7 | 3 | 3.0 | 15 | 2.4 | 46 | 3.0 |
| Sheep | | | | | | | | | | |
| Locally adapted breeds | 21 | 3.8 | 7 | 2.4 | 4 | 3.3 | 16 | 3.4 | 48 | 3.4 |
| Exotic breeds | 21 | 1.9 | 6 | 2.2 | 4 | 2.5 | 16 | 1.8 | 47 | 2.0 |
| Goats | | | | | | | | | | |
| Locally adapted breeds | 20 | 3.8 | 7 | 2.7 | 4 | 2.5 | 15 | 3.1 | 46 | 3.3 |
| Exotic breeds | 19 | 2.0 | 5 | 2.2 | 4 | 2.0 | 15 | 1.6 | 43 | 1.9 |
| Pigs | | | | | | | | | | |
| Locally adapted breeds | 19 | 3.4 | 5 | 2.2 | | | 13 | 2.8 | 37 | 3.0 |
| Exotic breeds | 18 | 3.2 | 4 | 4.3 | | | 14 | 2.9 | 36 | 3.2 |
| Chicken | | | | | | | | | | |
| Locally adapted breeds | 21 | 3.4 | 7 | 3.0 | 5 | 2.4 | 14 | 2.2 | 47 | 2.9 |
| Exotic breeds | 21 | 3.4 | 6 | 4.0 | 5 | 3.6 | 15 | 2.9 | 47 | 3.3 |

n = number of countries reporting; Score = average score for region

Scores (1 = none, 2 = little, 3 = regular, 4 = more, 5 = high) indicate the extent to which current policies support the use and development of the respective AnGR.

While several countries encourage the use of certain species and breeds through support and development efforts, direct influence on the choice of breed or breeding system being used by the livestock owners is rare. In most countries, there are government regulations that control the import of semen and animals, including breeding stock, for animal health reasons. Requirements for direct approval by the authorities and specific quality criteria for male breeding stock exist only in a few European countries. In order to conserve and protect specific local dairy breeds, regulations were issued in India and Pakistan which should have prevented cross-breeding with exotic cattle breeds. However, in practice these regulations could not be enforced.

5 Overview of breeding programmes by region

In most countries, production conditions and demands for livestock products have changed considerably during recent decades – accelerated by increasing urbanization. Depending on the type of country, these developments comprise increased demand, changing demands with respect to product quality, and shifts in demand between different livestock products. In different countries, government authorities, breeding organizations and livestock owners have reacted in different ways to these changes and challenges. The ways in which breeding interventions have contributed to the change also show considerable variation between countries, regions and species. This variation is highlighted in the following regional reviews.

5.1 Africa

Cattle are the most important livestock species in Africa, and 45 percent of countries expressed the need for intensification as their priority policy. To achieve this target, 26 percent of countries favour breed improvements for local breeds, 55 percent favour cross-breeding with exotic cattle, and 17 percent favour direct introduction of exotic cattle. These figures are also an indication of the nature of past and ongoing breeding efforts.

Development of local breeds is mentioned as a priority only by West African countries, while introduction of exotic cattle is mentioned by North African countries. The popularity of local breeds in West Africa is largely influenced by efforts to breed, improve, and in several countries to introduce, the trypanotolerant N'Dama breed. In order to improve production, however, farmers increasingly cross N'Dama with Zebu breeds or even with Holstein-Friesians. The establishment of peri-urban dairy production has led to the introduction of Holstein-Friesian cattle or their cross-breeds in many African countries. Several other exotic breeds have been tried in Africa, but among these only the Brown Swiss (in North Africa) has remained of any significance. In a large number of African countries, local cattle are kept on government stations, and breeding stock distributed to livestock owners. The Country Reports indicate that the number of breeding stock distributed is probably small and without significant effect on the general population. Government cross-breeding efforts in the countries surveyed have had almost no success in the development of specific new breeds. Lack of organizational structures and the nature of the production and breeding systems, have favoured unsystematic cross-breeding as the most common means of genetic improvement.

Box 24

Research and breed development in Africa

In Nigeria, a lot of investment was, in the past, made in the import and use of exotic AnGR for research purposes and for breed improvement, especially on government farms. The results of these initiatives have been mixed. In terms of research, the results have been positive but in terms of breed improvement there have been no significant gains.

Similarly in Ghana, exotic cattle such as Friesians, and Sahiwal were imported from Europe and India, respectively; and breeds such as N'Dama, White Fulani and Adamawa Gudali were imported from within the West Africa subregion. Various crosses were made with the West African Shorthorn. The Ghana Sanga is the only successful breed developed from the programme. The University of Ghana undertook cross-breeding of Sokoto Gudali and Ghana Shorthorn with Jersey and later with Friesian cattle to develop a milking animal. Most of the breeding programmes were hampered by lack of human resource, finance, disease outbreaks and other logistical problems.

In Côte d'Ivoire, cross-breeding between N'dama and Jersey started at the Centre de Recherches Zootechniques de Bingerville in 1962 and continued for 15 years. The objective of the work was to create a dairy breed adapted to the climatic conditions and husbandry in Côte d'Ivoire. No testing of the cross-breeding concept under farm conditions had been initiated when the programme was terminated due to financial problems in 1977.

Source: CR Côte d'Ivoire (2003); CR Ghana (2003); CR Nigeria (2004)

Intensification of sheep production is seen as a priority by only 19 percent of African countries. The figure for goat production is even lower, at 10 percent. Improvement of local sheep breeds is considered as important by 10 percent of countries and of local goat breeds by 5 percent. Seventeen percent of countries favour cross-breeding for both species. Successful breed developments among farmers' flocks have been implemented in some countries of North Africa.

Box 25**Sheep breeding in Tunisia**

In Tunisia, a national programme for the genetic improvement of sheep is implemented through 236 selected flocks. The growth performance of lambs is monitored through a process of six weighings, which form the basis for the selection of future breeding stock. This programme is entirely financed by the state, but proposals have been made to reduce costs and increase the involvement of the sheep owners through the establishment of breeders' associations. The present model of genetic evaluation is uniform and offers no choice to the stockbreeders – although they operate under varying production conditions and have varying production objectives. The large number of weighings is also a burden for the breeders. More flexibility and cooperation with the breeders has the potential to reduce costs, and increase the capacity and efficiency of the programme.

Source: CR Tunisia (2003)

An open nucleus breeding scheme with Djallonké sheep in Côte d'Ivoire has encouraged several similar schemes in other West African countries, but most have not been realized. Maintaining a relatively pure Merino breed for wool production has been a government priority in Lesotho, but enforcement of this policy has been weak. Dorper sheep have been introduced for cross-breeding with local sheep in several countries, but cross-breeding for sheep has not, overall, achieved the same importance as for cattle. The same applies in the case of goats, in which cross-breeding with European dairy breeds has not proved to be successful, and has recently been replaced by cross-breeding with the Boer breed for meat production. Some African countries keep local breeds of small ruminants on government stations, but as in the case of cattle, there is little influence on the general livestock population.

Intensification of chicken production is considered a priority by 36 percent of African countries and intensification of pig production by 17 percent. No recent breeding efforts for chickens are reported, and in most countries intensification relies on imported commercial hybrids. Intensification of pig production is largely done through cross-breeding with exotic breeds, or through direct use of these breeds in more intensive production systems. No breeding programmes for local pigs are reported from African countries.

5.2 Asia

In Asia, 56 percent of countries express the need for intensification of cattle production as their priority policy, with the same percentage favouring cross-breeding with exotic breeds, and 20 favouring direct introduction of exotic cattle. In fact, both approaches have been followed on a large scale. Extensive cross-breeding with exotic breeds, primarily Holstein-Friesians, has occurred in the Islamic Republic of Iran and the countries of South Asia, while the direct introduction of large numbers of exotic cattle has been the chosen approach in countries with newly developing dairy industries in Southeast and East Asia. CR Islamic Republic of Iran (2004) reflects these changes, and indicates an increase in the proportion of cross-bred cattle in the country from 11 percent to 35 percent during the period 1995 to 2003. In Central Asian countries, the change of ownership from government and cooperative farms to individual owners has caused a reduction in animal numbers, and has prevented systematic breeding efforts.

Box 26**Buffalo breeding in India**

In India, buffaloes are becoming the species of choice among large ruminants, favoured by price incentives for milk with higher fat content. The recommended state development policy was laid down in the mid-1960s and envisaged selective breeding of Murrah buffaloes, and the use of Murrah to grade up non-descript buffaloes. Central and state governments and the private sector have established 33 breeding farms in different parts of the country, which follow a scientific breeding policy and act as multiplication centres for production and dissemination of superior bulls. Progeny testing schemes have been initiated in institutional herds and among farmers to test superior Murrah and Surti bulls on the basis of the performance of their progeny rather than only on the basis of the dam's yield. Field progeny testing programmes supported by the government, cooperative dairies, research institutes and NGOs, however, lack the necessary performance recording. Most ongoing progeny testing programmes are, therefore, dependent on institutional herds, and exclude good animals kept by the farming community. The number of bulls tested and selected is also too small to make any appreciable impact on genetic improvement.

Source: CR India (2004)

The development of local breeds through pure-breeding is considered important for buffaloes, but not for cattle. Both cattle and buffaloes are still important for draught purposes, for which local breeds are utilized. In most Asian countries, dairy production is developing as the main purpose of cattle production. Cross-breeding with specialized beef cattle breeds has been carried out in Southeast Asian countries, especially for plantation grazing systems. Several Asian countries have established systematic breeding programmes either on government farms, or directly with livestock owners, both for introduced specialized dairy breeds and for new composite dairy breeds. However, the number of bulls selected through progeny testing is often small, and the import of semen is, therefore, important in many Asian countries. Examples of systematic efforts to develop composite breeds include the Sunandini in India and the Mafriwal in Malaysia. Active promotion of the general infrastructure for cattle development, including marketing facilities, has had a positive effect on breed development efforts.

The importance of sheep and goat production varies greatly between the different parts of the region. Sheep production is important in some countries of Central and South Asia, but overall more countries consider intensification important for goat production (12 percent) than for sheep production (4 percent). Substantial efforts were made to develop fine wool production by crossing local breeds with Merino-type sheep in Central Asian countries, India and Pakistan. However, poor demand for wool and the problems involved in producing sufficient quantities of good quality wool contributed to the limited success of these efforts and the return of livestock owners to their traditional breeds. In other Asian countries, breeding efforts for sheep production have also lacked success, which may explain the low priority given to future intensification of sheep production. Indian and European goat breeds have been utilized in Southeast Asian countries for cross-breeding with the local population and new composite breeds have been established in Malaysia and the Republic of Korea. In the latter country, extensive cross-breeding work was done with Boer and Australian Feral goats for increased meat production. Although local goat breeds are maintained in various Asian countries on government farms, no specific breed development activities are mentioned in the Country Reports.

Box 27**Goat breeding in the Republic of Korea**

Goats have been well adapted to the Korean Peninsula for more than 700 years. In addition to normal consumption, goat meat has long been regarded as a health or medicinal food. With increasing demand for goat meat in the early 1990s, Boer and Australian Feral goats were imported, and widely used for cross-breeding with the native Black Goats. Even though the Boer cross-breeds had a better growth rate than the native goats, they were not popular with the farmers because they did not have the same black coat colour as the local goats. This prompted the importation of goats from the Black Australian Feral breed, which has the same colour as the native animals. Saanen goats were also imported and widely distributed as a dairy breed, but competition from cow milk caused a drastic reduction of numbers. Recently, however, growing demand for goat milk has again led to the import of new breeding stock.

Source: CR Republic of Korea (2004)

Pigs are the most important livestock species in Southeast and East Asia, and poultry, especially chickens, are important throughout Asia. Intensification of chicken production is considered a priority by 48 percent of Asian countries, and of pig production by 29 percent. Breeding activities are largely focused on intensive production conditions, and include systematic cross-breeding programmes and the use of hybrids produced and marketed by commercial companies. The use of imported breeding stock is mentioned by all Asian countries that are interested in intensification as priority, and 14 percent mention cross-breeding as the preferred approach. In China and Viet Nam, the biggest pig producers, breeding activities are carried out through governmental nucleus breeding programmes, but both countries also import exotic breeding stock. While local pig breeds are still popular in Viet Nam, more than 50 percent of the population is already cross-bred, and the government is further promoting a “leanization programme” with exotic breeds. In India, China and Viet Nam, breeding stock for the intensive broiler and layer industry, and for duck production systems, is produced by government institutions and independent private companies. However, the countries’ markets are also supplied by a small number of international breeding companies, which in other Asian countries have become the exclusive suppliers.

Box 28

Duck breeding in Viet Nam

Viet Nam has the second largest duck population in the world. There are eight local duck breeds and an equal number of breeds have been introduced from other countries for pure-breeding and cross-breeding. Duck breeding is organized by the National Institute for Animal Husbandry through two duck breeding centres, which keep and develop grand-parent and parent stocks, and distribute breeding material to local producers. This pyramid breeding structure has significantly improved duck breeding in Viet Nam, and is considered as a model that can be applied to other livestock breeding systems in the country.

Source: CR Viet Nam (2003)

5.3 Europe and the Caucasus

Development of livestock production and breeding activities in western European countries are largely influenced by the Common Agricultural Policy (CAP) of the EU, which also determines the structure of breeding activities. These structures are also adopted by the new EU members in central Europe, and influence the non-EU countries in western Europe. Breeding structures in eastern European countries still largely reflect the state structures that existed under centrally planned economies – and in some cases reflect the collapse of these structures. In most western European countries, governments have withdrawn from active involvement in breeding activities and their role is now limited to the supervision of breeding organizations and companies. In eastern European countries, breeding activities are carried out through licensed “pedigree farms” – large state or former state farms, which are under the control of research or university institutes. A common market for semen and breeding stock leads to extensive trade and international competition between national breeding companies and breeding organizations. In addition to utilizing their own breeding stock, eastern European countries increasingly import semen and breeding stock.

Cattle breeding has come to focus on single-purpose breeds, with the Holstein-Friesian being the dominant breed in most European countries. In parallel, beef production from suckler cows has developed, either utilizing specialized beef breeds or commercial cross-breeds from out of the dairy herds. Intensive breeding programmes using the BLUP procedure, and the wide use of a small number of elite dairy sires, have achieved significant genetic progress, but also risk increased inbreeding and a reduction in genetic diversity in the main cattle breeds. Regular monitoring of the degree of inbreeding has, therefore, been included in the breeding programmes of several countries. Difficulties in controlling the degree of inbreeding also exist in the case of rare breeds with small population sizes.

The number of breeding organizations is decreasing, while the average population size of the remaining ones increases. Governed by market forces, livestock breeding is undergoing a shift from national cooperatives to international companies. Livestock farmers choose breeding stock from these breeding programmes for the superior economic qualities of their products, leaving less opportunity for local breeding programmes. In addition to production characteristics, selection is now focusing on

a wider range of attributes, with health, well-being and life expectancy increasingly included in the breeding objectives. In the Nordic countries, specific importance is given to fertility traits, calving and disease resistance, with the Norwegian Red (NRF)⁸ and the Swedish Red and White breeds as particular examples. The specific breeding objectives implemented in the NRF have meant that breeders see semen from this breed as a viable alternative to that produced by the large, international breeding companies.

In Europe and the Caucasus, the breeding of small ruminants is generally less organized than that of cattle. The collapse of the wool market has redirected breeding objectives in all countries towards meat production through cross-breeding and breed substitution. Dairy performance is an important breeding objective for goats and some sheep in southern Europe. In many European countries sheep and goats are still kept by traditional farmers who do not participate in structured breeding activities.

The breeding of pigs and poultry in Europe and the Caucasus is dominated by the production of hybrids through systematic cross-breeding schemes.

Box 29

Pig breeding in Hungary

In Hungary, pig breeding is the most important branch of livestock breeding. Based on the local Hungarian Large White and Landrace breeds, together with some other imported breeds, Hungary was among the first countries in Europe to start the breeding of hybrids in the 1970s. Today, three Hungarian hybrids are recognized, have the highest share of the local market, and can compete with the best foreign hybrids. The old lard-type pig has been almost completely replaced – except for the Mangalitsa breed which has gained popularity and increased numbers because of the unsaturated fatty acids in its fat.

Source: CR Hungary (2003)

While in the pig sector, breeding organizations and commercial companies continue to compete, and have different market shares in different countries, poultry breeding (with the exception of some east European countries) is dominated by transnational companies.

Box 30

Horse breeding – tradition and new requirements

In the Czech Republic, the Old-Kladrubby horse is a warm-blood breed, based on old-Spanish and old-Italian blood, which has been bred in the country continuously for more than 400 years. In 1995 this breed was recognized as part of the Czech Republic's national cultural heritage.

In Poland, the horse population is gradually decreasing and their importance as a source of draught power in the fields has been substantially reduced. With the increased opportunities to export horses for slaughter, some farmers are changing to the heavy built, cold-blooded type. However, there is also a growing interest in horses of various breeds and types for recreational uses such as agro-tourism, cross-country rallies, riding holidays and “hippo therapy”.

Sources: CR Czech Republic (2003); CR Poland (2002)

5.4 Latin America and the Caribbean

As a result of the varying ecological conditions, the livestock production systems in the countries of South and Central America and the Caribbean are very diverse. Cattle have the greatest importance in most countries, but development efforts during the last decade have concentrated more on pig and poultry production, and the relative importance of cattle has declined in some countries. Brazil is by far the most important country for livestock development in the region, not only as the country with the biggest commercial cattle population, but also having several advanced breeding programmes that cover a large population. Breeding efforts for cattle are focused on beef production traits such as reproductive efficiency and growth rate – especially for the Nelore which is the dominant breed in the country. There are also efforts to improve dairy characteristics for some composite breeds and for Holstein-Friesians. Semen and breeding animals from the Brazilian programme are also utilized in

⁸ Norsk Rødt Fe

other South and Central American countries, but it is reported that intensive use of a limited number of elite sires risks a considerable reduction in genetic variability.

Active breeding programmes using BLUP animal models exist for Zebu cattle in the Bolivarian Republic of Venezuela, and for Holstein-Friesians in Argentina and Mexico. However, as most countries do not have their own breeding programme and semen production, imported semen from Holstein-Friesians and other European dairy and beef breeds is widely used in the region. In many countries, extensive cross-breeding with Zebu cattle is reducing the population of the local Criollo breeds. Unsystematic rotational crossing involving Zebu breeds such as the Brahman, and European beef breeds or Criollos, is also widely practised. Several composite dairy breeds have been developed in Brazil, Cuba and Jamaica. Many separate breeders' associations exist for all important breeds in most countries of the region. These associations keep pedigree registers often with a long tradition. Their involvement in modern breeding practices based on performance records is, however, less common.

Box 31

Beef cattle breeding in Brazil

Brazil at present has the largest commercial cattle population in the world. There are approximately sixteen breeding programmes for the beef sector, of which all but one are for Zebu cattle. Thirteen programmes for different breeds and groups of breeds have the objective of increasing reproductive efficiency and growth rate in beef herds using classical breeding techniques allied with modern biotechnologies. The top 20 percent of the animals receive a Special Certificate of Identification and Production (CEIP). The Breeding Programme for Zebu Cattle (PMGZ), run by the Brazilian Association of Zebu Breeders (ABCZ) identifies superior animals by calculating expected progeny differences (EPDs) for weight and weight gain at different ages, as well as fertility traits and reproductive efficiency. With a database of more than 1.5 million animals and 65 000 new animals entering each year, this is a national programme for all Zebu breeds. Another breeding programme for Zebu cattle is GENEPLUS, which has a database of more than 700 000 animals and provides breeders with EPDs for age at first calving, calving interval, gestation period, service period and scrotal circumference, as well as weights and weight gains at different ages. PROMEBO operates a programme for beef cattle of taurine breeds. With the aim of improving Zebu cattle, the ABCZ also collaborates with various research societies as well as a dozen universities, offering them production and genealogy data.

Source: CR Brazil (2003)

Utilizing genetic material from Australia and New Zealand, Argentina has a large wool breeding programme for Merino and Corriedale sheep, which is implemented by breeding organizations. In other countries of the region, structured breeding of sheep and goats largely consists of cross-breeding programmes with the introduction of various exotic breeds. The exotic sheep breeds being used are numerous and range, depending on the ecological conditions, from the Corriedale and Rambouillet breeds for the High Andes, to British meat breeds in Chile, and hair sheep such as Barbados Black Belly and Pelibüey in the tropical coastal regions. Breeding programmes for the latter two breeds are reported from their original locations in Barbados and Cuba. Cross-breeding programmes for sheep have largely been implemented by government or international development programmes. However, countries do not have planned breeding activities for Criollo sheep. Genetic development of goats through cross-breeding programmes is carried out with a variety of European dairy goat breeds (Saanen, Toggenburg, Alpine, Anglo Nubian) and Boer goats, and is frequently implemented by NGOs. Breeding of goats for dairy performance utilizing BLUP procedures has been carried out for a few years in one Mexican state.

Breeding development for pigs and poultry in Latin America and the Caribbean is mainly carried out by companies that produce hybrids. Use of imported semen and breeding stock from outside the region is widespread. In pigs, three-breed crosses are common under intensive production conditions. Cuba is an exception, and has government breeding programmes for both species. The region has large numbers of horses, and there are breeders' organizations for specific breeds in many countries. However, no details are provided in the Country Reports about their activities. Unique to the region are government breeding programmes for llamas in Argentina, and guinea pigs in Peru. Several countries expressed interest in promoting planned breed activities for fibre characteristics and meat production in South American camelids, but these have yet to materialize.

Box 32
Breeding llamas in Argentina

In Argentina there are approximately 200 000 llamas. Systematic breeding of llamas is carried out at the INTA (Instituto Nacional de Tecnología Agropecuaria) research station at Abra Pampa which keeps an elite flock of about 600 animals divided into of three groups having white, brown and mixed coat colours respectively. Selection of the white group is for fibre production and quality, of the brown group for meat and fibre production and of the mixed group for meat production only. Improved breeding stock has been distributed from the institute to approximately 2 700 breeders.

Source: CR Argentina (2003)

5.5 Near and Middle East

For the Near and Middle East, 43 percent of the countries submitting a Country Report indicate intensification of cattle and poultry production as their priority. Although an important sheep rearing region, no countries mention intensification of the species as a priority, and only 14 percent mention intensification of goat production as a priority. Cross-breeding of cattle and the use of exotic poultry are a priority for all intensification efforts, and 29 percent of countries regard the direct introduction of exotic cattle as a priority.

Large numbers of Holstein-Friesian cattle for dairy production have already been imported to the region and this process may continue. The further genetic development of these populations depends exclusively on the import of semen. Cross-breeding of local cattle using exotic semen is widespread, and is planned to continue, while no genetic improvement programmes are envisaged for the local cattle breeds. Genetic development of buffaloes is a priority for Egypt. Breeding activities for sheep and goats are reported from research institutes and government stations, but with limited impact on the general population. There are no ongoing or planned activities for poultry breed development in the region, and the poultry industry depends exclusively on material from transnational companies. Although their role is decreasing, camels are still important livestock in several countries of the Near and Middle East. Reference is made in the Country Reports to government breeding stations for camels, but no details about breeding objectives or the impact of these activities on the general population are provided.

5.6 North America and Southwest Pacific

Among the countries of the Southwest Pacific region that submitted Country Reports, only Australia has structured breeding activities. In the majority of the small island states of the region, pigs and poultry are the most important livestock species; genetic improvement is exclusively based on imports.

In Australia, Canada and the United States of America, breeding programmes are implemented for all species of livestock, and have gained worldwide importance through extensive exchange of semen and breeding stock. The programmes in these countries are implemented by breeding organizations and large companies, while government retains only a minor role. The animal breeding sectors in all three countries have responded very effectively to demands for increased production by applying selection pressure to certain high-yielding breeds. Pure-breeding for dairy cattle, and structured cross-breeding schemes for beef cattle, sheep and pigs, applied through highly effective programmes, are the most common breeding methods.

In the United States of America, selection for increased milk production is a priority for the dairy industry, but there is also a growing interest in multiple-trait selection for characters such as disease resistance or structural soundness. Intensive recording programmes and selection have been used to choose animals that produce the standard commodity in the most efficient manner in a largely controlled industrial environment. Selection intensity and reproductive technology have reduced genetic variation in the commercially viable breeds, and this has led to inbreeding problems. There is, therefore, an increasing interest in cross-breeding to alleviate inbreeding depression, and in ensuring a better match between genotypes and production systems, by using European breeds such as

Montbeliarde and Scandinavian Red. Among beef cattle in the United States of America, there is increased use of composite bulls that fit well into structured cross-breeding programmes.

Box 33

Influence of market forces on livestock breeding in the United States of America

In the United States of America, market forces are a major influence on the utilization and conservation of AnGR. In the industry, there is a continuing drive for product uniformity and production efficiency. As the sector has become more industrialized, there have been greater efforts to increase the uniformity and consistency of the products. Part of this process is the identification of breeds, lines and stocks that meet a pre-specified set of product quality and biological performance standards, which enable the industry to meet consumer demands and control production costs. This type of specialization has taken place most clearly in the poultry, pig and dairy industries. However, similar consolidation exists among sheep (the use of Suffolk and Rambouillet breeds) and beef cattle (Angus).

Source: CR United States of America (2003)

Box 34

Sheep breeding in Australia

In Australia, conventional non-quantitative techniques for sheep selection have been practised widely in the sheep industry since its inception. They include visual and tactile appraisal by professional sheep classers and “biological” selection approaches such as “Elite” and “Soft Rolling Skin”. Systematic cross-breeding, based on recognizable breed populations, is normal in the meat sheep industry and includes a range of rotational and terminal cross-breeding strategies. There is extensive performance recording and selection for those animals that most efficiently meet current market needs for carcasses and wool type. LAMBPLAN is Australia's major system for genetic evaluation in the sheep meat industry. The system is based on estimated breeding values calculated from performance and pedigree information collected from breeders' flocks. In the wool sheep industry implementation of genetic evaluation programmes is not as widespread, reflecting a range of sociological and political characteristics of the industry.

Source: CR Australia (2004)

Market pig production in the United States of America has moved from pure-bred systems, to rotational cross-breeding programmes, and now to terminal crossing programmes utilizing specialized maternal and paternal lines or crosses. Compounding the shift away from pure-bred animals has been the rapid adoption of AI in commercial pig production. In Canada, corporate control of pig breeding is increasing and breed populations are used extensively to create selected lines, either pure or composite. Corporate breeding also dominates poultry breeding in Australia, Canada and the United States of America.

6 Conclusions and future priorities

Although livestock owners practise breeding interventions in most production systems, there is considerable variation in the extent of control over this process and the degree to which genetic change takes place in a planned direction. Structured breeding interventions have contributed greatly to the development of livestock production systems and their adaptation to changing conditions. However, standardized production conditions have also increasingly led to the worldwide spread of a few specialized breeds, especially for poultry, pig and dairy cow production, rather than the development of a broad range of genetic material. In addition to their actual or assumed quality, the spread of the popular breeds and their use worldwide for cross-breeding is favoured by the easy availability and marketing of semen and breeding animals. While some countries, especially in Africa, consider this as a threat to their local breeds, many regard it as a means of enriching their livestock population.

The review of the Country Reports reveals large differences between countries and species with respect to planned breeding activities and their support with public funding. It is possible to differentiate the following three broad groups:

- countries that have a tradition of effective breeding programmes for several species and which increasingly transfer these activities to the private sector;

- countries that are in the process of establishing national breeding programmes for one or more species; and
- countries that largely rely on the import of semen and animals for the improvement of their genetic resources.

While the reproductive capacity of pigs and poultry allows the effective implementation of planned breeding programmes under controlled conditions by a small number of breeders or breeding companies within a short period of time, this is more difficult for cattle and small ruminants. In order to achieve a sufficient population size, effective breeding programmes for ruminants have, been based either on larger numbers of individual breeders or on large, often government-owned, nucleus farms. Restructuring in formerly centrally planned economies has reduced the opportunity for breeding based on large government farms. In many developing countries, limited interaction between breeders and ordinary livestock owners, and the priority given to research objectives, have reduced the efficiency and impact of the planned breeding programmes conducted on these farms. The emergence of successful breeding programmes implemented through the involvement of individual breeders in Europe and the Americas was possible because of:

- appropriate organizational structures and the direct involvement of the livestock owners;
- interest in improving the traits under selection and real benefits for breeders and the general population;
- government support and the existence of scientific tools and qualified staff; and
- the existence or development of markets for products (including processing and innovative products) and input supply.

The opportunity which now exists to implement breeding programmes through private organizations is a consequence of the structures that were developed earlier. Breeding is a complex “package” technology. Although it may not be necessary in other countries to repeat the long evolutionary process which led to the development of these breeding programmes, the above-mentioned components are still essential for success. Efforts to establish new breeding programmes have to consider these requirements and should include them. For the breeding of ruminants in particular, there is a need for organized involvement of the livestock owners in close collaboration with cooperative and private breeding organizations. As the genetic variation within livestock species is partly accounted for by differences between breeds and partly by differences among individuals within breeds, selection both between and within breeds has potential to contribute to development.

The full information needed to implement optimum procedures is unlikely to be available at the outset in most medium and low-input systems. This need not be a serious obstacle at the start of a development programme, but it is important to understand the development objectives, and from these to specify the correct breeding goals. Increased research to support breeding activities is required for many production situations, especially in developing countries. Close cooperation with development efforts is necessary to ensure that the use of the scarce resources available for research is clearly focused on the needs of the breeders, and that results are utilized for action. Moreover, no genetic improvement programme should be established in isolation from a broader attempt to improve other aspects of the production and marketing system.

Livestock enterprises are continuously developing, particularly towards increased scale and greater specialization. These developments will demand different breeds and crosses. Particularly in developed countries, consumer priorities and choices may have an important influence on future breeding goals. Genetic improvement efforts must constantly bear these possibilities in mind and not concentrate solely on breeding objectives focused on today’s problems.

The cost of breeding activities, competition, and the international availability of suitable breeding material, are important criteria to be considered when taking decisions regarding support and public funding for national breeding programmes. These decisions are not easy, as a logical and comprehensive approach to the economic evaluation of breeding programmes is still unavailable. Many governments have decided to rely on international genetic material for breed development,

especially in poultry and pigs. The information in the Country Reports clearly indicates that countries face problems in the organization and implementation of effective and efficient breeding programmes. This is particularly true for low and medium external input production systems, which are in most cases associated with locally adapted breeds with limited production output. It is unlikely that the private sector will contribute significantly to the cost of new national ruminant breeding programmes in developing countries, in particular for systems with limited potential for increased production. Such costs would have to be borne by national institutions. Cooperation in breeding activities between countries with similar production conditions, such as already happens in Europe and the Caucasus, is an opportunity to share costs and make breeding programmes more sustainable.

7 References

CR (Country name). year. *Country report on the state of animal genetic resources.* (available in DAD-IS library at <http://www.fao.org/dad-is/>)

8 Annex

Table 67

List of subsample countries that provided information in predefined tables

| Africa | Asia | Europe & the Caucasus |
|----------------------------------|----------------------------|---|
| Benin | Bangladesh | Albania |
| Botswana | Bhutan | Armenia |
| Burkina Faso | India | Austria |
| Burundi | Iran (Islamic Republic of) | Azerbaijan |
| Cameroon | Kyrgyzstan | Bulgaria |
| Cape Verde | Malaysia | Croatia |
| Chad | Nepal | Cyprus |
| Congo | Republic of Korea | Czech Republic |
| Côte d'Ivoire | Uzbekistan | Greece |
| Democratic Republic of the Congo | | Iceland |
| Equatorial Guinea | | Latvia |
| Ethiopia | | Moldova |
| Gabon | | Norway |
| Gambia | | Romania |
| Ghana | Near & Middle East | Serbia and Montenegro |
| Lesotho | Egypt | Slovakia |
| Madagascar | Iraq | Slovenia |
| Mali | Jordan | Sweden |
| Namibia | Syrian Arab Republic | Switzerland |
| Niger | | The former Yugoslav Republic of Macedonia |
| Nigeria | | Turkey |
| Sao Tome and Principe | | Ukraine |
| Senegal | | |
| Swaziland | | |
| Togo | | |
| United Republic of Tanzania | | |

These countries provided the data shown in Tables 63, 64 and 66

Table 68
Strategies and tools used in sheep breeding

| | World | Africa | Asia | Europe & the Caucasus | LAC* | Near & Middle East | Southwest Pacific |
|-------------------------------------|-------|--------|------|-----------------------|------|--------------------|-------------------|
| No. of countries | 64 | 24 | 8 | 21 | 7 | 3 | 1 |
| Total no. of breeds | | | | | | | |
| Local | 419 | 85 | 81 | 186 | 49 | 17 | 1 |
| Exotic | 214 | 31 | 16 | 105 | 53 | 8 | 1 |
| Breeds with | | | | | | | |
| Breeding Goal | 33% | 14% | 33% | 52% | 5% | 16% | 0% |
| Strategy Implemented | 31% | 9% | 33% | 50% | 5% | 8% | 0% |
| Individual Identification | 28% | 9% | 2% | 45% | 31% | 8% | 0% |
| Performance Recording | 25% | 8% | 2% | 45% | 14% | 8% | 0% |
| Artificial Insemination | 14% | 2% | 17% | 12% | 35% | 0% | 0% |
| Genetic Evaluation | 19% | 5% | 18% | 21% | 37% | 0% | 0% |
| Breeds with system of use specified | | | | | | | |
| Pure-breeding | 297 | 34 | 33 | 137 | 87 | 4 | 2 |
| Cross-breeding | 57% | 65% | 91% | 64% | 29% | 75% | 100% |
| Both | 16% | 15% | 0% | 7% | 36% | 25% | 0% |
| | 27% | 21% | 9% | 29% | 36% | 0% | 0% |

Regional averages calculated from information from the subsample countries

**Latin America and the Caribbean*

Table 69
Strategies and tools used in goat breeding

| | World | Africa | Asia | Europe & the Caucasus | LAC* | Near & Middle East | Southwest Pacific |
|-------------------------------------|-------|--------|------|-----------------------|------|--------------------|-------------------|
| No. of countries | 64 | 24 | 8 | 20 | 8 | 3 | 1 |
| Total no. of breeds | | | | | | | |
| Local | 219 | 62 | 42 | 57 | 46 | 11 | 1 |
| Exotic | 118 | 34 | 17 | 40 | 21 | 5 | 1 |
| Breeds with | | | | | | | |
| Breeding Goal | 19% | 21% | 12% | 28% | 12% | 13% | 0% |
| Strategy Implemented | 16% | 15% | 12% | 25% | 12% | 13% | 0% |
| Individual Identification | 21% | 18% | 3% | 33% | 27% | 6% | 0% |
| Performance Recording | 20% | 21% | 3% | 30% | 22% | 13% | 0% |
| Artificial Insemination | 10% | 5% | 3% | 5% | 31% | 0% | 0% |
| Genetic Evaluation | 13% | 16% | 3% | 10% | 27% | 0% | 0% |
| Breeds with system of use specified | | | | | | | |
| Pure-breeding | 139 | 46 | 14 | 35 | 38 | 4 | 2 |
| Cross-breeding | 36% | 30% | 64% | 54% | 13% | 50% | 50% |
| Both | 30% | 39% | 21% | 23% | 29% | 25% | 0% |
| | 35% | 30% | 14% | 23% | 58% | 25% | 50% |

Regional averages calculated from information of the subsample countries

**Latin America and the Caribbean*

Table 70
Strategies and tools used in pig breeding

| | World | Africa | Asia | Europe & the Caucasus | LAC* | Near & Middle East | Southwest Pacific |
|-------------------------------------|-------|--------|------|-----------------------|------|--------------------|-------------------|
| No. of countries | 59 | 23 | 7 | 19 | 7 | 1 | 2 |
| Total no. of breeds | | | | | | | |
| Local | 161 | 39 | 17 | 61 | 40 | 1 | 3 |
| Exotic | 170 | 41 | 14 | 73 | 30 | 0 | 12 |
| Breeds with | | | | | | | |
| Breeding Goal | 35% | 18% | 26% | 66% | 7% | 0% | 0% |
| Strategy Implemented | 30% | 8% | 26% | 60% | 7% | 0% | 0% |
| Individual Identification | 35% | 8% | 19% | 67% | 20% | 0% | 0% |
| Performance Recording | 34% | 9% | 19% | 68% | 10% | 0% | 0% |
| Artificial Insemination | 28% | 0% | 19% | 49% | 29% | 0% | 0% |
| Genetic Evaluation | 21% | 3% | 10% | 49% | 0% | 0% | 0% |
| Breeds with system of use specified | | | | | | | |
| | 245 | 40 | 9 | 121 | 61 | 0 | 14 |
| Pure-breeding | 18% | 18% | 67% | 22% | 8% | | 0% |
| Cross-breeding | 34% | 65% | 33% | 21% | 36% | | 43% |
| Both | 49% | 18% | 0% | 58% | 56% | | 57% |

Regional averages calculated from information of the subsample countries

**Latin America and the Caribbean*

Table 71
Strategies and tools used in chicken breeding

| | World | Africa | Asia | Europe & the Caucasus | LAC* | Near & Middle East | Southwest Pacific |
|-------------------------------------|-------|--------|------|-----------------------|------|--------------------|-------------------|
| No. of countries | 58 | 24 | 8 | 16 | 6 | 2 | 2 |
| Total no. of breeds | | | | | | | |
| Local | 360 | 68 | 56 | 139 | 73 | 21 | 3 |
| Exotic | 532 | 146 | 33 | 249 | 83 | 9 | 12 |
| Breeds with | | | | | | | |
| Breeding Goal | 13% | 2% | 20% | 22% | 0% | 13% | 0% |
| Strategy Implemented | 11% | 1% | 17% | 20% | 0% | 0% | 0% |
| Individual Identification | 7% | 1% | 6% | 15% | 0% | 0% | 0% |
| Performance Recording | 7% | 1% | 6% | 14% | 0% | 0% | 0% |
| Artificial Insemination | 1% | 0% | 0% | 3% | 0% | 0% | 0% |
| Genetic Evaluation | 6% | 2% | 6% | 10% | 0% | 7% | 0% |
| Breeds with system of use specified | | | | | | | |
| | 350 | 17 | 21 | 183 | 106 | 13 | 10 |
| Pure-breeding | 51% | 24% | 76% | 39% | 67% | 85% | 50% |
| Cross-breeding | 21% | 47% | 14% | 20% | 26% | 8% | 0% |
| Both | 27% | 29% | 10% | 41% | 8% | 8% | 50% |

Regional averages calculated from information of the subsample countries

**Latin America and the Caribbean*

Table 72
Countries reporting structured breeding activities in minor animal species

| Regions | Horses | Camels | Turkeys | Ducks | Geese | Rabbits |
|---|--------|--------|---------|-------|-------|---------|
| Africa | 1 | 0 | 0 | 0 | 0 | 0 |
| Asia | 3 | 2 | 0 | 4 | 0 | 0 |
| Near & Middle East | 1 | 0 | 0 | 0 | 0 | 0 |
| Europe & the Caucasus | 22 | 0 | 3 | 4 | 4 | 4 |
| Caribbean & Central America | 1 | 0 | 0 | 0 | 0 | 1 |
| South America | 2 | 1 | 0 | 0 | 0 | 0 |
| North America | 0 | 0 | 1 | 0 | 0 | 0 |
| Southwest Pacific | 1 | 0 | 1 | 0 | 0 | 0 |
| World | 31 | 3 | 5 | 8 | 4 | 5 |
| % of countries keeping the respective species | 25% | 7% | 5% | 7% | 5% | 5% |

Table 73
Stakeholder involvement in structured cattle breeding activities

| Regions | Government | Private | Both | Research | Not mentioned |
|-----------------------------|------------|---------|------|----------|---------------|
| Africa | 9 | 0 | 4 | 0 | 0 |
| Asia | 5 | 2 | 4 | 2 | 3 |
| Near & Middle East | 1 | 0 | 0 | 0 | 0 |
| Europe & the Caucasus | 3 | 16 | 9 | 1 | 2 |
| Caribbean & Central America | 1 | 1 | 0 | 0 | 0 |
| South America | 0 | 2 | 2 | 1 | 2 |
| North America | 0 | 2 | 0 | 0 | 0 |
| Southwest Pacific | 0 | 1 | 0 | 0 | 0 |
| World | 19 | 24 | 19 | 4 | 7 |
| % of all actors | 26% | 33% | 26% | 6% | 10% |

Table 74
Stakeholder involvement in structured sheep breeding activities

| Regions | Government | Private | Both | Research | Not mentioned |
|-----------------------------|------------|---------|------|----------|---------------|
| Africa | 3 | 0 | 1 | 0 | 0 |
| Asia | 6 | 0 | 0 | 0 | 1 |
| Near & Middle East | 3 | 0 | 0 | 1 | 0 |
| Europe & the Caucasus | 4 | 12 | 5 | 2 | 3 |
| Caribbean & Central America | 1 | 0 | 1 | 0 | 0 |
| South America | 0 | 0 | 0 | 1 | 2 |
| North America | 0 | 1 | 0 | 1 | 0 |
| Southwest Pacific | 1 | 1 | 0 | 0 | 0 |
| World | 18 | 14 | 7 | 5 | 6 |
| % of all actors | 36% | 28% | 14% | 10% | 12% |

Table 75
Stakeholder involvement in structured goat breeding activities

| Regions | Government | Private | Both | Research | Not mentioned |
|-----------------------------|------------|---------|------|----------|---------------|
| Africa | 2 | 0 | 0 | 1 | 1 |
| Asia | 4 | 2 | 0 | 0 | 3 |
| Near & Middle East | 2 | 0 | 0 | 1 | 0 |
| Europe & the Caucasus | 1 | 12 | 5 | 0 | 4 |
| Caribbean & Central America | 0 | 0 | 0 | 0 | 1 |
| South America | 0 | 0 | 0 | 1 | 0 |
| North America | 0 | 1 | 0 | 1 | 0 |
| Southwest Pacific | 0 | 0 | 0 | 0 | 0 |
| World | 9 | 15 | 5 | 4 | 9 |
| % of all actors | 21% | 36% | 12% | 10% | 21% |

Table 76
Stakeholder involvement in structured pig breeding activities

| Regions | Government | Private | Both | Research | Not mentioned |
|-----------------------------|------------|---------|------|----------|---------------|
| Africa | 1 | 0 | 0 | 0 | 1 |
| Asia | 1 | 0 | 1 | 0 | 2 |
| Near & Middle East | 0 | 0 | 0 | 0 | 0 |
| Europe & the Caucasus | 2 | 16 | 4 | 0 | 2 |
| Caribbean & Central America | 1 | 0 | 0 | 0 | 0 |
| South America | 0 | 1 | 0 | 0 | 0 |
| North America | 0 | 2 | 0 | 0 | 0 |
| Southwest Pacific | 0 | 2 | 0 | 0 | 0 |
| World | 5 | 21 | 5 | 0 | 5 |
| % of all actors | 14% | 58% | 14% | 0% | 14% |

SECTION C: CONSERVATION PROGRAMMES

1 Introduction

The SoW-AnGR reporting process has significantly contributed to increasing the awareness of threats to the diversity of AnGR and the need for their conservation. In many countries, it resulted in the approval of national strategies for the management of AnGR conservation programmes, and better coordination of the existing often scattered activities. In countries with weak involvement of the state, it led to the establishment of national bodies for AnGR conservation. The rationale for conservation varies among countries and regions. In some cases, commitment to the principles of the CBD represents the major driving force, while in other cases the prevailing motivation is awareness of the potential importance that breeds currently at risk may have for future production. In some countries, conservation of AnGR is carried out within broader programmes of rural development and environmental management. In the majority of European and in some Asian countries, conservation of AnGR is regarded as an aspect of safeguarding cultural heritage.

The significance of threats to AnGR, particularly of the pressure towards the intensification of livestock production, varies from region to region, as does the current state of genetic diversity, and the economic and social importance of livestock. From a global perspective, a lack of adequate conservation measures is generally of greatest concern when it occurs in situations where the threats of genetic erosion are great and where losses, if they occur, will have large impacts on the diversity of the world's AnGR and on the future socio-economic functions of livestock. Unfortunately, in many such locations, governments lack awareness of the threats and their potential effects.

The prospects for a breed depend to a great extent on its present and future function in livestock systems. As circumstances change, certain breeds are set aside and are faced with the danger of extinction unless action is taken. There are several reasons why the implementation of conservation measures for a particular breed might be considered important: genetic uniqueness; a high degree of endangerment; traits of economic or scientific importance (unique functional traits); and ecological, historical or cultural value (Oldenbroek, 1999). The reason for conservation will, to some extent, determine the effectiveness of the conservation measures. This section discusses conservation from the perspective of ensuring that between and within-breed diversity is maintained for future functional use.

The section⁹ draws on the information provided in the 148 Country Reports available by July 2005, in order to describe the state of conservation around the world. The analysis is presented on the basis of seven regions and six species. Where relevant, differences between subregions are presented, and the roles of different stakeholders are discussed.

Only a very few Country Reports provide information on the specific values of breeds included in conservation programmes, or present information on the pedigree of animals under conservation programmes, the number of males and females per generation, or on mating schemes at the species or

⁹ Notes on the analysis

The quantification and assessment of conservation programmes is hampered by the following factors, which make it difficult to formulate strong conclusions:

Not all countries use the same definition for local breeds (e.g. all breeds present, breeds originating from the country, or breeds adapted to the local conditions). Thus, the numbers presented for local breeds in conservation programmes have to be treated with caution, and this is the reason why the proportion of local breeds conserved was not calculated.

There is some inconsistency in the Country Reports regarding the definition of *in vivo* conservation programmes. Some countries consider that a breed is being conserved *in vivo* when it is kept by small holders or hobbyists, whereas other countries do not consider this type of activity to be a conservation programme.

Some countries classify the storage of semen stock at an AI centre as an *in vitro* conservation programme, while others consider that an *in vitro* conservation programme exists only if there is a separate genebank facility.

The data are extracted from individual Country Reports written between 2002 and 2005. In this period conservation programmes were under development in many countries. So, for some regions the state of conservation programmes will already have progressed since the analysis was carried out.

breed levels. Thus, the status of conservation is presented here mainly by showing the number of breeds and species indicated by the Country Reports to be included in conservation programmes.

Theoretically, three types of conservation measures can be implemented: *in situ* conservation, *ex situ in vivo* conservation and *ex situ in vitro* conservation (see Box 94 in Part 4 – Section F). In practice, the distinction between *in situ* conservation and *ex situ in vivo* conservation can be rather vague. In the Country Reports, the distinction is often not clear. Therefore, for the purposes of the quantitative analysis presented below, only two types of conservation will be distinguished: *in vivo* (including both *in situ* and *ex situ in vivo*) and *in vitro* (*ex situ*) conservation. Another problem relates to the difficulty of distinguishing *in situ* conservation from “sustainable utilization” (see Part 4 – Section 1 for a discussion of this issue). It is therefore possible that some of the examples of *in situ* conservation mentioned in the Country Reports would in fact be better described as instances of sustainable utilization of the breeds in question.

2 Global status

Fifty-two percent of Country Reports indicate the presence of *in vivo* conservation measures, while only 37 percent indicate the presence of *in vitro* conservation (Table 77).

Table 77
Number of countries with conservation programmes

| Region | Subregion | Number of Country Reports analysed | Number of countries with <i>in vivo</i> conservation | Number of countries with <i>in vitro</i> conservation |
|-------------------------------|-----------------|------------------------------------|--|---|
| Africa | East | 7 | 2 | 1 |
| | North + West | 24 | 10 | 4 |
| | Southern | 11 | 6 | 4 |
| | Subtotal | 42 | 18 | 9 |
| Asia | Central | 6 | 2 | 2 |
| | East | 4 | 3 | 3 |
| | South | 7 | 4 | 3 |
| | Southeast | 8 | 4 | 4 |
| | Subtotal | 25 | 13 | 12 |
| Europe & the Caucasus | | 39 | 33 | 25 |
| Latin America & the Caribbean | Caribbean | 3 | 0 | 0 |
| | South America | 10 | 5 | 5 |
| | Central America | 9 | 3 | 1 |
| | Subtotal | 22 | 8 | 6 |
| Near & Middle East | | 7 | 1 | 0 |
| North America | | 2 | 2 | 2 |
| Southwest Pacific | | 11 | 2 | 1 |
| | Total | 148 | 77 | 55 |

For *in vitro* conservation well-established genebanks are present in Japan, India, the Nordic countries, France, the Netherlands, Poland, the Czech Republic and Hungary. In some countries, the establishment of genebanks is planned: the United States of America, China, the Republic of Korea and Viet Nam. Semen is preserved from all the main species, and embryos of cattle, sheep and goats are also stored. Only a few genebanks store poultry and horse semen. Sometimes tissue DNA samples are also collected in the main species. Genebanks have been initiated by governments or NGOs supported by universities and research centres. In a number of countries the SoW-AnGR reporting process accelerated measures aimed at ensuring coordination among genebanks and the establishment of national databases. In developed countries, there is a strong collaboration between genebanks and the animal breeding industry and breeders’ associations with respect to the collection of genetic

material. In developing countries that implement *in vitro* conservation measures, activities are limited to storage of semen from some local cattle and sheep breeds at private or governmental institutions.

3 Stakeholders

The Country Reports indicate that many stakeholders are involved in conservation: national governments, institutes for research and education such as universities, NGOs and breeders' associations, farmers and pastoralists, part-time farmers and hobbyists, and breeding companies. This chapter provides a brief overview of the roles of the various stakeholders.

3.1 National governments

In countries where conservation programmes for AnGR are established, it is national governments that play the crucial initiating role. They provide the legal base for conservation programmes either under legislation relating to the protection of biodiversity or under legislation regulating the management of AnGR, livestock production and breeding. They are partners in the development of national strategies for the management of AnGR, and they also provide funding for implementing institutions, including partial funding of conservation activities carried out by NGOs.

In some African and Asian countries, national governments are involved in breeding activities, often with the aim of increasing national self-sufficiency in food of animal origin. In most cases they own nucleus farms, where local or exotic cattle are kept. These nucleus farms sell breeding stock (males) to improve populations owned by (often small) farmers. The system plays an important role in the conservation of the breeds in question. The farmers keep a large number of animals, and the nucleus farms take care of the genetic diversity of the populations.

Box 35

Mali – role of the government

In Mali, conservation activities have been initiated by the government on research stations and experimental farms. These actions have mainly involved Maure, Peul Soudanais, Peul Toronké and N'dama cattle breeds.

Source: CR Mali (2002)

In a number of European countries, government policies are increasingly focused on conservation and landscape enhancement in rural areas where the economic viability of farming is limited. These policies are supported by state funds and, in case of the EU, by communitary funds (see the discussion of Council Regulation (EC) No. 870/2004 in Section E: 3.2).

Grazing animals, particularly well-adapted breeds of sheep, cattle and horses play an important role in nature management. This role offers an excellent opportunity for the conservation of these species as large numbers of animals are potentially involved. In parts of Europe, governments are also motivated to maintain livestock breeds for socio-economic or cultural/historic reasons. There are many types of governmental institutions, including therapeutic farms, prisons, demonstration farms, farm parks and museums, at which local breeds may be kept. The number of animals conserved in such locations is generally low, leading to risks of inbreeding and random loss of alleles that have a low frequency in the population.

3.2 Universities and research institutes

Farms linked to universities and research institutes are often involved in selling breeding animals or conserving local breeds. They combine these activities with their primary tasks of educating students and carrying out research. Many universities and research institutes try to conserve locally developed breeds, which are no longer used by the industry. They pay a lot of attention to the maintenance of genetic diversity within these populations. However, their role is threatened by cuts in public funding.

3.3 Civil society organizations and breeders' associations

In many developed countries, NGOs conserve and stimulate the keeping of local breeds by (often part-time) farmers and hobbyists. These NGOs and their members play an important role in the conservation of local breeds of chickens, horses, sheep, goats and cattle. One of their objectives is to demonstrate the cultural and historic aspects of breeds for the purpose of education and recreation; another is to produce special products for niche markets. In general, their knowledge of conservation genetics is limited, and the participation of individual breeders in breeding and conservation programmes is often on a voluntary basis. As such, the activities of these organizations do not guarantee the conservation of genetic diversity for future commercial/productive use. However, in many countries (e.g. the Czech Republic) research institutions and universities provide expertise and professional support for conservation activities carried out by breed associations. In addition, national coordinating bodies, governmental inspections, and control of state subventions ensure adherence to national conservation plans.

3.4 Farmers

In Europe and in North America, some farmers target niche markets where they can sell speciality products from local breeds, often kept in natural environments. In these circumstances, the local breeds are often an integral part of the brand – this provides an opportunity for profitable production utilizing breeds that would otherwise be uneconomic. Strict regulation of food production and the associated high levels of investment required can, however, present hurdles to the profitable exploitation of niche markets. In many countries, farmers or farmers' organizations have become involved in organic production. In some cases, traditional breeds are favoured in organic systems because of their good adaptation to the management conditions, and for marketing reasons. Potential opportunities to export organic products are increasingly recognized in many eastern European countries. These developments stimulate interest in a range of traditional or locally adapted breeds, and create a base for breeding and *in vivo* conservation programmes.

In a number of African countries, the continued use of local AnGR within traditional low external input production systems is considered to be the form of conservation that best suits the local conditions, and avoids problems related to the lack of financial resources for other forms of conservation. Uncontrolled mating, changes to traditional production systems and indiscriminate cross-breeding are, however, among the significant risks in this form of conservation.

3.5 Part-time or hobby farmers

The number of part-time farmers and hobbyists keeping farm animals is increasing in the Europe and the Caucasus, North America and Southwest Pacific regions. Most livestock species except the pig are kept for hobby purposes. These hobbyists play an important role in the conservation of local breeds. However, conservation is not their major goal, and their knowledge of the genetic management of populations is rather limited. Conservation programmes performed by hobbyists require special attention from the responsible authorities to make them effective.

3.6 Breeding companies

In Europe, North America and Australia, pork production is highly industrialized and a few transnational breeding companies dominate production chains. These companies develop a few lines from a limited number of breeds which are then used globally. Frozen semen is used for the dissemination of genetic progress, and frozen semen and frozen embryos are used to transfer genetic material on an international scale. In the poultry industry, only three transnational companies are actively selling highly specialized hybrid layers and broilers at the global level. The number of these specialized chickens is increasing very quickly, mainly as the result of intensive marketing by the layer and broiler industries. Specialized dairy and beef breeding is also a transnational activity in which frozen semen and embryos are used to disseminate the genetic progress achieved in the countries and herds of origin. In the pig and poultry sectors, the top-ranking animals in the breeding

populations are owned by the large breeding companies. In genetic improvement programmes for the pure lines, attention is paid to the effective population size in order to avoid inbreeding. The companies do not want to limit their future scope for selective breeding. Genetic diversity within the breeds kept is therefore conserved within these programmes.

4 Conservation at species level – status and opportunities

Table 78 gives the number of breeds per species conserved *in vivo* and *in vitro* at the global level.

Table 78
Conservation activities at the global level

| Breeds | Cattle | Sheep | Goats | Pigs | Chicken | Horses |
|---------------------------|--------|-------|-------|------|---------|--------|
| Local | 897 | 995 | 512 | 541 | 1077 | 570 |
| Regional transboundary | 93 | 134 | 47 | 25 | 55 | 63 |
| Conserved <i>in vivo</i> | 324 | 261 | 109 | 120 | 194 | 149 |
| Conserved <i>in vitro</i> | 225 | 111 | 44 | 140 | 87 | 33 |

Regional transboundary breeds are defined as breeds that occur in more than one country but only within one region (see Part 1 – Section B). The countries will probably consider most of these breeds to be local breeds with regard to their origin, as they have a limited regional distribution and have been developed under specific environmental conditions. The number of conserved local breeds stated in the Country Reports, may therefore include regional transboundary breeds. More than one country within a region may conserve the same “local” breed. Thus, the number of distinct breeds conserved may be lower than the number given in the table, which was obtained by summing the number of local breeds conserved in each country. In some countries, even international transboundary breeds (see Part 1 – Section B) might have been counted as locals if they have been in the country for a long time and have adapted to the local conditions. For example, some West African countries consider their Jersey cattle introduced 100 years ago as adapted local breeds.

4.1 Cattle

For high-input systems, specialized breeds of dairy or beef cattle are developed through intense selection, and their genetic material is widely disseminated. Nucleus breeding has started in dairy cattle, but there are still a lot of dairy farmers who participate in breeding activities. On a global level, intense selection for a few production traits, and a large exchange of semen from the best bulls has led to low effective population sizes in the most popular dairy breeds – with a real risk of losing genetic diversity in these breeds. The problem can be avoided by better genetic management at the global level, or by the use of breeding goals with multiple objectives, such as are utilized in some Nordic dairy cattle populations – best illustrated and documented in the Norwegian Red Cattle (Box 83 in Part 4 – Section D).

In the dairy sector, the Holstein-Friesian breed dominates, and in the beef sector, French beef breeds are likely to obtain a similar position in the future. In many countries, these specialized breeds are used for upgrading to improve the performance of local breeds. Only in a few situations are stable cross-breeding systems developed, in which populations of the local breeds are used and conserved. In some countries, dual-purpose cattle breeds are used for organic farming, for emerging functions such as landscape and nature management, or are kept as suckler cows by hobbyists. In all regions, conservation programmes need to be developed for local cattle breeds and for multipurpose breeds that will no longer be used for their original functions (e.g. traction).

In the development and use of specialized breeds, artificial reproduction techniques in combination with cryostorage play an important role. The availability of this technology has created the option of cryoconservation, which has been widely used in the case of semen, and to a lesser extent in the case of embryos and oocytes. Relatively large numbers of cattle breeds are involved in *in vitro* conservation programmes. However, in Africa, Asia, Latin America and the Caribbean, the Near and Middle East and the Southwest Pacific, the development of cattle conservation programmes should be further encouraged, particularly in view of the high adaptation of local breeds to the low to medium external input production systems which prevail in these regions.

4.2 Sheep

In regions and countries with high external input livestock systems, such as Europe and the Caucasus, North America and Australia, the number of sheep has declined in recent years. Sheep wool now has a low economic value, and this is a threat to some breeds. In Europe, nature management is emerging as an important function for this species. This role offers an excellent opportunity for *in vivo* conservation, because of the large flocks required for these purposes.

In small-scale farming systems in Africa, Asia and the Near and Middle East, as well as in eastern parts of the Europe and the Caucasus region, sheep are still important for meat or milk production, and in some religions have a ceremonial function. These roles guarantee continued utilization of the species. Nonetheless, *in vivo* conservation programmes need to be developed in regions such as the Southwest Pacific and Central Asia, where there are major declines in sheep numbers, and in regions or subregions with a high diversity in their sheep populations, such as the Near and Middle East.

AI and freezing techniques for sheep genetic material are well developed, but are not widely used. Semen is stored only in the genebanks of developed countries as a means to protect AnGR against disasters such as major disease epidemics. *In vitro* conservation programmes with similar objectives should be established in developing countries.

4.3 Goats

The goat's importance in small scale farming systems for milk and meat production, and the wide variety of conditions under which it can be kept, guarantee continued utilization. In general, this species is not faced with very significant threats. As such, *in vivo* conservation activities targeting goats do not generally seem to be a particularly high priority. AI is only practised in a limited number of breeds, almost exclusively in developed countries. This is the reason why only a few breeds are preserved by *in vitro* methods. As a precautionary measure, *in vitro* conservation of goat genetic material should be given more attention globally.

4.4 Pigs

As discussed above, in Europe, North America and Australia pork production is dominated by a few transnational companies. As the breeding industry becomes more concentrated, many breeds and lines are taken out of production. In a number of regions including Europe and the Caucasus, Africa and North America, relatively few local pig breeds exist. Conversely, in East Asia there are many local pig breeds. The latter need careful monitoring, and may require additional attention in future conservation programmes because of the threat posed by the increased use of exotic breeds.

The speed of industrialization and specialization, in combination with the lack of opportunities for the *in vivo* conservation of pigs means that this species requires special attention in conservation programmes. Frozen semen is used for the dissemination of genetic progress, and frozen semen and frozen embryos are used for intercompany exchange of genetic material between populations present in different countries. These activities have created a base for *in vitro* conservation in pigs. In Europe and Asia, many of the lines and breeds that are set aside in breeding and cross-breeding programmes, are conserved *in vitro*. However, the status of conservation measures should be monitored in order to identify additional activities that may be required.

4.5 Chickens

In Europe and North America many universities and research institutes try to conserve locally developed (dual-purpose) breeds of chicken that are no longer used by the industry. Many universities have developed experimental lines for a variety of purposes. In many cases, the birds are now scheduled to be culled for budgetary reasons. In eastern Europe, many highly selected lines, bred in the period of the "cold war", are still in existence and should be considered for conservation. In some European countries, some small companies remain involved in the production of layers and broilers, but their number is rapidly declining. In developing countries, the role of chickens in small-scale

farming, and the preference of local people for meat from local birds will promote the continued use of many local breeds. In the developed world, many people keep chickens as a hobby, and this is an opportunity for *in vivo* conservation.

For chickens, *in vitro* conservation of semen is a recent development. Frozen semen from local breeds is stored only in a few Asian and European countries. In this species, *in vitro* conservation of local breeds, recently developed dual-purpose breeds, and lines which are set aside, should get a high priority at the global level. The spread of highly pathogenic avian influenza (HPAI) in 2005/2006 illustrates the risks for a species kept at high densities all over the world.

4.6 Horses

In the past, horses were mainly used for draught and transport. The mechanization of transportation, and later of agriculture, has meant that in many parts of the world horses are now bred almost entirely for leisure purposes and are mainly kept by hobbyists. Many breeds are used in several countries, but international breeding management is rarely reported. The only exceptions are the Icelandic Horse and the Friesian Horse, for which the Icelandic and the Dutch herd books, respectively, coordinate breeding activities and keep control of genetic diversity within the breeds.

The existence of a wide variety of leisure activities involving horses may stimulate the maintenance of genetic diversity within the species. In general, however, the genetic diversity within local horse populations is threatened by the wide use of a few popular stallions. “Heavy” (cold blood) breeds, originally bred for draught purposes, are often threatened; in some countries they are now kept only for meat production.

For horses, *in vitro* conservation of semen is a recent development. In a few countries, frozen semen from local breeds is stored. *In vitro* conservation of local “heavy” breeds should be treated as a priority.

5 *In vivo* and *in vitro* conservation programmes at regional level

5.1 Africa

A large part of the human population of Africa is poorly nourished, and self-sufficiency in food production is a major objective for many governments. Policies aimed at increasing food production, have encouraged local breeders to use exotic germplasm to replace local breeds (chickens), or for cross-breeding/upgrading (cattle and sheep). These activities are not accompanied by adequate breeding and conservation programmes, and threaten many local breeds. The expansion of high external input livestock systems using exotic breeds, along with the threats to local breeds posed by droughts, disease epidemics and political instability reinforce the need to implement *in vivo* and *in vitro* conservation on a wide scale as soon as possible. Achieving this, however, will require a greater awareness of the issue.

Eighteen out of the 42 Country Reports from Africa describe *in vivo* activities. In nearly all these countries the conservation activities are restricted to a few breeds in each species. The number of breeds conserved in goats, pigs, chickens and horses is very low (Table 79).

In comparison to other species, phenotypic and genetic characterization in cattle and sheep is relatively well documented in past and recent literature. For the other species, some phenotypic characterization of local breeds can be found in (historic) handbooks and in recently developed databases. Breeding theory is well developed in various institutes and universities. However, breeding and conservation programmes are difficult to perform, because of a lack of data on population sizes, identification systems and pedigree recording. The knowledge and skills required to implement such programmes are scarce, and the necessary infrastructure is not available. Some countries mention that *in vivo* conservation is performed by pastoralists and small-scale farmers who keep the breeds. However, it is doubtful whether it is really appropriate to describe these activities as conservation programmes.

Table 79
Conservation activities in Africa

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|-------------------------------|--------|-------|-------|------|----------|--------|
| East Africa | | | | | | |
| Local breeds | 59 | 30 | 35 | 2 | 14 | 4 |
| Conserved <i>in vivo</i> | 4 | 1 | 1 | 0 | 0 | 0 |
| Conserved <i>in vitro</i> | 0 | 0 | 0 | 0 | 0 | 0 |
| North+West Africa | | | | | | |
| Local breeds | 44 | 49 | 29 | 25 | 49 | 24 |
| Conserved <i>in vivo</i> | 27 | 10 | 6 | 4 | 0 | 3 |
| Conserved <i>in vitro</i> | 5 | 1 | 1 | 0 | 0 | 0 |
| Southern Africa | | | | | | |
| Local breeds | 51 | 30 | 22 | 22 | 26 | 8 |
| Conserved <i>in vivo</i> | 12 | 7 | 3 | 2 | 1 | 2 |
| Conserved <i>in vitro</i> | 6 | 0 | 0 | 0 | 0 | 0 |
| Total Africa | | | | | | |
| Local breeds | 154 | 109 | 86 | 49 | 89 | 36 |
| Regional transboundary breeds | 35 | 27 | 15 | 2 | 6 | 7 |
| Conserved <i>in vivo</i> | 43 | 18 | 10 | 6 | 1 | 3 |
| Conserved <i>in vitro</i> | 11 | 1 | 1 | 0 | 0 | 0 |

Refer to footnote under Table 78

Most of the programmes described in the Country Reports, include an important role for nucleus herds of local animals kept at governmental or institutional farms. These farms sell breeding material and are used to educate local farmers. None of the Country Reports document a well-established conservation plan.

Box 36

Ethiopia – *in situ* conservation

In Ethiopia, four cattle ranches and one sheep ranch are operating *in situ* conservation measures. The overall objectives of these ranches are the multiplication and cross-breeding of Boran, Horo, Fogera and Arsi cattle, and Menz sheep.

Source: CR Ethiopia (2004)

The analysis reveals major differences with respect to conservation activities between the three African subregions. Only 9 of the 42 Country Reports indicate the presence of *in vitro* activities (Table 77). In nearly all these countries the conservation activities are restricted to a few cattle breeds (Table 79). The knowledge necessary to implement such programmes is scarce, and the required infrastructure (e.g. liquid nitrogen facilities) is not available, or cannot be adequately maintained. *In vitro* activities are limited to the storage of semen from some local cattle breeds at private or governmental institutions. Some countries also mention the storage of semen from imported exotic breeds as a strategic activity. Tissue DNA of individuals from local breeds is preserved at a few research stations.

Box 37**Morocco's Plan Moutonnier – designated breeding areas to sustain local sheep breeds**

Morocco has made great efforts to establish sustainable management of its sheep genetic resources. An important development was the establishment in 1980 of a programme known as the Plan Moutonnier. The main element of the plan has been the partitioning of the country into zones according to the genetic resources present and nature of the agricultural systems. Each zone has its own set of rules regarding sheep breeding. In the “breeding zones” (zones berceaux de race) only the breed that has existed in the local area for many years is allowed to be kept. In the “cross-breeding zones” (zones de croisement) cross-breeding is permitted without restriction on the choice of breeds. Elsewhere, in the “traditional sheep breeding zones” (zones d'élevage traditionnel), several varieties of sheep are permitted with no specific breed predominating.

The breeding zones are established in well-delineated geographical areas where a homogenous type of animal has been raised for a long period of time. The zones cover about 54 percent of the country's territory (see map). The breeds for which breeding zones have been established include the main local breeds – Timahdite, Sardi, Béni Guil, D'man, Béni Ahsen and Boujaâd. Some mountain breeds (Atlas Mountain or Berber breeds) are also included, but the programme is mainly focused on the aforementioned six breeds.

Distribution of breeding zones for local sheep breeds



Source: adapted from Boujenane (2005)

Note that D'Man are only present in the oases and valleys of the depicted zone, and that the delimitations of areas for Boujaâd have been estimated.

The plan has also included selection programmes for the improvement of local breeds in their home areas; the organization of farmers' associations; and encouragement for farmers to improve their local breeds. The plan has met with success thanks to the dynamic role of the sheep keepers' organizations and the support of the state. Largely as a result of the plan and the geographical restrictions on cross-breeding, the impact of exotic breeds on the indigenous sheep population has been limited. Indigenous breeds accounted for 53 percent of the total population in 1996/97 (the most recent census in Morocco categorizing sheep by breed). Since 1970, the Sardi population has increased, Timahdite and D'man have stabilized, and Béni Guil has decreased only slightly. However, the Béni Ahsen breed population decreased tremendously following the introduction of irrigation in its home zone, which caused a shift to the growing of fruit trees and the keeping of dairy cattle. The latter example illustrates that even if protective measures are in place, a major re-orientation of the farming system is liable to threaten the continued existence of traditional breeds.

Sources for more information: Boujenane (1999 and 2005)

5.2 Asia

In this region, approximately 50 percent of countries have an *in vivo* conservation programmes. In the developing countries of the region, identification of animals and the recording of pedigree and performance are lacking. Therefore, for many local breeds the basic information required to improve conservation measures is absent. *In vivo* conservation is restricted to state farms or university and institutional experimental farms. Within these programmes, phenotypic and genetic characterization has commenced.

Urbanization, the growth of the human population and increased income levels are leading to greater demand for animal products, and result in the intensification of production systems and the more widespread use of exotic breeds. Pigs and chickens play a major role in meat production in Asia. A rich diversity of breeds exists. The conservation of these two species gets a lot of attention in a small number of countries: China, Japan and Viet Nam (Table 80). Many Country Reports indicate the preference of local people for the meat of local pig and poultry breeds. This preference facilitates their future use and conservation. The speed of industrialization and specialization in the pig sector, however, gives rise to a need for special attention to be paid to the establishment of local and regional *in vitro* conservation programmes. This need is emphasized by the lack of opportunities for *in vivo* conservation of the species.

The conservation of cattle, sheep, goats and horses requires more attention in Asia, particularly in the western part of the region, where a rich diversity exists, without any significant conservation activities.

Table 80
Conservation activities in Asia

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|-------------------------------|--------|-------|-------|------|----------|--------|
| Central Asia | | | | | | |
| Local breeds | 29 | 74 | 28 | 3 | 12 | 32 |
| Conserved <i>in vivo</i> | 6 | 18 | 6 | 0 | 6 | 2 |
| Conserved <i>in vitro</i> | 11 | 11 | 0 | 0 | 0 | 0 |
| East Asia | | | | | | |
| Local breeds | 74 | 72 | 71 | 156 | 125 | 57 |
| Conserved <i>in vivo</i> | 22 | 12 | 13 | 51 | 80 | 8 |
| Conserved <i>in vitro</i> | 28 | 3 | 3 | 92 | 73 | 5 |
| South Asia | | | | | | |
| Local breeds | 86 | 106 | 64 | 18 | 45 | 20 |
| Conserved <i>in vivo</i> | 10 | 18 | 7 | 1 | 4 | 0 |
| Conserved <i>in vitro</i> | 8 | 8 | 6 | 0 | 0 | 0 |
| Southeast Asia | | | | | | |
| Local breeds | 50 | 13 | 19 | 52 | 61 | 32 |
| Conserved <i>in vivo</i> | 11 | 5 | 4 | 8 | 8 | 0 |
| Conserved <i>in vitro</i> | 8 | 4 | 2 | 0 | 0 | 0 |
| Asia total | | | | | | |
| Local breeds | 239 | 265 | 182 | 229 | 243 | 141 |
| Regional transboundary breeds | 19 | 13 | 11 | 2 | 2 | 10 |
| Conserved <i>in vivo</i> | 49 | 53 | 30 | 60 | 92 | 10 |
| Conserved <i>in vitro</i> | 55 | 15 | 11 | 92 | 73 | 5 |

Refer to footnote under Table 78

Fifty percent of countries in Asia have an *in vitro* conservation programme. The state of *in vitro* conservation at the national level is very variable. Well-established genebanks exist in Japan and India, and genebanks are under establishment in China, the Republic of Korea and Viet Nam. In other countries, there is some storage of semen at AI stations, while in others, particularly in the western part of the region, no *in vitro* activities exist. Semen is preserved from all the main species, and embryos from cattle, sheep and goats are also stored. In a few countries (e.g. Japan) tissue DNA is collected from all the main species. The governments of Asia undertake these *in vitro* activities in collaboration with industry.

Box 38**Conservation strategies in China**

The People's Republic of China has more than 1.2 billion people – about 22 percent of the world's population, but only around 10 percent of global farmland. The need to feed a growing population has resulted over the last 25 years in emphasis being placed on farm output. This resulted in a major importation of exotic breeds and considerable unplanned cross-breeding. However, the government realised that there was potential for a serious loss of livestock genetic diversity and, in 1994/1995, made several crucial decisions. In 1994, after drawing up a list of 576 farm animal breeds, the government issued the Regulations on Breeding Livestock Administration. Special funds were allocated to maintain indigenous breeds on state farms. The government established a National Commission for Domestic Animal Genetic Resources Administration, which hosts the National Focal Point for AnGR. A list of conservation areas for farm breeds was also produced, and state farms were linked with local farms. In 1999, a major survey was initiated in North Western and South Western Provinces, which identified 79 previously unknown breeds. The government also recognized the extinction of seven breeds to add to the ten lost up to 1983. As a result, there are around 600 recognized breeds in China.

Financial support was initiated in the Eighth Five-Year Plan (1991–1996), during which the government recognized 83 state-level key breeding farms and undertook the provision of infrastructure for several farms and conservation areas as well as some new AI stations. This support (legal and financial) has enabled Provinces, Prefectures and Counties to establish conservation areas and farms for their local breeds. In addition, pedigree (herd book) registration schemes and breed improvement schemes have been established. At present, the government is drafting an “Animal Husbandry Law”, which integrates AnGR activities into mainstream animal production. It requires conservation activities and prescribes legal requirements. The proper study of local and exotic breed performance is also a requirement.

The direct result of the funding is 83 projects – most are concerned with breed conservation; about 10 percent are linked to cryoconservation schemes. Genebanks have been established, with the main mammalian bank located in Beijing, and the poultry work being carried out in Jiangsu province. Sampling of breeds for cryoconservation started in the mid-1990s and the procedures have been improved over time as a result of experience and scientific advice. The requirement is now that 250 embryos and 1 600 doses of semen are stored for each breed kept. Seventeen endangered breeds have had semen stored, and embryos are stored from 16 different breeds. This exemplifies the dilemma of whether to sample a limited number of breeds fully, or to sample more breeds, but in a limited manner. In the long term, there is a need to cover all breeds with both techniques.

China has strengthened its basic research, although comprehensive breed comparisons between local and exotic breeds remain rare. The proposal is to fully characterize and evaluate breeds in a Test Centre located in Beijing. However, the replication of the proper environments for each breed involved is problematic.

The Ministry of Agriculture (MOA) has nominated 78 breeds at national level as Key Farm Animal Breeds. For poultry, some 40 breeds are proposed for *ex situ in vivo* flocks in Jiangsu province, with each breed having at least 300 hens and the relevant number of males. The recent avian influenza outbreak has raised questions about security and the need for *in vitro* conservation alongside *in vivo* work.

The development and industrialization of China has meant that the MOA is aware of the need to ensure public awareness of conservation and the importance of livestock genetic diversity. To mark the tenth anniversary of the China National Commission for Management of Farm Animal Genetic Resources, the government released a stamp collection of the 78 key breeds. Future plans include the “China Farm Animal Diversity Network”. Personnel training will be maintained to continually improve the expertise available to ensure the appropriate management of AnGR. Improved liaison between all those involved is required to achieve the most cost-effective means of maintaining China's rich store of animal genetic diversity.

Provided by Hongjie Yang and David Steane

5.3 Europe and the Caucasus

Throughout the Europe and the Caucasus region there is considerable awareness of conservation, and many breeding and conservation plans have been developed. Phenotypic characterization is carried out and several molecular genetic characterization studies have been undertaken. With the exception of the southeastern part of the region, recording of population sizes, animal identification and pedigree recording are well established.

In all important species many *in vivo* conservation programmes have been established for local breeds (Table 81). However, substantial differences exist between western and central Europe, and the

countries of the eastern parts of the region. In western and central Europe 27 countries have *in vivo* conservation programmes (Table 77). A few countries (e.g. Ireland, Finland and Germany) base their conservation policy heavily on the number of males and females in the population (effective population size). Some reports mention the low effective population size of popular cattle breeds such as the Holstein-Friesian and the Belgian Blue because of the use of a limited number of sires. Some countries (in western, northern and central Europe) have a history of AnGR conservation, and some have joined forces for reasons of efficiency (Nordic countries). In some countries, *in vivo* conservation is limited to a few species. It is performed in number of different ways. Animals are kept at a variety of farms (research farms, education farms, museums, prison farms), or are kept for nature management or as hobby animals. Part-time farming is increasing. Many of these small-scale farmers keep local breeds and try to sell regional products under quality labels in niche markets. In many Country Reports organic farming is mentioned as an opportunity for the use of local breeds. Many private organizations (NGOs) play a decisive role in *in vivo* conservation. However, the genetic management of the populations under programmes run by these organizations needs to be improved.

Political instability in the eastern part of the region and the dissolution of the Soviet Union had a serious impact on livestock systems and animal numbers. Many existing breeding and conservation programmes and the institutions involved were destroyed. Many competitive breeds and lines of cattle, pigs and chicken were developed in the Soviet Union, and were bred entirely separately from the breeds and lines of the Western World. These breeds and lines still exist, but are threatened by the introduction of Western genetics.

Box 39

Denmark – opportunities for *in vivo* conservation

In Denmark, beef cattle, horses, sheep, goats, rabbits, ducks, geese, turkeys, ostriches and deer are mainly kept by part-time, leisure-time and hobby breeders. There are a number of industrialized production enterprises, especially among beef cattle, turkeys and ducks, but most herds are small with medium or low levels of investment. The part-time, leisure-time and hobby breeders keep many different breeds. They, therefore, constitute an important target group with respect to conservation and utilization of AnGR. Leisure-related aspects of livestock keeping are of considerable significance in Denmark. Keeping farm animals is an important recreational activity for many people, and many others appreciate the effects that, grazing cattle, horses, sheep and goats have on the landscape and environment.

Source: CR Denmark (2003)

Table 81

Conservation activities in Europe and the Caucasus

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|-------------------------------|--------|-------|-------|------|----------|--------|
| Local breeds | 277 | 458 | 170 | 165 | 608 | 269 |
| Regional transboundary breeds | 28 | 79 | 13 | 17 | 45 | 38 |
| Conserved <i>in vivo</i> | 137 | 175 | 51 | 47 | 101 | 113 |
| Conserved <i>in vitro</i> | 106 | 51 | 15 | 28 | 6 | 23 |

Refer to footnote under Table 78

Most *in vitro* conservation programmes are found in western and central Europe. In many cases this is restricted to the storage of semen from a limited number of cattle and sheep breeds. A few countries (the Nordic countries, France, the Netherlands, Poland, the Czech Republic and Hungary) have genebanks preserving semen from the main species. In some cases, embryos of cattle, sheep and pigs are also preserved, and in a few countries, cattle oocytes or tissue DNA are stored. These banks are recently founded or are under construction. A strong collaboration with the animal breeding industry exists in most countries. The genebanks need to be further developed – with respect, for example, to ownership and access, information and documentation, and optimization of the core collection and the ratio between gametes and embryos. Despite the presence of a rich AnGR diversity in combination with real threats (such as political instability) *in vitro* conservation programmes are largely absent in the eastern parts of the region, with the exception of Ukraine.

5.4 Latin America and the Caribbean

In this region, the number of countries with active conservation programmes is low, although many countries report a very rich national biodiversity. Most of the species and breeds present in this region were imported from other regions hundreds of years ago. Some breeds were further developed in straight-breeding programmes. New composite breeds adapted to the specific and often extreme local conditions were also developed. In other cases, continuous cross-breeding takes place. As straight-breeding plays a less significant role than in Europe, conserving (pure) breeds is often not regarded as such a high priority. This does not apply to South America's unique domesticated species (e.g. llamas, alpacas and guinea pigs).

The quality of *in vivo* conservation activities is highly variable. Brazil has an intensive programme of *in vivo* conservation, while some countries lack any activity. In much of the Caribbean and Central America, animal identification and registration, performance recording and breeding are not developed, and this creates a weak base for conservation activities. In many South American countries, the export market makes it attractive to invest in animal identification and performance recording, and this contributes to the establishment of active breeding and conservation programmes.

In vivo conservation is mainly limited to cattle and horses kept at university and institutional farms (Table 82), which often function as nucleus breeding herds. In a few countries, molecular characterization activities have been initiated to support conservation decisions. In the countries which do have conservation activities, initiatives are taken by governments, universities and institutes.

Table 82
Conservation activities in Latin America and the Caribbean

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|---------------------------------|--------|-------|-------|------|----------|--------|
| Caribbean | | | | | | |
| Local breeds | 19 | 5 | 3 | 11 | 7 | 1 |
| Conserved <i>in vivo</i> | 0 | 0 | 0 | 0 | 0 | 0 |
| Conserved <i>in vitro</i> | 0 | 0 | 0 | 0 | 0 | 0 |
| South America | | | | | | |
| Local breeds | 74 | 36 | 20 | 35 | 43 | 39 |
| Conserved <i>in vivo</i> | 43 | 5 | 7 | 2 | 0 | 5 |
| Conserved <i>in vitro</i> | 15 | 5 | 6 | 2 | 0 | 5 |
| Central America | | | | | | |
| Local breeds | 36 | 6 | 3 | 21 | 34 | 25 |
| Conserved <i>in vivo</i> | 33 | 5 | 8 | 5 | 0 | 16 |
| Conserved <i>in vitro</i> | 1 | 0 | 0 | 0 | 0 | 0 |
| Latin America and the Caribbean | | | | | | |
| Local breeds | 129 | 47 | 26 | 67 | 84 | 65 |
| Regional transboundary breeds | 8 | 2 | 2 | 3 | 1 | 5 |
| Conserved <i>in vivo</i> | 76 | 10 | 15 | 7 | 0 | 21 |
| Conserved <i>in vitro</i> | 16 | 5 | 6 | 2 | 0 | 5 |

Refer to footnote under Table 78

In vitro conservation is limited to the storage of semen and sometimes also of embryos from a few breeds. The initiatives for establishing cryobanks are mainly taken by governments with help from universities and institutes. Brazil is the first country in this region to have established a genebank.

Box 40**Brazil – implementation of a genebank**

To minimize the threat of extinction faced by locally adapted breeds, the National Research Centre for Genetic Resources and Biotechnology – Cenargen, of the Brazilian Agricultural Research Corporation (Embrapa), included, from 1983, the conservation of AnGR in its conservation programme, which up to that date had included only plants. From that time, the conservation of AnGR began to be carried out, under the coordination of Cenargen, by various Embrapa research centres, universities, state research corporations and private farmers. The animal conservation programme includes the following stages: (a) identification of populations in an advanced state of genetic dilution; (b) phenotypic and genetic characterization; and (c) evaluation of their production potential. Conservation is being carried out in conservation nuclei, maintained in the habitats where the animals were naturally selected (*in situ*). At the same time, embryos and semen are stored (*ex situ*) at the Animal Germplasm Bank (AGB) in Brasilia. It is important that economic use for each one of the breeds being conserved is identified. Research alone is not able to conserve the endangered breeds, and a partnership with private breeders is of fundamental importance to the success of the programme.

Source: CR Brazil (2003)

5.5 Near and Middle East

The primary aim of the governments of the countries in this region is to increase animal production to decrease imports of food of animal origin. Thus, there is a focus on high-input systems. High-output exotic cattle and chicken breeds are imported. There is very little drive to improve or to conserve the local animals despite a rich breed diversity (Table 83).

Table 83

Conservation activities in the Near and Middle East

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|-------------------------------|--------|-------|-------|------|----------|--------|
| Local breeds | 43 | 50 | 34 | 1 | 24 | 14 |
| Regional transboundary breeds | 0 | 4 | 0 | 0 | 0 | 0 |
| Conserved <i>in vivo</i> | 5 | 4 | 3 | 0 | 0 | 0 |
| Conserved <i>in vitro</i> | 1 | 0 | 0 | 0 | 0 | 0 |

Refer to footnote under Table 78

CR Iraq (2003) mentions some *in vivo* conservation activities in the main species – cattle, sheep and goats, but details are not provided. In other countries, there is generally a lack of awareness of the value of the local breeds and the possibilities to improve and conserve them. Throughout most of the region, no identification, registration or performance recording exist. Characterization activity is extremely limited. No *in vitro* conservation programmes exist in this region.

5.6 North America

The United States of America and Canada have a close inter-relationship with respect to livestock. Canada provides a lot of livestock and livestock products to the United States of America. The latter is the base for breeding stock used in Canada.

Both countries have very active NGOs playing an important role in the *in vivo* conservation of the many local breeds. Support from scientists for these organizations in terms of their genetic management activities could, however, be improved. Universities and institutional farms take care of the conservation of dual purpose breeds and experimental selection lines of chickens. However, many of them are threatened by limited budgets for these activities. A lot of work on breed characterization is carried out by universities and research institutes.

In the United States of America and Canada, AnGR are seen as a strategic resource for national food security, which may be threatened by bioterrorism. This is one of the reasons why the United States of America invested in the establishment of an *in vitro* conservation programme and a genebank (Table 84). Collections are being built up very quickly, in close collaboration with the industry. Breeding companies use the genebank as a back up of their breeding work. In Canada, a programme for *in vitro* conservation has been developed and will be implemented in the near future. There will be close

collaboration between the United States of America and Canada in genebank activities. They share information and documentation programmes, and are discussing taking care of each other's back-up *in vitro* collections.

Table 84
Conservation activities in North America

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|-------------------------------|--------|-------|-------|------|----------|--------|
| Local breeds | 29 | 35 | 3 | 18 | 12 | 23 |
| Regional transboundary breeds | 3 | 6 | 5 | 1 | 1 | 3 |
| Conserved <i>in vivo</i> | 1 | 1 | 0 | 0 | 0 | 2 |
| Conserved <i>in vitro</i> | 36 | 39 | 11 | 18 | 8 | 0 |

Refer to footnote under Table 78

Box 41
United States of America – priorities in conservation programmes

Priorities are subdivided into biological issues and physical capacity issues. From the biological perspective, priorities include:

1. completing breed-level collections of cryopreserved germplasm and tissue;
2. increasing levels of *in situ* conservation by private and public entities;
3. creating a more thorough understanding of within and between-breed genetic diversity; and
4. developing more efficient and reliable cryoconservation protocols for semen, embryos and oocytes.

Physical capacity priorities include:

1. continuing the development of NAGP (National Animal Germplasm Program) infrastructure and staffing;
2. increasing awareness and support for university conservation efforts;
3. leveraging the complementarities of different federal agency programmes; and
4. increasing industry awareness of, and involvement in, various aspects of managing animal genetic diversity.

Source: CR United States of America (2003)

5.7 Southwest Pacific

In general, governments in this region show little awareness of the strategic value of the genetic diversity of livestock. In Australia, private farmers and NGOs are active in the conservation of small populations of threatened cattle breeds, and private breeding companies and NGOs store cattle semen and embryos.

Table 85
Conservation activities in the Southwest Pacific

| | Cattle | Sheep | Goats | Pigs | Chickens | Horses |
|-------------------------------|--------|-------|-------|------|----------|--------|
| Local breeds | 26 | 35 | 11 | 12 | 17 | 22 |
| Regional transboundary breeds | 0 | 3 | 1 | 0 | 0 | 0 |
| Conserved <i>in vivo</i> | 13 | 0 | 0 | 0 | 0 | 0 |
| Conserved <i>in vitro</i> | 0 | 0 | 0 | 0 | 0 | 0 |

Refer to footnote under Table 78

Box 42**Australia – involvement of diverse stakeholders**

In Australia, mainstream breeding of livestock has focused on achieving sustainable industries through adapted and productive livestock. Genetic inputs from many continents have been used to achieve this goal, and conservation of adaptive genotypes has been achieved by making the animals desirable for production purposes and ensuring their presence in sufficient numbers to provide responses to selection over the long term. Conservation of rare breeds in Australia is largely in the hands of private breeders and breed societies, or NGOs such as the Australian Rare Breeds Trust. These special interest groups support the *in situ* and on-farm conservation of breeds through breeding plans and genetic advice. *Ex situ* conservation is effected through genebanks maintained by breeding companies and conservation NGOs.

Source: CR Australia (2004)

6 Opportunities for improving conservation programmes

The effectiveness of the conservation of genetic diversity can be measured utilizing criteria such as the effective population size, the number of sires and dams used in each generation, and the mating schemes practised. Unfortunately, information on the number of animals conserved in *in vivo* programmes and the number of sires and dams from which genetic material is conserved *in vitro* is available only in a few countries. Thus, it is difficult to assess the effectiveness of existing activities. Some of the improvements required to establish sound conservation programmes can, however, be identified and are discussed below.

The intensification of animal production results, in some countries, in large areas of land being given over to nature conservation. Nature management facilitates *in vivo* conservation of herbivore species, but in some cases, the animals are kept outside their original environment and are not used for the type of production for which they were developed. Large populations of animals are needed for these activities, which, if managed properly (in genetic terms), offer a great opportunity to conserve genetic variation for future use.

While at a global level, food of animal origin will to a large extent be produced in high-input–high-output systems with highly specialized breeds or cross-breeds, small-scale farming continues to be important, and the significance of organic farming is increasing. These systems require well-adapted dual-purpose or multipurpose breeds. These breeds are better fitted to the production goals of less-intensive farming systems than are highly specialized breeds or cross-breeds. However, transnational breeding organizations rarely invest in these breeds because of the limited size of the markets. More emphasis should be given to the development of these breeds and to the conservation of their genetic diversity.

The development of special products for niche markets offers the possibility to use local breeds and to make them profitable again. This strategy can be enhanced by fostering the notion of “terroir” or the use of labels of origin. Conservation on a small scale on farms oriented towards producing for niche markets can lead to a profitable use of local breeds, but often results in a loss of genetic variation within the population. This can also be the case in small populations kept by hobby farmers if inbreeding is not properly controlled. However, small farmers and hobbyists play a very important role in the conservation of between-breed variation in chickens, horses, sheep, goats and cattle. The education of these livestock keepers in the genetic management of small populations should be improved, as should professional support from governmental and academic institutions. Proper breeding strategies coupled with AI and ET could effectively be used to maintain if not increase genetic diversity under the conditions of small-farm conservation or niche-market production.

In modern breeding schemes carried out by breeding organizations, the conservation of within-breed genetic diversity is often taken into account. Optimization techniques are well developed and effective. When, for example in cattle breeding, these techniques are introduced in the mating schemes used by farmers, inbreeding problems at the production level can be minimized. At present, there is a tendency to broaden breeding goals to include fitness traits as well as production traits. This will have a positive influence on the effective population size and on the maintenance of the genetic diversity

within the breeds in question. For some breeds, it might be wise to use breeding stock from related populations to enlarge the effective population size. Another alternative is to select the semen of “lost” founders from genebanks, and use these sires again.

Cryoconservation is a proven technology and is an important complement to *in vivo* breed conservation. Up to the present time, it has been used mainly to conserve genetic diversity within breeds; it is attractive to the breeding industry as a back up for their breeding material. Genebanks have to be further developed, with respect, for example, to ownership and access, storing back-up collections, information and documentation, optimization of the core collection, and the ratio between gametes and embryos.

7 Conclusions and priorities

In many countries in Africa, eastern parts of the Europe and the Caucasus region, the Near and Middle East, Central and South Asia, and the Caribbean, conservation programmes need to be developed. These regions and subregions have a rich diversity of AnGR, but its value is not sufficiently recognized by the national authorities. In most countries, awareness has to be increased in order to obtain financial resources for the improvement and conservation of local breeds. Capacity to develop animal breeding and production, and to implement the genetic management of local populations should be a high priority. In many developing countries, multilateral or bilateral aid programmes for conservation are necessary. Intercountry, subregional and regional programmes should be encouraged and supported through external technical and financial assistance. The establishment of regional conservation programmes and genebanks for regional transboundary breeds should be a high priority particularly in developing countries.

The number of breeds that are potential candidates for conservation is large, and conservation programmes for animals are expensive. Thus, in national conservation programmes, careful attention should be paid to the selection of breeds and methods for conservation. Effective prioritization of breeds for conservation programmes is facilitated by phenotypic and genetic characterization, and by knowledge of the size and structure of the population. Obtaining information on population structure and effective population size is a great challenge and requires cooperation with breeders and their registries.

To implement an adequate breed conservation programme (in which the conservation of the diversity within the breed is very important), the pedigree of the individual animals must be known, a required minimum number of males and females per generation must be kept to avoid random drift, and a mating scheme should be introduced to avoid inbreeding. *In vivo* conservation programmes must include identification and registration of animals, performance recording, and monitoring of populations and population sizes. Regional cooperation, establishment of intercountry or regional genebanks for cryoconservation is of particular importance.

In poultry, pigs and (beef and dairy) cattle, transnational companies develop only a limited number of breeds and lines. The breeding and production activities of these companies are spreading in Asia and Africa. Improved, highly selected breeds and lines will be used to meet the growing demand for meat, milk and eggs in the coming years. In these circumstances, many recently developed (dual-purpose) and local breeds of cattle, pigs and poultry have to be considered for conservation. The high speed of industrialization and specialization in pig breeding, in combination with a lack of *in vivo* conservation opportunities for this species requires that special attention should be paid to the *in vitro* conservation of pig populations (local breeds and recently developed lines). For all species, breeding programmes to improve and conserve local breeds and to enhance their performance in cross-breeding systems with exotics should be developed.

For local and recently developed breeds and lines that will not be used extensively in the future, opportunities for *in vivo* conservation should be further explored: nature management, organic farming, participatory breeding, niche markets and hobby farming. In sheep and in horses, production and breeding objectives have changed dramatically in recent years, with major consequences for the use and conservation of genetic resources. These developments illustrate the importance of

maintaining the genetic diversity necessary to meet new objectives. In sheep, between-breed diversity is threatened by a sharp decrease in the size of the population in many regions.

Education programmes on genetic management should have a high priority. In all regions, farmers and their organizations and advisors, require instruction on sustainable use, development and conservation of AnGR. Support for hobbyists and NGOs to improve their genetic management is also required. In many universities in developed countries these topics are increasingly integrated in the curricula for agricultural students. However, the number of these students is decreasing.

To safeguard genetic diversity, all countries should have their own or shared genebanks that contain cryopreserved material of their locally developed breeds and lines, to protect them against unpredictable threats. Because many transboundary breeds exist, coordination between countries is required. Cooperation would be facilitated if national and regional genebanks operated under internationally agreed protocols. These should include zoosanitary requirements for cryopreserved material, in addition to phenotypic description and genetic characterization. However, in some circumstances, it may be appropriate for countries to decide to immediately commence the establishment of a national gene bank, and tackle sanitary requirements and characterization at a later stage.

The operation of genebanks would also be improved by the regulation of ownership, access and the publication of documentation, and by the optimization of the contents of the collection. To facilitate the establishment of genebanks, training facilities are needed for cryoconservation techniques such as the sampling of breeds and individuals within breeds, and freezing and maintenance of semen, oocytes and embryos. *In vivo* and *in vitro* conservation sites and collections should be protected against human-induced and natural calamities by variety of measures, including the use of widely separated locations at both national and international levels.

8 References

- Boujenane, I.** 1999. *Les ressources génétiques ovines au Maroc*. Rabat. Actes Éditions.
- Boujenane, I.** 2005. Small ruminant breeds of Morocco. In L. Iniguez, ed. *Characterization of small ruminant breeds in West Asia and North Africa. Volume 2: North Africa*, pp. 4–54. Aleppo, Syria. International Center for Agricultural Research in the Dry Areas (ICARDA).
- CR (Country name).** year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).
- Oldenbroek, J.K.** 1999. *Genebanks and the conservation of farm animal genetic resources*. Lelystad, the Netherlands. DLO Institute for Animal Science and Health.

SECTION D: REPRODUCTIVE AND MOLECULAR BIOTECHNOLOGY

1 Introduction

The development of biotechnologies in the fields of breeding, reproduction and molecular genetics has advanced considerably in recent years. Among reproductive technologies, AI and multiple ovulation followed by embryo transfer (MOET) have already had a major impact on livestock improvement programmes in developed countries. These technologies speed up genetic progress, reduce the risk of disease transmission, and expand the number of animals that can be bred from a superior parent. The field of molecular genetics is also rapidly developing; characterization based on molecular markers, and marker assisted selection offer new opportunities in AnGR management (FAO, 2004). However, the extent to which the technologies are utilized varies greatly from country to country and between regions. The following chapters present an overview of the information presented in the Country Reports on the utilization of biotechnologies.

2 Global overview

Table 86 presents a region-by-region overview of the proportion of countries reporting the use of different classes of biotechnology. It can be seen that AI is by far the most widely used biotechnology. Nonetheless, particularly in the Africa and Southwest Pacific regions, there are many countries where it remains unavailable. In the case of ET and molecular techniques, the gap between the developed and developing regions is even greater. As Table 87 illustrates, the use of biotechnologies tends to be biased towards cattle. The table shows that this bias is greatest with respect to ET, but it can also be seen that in most regions the use of AI is also dominated by the cattle sector. In the Africa region in particular, few countries have extended the use of AI to other species. The evidence for this species bias is rather less clear in the case of molecular genetic technologies. The number of countries reporting the use of these technologies is quite low. However, among these countries, a relatively high number report studies of molecular characteristics in at least one species other than cattle. Nonetheless, cattle remain the single dominant species in most regions, particularly where commercial applications of the molecular technologies are concerned. Further details of the distribution of biotechnology use, and of the species to which the technologies are applied are included in the following regional descriptions.

Table 86
Use of biotechnologies by region

| Region | Artificial Insemination | | | Embryo Transfer | | Molecular Genetic Technologies | |
|---------------------------------|-------------------------|---------------------|---------------------------------|---------------------|---------------------------------|--------------------------------|---------------------------------|
| | No. of CRs | No. providing info. | Reporting use of the technology | No. providing info. | Reporting use of the technology | No. providing info. | Reporting use of the technology |
| Europe | 39 | 39 | 97% | 25 | 64% | 29 | 83% |
| Africa | 42 | 42 | 74% | 30 | 17% | 29 | 14% |
| Asia | 25 | 22 | 86% | 17 | 47% | 16 | 50% |
| Latin America and the Caribbean | 22 | 22 | 95% | 14 | 86% | 15 | 73% |
| Southwest Pacific | 11 | 11 | 55% | 10 | 10% | 9 | 11% |
| North America | 2 | 2 | 100% | 2 | 100% | 2 | 100% |
| Near and Middle East | 7 | 6 | 100% | 3 | 33% | 5 | 40% |

Table 87
Use of biotechnologies by species

| Region | Artificial Insemination | | | Embryo Transfer | | | Molecular Genetic Technologies | | |
|---------------------------------|--------------------------|----------------------------------|------------------|--------------------------|----------------------------------|------------------|--------------------------------|----------------------------------|------------------|
| | No. with info on species | Reporting use of the technology: | | No. with info on species | Reporting use of the technology: | | No. with info on species | Reporting use of the technology: | |
| | | In cattle | In other species | | In cattle | In other species | | In cattle | In other species |
| Europe | 38 | 100% | 66% | 11 | 100% | 36% | 18 | 89% | 100% |
| Africa | 31 | 100% | 10% | 4 | 100% | 0% | 3 | 100% | 33% |
| Asia | 18 | 94% | 56% | 6 | 100% | 50% | 7 | 86% | 100% |
| Latin America and the Caribbean | 21 | 100% | 71% | 12 | 100% | 33% | 9 | 78% | 89% |
| Southwest Pacific | 5 | 100% | 80% | 2 | 100% | 0% | 0 | - | - |
| North America | 2 | 100% | 50% | 0 | - | - | 1 | 100% | 100% |
| Near and Middle East | 6 | 100% | 33% | 1 | 0% | 100% | 2 | 0% | 100% |

2.1 Africa

The Country Reports indicate that AI is the reproductive biotechnology most commonly used in the management of AnGR in Africa. The Country Reports generally express an aspiration for greater use of the technology, mainly to facilitate breeding programmes and the introduction of exotic germplasm. This aspiration corresponds to the overall objective expressed in most African Country Reports of promoting food security through increased output of livestock products. In many cases, the desire for more widespread use of AI is tempered by concern regarding the implications for genetic diversity of its inappropriate or uncontrolled use. A number of Country Reports from the region also mention the potential use of AI facilities for cryoconservation purposes.

Thirty-one out of 42 countries report the use of AI. A few other countries report that AI has been carried out experimentally in the past, but never applied routinely, or that former AI programmes have been abandoned through lack of financial resources or other constraints. AI use in Africa is predominantly focused on cattle. All 31 Country Reports indicating the use of AI mentioned that the technology is used in cattle. Two countries report the use of AI in sheep, one in goats, one in horses and one in pigs. The semen used for AI tends to be from exotic breeds rather than local breeds. Nineteen countries indicate that AI is performed using semen from exotic cattle breeds, two report using semen from local breeds, and six report use of both local and exotic semen. Where details of programmes are provided, the objective is often the upgrading of indigenous livestock using semen from exotic breeds, most frequently of dairy cattle. Exotic beef cattle semen is also utilized in a number of countries.

Some Country Reports from West Africa mention the use of exotic semen for cross-breeding with trypanotolerant cattle breeds (CR Guinea, 2003; CR Côte d'Ivoire, 2003). A limited number of AI programmes utilizing semen from indigenous animals are reported, including in one country the use of semen from trypanotolerant cattle (CR Côte d'Ivoire, 2003). CR Madagascar (2003) notes the use of AI in *in situ* conservation programmes for the endangered Renitelo cattle breed. However, even in countries where indigenous breeds are included in AI programmes, the balance appears to favour exotics. CR Botswana (2003) indicates that 94.1 percent of AI services performed during the 1987 to 1995 period were carried out using the semen of exotic breeds. The use of AI by smallholders is largely restricted to dairy producers, and is concentrated in peri-urban areas. A small number of Country Reports mention efforts to promote a wider diffusion of the technology, including in less

easily accessible areas. CR Senegal (2003) notes considerable use of AI to introduce exotic germplasm for the breeding of race horses.

There is substantial variation from country to country in terms of the development of facilities and human resources for the implementation of AI programmes, in terms of the availability of services to the farmer, and in terms of the providers involved in service delivery. The public sector is the most frequently reported provider of AI services in the region. Among the 27 Country Reports providing information on service providers, 26 mention the public sector and 12 mention private companies. NGOs are mentioned as providers of AI services in eight Country Reports, while breeders' organizations are mentioned in two Country Reports (CR Burkina Faso, 2003; CR Madagascar, 2003). CR Niger (2003) mentions collaboration between two Italian universities, a local university and a local research station in establishing an AI programme for cattle. CR Zambia (2003) indicates that individual private farmers have imported exotic semen for the purposes of improving their cattle herds. A few countries have quite extensive AI programmes in place. Botswana, for example, in the context of its policy to improve the national herd, has a number of AI camps throughout the country and subsidizes the supply of semen to traditional farmers (CR Botswana, 2003).

Several countries report that problems with the financing of government services are a constraint to the provision of AI. Increased involvement by the private sector is noted as an objective in several Country Reports. A few countries are able to report significant progress in this direction (for example CR Kenya, 2004 and CR Zambia, 2003). CR Zambia (2003) notes that the private sector has taken the lead in providing imported semen, while the government trains and supervises AI technicians. However, as the figures above indicate the role of the private sector appears to be limited or absent in most countries. Few Country Reports discuss constraints to the involvement of the private sector in any detail. However, CR Côte d'Ivoire (2003) mentions that the single private operator in the country had ceased activities as a result of financial difficulties.

Five countries (CR Côte d'Ivoire, 2003; CR Kenya, 2004; CR Madagascar, 2003; CR Zambia, 2003; and CR Zimbabwe, 2004) report the use of ET technologies. Use of the technology appears to be limited. In one country, the technology is reported only to have been used on Holstein-Friesian cattle on a single private farm (CR Madagascar, 2003). CR Côte d'Ivoire (2003) notes that some individual cattle owners have introduced Brazilian Zebu genetic material through the import of frozen embryos. In Zimbabwe, the technology is reported to be available through two private breeding companies (CR Zimbabwe, 2004). Several Country Reports state that the introduction of ET is an objective. However, the specific role that the technology could be expected to play in the management of AnGR in the local production systems is rarely elucidated. There is a lack of discussion of how it could be integrated within organized breeding programmes. The potential use of the technology for purposes of cryoconservation is, however, noted in several Country Reports. Studies based on the use of molecular markers are mentioned in only four Country Reports from Africa.

2.2 Asia

Among the Asian Country Reports, 19 out of 22 countries providing information indicate the use of AI. From 18 countries providing details of the species inseminated, 17 mention cattle, eight pigs, five buffaloes, four sheep, three chickens, two goats, two horses, one camels and one ducks. Details of the breeds used as the source of semen are limited. However, in the case of cattle eight Country Reports indicate the use of semen from both local and exotic breeds, four mention only exotic breeds, and two mention only local breeds. Provision of AI services appears to be dominated by the public sector. Of 17 Country Reports giving details of service providers, all 17 mention the public sector, with 6 mentioning the private sector, five breeders' organizations, four NGOs and one universities. There is much variation from country to country in the extent to which AI is used. In an industrialized country such as Japan, almost all cattle breeding (99.4 percent in dairy herds and 97.8 percent in beef herds) is carried out using AI (CR Japan, 2003). In most other Asian countries, services are much more limited and tend to be focused on the dairy sector and peri-urban production systems. Several Country Reports indicate that service coverage is limited by financial and technical constraints. Indeed, a few Country Reports indicate a decline in the use of the technology.

The desire to establish or to increase the availability of AI services is expressed as an objective in many Country Reports. In a number of countries AI has served as a means of introducing exotic germplasm for the purposes of cross-breeding with local breeds. The technology has been used in the development of synthetic breeds incorporating both exotic and indigenous genes – an example being the Jermasia goat (CR Malaysia, 2003). In some cases, AI has also been used to upgrade cross-breeds back to indigenous breeds through back-crossing to promote hardiness. This approach has been applied, for example, using Kedah-Kelantan semen in cattle herds introduced to tree plantations (*ibid.*). In some cases AI services supply semen from indigenous breeds. CR Pakistan (2003) for example reports the use of semen from Sahiwal cattle. However, the same Country Report indicates that the collection of semen from some other indigenous cattle breeds was discontinued because of a lack of demand.

Eight out of 17 Asian countries providing information on the matter indicate some use of ET technology. Among the six countries providing details of the species in which the technology is implemented, 6 mention cattle, two buffaloes, one horses and one goats. The breeds involved are rarely detailed, but one Country Report mentions the transfer of embryos from indigenous cattle breeds and one mentions exotic breeds. In most countries, ET is used on a very limited scale and is often largely confined to research. CR Myanmar (2004) notes that an ET project initiated in the country met with some success at first, but soon declined because of a lack of funding. CR Malaysia (2003) mentions that ET technology was used in the development of the Mafriwal cattle breed. The potential role of the technology in cryoconservation programmes is, again, noted in several Country Reports.

Eight out of 16 Asian countries providing information on the matter report the use of molecular techniques. Among these countries, 6 specify genetic distancing studies, and two mention marker assisted selection. Among the 7 countries providing details of the species involved in molecular characterization studies, six mention cattle, five chickens, four sheep, four goats, four pigs, three buffaloes, two ducks, two horses, one camels, one deer, one quails and one guinea fowl. In the case of distancing studies, among the five countries providing details of the species involved, four mention chickens, three cattle, three sheep, three goats, two pigs, two buffaloes, two horses, one ducks, and one deer. With regard to the breeds involved, systemized studies on Asian breeds are being conducted by the Society for Research on Native Livestock in Japan including analysis based of genetic relationships based on mitochondrial DNA polymorphisms and other DNA markers (CR Japan, 2003). Native Japanese breeds covered by the studies include Mishima cattle and Kuchinoshima feral cattle (*ibid.*).

Other biotechnologies are very largely restricted to the most industrialized countries in the region. The use of *in vitro* fertilization is mentioned in CR Japan (2003) and CR Malaysia (2003). CR Japan (2003) indicates that a number of other reproductive biotechnologies with potential for use in the propagation of rare breeds, as well as commercial applications, have been utilized at an experimental level. The technologies include sperm microinjection to fertilize eggs – applied in pigs; primordial germ cell (PGC) and chimera germline techniques – applied in chickens; and cloning technologies – used in cattle, pigs and goats (*ibid.*).

2.3 Europe and the Caucasus

Thirty-eight of 39 countries in the region report the use of AI. All 38 mention the use of the technology in cattle, 23 in pigs, 16 in sheep, nine in horses, eight in goats, two in rabbits, and one in chickens. Most countries which give details report using semen from both local and imported breeds of cattle, pigs and sheep. While almost all countries are able to report the existence of some AI provision, there is great variation in the extent to which the technology is utilized. In many countries, particularly in western Europe, AI is widely available and used throughout the livestock sector, particularly in dairy cattle. However, a number of Country Reports from the eastern parts of the region, where the livestock sector has often faced substantial problems, indicate that capacity to provide AI services is severely limited as a result of the disintegration of formerly existing infrastructure.

A range of providers are involved in the delivery of AI services. Of the 32 countries giving details of providers, 24 mention the private sector, 20 the public sector, 19 breeders' organizations and three universities. In the countries of the eastern part of the region, services are more likely to be provided by the public sector. Conversely, elsewhere in the region, the private sector and farmers' organizations are the most frequently mentioned service providers, although in many countries there is still considerable involvement or support from the public sector. CR Turkey (2004), for example, mentions the provision of subsidies to private sector providers of AI. Transfer of services to the private sector has not always been without problems. For example, CR Romania (2003) notes that reorganization and greater independence of AI institutes, along with the introduction of service charges led to a decline in the uptake of the technology.

In some countries, AI using imported semen has been widely used to increase the production levels obtained from local breeds. However, some concerns are raised in the Country Reports. Attempts to upgrade local livestock using exotic semen have sometimes failed because the resulting cross-bred animals have proved to be poorly adapted to the local conditions. There is also a potential threat to genetic resource diversity. According to CR Greece (2004), inappropriate and unplanned use of AI contributed markedly to the loss of some indigenous breeds.

Sixteen of the 25 countries providing information on the matter report the use of ET. Of the 11 countries providing details of the species involved, all 11 mention cattle, three sheep, two goats, one pig, one horse and one rabbit. Where specified, ET is carried out using embryos from both imported and local breeds of cattle. Again, it is the dairy industry that is the main user of ET. The technology has contributed significantly to increasing the rate at which selective breeding has contributed to increasing the output of livestock products. However, as a result of the costs involved in applying the technology it is less widely used than AI, and in some countries, ET programmes have ceased as a result of the high costs. In the case of ET, out of eight countries providing details of service providers four mention the private sector, four the public sector, four breeders' organizations and three universities. Other reproductive technologies such as embryo sexing, cloning and transgenetics are mentioned in a very few Country Reports as subjects for research.

Twenty-four out of 29 Country Reports providing information on the matter indicate the use of molecular techniques. Marker assisted selection is used in commercial animal production in a number of European countries. The technology can be applied to eliminate a number of undesirable traits related to health or fertility from livestock populations, and to assist selective breeding for greater productivity.

The importance of ensuring that information on molecular biotechnologies, including their economic benefits, are made available to farmers and breeders' organizations is noted in one Country Report (CR Hungary, 2003). Another Country Report highlights the prospect that molecular biological methods will facilitate the discovery of genes for economically important traits in locally adapted breeds, thereby enhancing their value in breeding programmes (CR Germany, 2003). However, the same Country Report raises the concern that the use of molecular technologies in the context of market-driven attempts to increase production could exacerbate a trend towards inbreeding and loss of genetic diversity within livestock populations. Similar apprehensions are expressed in a small number of other Country Reports. Genetic distancing studies are considered important from the point of view of planning and prioritizing conservation efforts. One Country Report, however, notes that progress to this end has been limited as interest in the subject is largely restricted to universities, and funding is limited (CR Belgium, 2005). Another Country Report puts forward a potential role for such techniques in relation to the niche marketing of livestock breeds on the grounds of their close association with a particular geographical location (CR France, 2004).

Among the Country Reports providing details of the use of molecular technologies, 11 specify the implementation of molecular genetic distancing studies and seven mention the use of marker assisted selection. Out of 17 countries providing information on the species involved in molecular characterization studies, 14 mention cattle, 13 sheep, 11 pigs, eight horses, five goats, three chickens, one donkey, one turkey and one geese. Out of 12 countries providing information on the species involved in distancing studies, 11 mention sheep, nine cattle, five horses, four pigs, three chickens,

three goats, two geese, one ducks, one donkeys, one rabbits, and one deer. Out of four countries providing information on the species in which marker assisted selection is practised, four mention cattle, four pigs, one chickens and one horses. Details of the specific breeds to which technologies have been applied are quite limited in the Country Reports. Among the local breeds for which molecular characterization or distancing studies are mentioned in the Country Reports are the Turoplje and Black Slavonian pigs, Ruda sheep, sheep of the islands of Rab, Pag and KrK (CR Croatia, 2003); Wallachian and Sumava sheep, Brown goats and White goats (CR Czech Republic, 2003) and the Karakachanska sheep (CR The former Yugoslav Republic of Macedonia, 2003).

2.4 Latin America and the Caribbean

AI is widely practised in the countries of this region. Twenty-one out of 22 Country Reports indicate the use of the technology. All 21 countries report the use of AI in cattle, 13 mention pigs, eight sheep, eight goats, five horses, one rabbits, one buffaloes, one donkeys, one llamas, one alpacas and one turkeys. With regard to the cattle breeds providing the semen used for AI, 13 Country Reports mention only exotic breeds, while four mention both indigenous and exotic. In the cases of sheep, five Country Reports mention exotic breeds and one mentions both exotic and local. In the case of pigs, 9 Country Reports mention only exotic breeds while one mentions both local and exotic.

It is clear that the predominant objective is to increase the genetic merit of livestock populations using semen from exotic breeds. In many countries, semen is imported from overseas. Use of the technology is most common in the dairy sector. In some countries it is also quite widely used by commercial producers of beef cattle, pigs and small ruminants. However, there is marked variation between countries and between production systems in terms of the extent to which AI is used. In many small-scale or low external input systems, use of the technology is very limited. A number of countries indicate that improving the provision of AI services is an important objective. A small number of Country Reports, however, mention concerns regarding the decrease of genetic diversity arising as a result of the inappropriate use of AI. With regard to the providers involved in the delivery of AI services, the private sector plays an important role in this region. Of 17 Country Reports giving details of service providers, 11 mention the public sector, 9 mention the private sector, and five breeders' organizations. CR Barbados (2005) mentions the provision of subsidies to farmers' organizations for the purchase of semen for AI.

ET technology is increasingly being used by commercial livestock producers in several countries of the region. Twelve Country Reports, out of 14 providing information, report the use of ET. All 12 mention the use of the technology in cattle, three in horses, two in goats, two in sheep, one in llamas, one in alpacas and one in donkeys. Transplanted embryos largely come from exotic breeds – the six countries that provided details of the cattle breeds involved indicate the use of embryos only from exotic breeds. As in the case of AI, though on a more limited scale, use of ET technology is dominated by the dairy industry, with restricted use in other types of commercial livestock production. Some Country Reports indicate the importation of embryos from overseas. Information on the providers of ET services is limited. However, the CR Brazil (2004) and CR Chile (2003) mention private sector organizations involved in the provision of the technology. Additionally, two Country Reports indicate some commercial use of *in vitro* fertilization, while one mentions the development of embryo sexing and cloning technologies.

Eleven countries, out of 15 providing information, indicate some use of molecular techniques. With regard to molecular characterization studies, out of 9 countries providing information on the breeds involved, seven mention cattle, three sheep, three pigs, two chickens, two horses, one goats, one buffaloes, one llamas, one alpacas, one vicuñas, one guanacos and two unspecified camelids. Several countries indicate that locally adapted breeds have been included in such studies. CR Peru (2004) mentions molecular investigations of the genetic distances between South American camelid species. Few Country Reports, however, indicate that molecular technologies have been incorporated in breeding programmes. CR Colombia (2003) notes the potential significance of marker assisted selection programmes utilizing the genes of the Blanco Orejinegro cattle breed, which is reported to show resistance to brucellosis, and which has been the object of molecular characterization studies.

2.5 Near and Middle East

In this region all six countries providing information on the matter report the use of AI. With regard to the species involved, all 6 mention cattle, one camels and one rabbits. One Country Report (CR Oman, 2004) mentions the use of ET in camels. The semen used in AI programmes is largely obtained from exotic breeds, either from local populations or imported. A number of Country Reports note that the use of AI has had an adverse effect on genetic diversity and contributed to the decline of local livestock breeds. One Country Report (CR Syrian Arab Republic, 2003) mentions some use of semen from a local cattle breed (Shami). Some Country Reports indicate that the development of AI programmes for local breeds of sheep, goats and/or buffaloes is a priority. CR Syrian Arab Republic (2003), for example, notes that the local Awassi sheep and Shami goats are much sought after in neighbouring countries for breeding, and that plans are in hand to develop AI and ET programmes to meet the demand. Among 6 countries giving information on service providers, five mention the public sector, four the private sector and two breeders' organizations. Some Country Reports, however, indicate constraints to the provision of AI, such as a lack of trained personnel. Several Country Reports note the potential use of AI and ET technologies in cryoconservation. The use of other biotechnologies is limited. One Country Report (CR Jordan, 2003) indicates molecular characterization and genetic distancing studies in indigenous goats, while another (CR Egypt, 2003) notes that molecular genetic studies of buffalo, sheep and goats have recently been initiated with the aid of regional and international organizations.

2.6 North America

In the United States of America and Canada reproductive biotechnologies are readily available. AI is widespread in the dairy and pig industries, and is used to a lesser extent in other sectors such as beef cattle and small ruminants. Concern is expressed at the role of AI in contributing to a reduction in the effective population size of some dairy cattle breeds. Details of the utilization of other biotechnologies are limited in the Country Reports from this region. In the United States of America, molecular characterization studies have been carried out, by industry and public sector institutions, for the most widely kept breeds of dairy cattle and pigs, and also in a number of beef cattle breeds (CR United States of America, 2003). Molecular markers are particularly used for the identification of recessive defects in bulls used for AI. Molecular studies, providing measures of within and between-breed genetic diversity are also used by the National Animal Germplasm Program (NAGP) in the planning of conservation programmes for AnGR (*ibid.*).

2.7 Southwest Pacific

Biotechnologies are not widely used in this region. Six of the 11 Country Reports indicate the use of AI. Out of five countries indicating the species involved in AI programmes, five mention cattle, four pigs, one sheep and one goats. With regard to AI service providers, two Country Reports mention the public sector, two the private sector and one mentions an individual volunteer from a developed country. Several Country Reports from small island states note the potential of AI as a means of introducing exotic germplasm, but the use of the technology appears to be limited. In some countries a small number of private livestock producers are involved in the import of semen for the purposes of AI in their herds. Two Country Reports (CR Australia, 2004; CR Vanuatu, 2003) indicate the use of ET technology, both reports referring to cattle. Additionally, CR Samoa (2004) notes the use of the technology for the introduction of Piedmontese cattle during the 1980s. Capacity for the use of biotechnologies is well developed in Australia, which is the only country from the region reporting the use of molecular techniques to underpin characterization and selection efforts.¹⁰

¹⁰ New Zealand, a country with a well-developed biotechnology sector, did not submit a Country Report and is, therefore, not included in the analysis.

3 Conclusions

The information provided by the Country Reports unsurprisingly indicates that there is a large gap between developed and developing countries in terms of capacity to utilize biotechnologies in the management and development of AnGR. The focus, particularly in the case of reproductive biotechnologies, is on cattle, and the application of biotechnologies in the use, development or conservation of locally adapted breeds is generally limited. Provision is constrained by a lack of financial, human and technical resources, and problems related to access, affordability and acceptability within diverse local production systems.

In a number of regions, there is increasing diversity in terms of the stakeholders providing services, with greater involvement of the private sector and breeders' organizations. Such developments may have a role in overcoming constraints to the utilization of biotechnologies in developing countries, but it is evident from the Country Reports that progress in this respect is often very limited.

A further concern noted in many Country Reports is the inappropriate use of AI. Concerns largely relate to the unplanned use of the technology to introduce exotic germplasm, which may threaten the existence of indigenous genetic resources. With regard to high-output breeds kept under high external input conditions, there are also some concerns regarding a narrowing of within-breed genetic diversity. The successful application of technologies such as marker assisted selection necessitates high levels of inputs in terms of financial, human and technical resources. As such, the cost-effectiveness of strategies based on the use of such technologies has to be carefully evaluated. Implications for genetic diversity should also be considered. Successful introduction of marker assisted selection will tend favour the utilization of a limited number of breeds at the expense of others, and will also pose a threat to within-breed diversity.

4 References

CR (Country name), year. *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).

FAO. 2004. *The State of Food and Agriculture 2003-04. Agricultural Biotechnology – meeting the needs of the poor?* Rome.

SECTION E: LEGISLATION AND REGULATION

1 International legal framework – major instruments

1.1 Introduction

A number of international legal frameworks, relevant to the current and future management of AnGR are described in this section. The frameworks include both legally binding and non-binding instruments. The term “soft law” is used here to refer to non-binding legal instruments, which are utilized for a variety of reasons, including strengthening member commitment to agreements at the policy level, reaffirming international norms, and establishing informal precedents for subsequent treaties.

1.2 Legal framework for the management of biodiversity

This subchapter describes international-level legally binding instruments and soft laws by which national governments undertake to address the management and conservation of biodiversity, to develop policies on the issue, and to implement relevant actions.

Adopted in 1992, Agenda 21 is a plan of action to be undertaken at the global, national and local levels by governments, the organizations of the United Nations System and other stakeholders, to address all areas of human impact on the environment¹¹. The Agenda was prepared to coincide with the 1992 United Nations Conference on Environment and Development (Earth Summit) held in Rio de Janeiro, and was adopted at the time by 179 governments. Chapter 14 of Agenda 21, “Promoting Sustainable Agriculture and Rural Development”, addresses the question of increasing food production in a sustainable way and enhancing food security. Among the programme areas included in Chapter 14, is programme area (h) on the conservation and sustainable utilization of AnGR. The management-related activities specified in this programme stipulate that governments should: “a) draw up breed conservation plans for endangered populations, including semen/embryo collection and storage, farm-based conservation of indigenous stock and *in situ* conservation, b) plan and initiate breed development strategies, and c) select indigenous populations on the basis of regional importance and genetic uniqueness, for a ten-year programme, followed by selection of an additional cohort of indigenous breeds for development.” Subsequently, at the World Summit on Sustainable Development held in Johannesburg in 2002, sustainable agriculture and rural development was one of the issues considered in the Plan of Implementation. Paragraphs 6(i) and 38 of the Final Declaration stress the importance of sustainable agriculture and rural development to the implementation of an integrated approach to increasing food production and enhancing food security and food safety in an environmentally sustainable way.

The Convention on Biological Diversity (CBD)¹², a legally binding international framework for the management of biodiversity, was signed by 150 governments at the Rio Earth Summit. By 2005 it had 188 parties. The three objectives of the CBD, as set out in Article 1, are: the conservation of biological diversity, the sustainable use of components of biological diversity, and the fair and equitable sharing of the benefits arising from the utilization of genetic resources. Conservation of biological diversity clearly encompasses the conservation of the animal and plant genetic resources required for food and agriculture. The CBD states that, while states have the sovereign right to exploit their own resources (Article 3), they also have the duty to conserve them and to facilitate access for sound uses to other Contracting Parties (Article 15). The need for policy development and integration is acknowledged in the CBD, and governments are requested to develop national strategies on biodiversity (Article 6a), and to integrate “the conservation and sustainable use of biological diversity into relevant sectoral and

¹¹ <http://www.un.org/esa/sustdev/documents/agenda21/>

¹² <http://www.biodev.org>

cross-sectoral plans, programmes and policies” (Article 6b). In 2000, the CBD was supplemented by the Cartagena Protocol on Biosafety, which is considered in greater detail below.

The special nature of agricultural biodiversity has been consistently recognized by the Conference of the Parties (COP) to the CBD. Decisions V/5 and II/15 specifically mention “the special nature of agricultural biodiversity, its distinctive features, and problems needing distinctive solutions.” Decision V/5 supports FAO’s work on AnGR, and states that “Country-driven assessments of genetic resources of importance for food and agriculture ... shall be implemented, including through programmes of FAO.” Moreover, the COP’s Decision VI/5, “Invite[d] Parties, other Governments, the financial mechanism and funding organizations to provide ... support to enable countries ... to participate fully in the preparatory process for the first Report on the State of World’s Animal Genetic Resources, and implement follow-up actions identified through the process.”

The Commission on Genetic Resources for Food and Agriculture (CGRFA) was the first permanent intergovernmental forum dealing with agricultural genetic resources. At present, 167 Governments and the European Community are members. Its statutes provide that it shall:

“have a coordinating role and shall deal with policy, sectorial and cross-sectorial matters related to the conservation and sustainable use of genetic resources of relevance to food and agriculture ...

“provide an intergovernmental forum for negotiations and ... oversee the development, upon the request of the FAO Governing Bodies, of other international agreements, undertakings, codes of conduct or other instruments relating to genetic resources of relevance to food and agriculture, and ... monitor the operation of such instruments ...

“facilitate and oversee cooperation between FAO and other international governmental and non-governmental bodies dealing with the conservation and sustainable use of genetic resources, in particular with the Conference of Parties to the Convention on Biological Diversity and the UN Commission on Sustainable Development, and ... seek to develop appropriate mechanisms for cooperation and coordination in consultation with such bodies”.

The Commission was established in 1983, as the Commission on Plant Genetic Resources, and, in 1995, its mandate was extended to cover all components of biodiversity of relevance to food and agriculture. This mandate is being implemented through a step-by-step approach, and work has so far focused largely on plant and animal genetic resources for food and agriculture. Major achievements of the Commission include:

- the adoption, in 1983, of the International Undertaking on Plant Genetic Resources, a voluntary instrument that was the first international agreement dealing with the conservation and sustainable use of any component of genetic resources. Farmers’ Rights were first recognized, in 1989, in the context of the International Undertaking;
- the establishment, in 1994, of the International Network of *Ex situ* Collections of Plant Genetic Resources for Food and Agriculture under the auspices of FAO. This currently provides the legal framework under which the most important collections for food security and sustainable development are held, in trust for the international community, and under the Commission’s policy guidance;
- the adoption, in 1996, of the first report on the State of the World’s Plant Genetic Resources for Food and Agriculture¹³ and of the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture¹⁴;
- the adoption in 2001 of the legally binding International Treaty on Plant Genetic Resources for Food and Agriculture¹⁵ (IT-PGRFA);
- the launch of the preparation process for the State of the World’s Animal Genetic Resources for Food and Agriculture including the Strategic Priorities for Action, to be finalized in 2007.

¹³ <http://www.fao.org/ag/agP/AGPS/Pgrfa/pdf/swrfull.pdf>

¹⁴ <http://www.fao.org/ag/AGP/AGPS/GpaEN/gpatoc.htm>

¹⁵ <http://www.fao.org/AG/cgrfa/itpgr.htm>

The IT-PGRFA came into force on 29 June 2004, 90 days after 40 governments had ratified it. Article 1 of the Treaty states that “The objectives of this Treaty are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use, in harmony with the Convention on Biological Diversity, for sustainable agriculture and food security.” Further: “These objectives will be attained by closely linking this Treaty to the Food and Agriculture Organization of the United Nations and to the Convention on Biological Diversity.”

1.3 Access and benefit sharing

In the context of AnGR management, it is often the case that livestock breeds or varieties, and the knowledge associated with their management have been developed by local or indigenous communities. Scientific institutions and commercial enterprises may further develop such materials in the same country or elsewhere. In such circumstances, controversies may arise over access to genetic material and the distribution of benefits deriving from its utilization. A number of international frameworks attempt to address the issue.

The CBD recognizes the importance of ensuring “the fair and equitable sharing of the benefits arising out of the utilization of genetic resources”. With regard to access, Article 15 of the CBD acknowledges the sovereign rights of states over their natural resources, and states that access is subject to national legislation (Article 15.1). Access is to be granted on mutually agreed terms (Article 15.4) through bilateral agreements. Prior informed consent of the party providing the genetic resources is required (Article 15.5). The provisions can be taken to mean that the provider of genetic resources must be fully informed in advance by the access-seeking party about the objectives, as well as the economic and environmental implications of such access. The CBD foresees the necessity of legislative, administrative or policy measures to provide for fair and equitable sharing, with the party that provided the resources, the results of research and development and benefits arising from the commercial and other utilization of genetic resources (Article 15.7). A benefit-sharing component is also found in Article 8(j), which contains provisions to encourage the equitable sharing of the benefits arising from the utilization of knowledge, innovations and practices of indigenous and local communities, embodying traditional lifestyles relevant for conservation and sustainable use of biological diversity.

Under the IT-PGRFA, countries agree to establish a multilateral system of access and benefit sharing to facilitate access to plant genetic resources for food and agriculture, and to share the benefits in a fair and equitable way (Article 10). In the case of commercial products that may not be used without restriction by others for further research and breeding, the Treaty provides for a mandatory payment of an equitable share of the resulting benefits. It also identified capacity building, exchange of information and technology transfer as relevant mechanisms for non-monetary benefit sharing. The Treaty recognizes the enormous contribution that farmers and their communities have made and continue to make to the conservation and development of plant genetic resources. “Farmers’ Rights” under the Treaty, include the protection of traditional knowledge, and the rights to participate equitably in benefit sharing and in national decision-making about plant genetic resources. The Treaty makes national governments responsible for implementing these rights. The Treaty also foresees a funding strategy to mobilize funds for activities, plans and programmes particularly aimed at helping small farmers in developing countries. This funding strategy also includes the voluntary and mandatory sharing of the monetary benefits paid under the Multilateral System (Article 13) and voluntary payments by Contracting Parties and other stakeholders (Article 18). No similar treaty exists in the case of AnGR.

Falling within the category of “soft laws” are the Bonn Guidelines, which were developed by the CBD and adopted under Decision VI/24. It is, however, evident from the wording of the guidelines that they were drawn up with attention being paid to wild biodiversity rather than AnGR. The guidelines provide a set of voluntary rules which will assist parties, governments and other stakeholders when establishing legislative, administrative or policy measures on access and benefit sharing and/or when negotiating contractual arrangements for access and benefit sharing.

The Bonn Guidelines state that before collecting any genetic resources, a collector should have a written agreement that includes: prior informed consent of the national government of the country of origin; prior informed consent of the indigenous community or communities whose “traditional knowledge” is being accessed; details of the non-monetary and/or monetary benefits the collector will provide; and information on whether, and under what conditions, the collector may transfer the collected genetic resources to another party. The development of mutually agreed terms should be based on the principles of legal certainty and minimization of costs. The Bonn Guidelines set out a detailed description of the type of provisions that could form part of a contractual arrangement. Some of the proposed elements are quite innovative and include specification of the uses for which consent has been granted; the regulation of these uses in light of the ethical concerns of the parties to the agreement; provisions for the continuation of customary uses of genetic resources; possible joint ownership of intellectual property rights according to contributions; confidentiality clauses; and the sharing of benefits from commercial and other utilization of genetic resources including derivatives.

1.4 Legal framework for international trade

The main legal framework regulating international trade in livestock and livestock products is the WTO Agreement on Agriculture adopted in 1994. The basic principles of the WTO¹⁶ agreements include:

- Trade without discrimination – this principle was one of the foundations of the General Agreement on Tariffs and Trade (GATT). In the WTO Agreement, this principle is effected through the operation of various clauses included in the Multilateral Agreements on Trade in Goods, the General Agreement on Trade in Services (GATS), and the Trade-Related Intellectual Property Rights Agreement (TRIPS). The main elements include:
 - Most favoured nation (MFN) clause – requires WTO Members to grant to the products of other contracting parties treatment no less favourable than that accorded to products of any other country.
 - National treatment principle – condemns discrimination between foreign and national goods or services and service suppliers or between foreign and national holders of intellectual property rights.
- Transparency – provisions on notification requirements and the Trade Policy Review Mechanism are set out in the WTO Agreement and its annexes, with the objective of guaranteeing the fullest transparency possible in the trade policies of its Members in goods, services and the protection of intellectual property rights.

Further details relating to the TRIPS Agreement of the WTO are provided below in the discussion of international legal frameworks for intellectual property rights.

Of potential relevance to trade in animal products, and hence to the development of the livestock sector in developing countries, are preferential access regimes to important markets. Such access regimes are permitted, but not required, to be granted to developing countries. An example is the Cotonou Agreement between the African–Caribbean–Pacific (ACP) states and the EU and its Member States. The EU and the ACP States have agreed on a process to establish new trading arrangements to promote trade liberalization between the parties and formulate provisions in trade-related matters. The agreement’s Protocol 4 applies to several African countries (Botswana, Kenya, Madagascar, Namibia, Swaziland and Zimbabwe) which are traditional exporters of beef and veal. Within defined quantities of meat per year, set for each country, “customs duties other than *ad valorem* duties applicable to beef and veal ... shall be reduced by 92 percent.” While arrangements of this nature, can serve to promote export-oriented livestock production in developing countries, trade in animals and animal products is also greatly affected by the WTO Agreement on Sanitary and Phytosanitary Measures (SPS Agreement), which is discussed in greater detail below.

¹⁶ <http://www.wto.org>

1.5 Intellectual property rights

Rapid developments in the field of biotechnology have increasingly drawn attention to the issue of intellectual property rights in relation to AnGR. The prospect of patents being applied to livestock genes, genetic markers or methods for genetic improvement has given rise to much controversy. The issue potentially has substantial implications for the management of AnGR and access to the benefits arising therefrom (see Section E: 2.1 for further discussion of this issue).

The TRIPS agreement has been in force since January 1995. TRIPS requires WTO members to establish minimum standards for the protection of various forms of intellectual property. The scope of the agreement is broad, applying to copyright and related rights, trademarks, geographical indications, industrial design, patents, the layout designs of integrated circuits, and undisclosed information such as trade secrets and test data. TRIPS requires members to make patents available for any inventions, whether products or processes, in all fields of technology without discrimination, subject to the normal tests of novelty, inventiveness and industrial applicability. Several elements covered by the agreement potentially affect the management of AnGR. While it appears that no patents covering types or breeds of livestock used for food production have been granted, an increasing number of patents relating to genes have been issued. In the event of the introduction of transgenic technologies in animals used for agricultural production, the issue of animal patenting may become more prominent. Article 27.3(b) of TRIPS provides member countries with the option of excluding “plants and animals other than micro-organisms, and essentially biological processes for the production of plants or animals other than non-biological and microbiological processes” from the basic rule on patentability. There is, therefore, no all-embracing framework covering the issue of patentability with respect to AnGR, and approaches vary from country to country.

Some other elements covered by the TRIPS agreement may have an influence on the management of AnGR. For example, rules related to indications of geographical origin may have an important influence on the ability to market the products obtained from local livestock breeds.

The World Intellectual Property Organization (WIPO)¹⁷ is an intergovernmental organization whose mandate is to ensure that the rights of creators and owners of intellectual property are protected worldwide, and that inventors and authors are recognized and rewarded for their creativity. In a number of policy areas, including agriculture and genetic resources, concerns related to the exploitation of traditional knowledge systems have emerged. In an attempt to address the issue, WIPO's Intergovernmental Committee (IGC) on Intellectual Property and Genetic Resources, Traditional Knowledge and Folklore was established in 2000. The committee provides “a forum for international policy debate about the interplay between intellectual property and traditional knowledge, genetic resources and traditional cultural expressions (folklore)”. Key questions being addressed by the committee at the time of writing were a possible International Instrument on Intellectual Property in Relation to Genetic Resources and on the Protection of Traditional Knowledge and Folklore, and a possible requirement that patent applications include a disclosure of the source of the genetic material used. The committee has accomplished substantial work on traditional knowledge including a “toolkit” for managing intellectual property when documenting traditional knowledge and genetic resources; a survey of intellectual property protection of traditional knowledge; and a database of intellectual property clauses in bilateral access agreements. WIPO's General Assembly also authorized “the possible development of an international instrument or instruments.” However the matter remained contentious, with some South American and African countries favouring swift movement towards an international treaty, and developed countries favouring a more gradual approach.

Another significant development in this field is the Substantive Patent Law Treaty (SPLT), which at the time of writing was under negotiation in the WIPO Standing Committee on the Law of Patents in Geneva. The draft SPLT covers a number of basic legal principles underpinning the granting of patents in different countries, such as the definition of prior art, novelty, inventive step (non-obviousness), industrial applicability (utility), sufficiency of disclosure, and the structure and

¹⁷ <http://www.wipo.int>

interpretation of claims. The trend is towards upward harmonization of patent law, raising standards much further with little space for national adaptation.

1.6 Legal framework for biosecurity

FAO uses the term “biosecurity” to describe the “the management of biological risks in a comprehensive manner to achieve food safety, protect animal and plant life and health, protect the environment and contribute to its sustainable use” (FAO, 2003). Within the field of biosecurity, a range of laws and regulations have been put in place relating to plant and animal life and health, associated environmental risks, food safety, invasion by alien species, and some aspects of biosafety (Stannard *et al.*, 2004). Several international legal frameworks which affect the management of AnGR focus on issues of biosecurity, and are discussed in the following subchapters. The importance of information exchange at the international level and the establishment of international standards (agreed guidelines, recommendations and procedures) is recognized to be important in facilitating the implementation by developing countries of biosecurity measures (*ibid.*). FAO has launched an Internet-based International Portal for Food Safety and Animal and Plant Health¹⁸, which serves as a single access point for authorized official international and national information related to biosecurity.

Animal health and food safety

Matters related to animal health are of major international concern, particularly in the context of increasing levels of trade in livestock and livestock products. Governments are keen to ensure that national livestock industries are protected from the potentially devastating effects of transboundary livestock diseases. Serious threats to human health on an international scale, notably outbreaks of HPAI, intensify the need for effective measures at the global level. Marked differences between countries, in terms of their animal health status and standards for food safety, increase the potential for disputes related to international trade. Developing countries in particular tend to be affected by animal health-related trade restrictions. These restrictions can have major impacts on the movement of AnGR (Box 43).

The SPS Agreement of the WTO encourages governments to establish national sanitary and phytosanitary measures consistent with international standards, guidelines and recommendations. International standards are often higher than the national requirements of many countries, including developed countries. The SPS Agreement explicitly permits governments to choose not to use the international standards. However, if the national requirement that differs from the international standards results in a greater restriction of trade, the country imposing the different standard may be asked to provide scientific justification, demonstrating the need for the stricter measure. Countries must establish SPS measures on the basis of a realistic assessment of the risks involved. If requested, countries must make known the factors that were taken into consideration, the assessment procedures used, and the level of risk which was determined to be acceptable. Governments are required to notify other countries of any new or changed SPS requirements that affect trade, and to set up offices (called “Enquiry Points”) to respond to requests for more information on new or existing SPS measures. Governments must also open to scrutiny their methods of applying food safety and animal and plant health regulations. As far as animals are concerned, the relevant international standards under the SPS Agreement are those set by the World Organization for Animal Health (OIE) and the FAO/WHO Codex Alimentarius Commission.¹⁹

The OIE²⁰ is recognized as the standard-setting body for animal health under the SPS agreement. Health measures contained in the Terrestrial Animal Health Code (in the form of standards, guidelines and recommendations) have been formally adopted by the OIE International Committee. The Terrestrial Animal Health Code is a reference document for use by veterinary authorities, import/export services, epidemiologists and all those involved in international trade. Because of the relationship between animal health and animal welfare, the representatives of the OIE’s member

¹⁸ <http://www.ipfsaph.org/En/default.jsp>

¹⁹ http://www.codexalimentarius.net/web/index_en.jsp

²⁰ <http://www.oie.int>

countries have asked the OIE to take the lead role in the setting of international standards for animal welfare. A Permanent Working Group on Animal Welfare was established and held its first meeting in October 2002. In 2005, the International Committee of OIE Member Countries adopted a set of animal welfare standards to be included in the organization's Terrestrial Animal Health Code. The standards cover the transport of animals by land, the transport of animals by sea, the slaughter of animals, and the killing of animals for disease control purposes.

Box 43

Impact of international zoosanitary regulations on animal genetic resources management – the example of FMD

On a global scale, perhaps the most significant transboundary disease in terms of its impacts on trade is foot-and-mouth disease (FMD). Even a limited outbreak of FMD can be devastating for a country's livestock trade. The ability or failure to maintain FMD-free status is likely to have a marked effect on a country's patterns of livestock development. International trade-related rules associated with FMD control may affect the management of AnGR in several ways.

According to OIE rules, a distinction is drawn between disease-free countries where vaccination is practised, and those where vaccination is not practised. To achieve the latter status, and the resulting benefits associated with livestock exports, a country must: have a good record of disease reporting; declare to the OIE that during the past 12 months there has been no outbreak of FMD, no evidence of FMD virus infection, and no vaccination against FMD; have maintained required levels of surveillance; and not have imported any vaccinated animals since the cessation of vaccination.

To meet these requirements, disease-free countries, or those aiming to achieving disease-free status, often combat disease outbreaks with stamping-out or slaughter policies. The mass culling of animals following an outbreak potentially threatens rare-breed populations found in a restricted geographical area. Disease-free countries may also face problems if they require the import of genetic material from countries where FMD is endemic. This can particularly be a problem for tropical countries, as many countries with similar production conditions will be affected by the disease. This point is raised in the Country Report from Trinidad and Tobago (2005). Less direct impacts may relate to differences in the utilization of AnGR between disease-free and disease-endemic countries. Export-oriented producers in the former countries may adapt their production objectives to meet the demands of external markets, and adopt management practices associated with a more commercial outlook. These changes may result in shifts in the balance of breed utilization.

The Codex Alimentarius Commission was created in 1963 by FAO and WHO to develop food standards, guidelines and related texts such as codes of practice under the Joint FAO/WHO Food Standards Programme. In addition to food standards, the Codex has also addressed safety issues related to animal feed. One of its projects is the preparation of a Code of Practice for Good Animal Feeding, undertaken in response to food trade and health problems arising from animal feed. The Code applies to feed manufacturing and to the use of all feeds, other than those taken while grazing free-range. The primary objective of the Code is to encourage adherence to Good Manufacturing Practices during the production, harvesting, handling, storage, processing (however minimal) and distribution of feed for food-producing animals. A further objective is to encourage good feeding practices on the farm. In recent years, both the Codex Alimentarius and the OIE have also addressed issues related to the safety of genetically modified organisms. These matters will be considered further in the following subchapter on international legal frameworks for biosafety.

Biosafety

Potential for increased output and novel livestock products has stimulated interest in the development of transgenic livestock. The widespread introduction of these technologies would clearly have considerable implications for the management of AnGR. Recombinant DNA technologies are at present applied in the field of veterinary pharmaceuticals. Transgenic crops such as maize are used for animal feed in some countries. A number of environmental and health-related concerns have, however, been raised with regard to genetic modification. Several international frameworks seek to address issues related to the safety of genetically modified organisms (GMOs) or living modified organisms (LMOs) and products derived therefrom.

The Cartagena Protocol on Biosafety was adopted in January 2000 by the Conference of the Parties to the CBD as a supplementary agreement to the CBD, and entered into force on 11 September 2003. The Protocol seeks to protect biological diversity from the potential risks posed by LMOs. The Protocol applies to the transboundary movement, transit, handling and use of all LMOs that may have adverse effects on the conservation and sustainable use of biological diversity, as well as risks to human health. However, LMOs that are pharmaceuticals for human consumption are excluded from the scope of the Protocol if they are covered by another international agreement or arrangement.

The Cartagena Protocol establishes an Advanced Informed Agreement (AIA) procedure in order to ensure that countries are provided with the information necessary to make informed decisions before agreeing to the import of such organisms into their territory (Article 7). However, a number of LMOs are excluded from the AIA procedure because of the specific activity or the intended use of the LMO. The LMOs that may be excluded from the AIA procedure are: LMOs in transit, LMOs destined for contained use, and LMOs intended for direct use as food or feed or for processing. The Protocol reserves the right of countries to take decisions on imports on the basis of the precautionary principle in relation to both LMOs to be introduced into the environment and LMOs to be used for food, feed or processing. Socio-economic considerations arising from the impact of LMOs on biodiversity may also be taken into account in import decisions.

In 1999, the Codex Alimentarius Commission established an Ad Hoc Intergovernmental Task Force on Foods Derived from Biotechnology to consider the health and nutritional implications of such foods. In particular, the objectives of the Task Force are to develop standards, guidelines or recommendations, as appropriate, for foods derived from biotechnology or traits introduced into foods by biotechnology. This is to be done on the basis of scientific evidence, risk analysis and having regard, where appropriate, to other legitimate factors relevant to the health of consumers and the promotion of fair trade practices. An expert consultation on the "Safety Assessment of Foods Derived from Genetically Modified Animals including Fish" was held in November 2003, continuing the work of FAO and WHO on the safety assessment of genetically modified (GM) foods, and focused on GM animals, including fish, and the foods derived therefrom. The main purpose of this consultation was to discuss and describe ways to assess the safety and risk of GM animals. A working paper on the state of the art related to GM farm animals was produced (WHO/FAO, 2003). Environmental and ethical matters related to the production of GM animals/fish were discussed as additional issues.

In May 2005, the OIE International Committee adopted resolutions on genetic engineering applications for livestock and biotechnology products, and the implementation of standards in the framework of the SPS Agreement. Members requested the development of standards and guidelines relating to animal vaccines produced through biotechnology, animal health risks linked to cloning, the exclusion of unapproved animals and products from the livestock population, and genetically engineered animals.

1.7 Conclusions

Animal health-related trade regulations are probably the aspect of international legal frameworks that have the greatest impact on AnGR management at present – affecting both the exchange of genetic material, and the nature of production systems and disease control measures at the national level. The growth of trade in livestock and livestock products, and the associated need to maintain strict animal health standards without imposing unjustified restrictions on trade, has required the establishment of binding international regulations in this field. The increasing significance of international trade has also driven the establishment of international regimes to regulate other aspects of commerce. One area of potential importance to the management of AnGR is that of intellectual property rights. The TRIPS agreement of the WTO, however, allows for the exemption of animals from patenting, and it is national-level legislation, along with regional or bilateral trade agreements which, at present, have the greatest influence in this field.

The recognition that biological diversity is an important resource and aspect of the world's heritage has also motivated the development of legal measures on an international scale – the main instrument being the CBD. Although the distinctive nature of agricultural biodiversity is recognized by the COP

of the CBD, the main focus of the Convention's provisions is on wild biodiversity. There is a concern that legal instruments developed in accordance with the provisions of the CBD, for example in the field of access and benefit sharing, may fail to take sufficient account of the specific problems of AnGR management, and place unnecessary restrictions on exchange and utilization. The IT-PGRFA, established a legally binding international framework specifically for the crop sector, with the objective of ensuring conservation, sustainable use, and equitable sharing of the benefits of genetic resources. There is a need to clarify whether a similar instrument is required for AnGR.

Although many international instruments affect AnGR management, to date, most have paid little or no attention to the topic. Moreover, a number of ongoing and emerging forces are likely to drive further developments in the field of international legislation. Intellectual property rights and issues of access and benefit sharing, for example, may well be issues of increasing significance in coming years; and transboundary livestock diseases are a constant concern. It is vital to ensure that as international law develops, the need for effective and equitable frameworks for the utilization and conservation of AnGR is not overlooked.

1.8 References

FAO. 2003. *Technical consultation on biological risk management in food and agriculture*. Bangkok, Thailand, 13–17 January 2003. Report of the technical consultation. Rome. (also available at ftp://ftp.fao.org/es/esn/food/tc_bangkok/tc_brm_report_en.pdf).

Stannard, C., van der Graaff, N., Randell, A., Lallas, P. & Kenmore, P. 2003. Agricultural biological diversity for food security: shaping international initiatives to help agriculture and the environment. *Howard Law Journal*, 48(1): 397–430.

WHO/FAO. 2003. *Generation and use of genetically modified farm animals*, by M-L. Houdebine. Rome.

2 Emerging legal issues

This section introduces two policy issues in the field of AnGR management that are increasingly being discussed by stakeholders – patenting and Livestock Keepers' Rights.

2.1 Patenting

General principles and mechanisms

Intellectual property rights (IPRs) are granted in order to provide innovators with a greater opportunity to capture the benefits arising from the products of their inventiveness. The need for IPRs can be justified in economic terms as a means of overcoming a characteristic of market economies which tends to reduce the rate of innovation below the social optimum when innovations can be copied freely. This “market failure” arises as a result of the “public goods” nature of knowledge; the costs of research and development are borne by the innovator, but the benefits accrue to the wider society (Lesser, 2002). Moral arguments in favour of IPRs can also be put forward, related to the justice of rewarding those whose work results in useful innovations (Evans, 2002). However, these two general justifications are seldom tested with empirical data to find whether there is actually a need for stronger IPRs to stimulate research and development in a particular field of innovation.

The discussion below focuses largely on the issue of patents. However, it should be noted that other forms of IPR are of potential relevance to the management of AnGR, particularly trademarks, trade secrets and geographic indications. The holder of a trademark is given exclusive rights to use a name or symbol associated with a product. The goodwill that the holder has built up while providing the product under a given name cannot then be expropriated by others or dissipated through the supply of inferior products under the same name (Lesser, 2002). A relevant example would be Certified Angus Beef[®] protected by federal trademark law in the United States of America. Similar to trademarks are rights to geographical appellations of origin, which indicate that a product was produced in a particular geographical area where the production conditions are associated with distinct characteristics. These

rights are of considerable relevance to niche markets, and hence potentially to the utilization of local livestock breeds. In the EU, rules for the use of “geographical indications and designations of origin” are set out in Council Regulation (EEC) No 2081/92.

Trade secrets relate to the protection from misappropriation of any commercially sensitive information (and materials) that the holder takes reasonable precautions to conceal. Crop breeders have for many years used this approach to protect the parent lines and related information used in the production of hybrid seed for sale, and similar approaches are adopted in the poultry and pig industries (Lesser, 2002). Plant breeders’ rights (PBRs) (an example of so-called *sui generis* systems) have been developed to protect the IPRs of plant breeders. PBRs offer a protection that is adapted to the agricultural sector, and include certain levels of exemption for further breeding and for farmers to retain seed from the crop. An internationally harmonized framework for the management of PBRs is established under the auspices of UPOV, the International Union for the Protection of New Varieties of Plants. This body was established by the International Convention for the Protection of New Varieties of Plants signed in 1961 which came into force in 1968 and was subsequently revised in 1972, 1978 and 1991; the latter revision coming into force in 1998 (UPOV, 2005).

In the case of patents, the holder is given exclusive rights over the commercial use of an innovation for a set period of time, often 20 years, in the country in which the patent is granted. This competitive advantage serves to counteract the effects of the above-mentioned market failure. In order to obtain a patent, the innovation must be inventive or not obvious; it must be novel, in the sense of not being previously known through public use or publication (Lesser, 2002). A further formal criterion is that the invention must have a practical use; in Europe, the term “industrial application” is used in this context, while in the United States of America, “usefulness” or “utility” is a requirement. A patent can be obtained to cover, a product *per se* (in itself), a process, or a product derived through a process; it may be dependent on previous patents. The requirement for a description of the invention to accompany the application, in such a way that a person “skilled in the art” is able to reproduce it, promotes the dissemination of information and may stimulate research in related fields (*ibid.*).

While patents may serve to promote innovations, it must be recognized that once a new product has been developed, the existence of a patent inhibits competition and thereby reduces the availability of the product. The balance between the two effects, and hence the outcome in terms of the economic benefits to society as a whole, is a matter of complex interactions between the length and scope of the patent and the nature of demand for the product (Langinier and Moschini, 2002). Moreover, the propensity of patents to promote innovation has sometimes been challenged. Criticisms are advanced on the grounds that access to inputs, or procedures, vital to further innovation may be restricted through the exercise of patents, or that overly broad patents stifle further research in related fields (Evans, 2002; Lesser, 2005).

Patents and living organisms

The extension of patent law to cover plants and animals, or processes related to the production or genetic manipulation of living organisms, gives rise to additional concerns. The idea of asserting ownership over biological processes offends many people’s religious or spiritual sensibilities. In this respect, misgivings about patenting are to some extent tied to its association with technologies such as genetic modification. Such concerns are reinforced by fears about the health or environmental impacts of these technologies (Evans, 2002). Other objections to patents on living organisms relate to the belief that natural processes are part of the common heritage of humankind, which should not be alienated for private profit. Similarly, concerns relate to the expropriation of the genetic material developed by local communities, or the associated knowledge of crop/animal breeding activities, through the granting of patents to outside interests (*ibid.*). Moreover, in the context of food and agriculture, the impacts on food security and social justice of restricting access to animal or plant genetic resources are further causes for concern.

Many of the world’s countries do not permit the patenting of plants and animals. However, prominent exceptions include the United States of America and Japan (Blattman *et al.*, 2002). While the EU does not permit the patenting of plant or animal varieties, under Council Directive 98/44/EC of 6 July 1998, it allows patents for inventions concerning animals or plants the feasibility of which “is not confined

to a particular plant or animal variety”. Moreover, the fact that the term “variety” is not well-defined in the context of animal breeding means that the scope of the exemption is far from clear (see below for a further discussion of the EU Patent Directive).

Both the 1973 European Patent Convention (EPC), under Article 53(a), and EU Council Directive (98/44/EC) (Article 6), allow for patent applications to be refused if their exploitation is contrary to “ordre public” or “morality”. This exemption has been carried over into the TRIPS agreement of the WTO. Unsurprisingly, definitions of “ordre public” or “morality” have not been easy to establish, and the patenting in Europe of the “Harvard oncomouse” (Box 44) has been subject to ongoing legal challenges on the basis of the EPC’s “morality exemption” (Thomas and Richards, 2004). More generally, the TRIPS agreement allows countries to exclude plants and animals from patent protection (although there is a requirement for the protection of plant varieties by an effective *sui generis* system). Notwithstanding these exemptions, there is a concern that developing countries’ scope to exclude living things from patenting may increasingly be limited by bilateral and regional trade agreements (Correa, 2004).

Box 44

The first patented animal

While patenting has a long history, the inclusion of living things under patent laws is a relatively recent phenomenon. This text box focuses on historical developments in the United States of America related to the applicability of patents to living things and leading to the first case of a patent on a higher animal. Patent law in the United States of America dates back to 1793, but the original statute makes no reference to living things. Indeed, a ruling of 1889 established a precedent indicating that “products of nature” could not be patented. The first provision specifically related to the patenting of living organisms was the Plant Patent Act of 1930, which introduced a specially designed form of protection for asexually reproducing plants (except edible roots and tubers). European countries followed in the next decade with the introduction of their own “*sui generis*” Plant Breeders’ Rights laws.

The 1970s and 1980s saw the emergence of technologies that enabled scientists to manipulate the genomes of living organisms. Individuals or organizations undertaking these activities were in a position to claim that the resulting organisms were the products of their own inventiveness rather than simply products of nature. It was not long before the issue was tested in the courts, and in 1980 the case of *Diamond vs. Chakrabarty* established the precedent that micro-organisms were patentable in the United States of America. The case related to a bacterium engineered to consume oil slicks. Some years later, in 1987, the question of the patentability of higher organisms also came to court. This time, the organism in question was an oyster manipulated to make it more edible. While the application was rejected, the ruling in the case of *Ex Parte Allen* established that there was no legal restriction to the patenting of oysters on the grounds that they are higher animals. In the wake of this ruling the world’s first patent on an animal was soon issued. In this case, the animal was a type of mouse developed at Harvard University for use in the study of disease. The mouse had been genetically engineered to make it highly susceptible to cancer. Subsequently, in 1992 the “oncomouse” became the first patented animal in Europe. Not surprisingly, the production of animals deliberately rendered susceptible to a distressing disease provoked widespread public unease, and has served to fuel the controversy surrounding animal patenting.

For further reading see: Kevles (2002); Thomas & Richards (2004)

It was in the fields of medical research and pharmaceuticals that the first legal battles related to granting patents on higher animals were fought out (Box 44). The emergence of animal patenting as a significant issue in the field of food and agriculture has lagged somewhat behind. Patents on transgenic salmon have been granted in the United States of America (US Patent Number 5,545,808, August 13, 1996) and in the EU (EP 0578 635 B1, July 18, 2001). However, among the species covered by this Report, no examples of patents granted on any breeds or types of animal intended for food production could be found at the time of writing. Nonetheless, as has happened in the biomedical sciences, patenting is emerging as a significant issue in the livestock sector, driven in part by technological developments, and the desire to profit from or promote these developments. Once again, ethical objections are raised both regarding patenting as such, and regarding some of the biotechnologies to which it might be applied. It is, however, also important to note that there are numerous practical legal issues that also need to be addressed – particularly related to the scope of patent protection.

Among the factors complicating the application of patenting to farm animals is the tendency of livestock to reproduce, which complicates the process of identifying the animals to which patent rights

should apply (e.g. if patented animals were to be bred with non-patented) (Lesser, 2002). Similarly, long production cycles – particularly in the case of cattle, complicate decisions regarding when in the production cycle patent-related payments should apply (*ibid.*). The significance of these issues is to an extent dependent on species and production system. The problems are rather less significant in the case of commercial poultry and pig industries, where hybrid lines are provided by large breeding companies, animals are confined, and breeding management is highly controlled. However, even under these production systems, the legal basis for patent claims is debatable. It is not clear that the animals or their breeding methods can be considered non-obvious, or whether the requirement for a description that allows the reproduction of the innovation can be met. A parallel with plant breeders' rights is also difficult to implement in the case of animals, partly because the concepts of plant variety and animal breed differ significantly.

Patent claims related to livestock

Notwithstanding the absence of patents on types of livestock *per se*, patents have been granted on a number of innovations in the field of livestock breeding and genetics. For example, the patenting of biotechnological processes and biological materials derived through such processes is permitted under EU legislation (Council Directive 98/44/EC), even if the material has previously occurred in nature. "Essentially biological processes" consisting "entirely of natural phenomena such as crossing or selection" are exempted (*ibid.*). However, it is debatable whether any modern breeding technologies involve only "natural phenomena", and the scope of the exemption may therefore be limited.

With regard to the scope of patents on biological materials within the EU, Article 8(1) of the Patent Directive states that "The protection conferred by a patent on a biological material possessing specific characteristics as a result of the invention shall extend to any biological material derived from that biological material through propagation or multiplication in an identical or divergent form and possessing those same characteristics". Similar rules apply to "patent on a process that enables a biological material to be produced possessing specific characteristics" (Article 8(2)). Thus, under EU legislation patent protection is not necessarily limited to an initial process or to the material directly obtained therefrom. Articles 10 and 11 of the Directive place some restrictions on the protection conferred by such patents. In particular, Article 11 indicates that even if breeding stock or genetic material is subject to a patent, a farmer who purchases the material is allowed to use the "animal or other animal reproductive material ... for the purposes of pursuing his agricultural activity" without infringing the patent. However, this does not include sale of the genetic material for the purposes of "commercial reproduction activity". These provisions limit to some extent the potential impact of patenting on AnGR management. However, the border between "agricultural activity" and "commercial reproduction" is not easy to establish. The precise implications of these rules, thus, remain to be tested in practice.

Patents covering genes and markers associated with a range of economically important traits have been granted in several livestock species (Rothschild *et al.*, 2004). There are also patents covering several methods for breeding management and breeding-related computer applications (Schaeffer, 2002). In some cases, the technologies have been successfully commercialized based on these patent rights (Barendse, 2002; Rothschild *et al.*, 2004; Rothschild and Plastow, 2002).

Among the patents granted on breeding-related technologies, it has often been those covering genes or genetic markers (normally as a part of a patented method to enhance the efficiency of selective breeding) that have proved to be controversial. Patenting naturally occurring sequences of genetic material provokes those who are concerned about the implications of patenting "life". Moreover, the granting of a patent which is in some way related to a breed from another country or a breed which has been developed by local communities, may give rise to accusations of "biopiracy". Additionally, the owners of animals naturally carrying the genes in question, or those wishing to utilize the offspring of animals produced by the patented method, may be alarmed about the implications of the patent. The latter issue gave rise to some initial objections within the livestock breeding industry and the research community to the patenting of genetic markers (Rothschild and Plastow, 2002). However, objections from this quarter declined as it became clear that the patents in question did not restrict the utilization of the genes or animals as such, but applied to the methods or processes involving the genes (*ibid.*).

Applications placed at WIPO by the Monsanto Company for patents on a breeding method and gene sequence in pigs, however, provoked a storm of controversy in 2005. If granted, these patents would include rights over the pigs produced by the patented method and their offspring (WO 2005/017204; WO 2005/015989), and the broad scope of the patent applications has raised fears that the activity of many pig breeders could be affected.

In contrast to the criticisms outlined above, an alternative view is that the extension of patenting offers a feasible means of facilitating beneficial scientific developments. Modern biotechnological innovations generally require considerable investments. In the absence of large amounts of public funding for research and development, it can be argued that the availability of patents serves to stimulate the investments required to enhance the efficiency of livestock breeding (Rothschild and Plastow, 2002; Rothschild *et al.*, 2004). General arguments of this kind related to the impact of patenting on investment, while they may be relevant, are unlikely to answer the concerns of the critics, and it is safe to say that controversy over the issue is unlikely to go away.

Concluding remarks

To conclude, the extension of patenting into the fields of livestock genetics and breeding is rife with controversy and practical difficulties. Factors influencing future trends will include developments in biotechnology, and the political debate regarding the ethics and socio-economic implications of applying patenting to farm animals. As in the medical field, the introduction of GM technologies is potentially a driving force promoting the wider use of patenting in animal breeding. The extension of cloning technology to commercial livestock production could be a further factor encouraging patent applications. However, the use of these biotechnologies in the livestock sector is, in itself, highly controversial. Patents for breeding-related technologies have already been granted in a number of countries, and the commercialization of these technologies will have had some impact upon the management of AnGR, mainly in commercial production systems. Successful applications for broader-scope patents related to breeding methods, or patents which cover the animals *per se* or their offspring, could have considerable implications for commercial producers. Such technologies are of little direct significance in the lower external input production systems where much of the world's livestock genetic diversity is to be found. However, developments in large-scale commercial production systems are not isolated. If wider use of patenting reinforces trends towards greater concentration within, and dominance by, the commercial sector, this would have consequences for the structure of the livestock industry more broadly. Moreover, if the critics' fears are realized, and gene-related patents become widely used to restrict access or demand payments, implications for the utilization of AnGR would be considerable.

References, legislation cited and patent applications

- Barendse, W.** 2002. Development and commercialization of a genetic marker for marbling of beef in cattle: a case study. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 197–212. Wallingford, UK. CAB International.
- Blattman, A., McCann, J., Bodkin, C. & Naumoska, J.** 2002. Global intellectual property. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 63–84. Wallingford, UK. CAB International.
- Correa, C.M.** 2004. *Bilateral investment agreements: Agents of new global standards for the protection of intellectual property rights?* Grain Briefing. (available at <http://www.grain.org/briefings/?id=186#ten>).
- Evans, D.** 2002. Animals, ethics and patents. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 163–178. Wallingford, UK. CAB International.
- Kevles, D.J.** 2002. The advent of animal patents: innovation and controversy in the engineering and ownership of life. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 17–30. Wallingford, UK. CAB International.
- Langinier, C.L. & Moschini, G.** 2002. The economics of patents. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 31–50. Wallingford, UK. CAB International.

- Lesser, W.** 2002. Patents, trade secrets and other forms of intellectual property rights. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 1–15. Wallingford, UK. CAB International.
- Lesser, W.** 2005. Intellectual property rights in a changing political environment: perspectives on the types and administration of protection. *Agbioforum*, 8(2-3): 64–72.
- Rothschild, M.F. & Plastow, G.S.** 2002. Development of a genetic marker for litter size in the pig: a case study. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 179–196. Wallingford, UK. CAB International.
- Rothschild, M.F. & Plastow, G.S. & Newman, S.** 2004. In A. Rosati, A. Tewolde & C. Mosconi, eds. *WAAP Book of the Year 2003: A Review on Developments and Research in Livestock Systems*, pp. 269–278. Wageningen, the Netherlands. Wageningen Academic Publishers.
- Schaeffer, L.R.** 2002. Dairy test day models: a case study. In M. Rothschild & S. Newman, eds. *Intellectual property rights in animal breeding and genetics*, pp. 233–246. Wallingford, UK. CAB International. .
- Thomas, D. & Richards, G.A.** 2004. The importance of the morality exception under the European Patent Convention. The oncomouse case continues. *European Intellectual Property Review*, 26(3): 97–104.
- UPOV.** 2005. *International Union for the Protection of New Varieties of Plants: what it is, what it does*. UPOV Publication No. 437(E) September 15, 2005 edition. Geneva, International Union for the Protection of New Varieties of Plants. (also available at <http://www.upov.int/en/about/pdf/pub437.pdf>).

Legislation cited

- COUNCIL REGULATION (EEC) No 2081/92 of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuff
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992R2081&model=guichett
- DIRECTIVE 98/44/EC of the European Parliament and of the Council of 6 July 1998 on the legal protection of biotechnological inventions
http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31998L0044&model=guichett

Patent applications at WIPO

- (WO 2005/015989) Method for genetic improvement of terminal boars.
- (WO 2005/017204) Use of single nucleotide polymorphism in the coding region of the porcine leptin receptor genet to enhance pork production.

2.2 Livestock Keepers' Rights

The prospect of increased exertion of IPRs in the field of animal breeding (see Section E: 2.1) is raising concerns about the continued freedom of livestock keepers to use and develop their own breeding stock and breeding practices. In response to these developments there have been calls by Civil Society Organizations (CSOs) for the establishment of “Livestock Keepers Rights” – initially in allusion to the “Farmers’ Rights” that have been enshrined in the International Treaty on Plant Genetic Resources for Food and Agriculture (IT-PGRFA). In light of intense global exchange of PGR, a legal instrument was considered necessary to facilitate access and ensure benefit sharing. The IT-PGRFA relies strongly on the institutions of the seed sector, which were already heavily involved in the international movement of germplasm.

The situation of exchange in the livestock sector is different from that in PGR. The global movement of live animals is limited by strict sanitary regulations designed to protect the health of national herds, and by the high costs involved. The movement of germplasm is based on commercial agreements and mainly involves international transboundary breeds. Collection and testing of AnGR from the

developing world rarely occur, and it is therefore essential that potential regulations governing access and benefit sharing do not further limit these activities.

The development of legal agreements to define Livestock Keepers' Rights with regard to AnGR and to address international transfers of AnGR was proposed by some NGOs during the World Food Summit in 2002. It is feared that the increased use of IPRs could have negative impacts for both within and between-breed diversity, as well as on the livelihoods of poor livestock keepers. Moreover, it is argued that there is an inherent injustice in the fact that the traditional knowledge that has gone into the development of many local and indigenous breeds, and often forms the foundation and prerequisite for the scientific improvement of breeds, remains unrecognized and unprotected. The objective of any such arrangements should be to ensure rights for those that maintain AnGR without discouraging further characterization, development and utilization.

3 Regulatory frameworks at regional level

3.1 Introduction

Legal frameworks are frequently negotiated in political and regional country groupings to improve cooperation, coordinate activities, and minimize duplication of work. In the field of AnGR management, the EU is the regional grouping with by far the most comprehensive body of legislation, and is the focus of the following discussion. Examining these frameworks gives an indication of how the objectives of the CBD are interpreted and further developed at the regional level, and how different areas of regulation, and their interactions, affect AnGR management. In addition to binding legal frameworks, groups of countries have the option of establishing so-called "soft laws," which may serve to strengthen member country commitment to agreed goals, or act as a model for national-level legislation. One such example is the Model Law drawn up by the African Union (Box 45).

Box 45**The African Union Model Law**

The African Model Law for the Protection of the Rights of Local Communities, Farmers and Breeders and for the Regulation of Access to Biological Resources was adopted in 1998 by the Ministerial Session of the African Union. The Model Law was developed to assist Member States deliberate on, formulate, and implement national policies and legal instruments compatible with their national goals and political aspirations, while at the same time satisfying their international obligations. So far, the Model Law has not been adopted by any country.

The Model Law provides a legal framework for the conservation, evaluation and sustainable use of biological resources, and associated knowledge and technologies. In particular, it provides for the rights of local communities, farmers and breeders, over these resources. Although the framework includes agricultural genetic resources, it was developed mainly for plant genetic resources and does not address specific issues related to AnGR in great depth. The Model Law is clear with respect to patents related to forms of life and biological processes, in that such patents are not recognized and cannot be applied for.

Under the Model Law, access to biological resources, community knowledge and technologies, will be subject to the prior informed consent of the state and the affected local communities. Access to biological resources is considered invalid when no such consent has been granted. This is considered to be the case even when permission has been granted but consultation has not taken place, is incomplete, or does not comply with the criteria for genuine and equitable participation. Countries must designate a competent authority to act as the focal point for receiving and processing applications for access. The Model Law recognizes benefit sharing as a right of local communities; the state must guarantee that a specific percentage (minimum 50 percent) of any financial benefit accruing from the utilization of the resources returns to the local community.

With regard to farming communities, this right is reiterated in the section of the Model Law that deals with farmers' rights. Non-financial benefits may include participation in research and development, in order to build capacity; the repatriation of information on the biological resources accessed; and access to the technologies used to study and develop the biological resources. One of the proposed mechanisms for financial benefit sharing by communities in the Model Law is the establishment of a Community Gene Fund. The fund would be established as an autonomous trust and used to finance projects developed by the farming communities.

For further information see: http://www.grain.org/brl_files/oau-model-law-en.pdf

3.2 European Union legislation: an example of a comprehensive regional legal framework

The EU regional framework has been established in the context of economic and political integration among Member States. EU legislation consists of Directives and Regulations, which must be implemented at the Member State level. Directives define the outcomes to be achieved, but leave Member States to decide on the means by which the Directive is transposed into national laws. Regulations are binding in their entirety, and automatically enter into force on a set date in all Member States. The EU has built up a significant body of legislative texts relevant to AnGR management in fields such as conservation, zootechnics (animal breeding), food hygiene, animal health, trade in animals and animal products, organic agriculture, animal feed safety and GMOs.

The Common Agricultural Policy (CAP) is comprised of a set of rules and mechanisms which regulate the production, trade and processing of agricultural products in the EU. The CAP's objectives, as set out in Article 33 of the EC Treaty, are:

- to increase agricultural productivity by promoting technical progress and by ensuring the rational development of agricultural production and the optimum utilization of the factors of production – in particular labour;
- to ensure a fair standard of living for the agricultural community, in particular by increasing the individual earnings of persons engaged in agriculture;
- to stabilize markets;
- to ensure the availability of supplies; and
- to ensure that supplies reach consumers at reasonable prices.

Recent years have seen various moves to reform the CAP. These changes have been partly driven by developments at the international level, notably by agricultural negotiations within the WTO framework. Substantial changes began in 1992; further changes were introduced under the Agenda 2000 policy agreed in 1999. The CAP reform adopted by the Council in June 2003 means that the vast majority of agricultural subsidies will be paid in the form of single farm payments, and are, thus, independent of the volume of production. The new payments are linked to environmental, food safety and animal welfare standards. This shift in policy objectives potentially has significant implications for the utilization of AnGR. Relevant EU legislation in this context included Council Regulation (EEC) No. 2078/92, one of the so-called “accompanying measures” to the 1992 reforms of the CAP, which introduced agri-environment measures intended to promote environmental protection and the conservation of the countryside. This Regulation was subsequently replaced by Council Regulation (EC) No. 1257/99, which in turn is replaced by Council Regulation (EC) No. 1698/2005, which will provide the framework for the work of the new European Agricultural Fund for Rural Development (EAFRD) from 2007 onwards.

More broadly, EU policy aims to promote sustainable and integrated rural development, and to encourage the participation of local stakeholders in the development process. To this end, Council Regulation (EC) No. 1257/1999 “on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF)” established the framework for support for sustainable rural development, including protection of the environment. The CAP also seeks to promote economic and social cohesion, by encouraging the development of new activities and sources of employment. In this context, the LEADER+ initiative (described in Commission Notice 2000/C 139/05) has been established to encourage rural stakeholders to consider the longer-term potential of their area, and to develop new ways of enhancing its natural and cultural heritage. This is intended to reinforce economic development and job creation, and to improve the organizational capabilities of rural communities.

Management of genetic resources

This subchapter discusses legislation directly related to the management of AnGR – the legal framework for conservation and animal breeding. In the field of conservation, Commission Regulation (EC) No. 817/2004 provides for financial support to be given to farmers rearing farm animals of “local breeds indigenous to the area and in danger of being lost to farming” under the framework of Regulation 1257/1999 (see above). The breeds in question must contribute to the maintenance of the local environment. Threshold population sizes, determining the eligibility of local breeds (of cattle, sheep, goats, pigs, equines or poultry) for inclusion in the scheme are set out in Commission Regulation (EC) No. 817/2004. Population thresholds (number of breeding females) below which a breed is considered to be endangered for the purposes of incentive payments are set out. The figures are based on the number, summed across all Member States, of breeding females available for pure-bred reproduction, included in a register (e.g. herd book or flock book) recognized by a Member State. The thresholds are 7 500 for cattle, 10 000 for sheep, 10 000 for goats, 5 000 for equidae, 15 000 for pigs and 25 000 for avian species. Opportunities to support conservation measures are to be further strengthened from 2007 onwards under Commission Regulation (EC) No. 1698/2005. The objective is to compensate farmers who provide environmental services for the “additional costs and income foregone ... [and where necessary] ... may cover also transaction cost” (Article 39:4). The Regulation specifies that payments can be made for the “conservation of genetic resources in agriculture” (Article 39:5). The Regulation provides for the adoption of strategic guidelines for rural development at the Community level for the period 2007 to 2013, and requires that Member Countries establish national strategy plans setting out details of agri-environmental payments. A further Regulation, intended to replace Commission Regulation (EC) No. 817/2004, was in preparation at the time of writing.

Some concerns have, however, been raised regarding the effectiveness of incentive payment schemes under Regulations 1257/1999 and 817/2004, in that payments to farmers did not take into account differences between breeds in terms of their extinction probabilities, and that subsidy payments were frequently insufficient to compensate farmers for the losses involved in keeping the local breeds

(Signorello and Pappalardo, 2003²¹). Only around 40 percent of breeds classified as at risk by FAO were covered by the payment schemes established under these Regulations, and in some countries no schemes existed (*ibid.*).

The EU is a party to the CBD and, as a consequence, all EU countries are obliged to develop national biodiversity strategies which, in the context of agricultural biodiversity, address conservation of AnGR. *In situ* conservation is regarded as the preferable approach, as it enables utilization and further characterization of AnGR. At the regional level, the Biodiversity Action Plan for Agriculture²² was adopted in 2001. The CAP instruments, as shaped by Agenda 2000 and subsequent reforms, provide the framework for integrating biodiversity concerns into EU agricultural policy. The priorities of the Action Plan are: the promotion and support of environmentally friendly farming practices and systems that benefit biodiversity; the support of sustainable farming activities in biodiversity-rich areas; the maintenance and enhancement of good ecological infrastructures; and the promotion of actions to conserve local or threatened livestock breeds or plant varieties. All these priorities are supported by research, training and education. Biodiversity conservation greatly depends on the appropriate application of measures within the CAP, notably compensatory allowances for less favoured areas, and agri-environmental measures.

A Regulation, related to the implementation of the Action Plan, is Council Regulation (EC) No. 870/2004. This Regulation explicitly aims to increase the emphasis on the conservation of AnGR. There was a concern that under previous legislation in the field, such as Council Regulation (EC) No. 1467/94, livestock received less attention than crops. “Targeted actions”, under Article 5, of Regulation 870/2004 include: the promotion of characterization, collection, utilization and *ex situ* and *in situ* conservation of genetic resources; the establishment of a Web-based inventory of genetic resources included in conservation programmes, and of *in situ* and *ex situ* conservation facilities; and the promotion of the exchange of relevant scientific and technical information. For AnGR kept on farms, the focus is to be on a network of inventories of administrative aspects (funding, endangerment status of breeds, location of herd books etc.). Transnational “concerted actions”, under Article 6, will promote information exchange to improve the coordination of actions and programmes for the management of genetic resources in Community agriculture. “Accompanying actions”, under Article 7, will cover the dissemination of information and advice to stakeholders such as NGOs; the provision of training courses; and the preparation of technical reports. Proposals for actions may be put forward by stakeholders such as genebanks, NGOs, breeders, technical institutes and experimental farms.

Areas related to AnGR eligible for funding under the Regulation include: the development of standardized criteria to identify priorities in the field AnGR management; the establishment of European genebanks based on national or institutional genebanks; the characterization and evaluation of AnGR; the establishment of a standardized performance testing regime for AnGR, and documentation of characteristics of endangered breeds; the establishment and coordination of a European-wide network of “Ark farms”, rescue-stations and parks for endangered breeds; the development of cross-national breeding programmes for endangered breeds and the establishment of rules for the exchange of information, genetic material and breeding animals; the development of strategies to promote linkages between local breeds and niche markets, environmental management and tourism; and the development of strategies which promote the use and development of underutilized AnGR that could be of interest on a European level. It should, however, be noted that Council Regulation (EC) No. 870/2004 only allows for joint actions involving several countries, and, therefore, its value to the implementation of national measures as part of national action plans is limited. The new Commission Regulation (EC) 1698/2005 will be an improvement in this respect.

A further body of EU legislation relates to the management of livestock breeding. The efficient management of AnGR is dependent on the availability of trustworthy information relating to animals’ pedigrees and performance data. Reliable mechanisms must be in place for animal identification,

²¹ Signorello, G. & Pappalardo, G. 2003. Domestic animal biodiversity conservation: a case study of rural development plans in the European Union. *Ecological Economics*, 45(3): 487–499.

²² Communication from the Commission to the Council and the European Parliament Biodiversity Action Plan for Agriculture. Commission of the European Communities, Brussels, 27.3.2001. http://europa.eu.int/comm/agriculture/envir/biodiv/162_en.pdf.

recording, and the definition of breeding objectives. An effective legal framework covering livestock breeding activities is, therefore, required. A number of laws have been put in place to regulate intra-Community trade of pure-bred breeding animals. The legislation covers bovine, porcine, ovine, caprine and equine animals. Poultry and rabbits, although they are important commercial species, are not covered. For bovine animals, Council Directives 77/504/EEC and 87/328/EEC require that Member States do not allow restriction, on zootechnical grounds, of trade with other Member States in pure-bred breeding animals, semen, ova or embryos. Countries must enable the establishment of herd-books and breeders' organizations, and not prevent the entry in their herd books of pure-bred animals from other Member States. EU legislation defines a pure-bred animal as an "animal the parents and grandparents of which are entered or registered in a herd-book of the same breed, and which is itself either entered or registered and eligible for entry in such a herd-book."

Detailed rules are set out for bovine animals in Commission Decision 84/247/EEC, covering the recognition of breeders' organizations; Commission Decision 84/419/EEC, covering the keeping of herd books; Commission Decision 2005/379/EC, covering pedigree certificates; Commission Decision 86/130/EEC, covering performance testing and genetic evaluation; and Council Directive 87/328/EEC, covering acceptance of animals for breeding. The latter Directive is of considerable importance in terms of liberalization and reducing trade barriers in cattle breeding. Similar sets of rules are in place for other species/classes of livestock. In the case of hybrid pigs (but not breeding programmes for pure-bred animals), private undertakings can be approved to maintain breed registers (Commission Decision 89/504/EEC). With regard to bovines, Council Decision 96/463/EC establishes the INTERBULL Centre in Uppsala Sweden as the reference body for uniform testing and genetic evaluation for pure-bred animals. In the case of equidae, Commission Decision 93/623/EEC sets out provisions relating to identification documents (passports) for animals registered in stud books (legislation related to animal identification is discussed further in the subchapter on animal health below).

Several points arise from this body of breeding-related legislation: breeders' associations are state-approved, and as such are mandated to keep herd books for pure-bred animals, and to perform breeding programmes including conservation breeding programmes. Provided certain conditions related to the organization's capacities and its rules are met, breeders' associations have to be approved. Any group of breeders can set up a new breeding organization for an existing breed, unless it is considered that a partition of the population would endanger the conservation of the breed or jeopardize the zootechnical programme of an existing organization. As such, an existing breeding organization has no property right on the basis of which it can exclusively breed the breed in question. In the case of equines, some additional legal privilege is given to breeders' organizations which maintain the "stud-book of the origin of the breed", as it can set rules that must be followed by newly established "filial stud-books".

Specialized food products and organic agriculture

Niche markets for distinctive livestock products are recognized as being potentially important to the economic viability of many local breeds. EU legislation provides for a number of schemes under which distinctive products can be registered so that producers are protected against imitation and can take advantage of the higher prices that consumers are willing to pay. One aspect of these schemes relates to the association of a product with a distinct geographical area. Council Regulation (EEC) No. 2081/92 states that to qualify for a protected "designation of origin" a foodstuff must have "quality or characteristics ... which are essentially or exclusively due to a particular geographical environment with its inherent natural and human factors, and the production, processing and preparation of which take place in the defined geographical area". Similar, but less narrowly defined, criteria are set out for the registration of a "geographical indication". Under Article 4 of the Regulation, requirements for product specification are outlined. Among the requirements are a name and description of the product; definition of the geographical area involved; evidence regarding the origin of the product and its links to the local area; an outline of methods used to obtain the product; a description of inspection structures; and details of labelling. Although not always the case, some product specifications prepared under these rules indicate that products or the raw materials used in their manufacture are to be sourced from specific livestock breeds. Even where a breed is not specified, the marketing of

specialized local products may promote the survival of traditional management systems in the specified locations and thereby support the continued utilization of well-adapted local breeds.

In a similar manner, Council Regulation (EC) No. 2082/92 sets out the rules whereby a “certificate of specific character” can be obtained for a foodstuff or product. The Regulation allows for the registration of distinguishing features that are not a matter of provenance or geographical origin and that do not relate solely to the application of a technological innovation. In order to appear in the register of certificates of specific character set up by the Commission a product or foodstuff “must either be produced using traditional raw materials or be characterized by a traditional composition or a mode of production and/or processing reflecting a traditional type of production and/or processing”. Once again, the promotion of diverse products of this kind potentially has positive implications for the genetic diversity of livestock populations. Some EU countries actively promote and provide support for a wider use of “certificates of specific character” as a means to valorize, and thereby protect, rare breeds.

The management of AnGR may also be affected by EU legislation related to organic agriculture. This legislation aims to establish a harmonized framework for the production, labelling and inspection of products, in order to increase consumer confidence and ensure fair competition between producers. Council Regulation (EEC) No. 2092/91 establishes a framework for the labelling, production and control of agricultural products bearing or intended to bear indications referring to organic production methods. Regulation (EEC) No. 2092/91, however, did not include any standards for livestock and was, therefore, supplemented by Regulation (EC) No. 1804/1999.

The latter Regulation sets out detailed rules covering conversion to organic farming, the origin of the animals, feed, disease prevention and veterinary treatment, husbandry practices, transport, identification of livestock products, utilization of manure, free range areas and housing (animals must, providing conditions allow, have access to open-air grazing or exercise areas), stocking densities, and overgrazing. The Regulations cover bovine, porcine, ovine, caprine, equine and poultry species. Separate rules are set out for bees. With regard to the origin of the animals, the rules state that:

“In the choice of breeds or strains, account must be taken of the capacity of animals to adapt to local conditions; their vitality, and their resistance to disease. In addition, breeds or strains of animals shall be selected to avoid specific diseases or health problems associated with some breeds or strains used in intensive production (e.g. porcine stress syndrome, PSE syndrome, sudden death, spontaneous abortion, difficult births requiring caesarean operations, etc.). Preference is to be given to indigenous breeds and strains.”

The rules further specify that the first principle to be applied in the prevention and control of disease is the choice of appropriate livestock breeds; the use of veterinary pharmaceuticals is highly restricted. As such, adaptations required of livestock kept under organic systems are often quite different to those required under non-organic systems, most notably in terms of animal health and housing conditions. While much organic livestock production makes use of conventional high-output breeds, there is considerable potential for the utilization of rarer, locally adapted breeds.

In 2004 the European Action Plan for Organic Food and Farming²³ was adopted with a view to ensuring a further development of the organic sector in the coming years and to providing an overall strategic vision for organic farming’s contribution to the CAP. One of the actions was to render the public benefits of organic farming explicit by defining its objectives and basic principles. To this end EU Member States were, at the time of writing, negotiating a proposal for a new legal framework which will eventually replace Council Regulation (EEC) No. 2092/91. With regard to biodiversity, the proposed objectives state that “The organic production system shall maintain and enhance a high level of biological diversity on farms and their surrounding areas.”²⁴

²³ Communication from the Commission to the Council and the European Parliament European Action Plan for Organic Food and Farming. Commission of the European Communities, Brussels, 10.06.2004 COM(2004)415 final. http://europa.eu.int/comm/agriculture/qual/organic/plan/comm_en.pdf

²⁴ Proposal for a Council Regulation amending Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto in agricultural products and foodstuffs.

Animal health

The EU has a body of legislation aimed at improving animal health within the Community, while permitting intra-Community trade and imports of animals and animal products in accordance with health standards and obligations under international law. Specific sets of laws apply to bovines, ovines and caprines, equines, porcines, poultry and hatching eggs, as well as aquaculture, pets and non-commercial animals, and other live animals. A distinction is drawn between imports and intra-Community trade – in many respects, separate legal frameworks apply to each. Preventive health measures cover live animals, semen and embryos, and animal products.

Restrictions on the movement of genetic material have the potential to constrain the activities of livestock breeders in EU Member States. Moreover, animal health-related restrictions on imports of animals, germplasm and animal products to the markets of the EU will, in some cases, limit the development of export-oriented livestock production in countries which are not members of the EU, and hence affect decisions regarding the utilization of AnGR in these countries.

For intra-Community trade in bovines and porcines, rules are set out in Council Directive 64/432/EEC and subsequent amendments. Rules are laid down relating to measures required to prevent the spread of disease during the transport of animals; diagnostic tests for specific diseases; animal identification to ensure traceability; and the harmonization of veterinary health certification. With regard to imports, bovines and porcines imported from non-member countries must comply with the standards stipulated in Council Directive 72/462/EEC. Standards which must be met by the exporting country are set out, covering the state of legislation; the health status of livestock and other animals; the state of disease reporting to the OIE; standards for the production, processing and transit of animal products; disease control measures, and the state of national veterinary services. Conditions also stipulate that the exporting country must be free of specific livestock diseases. Standards must be verified by the European Commission's Food and Veterinary Office. Once this verification is completed the exporting country can be included, under Council Decision 79/542/EEC, in a list of third countries from which the Member States authorize imports. Rules covering certification for import, and veterinary border inspection posts for live animals are set out in Council Decision 79/542/EEC and Council Directive 91/496/EEC, respectively. Similar legislation is in place covering other animal species.

Intra-Community trade and imports of bovine semen and embryos are regulated by Council Directive 88/407/EEC and Council Directive 89/556/EEC, respectively. The Directives set out health standards that semen and embryos must meet in order to be imported or traded within the EU, and conditions required for the approval of semen collection and storage centres. Lists of approved countries for the importation of semen and embryos and approved centres are drawn up. Rules are also set out covering the health certification of traded semen and embryos. Similar rules are in place for other livestock species. Council Directive 88/407/EEC was subsequently amended by Council Directive 2003/43/EC, which allows semen storage centres in addition to semen collection centres (having their own bulls) to engage in trade in bovine semen between Member States – a significant step towards the liberalization of this market.

The objectives of these Directives are to regulate intra-Community trade and import of semen, rather than to facilitate the cryoconservation of genetic material. Indeed, the legislation may present problems with regard to obtaining semen from endangered breeds for conservation purposes. Collecting semen at an AI centre is costly compared to on-farm collection, and collecting semen from rare breeds is usually not of commercial interest to the AI industry. A further issue relates to the long-term storage of genetic material for conservation purposes. Material collected in the past inevitably fails to conform to current standards. The dissemination of the material to breeders, therefore, becomes legally problematic. This is particularly the case for exchange of genetic material between Member States. However, in some countries, the rules set out in the Directives, when incorporated into national legislation, are applied not only to semen destined for intra-Community exchange, but also to semen used at the national level.

Trade in fresh meat is regulated by Council Directive 2002/99/EC. The objective is to ensure harmonization of health-related requirements across all Member States, and to prevent the entry into

the EU of products that may be carrying infectious diseases dangerous to animals or humans. Conditions relating to animal health status are set out for importing countries. The conditions are similar to those for live animals, but include the requirement that meat comes from an approved establishment (slaughterhouse etc.). Additional guarantees may be required in response to specific disease problems, such as the deboning and maturation of meat from animals vaccinated against FMD. It is also possible that a third country may only be permitted to export meat from certain categories of animals to the EU. Further rules relate to chemical residues, BSE (bovine spongiform encephalopathy) and animal welfare at the time of slaughter. Separate legislative frameworks are in place for meat products, poultry, milk and milk products, and for other categories such as game meat.

In addition to the trade-related laws outlined above, the EU has a body of laws dealing with the prevention, control, monitoring and eradication of specific diseases. Separate Directives cover African horse sickness (Council Directive 92/35/EEC), African swine fever (ASF) (Council Directive 2002/60/EC), FMD (Council Directive 2003/85/EC), avian influenza (Council Directive 2005/94/EC), bluetongue (Council Directive 2000/75/EC), classical swine fever (CSF) (Council Directive 2001/89/EEC), Newcastle disease (Council Directive 92/66/EEC), and certain diseases of fish and molluscs. A further Directive (Council Directive 92/119/EEC) covers a number of other exotic livestock diseases. Eradication and monitoring programmes aim to progressively eliminate diseases that are endemic in parts of the EU. Council Decision 90/424/EEC relates to the provision of funding for such programmes, and Council Decision 90/638/EEC sets out criteria which have to be met in their preparation. Disease control measures may specify restrictions on livestock movement in the case of an outbreak, requirements for vaccination or vector control, or in the case of certain serious diseases, require the culling of infected and in-contact herd/flocks. The latter action potentially has serious consequences for rare-breed populations located in the affected areas.

In recognition of the threat posed by culling measures, provisions for the exemption of rare breeds are included in Directives related to several diseases. For example, Council Directive 2003/85/EC, which relates to FMD, allows (under Article 15) for the derogation of the requirement for immediate slaughter of affected herds/flocks in the case of “a laboratory, zoo, wildlife park, and fenced area or in bodies, institutes or centres approved in accordance with Article 13(2) of Council Directive 92/65/EEC and where animals are kept for scientific purposes or purposes related to conservation of species or farm animal genetic resources” becoming infected with the disease. A list of premises that are identified as a “breeding nucleus of animals of susceptible species indispensable for the survival of a breed” must be established in advance (Article 77). The Commission must be notified in the event of a Member State deciding to derogate slaughter measures, and it must be ensured that “the animal health status of other Member States, are not endangered and that all necessary measures are in place to prevent any risk of spreading foot-and-mouth disease virus.”

Similarly, Directive 2005/94/EC relating to avian influenza, allows for derogation of slaughter measures the case of “an outbreak of HPAI in a non-commercial holding, a circus, a zoo, a pet bird shop, a wild life park, a fenced area where poultry or other captive birds are kept for scientific purposes or purposes related to the conservation of endangered species or officially registered rare breeds of poultry or other captive birds, provided that such derogations do not endanger disease control” (Article 13). Requirements relating to the confinement and restrictions on the movement of birds covered by such derogations are set out in Article 14. The Directives relating to CSF and ASF also allow for exemptions for rare-breed populations if specified conditions are met. It should, however, be noted that similar provisions, designed to protect rare genetic resources, are not included under older Directives relating to other serious livestock diseases (e.g. Newcastle disease and African horse sickness).

As discussed in Part 1 – Section F: 4, measures outlined in Commission Decision 2003/100/EC on breeding programmes for the elimination of scrapie have also raised concerns. Rare sheep breeds that lack or have low frequency of the resistant genotypes may be threatened. Participation in breeding schemes will be compulsory for flocks of “high genetic merit”, and will result in the castration or slaughter of rams carrying the “VRQ” allele associated with susceptibility to the disease. The Decision does, however, allow for derogations of these requirements in the case of breeds which have low frequencies of the resistant ARR allele and which are in danger of being lost to farming.

The implementation of animal health-related rules is backed up by a body of legislation on animal identification. These laws are also relevant to food safety and traceability, management and supervision of livestock premiums, and to the certification of animals for breeding purposes. In the case of bovine animals, for example, rules are set out in Regulation (EC) 1760/2000. The identification system for bovines comprises ear tags for individual animals, computerized databases, animal passports and individual registers kept on each holding.

The identification requirements (specifically ear tagging) present practical problems with respect to the keeping of animals for certain specific purposes or under some management conditions. There could, thus, be implications for particular AnGR normally kept in such circumstances. Some steps have been taken to adapt legal measures in order to address these problems. In the case of bovine animals kept for cultural and historical purposes on approved premises, provisions are made under Commission Regulation (EC) No. 644/2005 for alternative means of identification. There are also separate rules for bulls kept for sporting or cultural purposes (Commission Regulation (EC) No. 2680/1999); and in the case of cattle kept on nature reserves in the Netherlands for landscape and conservation purposes, the maximum period for the application of ear tags (normally 20 days after birth) can be extended up to 12 months (Commission Decision 2004/764/EC). Similarly in Spain, an extension of up to six months was permitted, under Commission Decision 98/589/EC, for animals of certain breeds, kept under extensive conditions in specified geographical regions. The specific provisions for Spain were subsequently repealed when a more general provision was introduced (Commission Decision 2006/28/EC) covering all Member States. The rules allow extensions of up to six months for holdings where cattle are kept under extensive conditions, where ear tagging presents practical problems because of geographical conditions and the animals are unused to handling, and provided the calves can be clearly assigned to their mothers at the time of tagging.

Animal welfare

Council Directive 98/58/EC sets out rules protecting the welfare of farmed animals. Further Directives deal specifically with laying hens, calves and pigs. The legislation outlines standards for veterinary care; freedom of movement for animals in accordance with their physiological and behavioural needs; shelter, cleanliness, ventilation and lighting in buildings and accommodation; provision of feed and water; mutilations and breeding procedures; as well as staffing levels, inspection of animals, and record keeping. With specific regard to animal breeding, the Directive states that “natural or artificial breeding procedures which cause, or are likely to cause, suffering or injury to any of the animals concerned shall not be practised”, and that “no animal shall be kept for farming purposes unless it can reasonably be expected, on the basis of their genotype or phenotype, that they can be kept without detrimental effect on their health and welfare.”

Council Regulation (EC) No. 1/2005 provides for the protection of animals during transport. The Regulation radically overhauls existing EU rules on animal transport. Salient features include new rules to cover the treatment of animals before and after transportation at locations such as farms, markets, slaughterhouses and harbours; training and certification of drivers; improved enforcement, including tracking of vehicles by satellite navigation systems; stricter standards for journeys over eight hours – including improved standards for lorries; and stricter standards for the movement of young and pregnant animals. Council Directive 93/119/EEC relates to the minimizing the pain and suffering undergone by animals at the time of slaughter. The regulations cover the equipping of slaughterhouses; the competence of slaughter house staff; and specify that animals must be stunned before slaughter or killed instantaneously.

Food safety

EU legislation related to food safety has in recent years undergone significant reform. Legislative and other actions have been developed, to ensure compliance with EU food safety standards in Member States; to manage international relations with non-member countries and international organizations concerning food safety; to manage relations with the European Food Safety Authority (EFSA); and to ensure science-based risk management. The central element of legislation in this field is Regulation (EC) No. 178/2002.

Food safety measures may have negative implications for the production of specialized foodstuffs such as cheeses made with raw milk from local breeds, and thereby undermine the potential contribution of niche markets to breed conservation. Concerns about food safety are also a driving force behind legislation aimed at the eradication of scrapie. As described above and Part 1 – Section F: 4, these measures pose a threat to some rare breeds of sheep. A further outcome is that many developing countries are concerned that they are unable to meet increasingly complex and burdensome EU standards and regulations. Indeed, environmental, and SPS measures are considered by a number of countries to be a greater constraint to exports to the EU than are tariffs and quantitative restrictions. The EU legislative framework for food safety, thus, affects livestock production and marketing, and, hence, the utilization of AnGR, both within the EU and elsewhere in the world.

The production, marketing and utilization of livestock feed is also covered by EU legislation. Developments in this field are increasingly driven by concerns about human and animal health. These laws do not directly impact the management of AnGR, but form a part of the framework within which livestock producers have to operate and take decisions regarding their management practices. Regulation (EC) No. 882/2004 sets out rules designed to ensure that impacts on feed and food safety are considered at all stages in the process of feed production and utilization. With regard to the inclusion of GMOs in livestock feed, Regulation (EC) No. 1829/2003 covers applications for the placing on the market of GMOs, and products containing or derived from GMOs. The labelling and traceability of such products is covered by Regulation (EC) No. 1830/2003.

3.3 Conclusions

Many regulatory aspects of AnGR management would benefit from regional or subregional coordination. Regional transboundary breeds are found in substantial numbers in most regions of the world, and thus conservation measures should be planned at subregional or regional level. Trade in livestock products can be promoted by common standards guaranteeing quality and safety. Breed improvement is facilitated if a common framework for registration and genetic evaluation is put in place.

The EU provides an example of a comprehensive set of regional regulations affecting AnGR management. Legislation promoting conservation measures has been in place for some years, and has recently been strengthened. Incentive payments for breed conservation appear to fit well with the need to find alternatives to production-related subsidies. However, the evidence suggests that schemes have not always been sufficiently well targeted to effectively promote the conservation of some of the most endangered breeds. The overall focus of the EU legislative framework is less on conservation than on providing an enabling environment for breed improvement, promoting free trade in breeding material among Member States, and ensuring an effective regime for the control of livestock diseases. Unsurprisingly, regulations promoting these objectives have at times clashed with conservation goals. It is, however, interesting to note that in some such cases the problems have been recognized, and relevant adaptations to the legislative framework implemented.

3.4 Legislation cited

COMMISSION DECISION 84/247/EEC of 27 April 1984 laying down the criteria for the recognition of breeders' organizations and associations which maintain or establish herd-books for pure-bred breeding animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31984D0247&model=guichett

COMMISSION DECISION 84/419/EEC of 19 July 1984 laying down the criteria for entering cattle in herd-books.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31984D0419&model=guichett

COMMISSION DECISION 86/130/EEC of 11 March 1986 laying down performance monitoring methods and methods for assessing cattle's genetic value for pure bred breeding animals of the bovine species. <http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/consleg/1986/D/01986D0130-19940728-en.pdf>

COMMISSION DECISION 89/504/EEC of 18 July 1989 laying down the criteria for approval and supervision of breeders' associations, breeding organizations and private undertakings which establish or maintain registers for hybrid breeding pigs. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31989D0504&model=guichett

COMMISSION DECISION 93/623/EEC of 20 October 1993 establishing the identification document (passport) accompanying registered equidae. http://europa.eu.int/eur-lex/en/consleg/pdf/1993/en_1993D0623_do_001.pdf

COMMISSION DECISION 98/589/EC of 12 October 1998 concerning an extension of the maximum period laid down for the application of eartags to certain bovine animals belonging to the Spanish herd. http://eur-lex.europa.eu/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31998D0589&model=guichett

COMMISSION DECISION 2003/100/EC of 13 February 2003 laying down minimum requirements for the establishment of breeding programmes for resistance to transmissible spongiform encephalopathies in sheep. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32003D0100&model=guichett

COMMISSION DECISION 2004/764/EC of 22 October 2004 concerning an extension of the maximum period laid down for the application of eartags to certain bovine animals kept in nature reserves in the Netherlands. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32004D0764&model=guichett

COMMISSION DECISION 2005/379/EC of 17 May 2005 on pedigree certificates and particulars for pure-bred breeding animals of the bovine species, their semen, ova and embryos (notified under document number C(2005) 1436). http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32005D0379&model=guichett

COMMISSION DECISION 2006/28/EC of 18 January 2006 on extension of the maximum period for applying eartags to certain bovine animals. http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_019/l_01920060124en00320033.pdf

COMMISSION REGULATION (EC) No 2680/1999 of 17 December 1999 approving a system of identification for bulls intended for cultural and sporting events. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31999R2680&model=guichett

COMMISSION REGULATION (EC) No 817/2004 of 29 April 2004 laying down detailed rules for the application of Council Regulation (EC) No 1257/1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF). http://europa.eu.int/eur-lex/pri/en/oj/dat/2004/l_153/l_15320040430en00300081.pdf

Commission Regulation (EC) No 644/2005 of 27 April 2005 authorising a special identification system for bovine animals kept for cultural and historical purposes on approved premises as provided for in Regulation (EC) No 1760/2000 of the European Parliament and of the Council. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005R0644:EN:HTML>

COUNCIL DECISION 79/542/EEC of 21 December 1976 drawing up a list of third countries from which the Member States authorize imports of bovine animals, swine and fresh meat.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31979D0542&model=guichett

COUNCIL DECISION 90/424/EEC of 26 June 1990 on expenditure in the veterinary field.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31990D0424&model=guichett

COUNCIL DECISION 90/638/EEC of 27 November 1990 laying down Community criteria for the eradication and monitoring of certain animal diseases.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31990D0638&model=guichett

COUNCIL DECISION 96/463/EC of 23 July 1996 designating the reference body responsible for collaborating in rendering uniform the testing methods and the assessment of the results for pure-bred breeding animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31996D0463&model=guichett

COUNCIL DIRECTIVE 64/432/EEC of 26 June 1964 on animal health problems affecting intra-Community trade in bovine animals and swine.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31964L0432&model=guichett

COUNCIL DIRECTIVE 72/462/EEC of 12 December 1972 on health and veterinary inspection problems upon importation of bovine animals and swine and fresh meat from third countries.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31972L0462&model=guichett

COUNCIL DIRECTIVE 77/504/EEC of 25 July 1977 on pure-bred breeding animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31977L0504&model=guichett

COUNCIL DIRECTIVE 87/328/EEC of 18 June 1987 on the acceptance for breeding purposes of pure-bred breeding animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31987L0328&model=guichett

COUNCIL DIRECTIVE 88/407/EEC of 14 June 1988 laying down the animal health requirements applicable to intra-Community trade in and imports of deep-frozen semen of domestic animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31988L0407&model=guichett

COUNCIL DIRECTIVE 89/556/EEC of 25 September 1989 on animal health conditions governing intra-Community trade in and importation from third countries of embryos of domestic animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31989L0556&model=guichett

COUNCIL DIRECTIVE 91/496/EEC of 15 July 1991 laying down the principles governing the organization of veterinary checks on animals entering the Community from third countries and amending Directives 89/662/EEC, 90/425/EEC and 90/675/EEC.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31991L0496&model=guichett

COUNCIL DIRECTIVE 92/35/EEC of 29 April 1992 laying down control rules and measures to combat African horse sickness.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992L0035&model=guichett.

COUNCIL DIRECTIVE 92/65/EEC of 13 July 1992 laying down animal health requirements governing trade in and imports into the Community of animals, semen, ova and embryos not subject to animal health requirements laid down in specific Community rules referred to in Annex A (I) to Directive 90/425/EEC.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992L0065&model=guichett

COUNCIL DIRECTIVE 92/66/EEC of 14 July 1992 introducing Community measures for the control of Newcastle disease.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992L0066&model=guichett

COUNCIL DIRECTIVE 92/119/EEC of 17 December 1992 introducing general Community measures for the control of certain animal diseases and specific measures relating to swine vesicular disease.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992L0119&model=guichett

COUNCIL DIRECTIVE 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes. http://europa.eu.int/eur-lex/pri/en/oj/dat/1998/l_221/l_22119980808en00230027.pdf

COUNCIL DIRECTIVE 2000/75/EC of 20 November 2000 laying down specific provisions for the control and eradication of bluetongue.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32000L0075&model=guichett

COUNCIL DIRECTIVE 2001/89/EC of 23 October 2001 on Community measures for the control of classical swine fever.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32001L0089&model=guichett

COUNCIL DIRECTIVE 2002/60/EC of 27 June 2002 laying down specific provisions for the control of African swine fever and amending Directive 92/119/EEC as regards Teschen disease and African swine fever.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32002L0060&model=guichett

COUNCIL DIRECTIVE 2002/99/EC of 16 December 2002 laying down the animal health rules governing the production, processing, distribution and introduction of products of animal origin for human consumption.

http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_018/l_01820030123en00110020.pdf

COUNCIL DIRECTIVE 2003/85/EC of 29 September 2003 on Community measures for the control of foot-and-mouth disease repealing Directive 85/511/EEC and Decisions 89/531/EEC and 91/665/EEC and amending Directive 92/46/EEC.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32003L0085&model=guichett

COUNCIL DIRECTIVE 2003/43/EC of 26 May 2003 amending Directive 88/407/EEC laying down the animal health requirements applicable to intra-Community trade in and imports of semen of domestic animals of the bovine species.

http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32003L0043&model=guichett

COUNCIL DIRECTIVE 2005/94/EC of 20 December 2005 on Community measures for the control of avian influenza and repealing Directive 92/40/EEC. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32005L0094:EN:NOT>

COUNCIL REGULATION (EEC) No 2092/91 of 24 June 1991 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31991R2092&model=guichett

COUNCIL REGULATION (EEC) No 2078/92 of 30 June 1992 on agricultural production methods compatible with the requirements of the protection of the environment and the maintenance of the countryside. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992R2078&model=guichett

COUNCIL REGULATION (EEC) No 2081/92 of 14 July 1992 on the protection of geographical indications and designations of origin for agricultural products and foodstuffs http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992R2081&model=guichett

COUNCIL REGULATION (EEC) No 2082/92 of 14 July 1992 on certificates of specific character for agricultural products and foodstuffs. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31992R2082&model=guichett

COUNCIL REGULATION (EC) No 1467/94 of 20 June 1994 on the conservation, characterization, collection and utilization of genetic resources in agriculture. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31994R1467&model=guichett

COUNCIL REGULATION (EC) No 1257/1999 of 17 May 1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF) and amending and repealing certain Regulations. http://europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_160/l_16019990626en00800102.pdf

COUNCIL REGULATION (EC) No 1804/1999 of 19 July 1999 supplementing Regulation (EEC) No 2092/91 on organic production of agricultural products and indications referring thereto on agricultural products and foodstuffs to include livestock production. http://europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_222/l_22219990824en00010028.pdf

REGULATION (EC) No 1760/2000 of the European Parliament and of the Council of 17 July 2000 establishing a system for the identification and registration of bovine animals and regarding the labelling of beef and beef products and repealing Council Regulation (EC) No 820/97. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=32000R1760&model=guichett

REGULATION (EC) No 178/2002 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. http://europa.eu.int/eur-lex/pri/en/oj/dat/2002/l_031/l_03120020201en00010024.pdf

REGULATION (EC) No 1829/2003 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 September 2003 on genetically modified food and feed. http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_268/l_26820031018en00010023.pdf

REGULATION (EC) No 1830/2003 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 September 2003 concerning the traceability and labelling of genetically modified organisms and the traceability of food and feed products produced from genetically modified organisms and amending Directive 2001/18/EC. http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_268/l_26820031018en00240028.pdf

REGULATION (EC) No 882/2004 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 April 2004 on official controls performed to ensure the verification of compliance with feed and food law, animal health and animal welfare rules. http://europa.eu.int/eur-lex/en/refdoc/L_165/L_2004165EN_1.pdf

COUNCIL REGULATION (EC) No 870/2004 of 24 April 2004 establishing a Community programme on the conservation, characterisation, collection and utilisation of genetic resources in agriculture and repealing Regulation (EC) No 1467/94. http://europa.eu.int/eur-lex/pri/en/oj/dat/2004/l_162/l_16220040430en00180028.pdf

COUNCIL REGULATION (EC) No 1/2005 of 22 December 2004 on the protection of animals during transport and related operations and amending Directives 64/432/EEC and 93/119/EC and Regulation (EC) No 1255/97. http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/oj/2005/l_003/l_00320050105en00010044.pdf

COUNCIL REGULATION (EC) 1698/2005 of 20 September 2005 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) http://europa.eu.int/eur-lex/lex/LexUriServ/site/en/oj/2005/l_277/l_27720051021en00010040.pdf

COMMISSION NOTICE TO THE MEMBER STATES 2000/C 139/05 of 14 April 2000 laying down guidelines for the Community initiative for rural development (Leader+) http://europa.eu.int/eur-lex/pri/en/oj/dat/2000/c_139/c_13920000518en00050013.pdf

4 National legislation and policy

4.1 Introduction

Functioning legal frameworks, or at minimum, clear policies and programmes, are prerequisites for effective management of AnGR. Clear legislation, and the security which it provides, is important both for economic activities such as international and domestic trade, and for the definition of the competences, rights and duties of the stakeholders involved in AnGR management.

From a country-level perspective, the effectiveness of a legal framework can be assessed on the basis of the extent to which it promotes or hinders the achievement of the country's agricultural development goals. These goals are manifold and trade-offs between them are often necessary. National-level goals may include ensuring food security and food safety, promoting national economic growth, enhancing the income and livelihoods of the rural population, preventing the degradation of the natural environment, or maintaining biological diversity. Countries are also very diverse in terms of their ecological, cultural and political environments. This section describes both general frameworks and specific solutions that have been developed in the field of legislation and policy. It aims to highlight difficulties and gaps in existing provisions, and to facilitate the exchange of ideas, solutions and experiences.

4.2 Methods

The analysis draws on information from the following sources:

- the Country Reports submitted as part of the SoW-AnGR preparation process, supplemented in some cases by e-mail correspondence with the NCs;
- an earlier survey carried out in 2003 by FAO's Development Law Service; and
- additional information found in FAO's legal data bank (FAOLEX²⁵).

The starting point for the analysis was a broad definition of both "management of AnGR" and "legal framework". The former term was taken to encompass conservation of AnGR (including the indirect effects of sustaining the production systems where the genetic resources are utilized); genetic improvement (including regulation of specific techniques and the associated infrastructure); and animal health (including provisions related to trade, breeding and transport). Supporting factors, such as institutional structures and incentive measures were also taken into account.

For the purposes of the analysis, "legal framework" was taken to include all types of legislation reported as being relevant to AnGR management. Additionally, as many countries mentioned policies and strategies or similar instruments for the management of AnGR, these instruments were taken into consideration, even if in many instances the legal basis for their implementation was not clear.

The descriptions provided by the Country Reports present a differentiated picture, which cannot be fully represented here. The objective of the following discussion is, therefore, to offer an overview of the subject and to describe general patterns and models. Examples drawn from the Country Reports are included to illustrate typical cases or those that are particularly useful or creative. Region-specific statistical overviews are presented where this illustrates particular points of interest. However, it should be noted that not all Country Reports present the same degree of detail in their discussion of legal frameworks. The statistics presented should not, therefore, be taken to represent a complete picture of the state of legal provision, but rather as broad indicators of regional capacities with respect to AnGR-related laws and policies.

²⁵ <http://faolex.fao.org/faolex/>

4.3 Implementation of AnGR legislation and programmes

Management, sustainable use and conservation of AnGR may involve the mandates of different public agencies, and involve a great variety of private actors – from farmers and breeders, to food processing and marketing enterprises. It entails a great amount of knowledge (both traditional and related to modern biotechnologies). The creation and implementation of legislation is a multifaceted task, requiring a high degree of coordination and organization.

Legal frameworks are, clearly, not the only option for achieving policy goals. An important question to be considered is the relative efficiency of legal means (often requiring expensive control measures) as compared to other policy measures (creating incentives and supporting mechanisms of various kinds, and removing distortions or disincentives). Thus, the following thematic sections describe examples of both legislative and policy measures.

Institutional Framework

Institutions that have a clear mandate and that function well are the backbone of the implementation of laws and policies. A basic institutional structure is essential for the coordination of strategies for AnGR management. Clear legal definitions of institutional roles are important. Complicated or unclear arrangements may cause problems for coordination and communication between stakeholders.

Institutional mechanisms for the implementation of AnGR-related laws are diverse. Frameworks vary between countries according to the characteristics of national administrative systems, the availability of financial resources, and the overall economic and social conditions. Two main approaches to institutional development can be discerned: 1) the establishment of *ad hoc* bodies to meet particular needs; and 2) the optimal use of existing institutions with possible adjustment of their mandates or structures (FAO, 2005).

A great variety of institutions are reported to have a role in AnGR management. However, as a rule, AnGR management at the national level is the responsibility of the Ministry of Agriculture; health-related issues may be the responsibility of the Ministry of Health, other Ministries such as Trade or Environment may also play a role. The discussion presented below focuses only on the specific institutions involved (i.e. not the “basic” ministries). These may include government agencies, private organizations to which tasks are delegated, or mixed public–private ventures. Competences and duties of such institutions (or at least of higher-level bodies) ought to be defined by law. The legal mechanisms involved are, not always clear from the information contained in the Country Reports. However, wherever possible an analysis of the legal basis for the roles of institutions is included in the following discussion.

Economic Instruments

Because the management of AnGR is a complex task, which involves a variety of stakeholders, implementation of legal measures may be difficult and costly. As noted above, it may be more cost-effective to use other mechanisms to achieve the desired objectives. Measures might include subsidies of various kinds – this of course is dependent on the economic means of the country and on compliance with international trade regulations. Measures to support the marketing of livestock products may be another means to foster and maintain AnGR diversity.

4.4 Country Reports analysis

In the following subchapters, legislative measures, institutional frameworks and other mechanisms for the management of AnGR at the country level are discussed.

Biodiversity-related legislation

Several countries report that they have legislation in place to implement the provisions of the CBD (see section E: 1). Some countries mention having instruments related to the conservation of biodiversity in general, without specifying whether AnGR is included. With respect to access issues, some countries report laws regulating access to genetic resources in general – examples include

Malawi²⁶, the Bolivarian Republic of Venezuela²⁷ and Colombia²⁸. Others explicitly indicate that laws are in place to regulate access to AnGR. One example is India's Biodiversity Act (2002) which regulates access to plant and animal genetic resources by foreigners (Legal Questionnaire, 2003). CR Sri Lanka (2002) reports the preparation of a Biodiversity Act which covers access and benefit sharing for genetic resources including domestic animals.

Box 46

Malawi's Environmental Management Act

Articles 35 and 36 of the Environmental Management Act contain provisions on the conservation of biodiversity and on access to genetic resources. The Minister may assess and identify Malawi's biological resources before formulating and implementing policies and frameworks for their protection. The Act also contains suggested actions that the Minister may undertake for the conservation of biological resources. The Minister may also restrict access to Malawi's genetic resources, or impose fees or benefit sharing measures involving the owner of the technology and the government.

Source: Legal Questionnaire (2003)

Instruments related to supporting livestock production systems

This subchapter analyses legal instruments that create a facilitating environment for the management of AnGR. The link to AnGR is indirect – by sustaining specific production systems, these measures also sustain the associated AnGR. The Country Reports describe quite a diverse set of instruments of this type, varying according to the specificities of the production systems, and the objectives and challenges associated with the country in question.

Instruments related to agricultural development and land use

Included under this heading are instruments that aim to promote the development of rural areas and rural communities. These instruments may take the form of policy measures – see for example CR United Republic of Tanzania (2004) and CR Lesotho (2005); or be defined in legislative acts – such cases are reported from the Republic of Korea²⁹, Viet Nam³⁰ and Slovakia³¹. They may form part of a country's strategy for poverty reduction and food security (Box 49). Some explicitly regulate the development and modernization of agriculture (Honduras³², Ecuador³³), or the use of agricultural or arable land (Bosnia and Herzegovina³⁴, Georgia³⁵, Mexico³⁶). Measures may also be put in place to address the problems of specific production systems. Mongolia for instance has created the legal basis for support of, and incentives for, grassland systems affected by severe weather conditions. Its National Program on Protecting Livestock from Natural Disaster, Dzd and Drought, approved under Resolution 144, of 2001 aims to strengthen damage relief systems – creating aid distribution networks, and enhancing the involvement of livestock keepers and administrative institutions (CR Mongolia, 2004).

Instruments related to pasture and rangeland management

In countries with large areas of rangeland and scarce water resources, a variety of measures are put in place to regulate access and management. These measures may fall under general legislation related to pastures and rangelands or be included in specific acts.

²⁶ Environmental Management Act (Legal Questionnaire, 2003)

²⁷ Law of Seeds, Material for Animal Reproduction and Biological Inputs. Official Gazette of the Bolivarian Republic of Venezuela Number 37.552 of 18/10/2002 (CR Bolivarian Republic of Venezuela, 2003)

²⁸ Article 81 of the Political Constitution of Colombia, 1991 (CR Colombia, 2003)

²⁹ Rural Development Law and Rural Community General Law (CR Republic of Korea, 2004)

³⁰ Resolution No. 06 of Central Government (10/11/1998) (CR Viet Nam, 2003)

³¹ Act No. 240 of 1998 (on Agriculture); Rural Development Plan of the SR 2004–2006 (E-mail Consultation Czech Republic, 2005)

³² Decree No. 31/92 – Law for the Modernization and Development of the Sgricultural Sector (CR Honduras, undated)

³³ Law of Agricultural Development, Official Register No.55 of 30 April 1997 (Legal Questionnaire, 2003)

³⁴ Law on Arable Land, 1998 (CR Bosnia and Herzegovina, 2003)

³⁵ Agricultural Land Act (CR Georgia, 2004)

³⁶ Agricultural Law, 1992 (Legal Questionnaire, 2003)

Legislation in the area of general pasture and rangeland management is reported by countries including Kyrgyzstan³⁷ and Oman³⁸. Measures may also be integrated into other legislation. CR Yemen (2003) reports that measures related to rangeland management are included under the country's environmental law, and Australia has a range of legal instruments at the Commonwealth and State Government levels that deal with biodiversity conservation and rangelands management. Other countries report having corresponding policies in place (examples include Uganda³⁹, Lesotho⁴⁰, Algeria⁴¹ and Bhutan⁴²), but the legal basis for these is not always clear.

The instruments may be directed specifically at the maintenance and/or improvement of pastures – examples include the laws reported by Uzbekistan⁴³, Pakistan⁴⁴, the Republic of Korea⁴⁵ and China⁴⁶. Iraq's Government Law number 2, 1983 contains measures to improve natural pastures, to provide for rotational grazing, and to control toxic plants (CR Iraq, 2003). Turkey has integrated measures on pasture improvement in its leasing regulation (Box 47).

A number of countries indicate regulations relating to the prevention of pollution by manure run-off. Examples include the Republic of Korea's Sewage, Faeces and Urine, Waste and Water Treatment Law (CR Republic of Korea, 2004). The impact of laws regulating the run-off of manure is also mentioned in CR United States of America (2003) and CR United Kingdom (2002). CR Cook Islands (2003) indicates that the country's Environmental Law has had some effect on the size and distribution of livestock holdings, particularly pig farms. Similarly CR Kiribati (2003) mentions that under the Environmental Act of 1999, livestock development is a prescribed activity, and that new livestock farms require ministerial approval.

Norway promotes the organized use of pastures by grazing associations – the Decree Relative to Incentives for Organized Use of Pastures regulates the efficient use of pastures in outlying lands (FAOLEX). Incentives are provided for organized grazing under the control of registered grazing associations which meet set criteria (*ibid.*). Pakistan also has a substantial set of measures to regulate pasture use⁴⁷.

In extensive grassland systems, access to grazing land and water sources is crucial. This is especially true in the case of mobile pastoralism. Regulations covering the access of transhumant pastoralists to pastures are included in the pastoral codes and similar legislation, which exist in a number of African countries such as Benin⁴⁸, Botswana⁴⁹, Guinea⁵⁰, Mali⁵¹ and Mauritania⁵². Guinea's Pastoral Code, for example, regulates pastoral land-use rights and provides for conflict resolution. It regulates the use of pastures, use of water resources, transhumance and protection of the environment (CR Guinea, 2003). Botswana's Tribal Land Act restricts the granting of land-use rights in land specified to be for grazing; grazing land may be set aside for commonage (FAOLEX). Access to pastures may also be important for sedentary livestock keeping communities. Laws relating to the allocation of pastures at the community level are found for instance in Turkey (Box 47) and Albania⁵³.

³⁷ Law "on pastures" (CR Kyrgyzstan, 2003)

³⁸ Royal Decree No. 8 of 2003 issuing Law on Pasture and Animal Resources Management, 21 January 2003 (FAOLEX)

³⁹ Pasture and Rangelands Policy (CR Uganda, 2004)

⁴⁰ Livestock and Range Management Policy, 1994 (CR Lesotho, 2005)

⁴¹ National Agricultural Development Plan (CR Algeria, 2003)

⁴² National Pasture Policy (CR Bhutan, 2002)

⁴³ Law No 543-1 of 1997 on protection and usage of vegetation (FAOLEX)

⁴⁴ Punjab Frontier Grazing Regulation (E-mail Consultation Pakistan, 2005)

⁴⁵ Grassland Law (CR Republic of Korea, 2004)

⁴⁶ Grassland Law (CR China, 2003)

⁴⁷ Punjab Frontier Grazing Regulation, 1874; Grazing of Cattle in Protected Forests (Range Lands) Rules, 1978; By-laws for Regulating Grazing of Animals, 1981; Pasturage of Animal Rules, 1900 (Email Consultation Pakistan, 2005)

⁴⁸ Law No. 87 of 21 September 1987 on the regulation of the animal guard, common grazing (la vaine pâture) and transhumance (Legal Questionnaire, 2003)

⁴⁹ Tribal Lands Act (FAOLEX)

⁵⁰ Pastoral Code (CR Guinea, 2003)

⁵¹ Law No. 01-004 on the Pastoral Charter in the Republic of Mali (Legal Questionnaire, 2003)

⁵² Law No. 44-2000 on the Pastoral Code in Mauritania (CR Mauritania, 2004)

⁵³ Instructions No. 1 of the General Directorate of Forests and Pastures on technical criteria for leases of pastures and meadows, 23 May 1996, implementing Law No. 7917 on protecting pastures and meadows, 13 April 1995 (FAOLEX)

Box 47**Turkey's Law on Pastures No. 4342 (1998)**

This law sets out basic procedures and rules for the allocation of pastures to villages and municipalities. The Ministry of Agriculture and Rural Affairs is authorized to determine the boundaries of pastures, and their allocation to relevant entities. The finalized boundaries are recorded in corresponding title deeds. The allocation process is renewed every five years. Areas that can only be used after improvement measures can be leased to individuals and companies who undertake the improvement. Areas that are allocated under this law cannot be used for any other purposes unless written consent is obtained from the Ministry of Agriculture. This consent can only be given under specific conditions that are set out in the law. The law also has provisions to prevent overgrazing in these areas. A "Pasture Fund" will be established under the direct management of the Ministry of Agriculture for financing the activities set out in this law

Source: Legal Questionnaire (2003)

Several countries report laws regulating access to water. Examples include Chad's Order on Pastoral and Village Hydrology⁵⁴, and Mongolia's Resolution on the National Program on Protecting Livestock from Natural Disaster, Dzung and Drought (see above). Access to water may be included in other regulations, such as the above-mentioned pastoral codes. It is integrated, for example, under Australia's Land Protection Act⁵⁵.

Conservation of rural areas and organic/ecological agriculture

In industrialized countries, measures tend to be focused on conservation of the natural environment or maintaining rural areas rather than being aimed primarily at assuring food security. Such measures may indirectly foster the use of traditional, locally adapted breeds of livestock.

Box 48**Slovenia's Livestock Breeding Act (2002)**

The principal objective of this act is to harmonize Slovenia's livestock breeding legislation with the "acquis communautaire" of the EU, and to adapt to the CAP. It also sets out principles in accordance with the goals of agricultural policy, and outlines the economic, spatial, ecological and social roles of animal husbandry and sustainable agricultural development. The more specific objectives of the act are:

- regulating the field of animal husbandry, with the aim of promoting stable production of quality food and ensuring food safety;
- conserving settlements in rural areas, and the cultivated landscape;
- utilizing natural resources for food production in such a way as to maintain the productive capacity and fertility of the land;
- managing the operation of recognized breeding organizations and the implementation of breeding programmes;
- providing a higher level of education in the field of animal husbandry;
- maintaining biodiversity in animal husbandry and protecting the environment; and
- providing a suitable income for those involved in agriculture.

Source: CR Slovenia (2003)

Legislation promoting the conservation of rural areas is particularly reported by European countries. Examples include Slovenia (Box 48) and Bosnia and Herzegovina⁵⁶. Legal measures may be used to promote desirable changes in agriculture, and may support specific production methods such as ecological/organic farming. A number of European countries report such legislation. CR United States of America (2003) also mentions its National Organic Standards, and CR Brazil (2004) mentions programmes furthering organic meat production. In the case of organic production in particular, a clear legal framework is necessary to ensure consumer confidence (rules for production standards, labelling

⁵⁴ Ordinance No. 2/PR/MEHP/93, on the creation of the Office of Pastoral and Village Hydrology (CR Chad, 2003).

⁵⁵ Land Protection (Pest and Stock Route Management) Act 2002 – reprinted on 19 May 2005; Rural Lands Protection (General) Regulation, 2001 (FAOLEX)

⁵⁶ Law on Arable Land, 1998 (CR Bosnia and Herzegovina, 2003).

etc.). Industrialized countries may also have legislation supporting the maintenance of agricultural production in unfavoured areas. Examples include Switzerland's Agricultural Law (CR Switzerland, 2002). Slovenia's Livestock Breeding Act follows an integrated approach, outlining the economic, spatial, ecological and social roles of animal husbandry (Box 48).

Table 88
Instruments for sustaining livestock production systems

| Types of instruments | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|--|--------|--------------------|-------------------|-----------------------|------|-------------------------------|---------------|
| Agricultural development | [3] | | | 3 | 2 | 2 | |
| Pasture and rangeland management | 3 [3] | 3 [1] | 3 | 4 | 5 | | 1 |
| Access to pastures and water | 6 | | 1 | 2 | 2 | | |
| Conservation of rural environments, ecological/organic farming | | | | 10 | | 1 | 1 |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

[n] = policies/strategies

Note that inclusion of instruments under two categories is possible

Some countries, particularly in Africa, mention that they have policies and strategies in place for agriculture, rangeland management or livestock production. However, from the information in the Country Reports it is difficult to know the legal basis of these measures – for example, whether they are based on a general legal frameworks relating to agriculture and land use, or on legislation relating to the competences and duties of a government agency. Similarly, it is often unclear whether they have to be approved by a legislative body. The example from Mozambique presented in Box 49 illustrates a strategy that is explicitly integrated in the context of the country's policies promoting poverty reduction and food security.

Box 49
Mozambique's Livestock Development Policy and Strategies

A new document on Livestock Development Policy and Strategies is presently submitted for approval. Its objectives are to contribute to poverty reduction and food security in rural areas, stimulating the role of livestock in families' socio-economic growth, and contributing to satisfying the needs of the national market. This policy has a lifespan of ten years.

Source: CR Mozambique (2004)

Institutions supporting livestock development

This subchapter discusses regulations related to institutions that have specific functions in AnGR management. Such institutions may be organized in a centralized or in a decentralized way. Several countries mention specialized central institutions involved in the management of livestock. Examples include Cape Verde's National Institute of Agriculture and Livestock⁵⁷.

The role of decentralized organizations such as cooperatives, community groups and farmers' associations varies from region to region. Organizations of this type are usually involved in a variety of activities related to AnGR management. Several African countries report legislation related to the recognition and functioning of rural cooperative groups at local level. CR Chad (2003), for example,

⁵⁷ Regulation No. 125/92 approving the constitution of the National Institute of Agriculture and Livestock, 1992 (FAOLEX)

mentions a decree⁵⁸ related to the recognition and functioning of rural groups, and an order⁵⁹ regulating the status of cooperative groups. Regulations affecting rural community organizations are reported in the Central African Republic,⁶⁰ and have also been put in place in Equatorial Guinea⁶¹. Botswana has instituted tribal Land Boards as corporate bodies – tilling rights and titles to land are vested in the Land Boards, which determine and grant customary forms of land tenure (FAOLEX).

Some countries in Latin America (e.g. Mexico⁶²) and Europe (e.g. Poland⁶³ and Bosnia and Herzegovina⁶⁴) report legislation regulating farmers' and breeders' organizations. These groups are conceived as professional associations, and represent the (economic) interests of the producers. Malaysia⁶⁵ and Pakistan⁶⁶ also report legislation on farmers' organizations and agricultural cooperative societies respectively.

Access to Credit

Access to credit provision tailored to the specific needs of livestock keepers is an important institutional requirement. This is a particular issue in countries with a poorly developed banking infrastructure. In some countries, especially in Africa, the state has taken initiatives in this field. Examples include the creation of the "Caisse de Développement de l'Élevage du Nord" in Cameroon⁶⁷; the "Mutualité Agricole" in the Central African Republic⁶⁸, the projected law on an agricultural fund in the Congo⁶⁹; Senegal's credit fund for crop and animal production⁷⁰, and Mozambique's Livestock Development Fund⁷¹. Another example of legislation in this field is Pakistan's "Cooperative Societies and Cooperative Banks (Repayments of Loans) Ordinance" of 1966 (E-mail Consultation Pakistan, 2005).

Instruments related to conservation

This subchapter covers legislative measures, policies and strategies for the conservation of AnGR (for definitions of the different types of conservation referred to in this subchapter, see Box 94 in Part 4 – Section F). A first step for the conservation of AnGR diversity is to identify and designate the breeds to be conserved. Conservation may have various motivations, including economic, sociocultural and scientific objectives. It may be aimed at conserving specific endangered breeds, or at maintaining AnGR diversity more generally.

Several examples of legislation relating to AnGR conservation are clearly culturally motivated. The Republic of Korea, for example, protects specific breeds as "national monuments" under the Cultural Properties Protection Law (CR Republic of Korea 2004). Some Canadian Provinces have designated "heritage breeds" or "heritage animals" in their legislation – the Canadienne cow, Canadien horse and Chantecler chicken in Quebec, and the Newfoundland Pony in Newfoundland and Labrador (CR Canada, 2003). In Peru, the Peruano de Paso horse, along with alpacas and llamas are regarded as national symbols (CR Peru, 2004), and legal measures have been put in place to protect them⁷². In the case of Japan, scientific value is also mentioned as a criterion – the Law for the Protection of Cultural

⁵⁸ Decree No. 137 /P.R./MA/93 determining the modalities for the recognition and the functioning of rural groups and to allow women and men to be given responsibility in the development of the livestock sector

⁵⁹ Order No. 25/PR/92, regulating the status of cooperative groups and cooperatives

⁶⁰ Decree No. 61/215 of 30 September 1961 regulating agricultural cooperatives and mutual plans in the Central African Republic (CR Central African Republic, 2003)

⁶¹ Law of Cooperatives, Ministry of Labour, Malabo (Legal Questionnaire, 2003)

⁶² Law of Agricultural Associations, 1932 and Law of Livestock Organizations, 1999 (Legal Questionnaire, 2003)

⁶³ Act on Social and Professional Agricultural Organizations, 1982 (Legal Questionnaire, 2003)

⁶⁴ Law on Farmers's Associations (CR Bosnia and Herzegovina, 2003)

⁶⁵ Farmers' Organization Act, 1973 (CR Malaysia, 2003)

⁶⁶ Punjab Livestock Associations and Livestock Associations Unions (Registration and Control) Ordinance, 1979 (E-mail Consultation Pakistan, 2005)

⁶⁷ Decree No. 81/395 of 9 September 1981 modifying and completing Decree No. 75/182 of 8 March 1976 (Legal Questionnaire, 2003)

⁶⁸ Decree No. 61.215 of 30 September 1961 (Legal Questionnaire, 2003)

⁶⁹ Projected law on the creation of the Agricultural Fund (Legal Questionnaire, 2003)

⁷⁰ Decree No. 99-733 (Legal Questionnaire, 2003)

⁷¹ No legal basis indicated

⁷² Decree No. 25.919 – declaring the De Paso horse as a native species of Peru, 1992

Properties (1950) designates autochthonous species, including livestock that have high scientific value, as “natural treasures” (CR Japan, 2003). In other cases, the motivation for legislative measures is more related to broader concerns about biodiversity (see for example Box 50 describing Slovenia’s Regulation on Conservation of Farm Animal Genetic Resources of 2004).

In some cases, strategies may be directed at the conservation of particular species, – for example Peru’s *in situ* and *ex situ* measures to conserve alpacas and vicuñas (CR Peru, 2004). In other cases, conservation measures are integrated within broad programmes for the management of AnGR such as Mongolia’s programme on “Improving Livestock Quality and Breeding Services”⁷³. Programmes may be supported by additional measures such as promoting scientific research (CR Kazakhstan 2003; E-mail Consultation the Netherlands, 2005; CR Ukraine 2004), or awareness building among farmers (CR India, 2004). If programmes are to be properly targeted, measures for the characterization and inventory of AnGR are required, along with the establishment of procedures for the identification and registration of the breeds and animals to be covered by the programmes (Box 50).

Box 50

Slovenia’s regulation on Conservation of Farm Animal Genetic Resources

This regulation establishes systematic procedures for monitoring and analysing the state of AnGR diversity, and defines means and instruments for *in situ* and *ex situ* conservation. It establishes a register which includes a zootechnical assessment of breeds and species. It also provides definitions of degrees of breed endangerment and criteria for the estimation of genetic variability within breeds.

Source: E-mail Consultation Slovenia (2005)

In situ in vivo conservation

In contrast to the above-mentioned measures providing general support to livestock production systems, the measures analysed in this section relate directly to the conservation of AnGR. Only a small minority of countries (mostly from the Europe and the Caucasus region) report legislation covering *in situ* conservation of AnGR (Table 89). Various strategies and mechanisms to support this type of conservation can be implemented. Some countries grant financial support to breeders, breeders’ organizations, or other institutions that maintain traditional breeds (e.g. Japan⁷⁴ and Greece⁷⁵); or to NGOs that promote and manage *in situ* conservation (e.g. Switzerland⁷⁶).

Few such measures are reported from developing countries. CR Ghana (2003) mentions efforts by the Animal Research Institute to support five communities in the Northern Region keeping Ghana Shorthorn cattle. However, the exact mechanisms involved are unclear. In India, conservation programmes under the National Bureau of Animal Genetic Resources include the establishment of *in situ* conservation units in the native tract of the breed, performance recording, selection and registration of genetically superior animals, and the provision of incentives to the owners of the animals to retain them for breeding. These measures are combined with *ex situ in vivo* and *in vitro* conservation for specific breeds (CR India, 2004). However the Country Report does not provide information on the legal framework for these measures. Another type of programme is reported in CR Peru (2004) – involving the designation of specific zones for the rearing of vicuñas in semi-liberty to reclaim their wool.

Ex situ in vivo conservation

Again, only a limited number of countries indicate that they have instruments in place related to *ex situ in vivo* conservation (Table 89). Examples include Slovenia and Ukraine (Boxes 50 and 52). In Indonesia, the Law on Animal Husbandry and Health⁷⁷ requires that conservation programmes are conducted in well-managed areas such as on smaller islands, and or in certain Village Breeding

⁷³ Based on the Law on Livestock Gene-pool Protection and Health (CR Mongolia, 2004)

⁷⁴ Law for the Protection of Cultural Properties – grants provided to municipalities affected by measures (CR Japan, 2003)

⁷⁵ Presidential Decree No. 434/95; Decision 280/343571/4969/8.9.97 of the Ministers of Agriculture and Economy; 167/08.03.95 Decision of the Minister of Agriculture (CR Greece, 2004)

⁷⁶ Subsidy based on the Law of Agriculture (CR Switzerland, 2002)

⁷⁷ No. 6 of 1967, Article 13 (CR Indonesia, 2003)

Centres, or on private and government farms (CR Indonesia, 2003). Malaysia,⁷⁸ and India (CR India, 2004) have networks of conservation farms, and Sri Lanka's Zoological Garden Act covers zoo farms (E-mail Consultation Sri Lanka, 2005).

In vitro conservation (cryoconservation)

Several countries report legislation relating to conservation in *in vitro* facilities. One example is Uganda, which has comprehensive legislation in the field AnGR management (Box 59). In the United States of America, the Food Agriculture, Conservation and Trade Act (1990) established the conservation of AnGR as a national priority (CR United States of America, 2003). As a result, the National Animal Germplasm Program was initiated in 1999, and is developing a comprehensive management strategy for AnGR, including the establishment of cryoconservation measures. Measures regulating procedures for access to gene-banks and transfer of genetic material are reported only by the Czech Republic. Its Breeding Act Amendment⁷⁹ and the associated implementing regulation and programme also include a model "genetic material provision and transfer agreement".

Table 89
Instruments in the field of conservation

| Type of Conservation | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|-------------------------|--------|--------------------|-------------------|-----------------------|------|-------------------------------|---------------|
| In situ | | | | 8 | 3 | 1 | 1 |
| <i>Ex situ in vivo</i> | | | | 2 | 4 | | |
| <i>Ex situ in vitro</i> | 1 | | | 6 | 3 | 2 | 1 |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

Note that a measure may be included under more than one category. Details of conservation programmes are reported in Section C.

Institutions involved in the conservation of AnGR

A number of countries report measures to establish institutions responsible for conservation. For example, Uganda's Animal Breeding Act (2001) established the National Animal Genetic Resources Center and Databank, which is responsible for overseeing conservation measures (Box 51).

Box 51 **Uganda's National Animal Genetic Resources Programme**

The main objectives of the National Animal Genetic Resources Programme are to ensure the conservation and sustainable full use of AnGR diversity. The programme is charged with developing a national AnGR conservation policy including *in situ* and *ex situ* measures; establishing an appropriate institutional framework for coordinating, regulating and monitoring conservation activities; creating awareness among the population of current initiatives related to AnGR management; characterizing and documenting the country's livestock breeds; and promoting research.

Source: CR Uganda (2004)

Other examples include Ukraine (Box 52), Kazakhstan⁸⁰ and the above-mentioned National Animal Germplasm Program in the United States of America.

⁷⁸ Based on Animals Ordinance of 1953 and the National Policy on Biological Diversity, launched by the Ministry of Science, Technology and Environment (CR Malaysia, 2003; Legal Questionnaire, 2003)

⁷⁹ Breeding Act Amendment 154/2000 (E-mail Consultation Czech Republic, 2005)

⁸⁰ Law of Pedigree Animal Breeding, and respective sublegislative acts (CR Kazakhstan, 2003)

Box 52**Ukraine's Law on Animal Breeding**

In Ukraine, the conservation of threatened breeds of all species is an integral part of the Law on Animal Breeding. Conservation work is implemented by a specially created centralized body with executive authority financed from the state budget. The programme involves a range of activities, including preserving frozen semen from high-output breeds, strains and breeding groups that are at risk of extinction; the use of reproductive biotechnologies in breeding and selection work; and the organization of exhibitions and auctions of breeding animals.

Source: CR Ukraine (2004).

CR Bolivarian Republic of Venezuela (2003) reports a National Centre for the Conservation of Genetic Resources (animal and plant species) under the Ministry of Environment, created by the Law on Biological Diversity. Turkey has established an interministerial and multistakeholder committee for AnGR (Box 53).

Box 53**Turkey's Regulation on Protection of Animal Genetic Resources (2002)**

This regulation, based on the Livestock Improvement Act No. 4631, sets forth procedures and principles regarding all activities related to the protection and registration of AnGR in Turkey. A National Committee on Protection of AnGR is established, composed of representatives of: (a) the General Directorate of Agricultural Research; (b) the General Directorate of Agricultural Enterprises; (c) the Faculty of Veterinary Sciences; (d) the Faculty of Agriculture; (e) the Ministry of Environment; (f) the Ministry of Forestry; (g) the Central Council of the Union of Turkish Veterinarians; (h) the Society for Protecting Wildlife; (i) the Society for Protecting Turkish Habitat; and (j) the Anatolian Horse Breed Development Society. The functions of this Committee include: determining activities regarding the protection of AnGR; reviewing past activities and planning future actions; specifying breeds under threat of extinction; formulating policies for the protection of AnGR; and taking decisions regarding the import and export of AnGR.

Source: Legal Questionnaire (2003)

Instruments related to genetic improvement

Genetic improvement encompasses a broad range of activities related to the breeding process, including animal identification and herd book keeping, performance recording, genetic evaluation, and the dissemination of improved genetic material. Many countries have legal measures in place to regulate some or all of these activities. Legislation may also cover the exchange of breeding stock, both within and between countries. The following aspects of legal frameworks are discussed in this subchapter:

- the definition of breeding strategies and programmes;
- animal identification and registration systems;
- infrastructure and institutional issues related to AI and natural service – including sanitary control measures.

Table 90
Instruments in the field of genetic improvement

| Type of measure | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|--|--------|--------------------|-------------------|-----------------------|------|-------------------------------|---------------|
| Definition of breeding strategies, genetic improvement and selection | 6 | 0 | 2 | 17 | 11 | 4 | 0 |
| Registration, Branding | 5 | 1 | 1 | 21 | 5 | 10 | 0 |
| Laws for reproductive biotechnology | 2 | | 1 | 18 | 5 | 5 | 1 |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

Details of genetic improvement programmes are reported in Section B.

Table 90 shows that Europe and Asia have the greatest density of legal regulations in the field of genetic improvement. Conversely, in African countries, policies are less likely to be backed up by legal frameworks. In some countries, legislation is currently being developed and has not yet been implemented. A number of developing countries report difficulties in implementing their policies and programmes in this field.

The definition of breeding strategies

The goals of the breeding strategies differ from country to country. Several countries mention breeding policies directed at optimizing the utilization of indigenous breeds, either by straight-breeding or focused cross-breeding. In Nigeria, for example, breeding and selection of indigenous breeds the ecological zones to which they are adapted is encouraged; but there is also promotion of controlled cross-breeding of indigenous dairy cattle to a level not exceeding 50 percent exotic blood (E-mail Consultation Nigeria, 2005). Other examples include India, which has a strategy promoting genetic improvement in indigenous cattle and buffalo breeds, but also promotes the cross-breeding of local animals with Jerseys or Holstein-Friesian (CR India, 2004), and Trinidad and Tobago which promotes genetic improvement of the local Criollo goat breed (CR Trinidad and Tobago, 2005). Serbia and Montenegro⁸¹ and China⁸² have measures in place promoting the use of both, indigenous and exotic cattle breeds. Some countries have laws relating to specific species or breeds. Examples include Argentina's recovery programme for sheep⁸³. Lesotho has legislation limiting the import of livestock to those meeting the requirements of the national breeding objectives (Box 54).

⁸¹ The law on Measures for Livestock Improvement regulates the sustainable management of both locally adapted breeds and imported foreign breeds (FAO, 2005)

⁸² CR China (2003); Legal Questionnaire (2003)

⁸³ Law for the Revival of Sheep Keeping N 25422, 27 April 2002 (Legal Questionnaire, 2003)

Box 54**Lesotho's Importation and Exportation of Livestock and Livestock Products Proclamation**

The Importation and Exportation of Livestock and Livestock Products Proclamation 57 of 1952 amended in 1953, 1954, 1965 and 1984 dictates: (a) that livestock should not be imported or exported without permit; (b) that no permit shall be granted for importation of "undesirable livestock", including but not limited to bastard sheep and goats; (c) that conditions for importation should include desirability of the animals including their ability to improve the standard of livestock in the country.

These legal instruments influence breed utilization. Merino sheep and Angora goats are being reared in larger numbers than any other breeds. The laws also encourage use of Merino sheep in mountain zones, and higher concentrations of the breeds are, therefore, found in these areas. The import controls have allowed improvement of the country's livestock, as imports are restricted to superior Merino rams, Angora bucks, and beef and dairy bulls.

Source: CR Lesotho (2005)

Another example of laws regulating the use of animals for breeding is Malaysia's Animals Ordinance (Box 55).

Box 55**Malaysia's Animals Ordinance**

This ordinance prohibits the possession of a bull, older than 15 months, that is not sterilized. Exceptions can be granted for bulls suitable for reproduction. These bulls are tested (health and breeding criteria) and registered by an official agency. Breeding is only allowed utilizing registered stud bulls.

Source: CR Malaysia (2003)

Animal registration and identification

Various aspects of AnGR management require systems for animal identification and registration if they are to be effective. Examples include the implementation of veterinary control measures or traceability rules related to food safety, the prevention of theft, monitoring the status of breed populations, and the implementation of breeding and conservation programmes. A clear and enforceable legal basis for registration and identification is likely to be particularly necessary where public goods such as food safety or the prevention of epidemic livestock diseases are the main objectives. For targeted breeding, more elaborate recording methods (e.g. herd books) are required and normally encompass the documentation of the genealogy of pedigree animals and the performance of the offspring. Systems of this type necessitate regulation to ensure uniform standards.

Identification and registration may be organized in different ways depending on the objectives and the availability of resources. Tasks may be implemented by a central state agency, or be delegated to decentralized institutions, such as breeders' organizations or state breeding farms. Elaborate registration systems require a high degree of organization and cooperation. In some countries registration is, therefore, limited to specialized breeding herds or breeding farms (E-mail Consultation Nepal, 2005), to species of particular importance, or to commercially oriented farms and enterprises.

Europe, with its highly organized breeding systems (breeders' organizations in western Europe and state agencies in eastern Europe), has the highest density of measures related to animal registration (Table 90). Elsewhere in the world, some countries mention animal identification and registration as a "big goal" or "urgent need", that they would like to review or improve their current practices, or that they are at present developing a policy. Some also indicate that at present they are unable to monitor the population status of their breeds, and that a lack of registration measures for pure-bred traditional breeds hinders their further development.

Reproductive biotechnology

In this subchapter, an overview of regulations and policies related to the utilization of biotechnology (principally AI and ET) for genetic improvement is presented. Table 90 gives a regional breakdown of the instruments in place. In parallel with the greater use of reproductive biotechnologies in developing countries, Europe and the Caucasus has the highest density of legislation in this field. Many

developing countries regard the use of reproductive biotechnologies as an important means of improving productivity, particularly in dairy production. Examples include the AI programme in Sri Lanka, which aims to upgrade cattle, buffalo, goat and pigs in order to promote commercial production systems; cattle semen used in the country is mostly of the *Bos taurus* type imported from the EU, North America or Australia (E-mail Consultation Sri Lanka, 2005). Legislation related to technical requirements such as the production and transportation of semen, health controls, and the organization of AI centres and semen banks, is reported by a number of countries. Hungary's Decree No 39 of 1994 serves as an example of such legislation (Box 56).

Box 56
Hungary's Decree No 39

Decree 39 of 1994 of the Ministry of Agriculture regarding artificial insemination (AI), embryo transfer (ET) and the production, supply, marketing and utilization of breeding materials, applies to cattle, sheep, goats, horses, pigs and red deer. Articles 2 to 6 deal with AI centres. Such centres require authorization for their operation, issued by the National Agricultural Classification Institute (NACI). Authorization depends on certain conditions specified in Article 2. Centres shall contract with interested breeding organizations, to perform the duties listed in Article 5. Semen may be collected only from animals authorized for AI. Provisions regarding authorization for AI are laid down in Articles 7 and 8. Article 9 deals with the supply of semen, which may be produced only by AI centres. The marketing of semen is regulated by Article 10. Special regulations regarding the marketing of imported semen are set out in Article 11. Inspection of AI centres is performed annually by the NACI, which may prolong authorization, specify conditions, or withdraw authorization if standards are not met (Article 14). ET is regulated in Articles 15 to 24, and centres again require authorization to operate. Standards related to all these activities are controlled by the NACI. A list of authorized centres, prohibited reproductive material in the case of cattle, and the list of male animals authorized for AI are published in the official gazette of the Ministry.

Source: Legal Questionnaire (2003)

Control of the health of breeding stock and of genetic material

Several countries, particularly in Europe, indicate that they have regulations related to the health of breeding animals (either in the context of the production of semen for AI or covering animals used for natural service).

Box 57
Botswana's Stock Diseases (Semen) Regulations

According to these regulations, a permit is required for introducing semen into the country (to prevent the introduction and spread of disease); for disposing of semen (sale, gift, exchange, or in any other manner); and for using any such semen for artificial insemination of any stock that are not the property of the owner of the semen.

Source: Legal Questionnaire (2003)

Other examples include Malaysia's Animals Ordinance (Box 55), and Japan's requirement for all breeding animals (cattle, horses and pigs) to have a breeding stock certificate⁸⁴. The certificate is issued after annual inspection, which includes inspection for infectious diseases and genetic disorders. Some countries have rules in place related to the prevention of specific livestock diseases. For example, Norway's BSE-related restrictions on imports of cattle and beef from the United Kingdom include restrictions on the import of embryos.⁸⁵

Incentives for genetic improvement

Many countries report incentives that in one way or another influence breeders' activities and may indirectly promote genetic improvement – examples include subsidies for capital investments or subsidized provision of inputs of various kinds. In this subchapter, only subsidies directly connected with livestock breeding are discussed.

⁸⁴ Law for Improvement and Increased Production of Livestock (E-mail Consultation Japan, 2005)

⁸⁵ Decree No. 548 of 2000 relative to protection measures against BSE in relation with importation from the United Kingdom (FAOLEX)

There are various types of subsidies which may be granted. Viet Nam⁸⁶, for example, reports a subsidy fund for maintaining and improving livestock and poultry breeding herds/flocks. Kazakhstan subsidizes measures that enhance availability of pedigree breeding materials to farmers (CR Kazakhstan, 2003). Several countries report subsidies supporting breeding infrastructure and technology. In many countries, the public sector is involved in the provision of services such as AI at subsidized rates, or may subsidize private sector providers (see Section D).

Box 58

Barbados's incentive programme

Because of high prices for fresh pork offered by supermarkets and other wholesale buyers, many producers have been selling underweight animals, including gilts, for slaughter. This could undermine the genetic base of the national pig herd. In response, the government has proposed offering producers an incentive of BDS\$500 (approximately US\$250) not to slaughter, or sell for slaughter, any gilt deemed by the Ministry of Agriculture and Rural Development to be suitable for breeding. The programme is to be carried out in collaboration with the Barbados Agricultural Society and the Barbados Pig Farmers' Cooperative Society Limited.

Source: CR Barbados (2005)

Other measures may include enhancing access to credit, granting tax advantages, providing loans at preferential terms, or providing emergency funding for breeding activities. Examples include measures put in place in Mexico, which allow a tax break for those involved in raising cattle⁸⁷ and Argentina, which has created a sheep bank and emergency fund⁸⁸.

Institutions dedicated to genetic improvement

This subchapter discusses the various institutions described in the Country Reports that facilitate planned and structured genetic improvement programmes.

A number of countries report specialized institutions dedicated to AnGR development. Such institutions may be mandated to perform activities in various areas of AnGR management, including: the elaboration of programmes and strategies (e.g. Uganda⁸⁹); management of a specific branch of AnGR development and production (e.g. AVICOLA in Mozambique⁹⁰ and Moldova's institutions for pigs and poultry production – see below); research and extension (e.g. Costa Rica⁹¹ and Mauritius⁹²); and research on breed improvement (e.g. Bolivia⁹³ and Canada⁹⁴). The institutions may be specialized governmental agencies, possibly combining experts from different departments (CR Costa Rica, 2004), or consultative groups of experts such as the Commission on Biotechnology in the Netherlands (E-mail Consultation the Netherlands, 2005). Tasks may be delegated to private or public-private bodies.

Specialized governmental institutions for research, extension and the elaboration of development programmes have been created in Uganda – National Animal Genetic Resources Steering Committee under the Ministry of Agriculture⁹⁵, Costa Rica – the National Institute for Agricultural Innovation and Technology Transfer (INTA)⁹⁶, Chile – the National Commission for the Development of Technology,⁹⁷ and Bolivia – National Centre for the Genetic Improvement of Bovine Cattle⁹⁸.

⁸⁶ Decision 125/CT dated 18/4/1991 (CR Viet Nam, 2003)

⁸⁷ Decree (tax benefits) n 6/2/94, 02 June 1994 (Legal Questionnaire, 2003)

⁸⁸ Resolution (Sheep Bank for Agriculture and Livestock Emergency) N. 143, 25 July 2002 (Legal Questionnaire, 2003)

⁸⁹ The National Animal Genetic Resources Databank, under the Animal Breeding Act (CR Uganda, 2004)

⁹⁰ Decree No. 5/78 creating the National Institution of Poultry Breeding (AVICOLA) under the Ministry of Agriculture. Its range of action covers all types of poultry production (industrial or traditional) (Legal Questionnaire, 2003)

⁹¹ INTA (National Institute for Agricultural Innovation and Technology Transfer), (Law No 8149, 5 November 2001) (CR Costa Rica, 2004)

⁹² AREU (Agricultural Research and Extension Unit) (CR Mauritius, 2004)

⁹³ National Center for the Genetic Improvement of Bovine Cattle. Ministerial Resolution 080/01 of MAGDER (Ministerio de Agricultura Ganadaria y Desarrollo Rural) (CR Bolivia, 2004)

⁹⁴ Experimental Farm Stations Act (CR Canada, 2004)

⁹⁵ Animal Breeding Act, 2001 (CR Uganda, 2003)

⁹⁶ Organic Law of the Ministry of Livestock Law No. 8149, of 5 November 2001 (CR Costa Rica, 2004)

⁹⁷ Decree (National Commission for the Development of Biotechnology) n.164, 21 June 2002 (Legal Questionnaire, 2003)

⁹⁸ Ministerial Resolution 080/01 (CR Bolivia, 2004)

Private organizations and mixed public–private institutions may also be involved in the management of AnGR. Such organizations are reported from Cameroon – Société de Développement et d'Exploitation des Productions Animales (SODEPA)⁹⁹; and Moldova – scientific production institutions for pigs and for poultry (“Progress” and “Moldpitseprom”) (CR Moldova, 2004). Another example is the United Kingdom’s Milk Council¹⁰⁰.

As mentioned above, registration of breeding livestock or breeds can either be organized by central or decentralized governmental agencies, or be delegated to private stakeholder groups, frequently to recognized breeders’ organizations.

Legislation on centralized breeding registers is reported by Uganda (combined with the National Genetic Resources Databank), Cuba¹⁰¹, the Russian Federation¹⁰², Ukraine¹⁰³ and Estonia¹⁰⁴. Decentralized institutions are reported by Jamaica¹⁰⁵, Guatemala¹⁰⁶, and Canada¹⁰⁷. Nepal has registration schemes for organized farms and governmental farms (E-mail Consultation Nepal, 2005). The EU has a body of legislation regulating pedigree certificates, the keeping of herd books, genetic evaluation and performance testing (see Section E: 3.2). Examples of measures for the registration of specific breeds include Slovenia’s Law on Conservation of Farm Animal Genetic Resources, which establishes a register of breeds including a zootechnical estimation (see above) and the provisions for breed registration mentioned in CR Russian Federation (2003). In China, the Stockbreeding Law of 2005 provides for the establishment of a national protection list of livestock and poultry genetic resources (FAOLEX).

In some countries, in particular where there is a lack of strong, decentralized breeding organizations, specific institutions, such as governmental farms and controlled nucleus herds play the dominant role in developing and producing breeding material. These institutions may also be involved in conservation programmes. Examples include Indonesia’s policy for conservation and utilization of AnGR¹⁰⁸. Mongolia has a programme on “improving livestock quality and breeding services¹⁰⁹.” Its major objective is to improve yield and product quality by creating nucleus herds and corresponding livestock breeding services (CR Mongolia, 2004).

Box 59

Uganda’s Animal Breeding Act (2001)

The government has taken steps to support the breeding structure by identifying National Animal Genetic Resources Centre farms and ranches where specific breeding activities can be undertaken. However, securing sufficient funding for operationalizing the infrastructure remains a problem.

Source: CR Uganda (2004)

Breeders’ associations and, in some cases, private companies may be delegated various functions in the process of genetic improvement. Breeders’ associations often take responsibility for herd book keeping. Their duties and competences are usually defined in livestock breeding acts. The role of breeders’ associations is particularly prominent in Europe. The EU has a body of legislation in place covering the recognition of breeders’ organizations and regulating their activities (see Section E: 3.2). Few African countries report the existence of breeders’ associations. The fostering of such societies is, however, one of the objectives of Uganda’s National Animal Genetic Resources Centre and Databank established under the Animal Breeding Act of 2001 (CR Uganda, 2004).

⁹⁹ Decree No. 81/395 of 9 September 1981 modifying and completing Decree No. 75/182 of 8 March 1975 on the creation of SODEPA (Société de Développement et d'Exploitation des Productions Animales) (Legal Questionnaire, 2003)

¹⁰⁰ Milk Development Council (Amendment) Order 2004 (FAOLEX)

¹⁰¹ Law No. 1.279 – Law of Livestock Registration, 1974 (Legal Questionnaire, 2003)

¹⁰² CR Russian Federation (2003)

¹⁰³ Law “About Animal Breeding” (CR Ukraine, 2004)

¹⁰⁴ Animal Breeding Act (CR Estonia, 2004)

¹⁰⁵ Recording by breed societies (CR Jamaica, undated)

¹⁰⁶ Governmental Accord 843-92 (CR Guatemala, 2004)

¹⁰⁷ Animal Pedigree Act, 1985 (CR Canada, 2004)

¹⁰⁸ Law on Animal Husbandry and Veterinary Act No. 6/1967, Article 13 (CR Indonesia, 2003)

¹⁰⁹ Based on the Act on Livestock Gene-Pool and Health Protection 1993; amended 2001 and approved by Resolution 105, 1997

Box 60**Guatemala – decentralization of the registration of pure-bred animals**

Guatemala initially established a centralized register in 1915. A regulation in this field was introduced in 1933. It defined the criteria for inclusion in the register of pure-bred animals. Its goal was to resolve the problem of registering the many pure-bred animals that at the time did not have pedigree documentation. This situation prevented an “open-book” strategy at this time. In 1965, the regulation was adopted by all Central American countries as a basis for registration procedures. In 1992, a law for the decentralization of registration was adopted, and in the following years, the herd books of breeders’ associations were officially recognized in several livestock species.

Source: CR Guatemala (2004)

Table 91**Instruments related to institutions active in genetic improvement**

| Institutions | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|--|--------|--------------------|-------------------|-----------------------|--------|-------------------------------|---------------|
| Institutions R+D incl. scientific councils: | | | | | | | |
| Government | 5 | | | 3 (+1 mixed) | | 3 | 2 |
| Stakeholder | | | | 4 | | | |
| Breeding infrastructure | 2 | | | 1 | 2 [2]* | 1 | 1 |
| Registration by government | 2 | | | 4 | 3 | 1 | 1 |
| Stakeholder associations | | | | | | | |
| Registration | | | | 6? | 4 | 2 | 1 |
| Improvement | | | | 2 | | | |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

[n] = created by policies

Instruments related to marketing and trade

This subchapter discusses instruments put in place to promote and regulate the marketing and trade of livestock and livestock products. Such measures include those related to the setting of standards for marketed products, those that promote trade or establish institutions in this field, and those that regulate the movement and exchange of animals both internationally and within countries.

Standard setting

There are two main objectives of legislation related to standard setting: 1) to ensure food safety and to address food-related aspects of human health through setting minimum quality standards; and 2) to provide for the identification of quality products by the consumer in the marketplace.

Various types of instruments related to ensuring food safety are reported. Examples include the Comoros’s Decree No 87-019/PR, which relates to the production, storage, distribution and inspection of food products (CR Comoros, 2005). Other countries report regulations on grading of various animal products. Pakistan, for example, has rules related to the grading of agricultural products in general, and specific rules for milk, animal hair, eggs, ghee and creamy butter (E-mail Consultation Pakistan, 2005). Other regulations cover the production of specific food products, such as meat (including measures related to slaughtering), eggs and milk products (including the sale of raw milk). These various types of measure may be integrated into a general regulatory framework – as is the case in Pakistan (ibid.).

Instruments aimed at providing information for the consumer may have various goals: the assurance of quality standards; identification of geographical provenance or a specific production method (e.g. organic); or to indicate the source of the raw materials to provide reassurance regarding food safety. The most frequently mentioned instruments are those related to organic production. The EU has a body of legislation in this field, covering the production, labelling and inspection of organic products, and establishing rules for the use of geographical indications and similar designations (see Section E: 3.2).

Table 92
Instruments in the field of standard setting

| Instruments in place for Standard Setting | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|---|--------|--------------------|-------------------|-----------------------|------|-------------------------------|---------------|
| Food Safety | 4 [1] | 0 | 1 | 3 [1] | 4 | 3 | 0 |
| Consumer Information | 0 | 0 | 0 | 6 | 0 | 1 | 1 |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

[n] = policies or legal basis unclear

Instruments to foster trade in livestock products

Marketing measures can be used for a variety of purposes. The objective may be to support the incomes of livestock keepers or to promote exports. Measures of this kind may also serve to foster AnGR diversity by helping to make production from a broader range of breeds economically viable. Various instruments can be used to promote trade and marketing, including:

- the establishment of governmental institutions to further marketing in general, such as Malaysia's Federal Marketing Authority¹¹⁰ or the establishment of the Animal, Animal Products and By-products Marketing Development Authority in Ethiopia¹¹¹;
- the creation of governmental institutions to foster specific products – such as Nicaragua's National Dairy Products Company¹¹² and Sri Lanka's National Livestock Development Board¹¹³;
- the creation of public–private partnerships – this occurs mainly in the dairy sector;
- the implementation of policies, strategies and programmes, either to support animal product marketing in general or the marketing of specific products – such as Mongolia's programmes for milk and wool products (Box 61) and the Philippines' "White Revolution" programme (Box 62);
- development of niche markets – reported examples include efforts in Botswana to promote exports of donkey meat, and ostrich meat and skin, and in Eritrea to market products from rare breeds (CR Botswana, 2003; CR Eritrea, 2003);
- supporting and regulating specific production methods (e.g. by legislation on organic agriculture or labelling);
- the implementation of measures to protect local producers from competition by imports (importation quota, taxes) – examples mentioned in the Country Reports include the Dominican Republic's Tariff Protection for Chicken Meat¹¹⁴, and several regulations by which Egypt banned the importation of fertilized eggs and chicken meat in order to foster the development of its poultry industry (CR Dominican Republic, 2004; CR Egypt, 2003) (measures of this type have in recent years tended to be replaced by other means of supporting local farmers);
- the regulation of specific marketing methods (such as the regulation of public auctions of alpacas and llamas in Peru¹¹⁵): and

¹¹⁰ Federal Agricultural Marketing Authority Act, 1965 – revised 1974 (CR Malaysia, 2003)

¹¹¹ Animal, Animal Products and By-products Marketing Development Authority Establishment Proclamation (No. 117/1998 (FAOLEX)

¹¹² Decree 364. Law of the Nicaraguan Dairy Agroindustry Corporation 31/05/88 (CR Nicaragua, 2004)

¹¹³ State Agriculture Cooperation Act. No. 11 of 1972 by a gazette order dated 4th May 1972 (CR Nicaragua, 2004)

¹¹⁴ Decree Number 505-99, November 1999

¹¹⁵ RM Number 0424-AG (regulation of public auction of alpacas and llamas) (CR Peru, 2004)

- the establishment of networking opportunities for stakeholders in the food-processing and marketing sectors such as Mongolia's Wholesale Network Programme (CR Mongolia, 2004).

Box 61

Mongolia's White Revolution Programme

The "White Revolution" Programme, which has been in place since the adoption of Government Resolution 105 of 1999, aims to mobilize local resources in the livestock sector; improve the supply of dairy products, and increase the incomes of herders and rural people by reviving traditional processing of dairy products, developing small and medium-scale enterprises, and creating favourable conditions for marketing.

The Cashmere Programme was adopted by Government Resolution 114 of 2000 with the objectives of improving the competitiveness of cashmere products through improving the processing facilities. The Wool Sub-Programme was approved by Government Resolution 26 of 2001. Its objective is to enhance the capacity of factories involved in wool, skin and hide processing.

Source: CR Mongolia (2004)

Box 62

The Philippine's White Revolution

The approach to dairy development has involved both smallholders and commercial producers. The Philippine Dairy Corporation was created in 1979 to spearhead the development of the dairy industry based on small-scale production to increase rural income. Import of 2 400 head of Holstein-Friesian-Sahiwal cattle started in 1984 under an ADB-IFAD project. These animals were dispersed to various farmers' cooperatives. The National Dairy Authority (NDA) was created under the National Dairy Development Act RA 7884 to accelerate the development of the country's dairy industry.

The "White Revolution" was launched in 1999 under the leadership of the NDA and the Philippine Carabao Center. It aimed to drum up support from all sectors of society – farmers and rural families, the government extension and financing organizations, legislators, private investors, consumers, children and commercial processors.

Source: CR Philippines (2003)

Institutional Aspects of Marketing

Institutions for the marketing of AnGR products, sometimes as public-private partnerships, exist in a number of countries. These measures can either be focused on livestock products in general, as in case of the Livestock Development Council in the Philippines, which has the task of increasing the supply of livestock and livestock products to attain self-sufficiency (CR Philippines, 2004). Alternatively, they target specific markets such as dairy products¹¹⁶, meat¹¹⁷ or poultry¹¹⁸. Several examples of this second type of institution are reported. For instance, Mozambique has established "Avicola", the National Institution for Poultry Breeding, under the Ministry of Agriculture¹¹⁹. Egypt has a General Union of Poultry Producers.¹²⁰ Cameroon mentions its Société du Développement et de l'Exploitation des Productions Animales¹²¹. Nicaragua reports associations in various production areas – the dairy agro-industry¹²², bird raising¹²³, and meat¹²⁴.

¹¹⁶ Jamaica's Dairy Board; Nepal's National Dairy Development Board Act, the Milk Development Council in the United Kingdom; and Nicaragua's of the Dairy Agroindustry Corporation (CR Jamaica, 2002; CR Nepal, 2004; CR Nicaragua, 2004; FAOLEX)

¹¹⁷ Sri Lanka's National Livestock Development Board (CR Sri Lanka, 2002)

¹¹⁸ Punjab Livestock, Dairy and Poultry Development Board (CR Pakistan, 2003)

¹¹⁹ Decree No. 5/78 creating the National Institution of Poultry Breeding (AVICOLA), 1978 (Legal Questionnaire, 2003)

¹²⁰ Ministerial Resolution No. 97 implementing Law No. 96 of 1998 regarding the creation of the General Union of Poultry Producers (FAOLEX)

¹²¹ Decree No. 81/395 of 9 September 1981, modifying and completing Decree No. 75 of 8 March 1976 (CR Cameroon, 2003)

¹²² Decree 364, Law of the Nicaraguan Dairy Agroindustry Corporation, 31/05/88; Decree No. 82. Creating a Development Fund for the Dairy Industry, 23/07/66 (CR Nicaragua, 2004)

¹²³ Decree 357, Law creating the Nicaraguan Poultry Corporation, 31/05/88 (CR Nicaragua, 2004)

¹²⁴ Decree 360, Law creating the Nicaraguan Meat Corporation, 31/05/88 (CR Nicaragua, 2004)

Table 93
Instruments for promoting trade in livestock products

| Instruments | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|--|--------|--------------------|-------------------|-----------------------|-------|-------------------------------|---------------|
| Legislation to foster trade in AnGR products | | | | | | | |
| Marketing in general | 2 [1] | | | 2 [1] | [2] | 1 | |
| Specific Products | 1 [1] | | | | 3 [1] | 1 | |
| Organic/ Niche | [2] | | | 3 [3] | | 1 | 1 |
| Institutions | 3 [1] | 1 | | | 3 | 3 | |
| Protective measures, and subsidies | 2 | | 1 | 2 | 1 | | |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

[n] = policies or legal basis unclear

Note that institutions may promote specific products or marketing of products in general. These cases are indicated under both, "institutions" and "laws to foster trade".

Import and export of genetic material

Under this heading, legislation on the import and export of genetic material in the narrow sense (semen and embryos) is presented. Import and export of live animals is discussed below under livestock movement and trade. In several cases it is not clear from the information available whether import/export of semen and embryos is included under regulations covering livestock trade, or on the import/export of livestock products. Regulations on import and export of genetic material are motivated by a variety of objectives, which vary from country to country. Preventing the introduction of livestock disease is an important motivation. Other objectives may include ensuring that the imported genetic material is adapted to local ecosystems, or increasing the output of national livestock production. There may also be legislation in place implementing the provisions of the CBD related to the need to obtain governments' prior informed consent for the export of genetic resources.

Table 94
Instruments regulating import and export of genetic material

| Regulations relating to | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|-------------------------|--------|--------------------|-------------------|-----------------------|------|-------------------------------|---------------|
| Import | 7 | 3 | 3 | 26 | 6 | 5 | |
| Export | 4 | 2 | 0 | 23 | 1 | 0 | |
| CBD implementation | 1 | | | | 1 | 1 | |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

In Europe in particular, there is a high density of regulation related to the import and export of genetic material. Box 63, which describes regulations controlling semen imports to the Russian Federation, provides an illustrative example.

Box 63**Russian Federation – Veterinary and Sanitary Requirements No. 13-8-01/1-8 (1999)**

For boar semen to be admitted to the territory of the Russian Federation, it must have been collected at AI centres that are kept under permanent supervision by the state veterinary service of the exporting country. Animals must be kept, and semen must be collected, in compliance with the veterinary and sanitary requirements currently in force. Boars supplying sperm for export must not be vaccinated against classical swine fever. Boars must be kept at the AI centres for six months before collection of sperm, and must not be used for natural insemination during this period. Boars must not have been fed on feedstuffs produced using genetically modified additives or other genetically modified products. Semen must be free of pathogenic and toxic micro-organisms. Compliance with these veterinary and sanitary requirements must be certified by a veterinary certificate, signed by the state veterinary inspector of the exporting country, and drawn up in the language of the country of origin and in Russian. The veterinary certificate must contain the date and the results of diagnostic examinations. Semen destined for export must be packed and transported in special containers (vessels) filled with liquid nitrogen. Dispatch of semen to the Russian Federation is possible only after authorization issued to the importer by the Veterinary Department of the Ministry of Agriculture and Food.

Source: Legal Questionnaire (2003)

Some Country Reports mention the possibility of preventing the import of semen for ecological reasons. CR Algeria (2003) indicates that in certain cases the government can exercise its regulatory powers to ensure that inappropriate exotic semen is not imported or promoted to the detriment of local breeds that are better adapted to local conditions and the production objectives of small producers. CR Ecuador (2003) mentions that improved seeds, animals, technologies and equipment can be freely imported if they are not deemed harmful to local ecosystems.¹²⁵ Colombia has a constitutional regulation stating that “the state will regulate the entry and exit of genetic resources from the country, and their utilization, in accordance with national interests”.¹²⁶

CR Burkina Faso (2003) mentions the country’s participation in a number of regional agreements relating to the management, utilization and exchange of genetic material, but indicates that these have not yet been implemented.

Import and Export of live animals

Controls on the international exchange of livestock are of great importance for the control of livestock disease. The introduction of diseases across a country’s borders can have severe consequences for the livestock sector. CR Kenya (2004) for example, mentions that cross-border movement of livestock has caused the re-introduction of some previously eradicated notifiable diseases, which has led to the loss of disease-free zones in the country and the loss of external markets. Zoosanitary regulations are, however, significant barriers to the international exchange of AnGR. Instruments mentioned in the Country Reports include the definition of health standards for the import of live animals, requirements related to the animal health status of exporting countries, and quarantine requirements for imported animals.

Some countries indicate zoosanitary regulations for both import and export of live animals in general – for example, Mali¹²⁷, or for specific species – for example, Myanmar¹²⁸ (pigs, horses, sheep, goats, and cattle and buffaloes). Conversely, some countries indicate zoosanitary requirements and control for the import of live animals only.¹²⁹ See Section E: 3.2 for a discussion of EU laws covering health-related restrictions on trade in livestock and livestock products.

Quarantine measures are mentioned by many countries. Provisions for further quarantine measures to be applied in the case of disease epidemics are also often mentioned (see below). Some countries have

¹²⁵ Law of Agricultural Development the codification of which was published in the Official Register No. 55 of 30 April 1997

¹²⁶ Political Constitution of Colombia, 1991, Article 81 (CR Colombia, 2003)

¹²⁷ Decree 372/P-RM regulating sanitary control of animals on the territory of the Republic of Mali (Legal Questionnaire, 2003)

¹²⁸ In the case of pigs: Regulation for importation and exportation of breeding swine into Myanmar, 2003; similar laws for the other species were also passed in 2002 (FAOLEX)

¹²⁹ Kiribati’s Importation of Animals Regulation, 1965 (FAOLEX); Palau’s Plant and Animal Control – Chapter 20 of Title 25 of the Palau National Code, 1966 (FAOLEX)

instruments in place related to the import of animals from countries of regions particularly affected by animal health problems. Botswana's, Diseases of Animals Act 1977, for example, allows the prohibition of the import of animals from areas that are known to be affected by major diseases (CR Botswana, 2003). Other examples include El Salvador's legislation prohibiting the import of animals from countries affected by FMD¹³⁰ and Cape Verde's legislation prohibiting bovine imports from areas infected by BSE¹³¹.

There are countries that have regulations regarding import and export of breeding animals. Chad, for example, prohibits the export for slaughter of female animals of breeding age.¹³² CR China (2003) notes that the country's Ministry of Agriculture formulated an Administrative Regulation on Exportation of Breeding Animals during the 1980s, which was updated and adjusted in 1993. Examples from Europe include Hungary which reports regulations covering exports and imports (E-mail Consultation Hungary, 2005), and Germany¹³³ which reports legislation regulating the import of breeding animals. Ecuador's Law on Agricultural Development (1997) enables the import of breeding animals deemed unsuitable for local ecosystems to be restricted (CR Ecuador, 2003).

Livestock movement internal and regional

Livestock movement is one issue usually covered by legislation related to animal health. In countries where risks of disease outbreaks are high, separate laws tend to be adopted setting out strict rules on stock movement within the country and measures to enforce their observation (FAO, 2005).

Several countries indicate specific requirements related to livestock shows. CR Mozambique (2005), for example, reports provisions related to transportation to and from cattle shows. Similarly, in the United Kingdom, the Animal Gatherings (England) Order of 2003 specifies the zoosanitary measures that have to be included when organizing events such as shows or markets (Legal Questionnaire, 2003). In Japan, a health certificate is required for livestock to cross the border of a province (E-mail Consultation Japan, 2005). In the event of a disease epidemic, stricter regulations are implemented. Several countries have regulations regarding the welfare of transported live animals. One example is India (Box 64).

Box 64

India – rules for transportation

The rules provide for the transportation of poultry and pigs by rail, road or plane. Containers must be properly fitted for transportation – providing shelter from sun, heat, rain or cold, and allowing poultry and pigs to be comfortable during the journey. A table details the rules regarding the containers and the timing of journeys according to the size and age group of the animals. Vaccination and other health requisites are listed.

Source: FAOLEX

African countries where pastoralist production systems are widespread have adopted the use of transhumance certificates at both national and regional levels.

Box 65

West Africa – pastoralist crossing borders

Decision A/DEC.5/10/98, taken in Abuja in 1998 by the heads of state and government of the Economic Community of West African States (ECOWAS) relates to the use of transhumance certificates by mobile pastoralists within Member States. In Nigeria, efforts have been made to, *inter alia*, stipulate conditions for movement of nomadic livestock, i.e. their arrival to and departure from Nigeria.

Source: E-mail Consultation Nigeria (2005)

¹³⁰ Accord No. 54 – 2001. Prohibiting the import of bovine, ovine, caprine and porcine livestock and other cloven-hoofed species from countries affected by foot-and-mouth disease (FAOLEX)

¹³¹ Order No. 10/2001 (FAOLEX)

¹³² Decree No. 138 bis /PR/MEHP/88 regulating the unlimited export of and livestock products with the exception of reproductive females (CR Chad, 2003)

¹³³ Animal Breeding Import Ordinance (Legal Questionnaire, 2003)

Table 95
Instruments regulating livestock movements and import and export of live animals and livestock products

| Legislation on Trade | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|---------------------------|--------|--------------------|-------------------|-----------------------|------|-------------------------------|---------------|
| Import (Health standards) | 2 | 2 (1) | 4 (3) | 8 (5) | 5 | 6 (4) | (1) |
| Export | 3 | 1 | | 3 | 3 | | |
| Products | 4 | | | 2 | | 1 | |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

[n] = policies or legal basis unclear.

Instruments related to animal health

The number of countries that have developed and implemented legislation related to animal health is larger than in any other field (see previous subchapter for further discussion of measures related to animal movement and trade). Animals' health status has enormous impact on individual performance, on the production output and efficiency of the livestock sector, and on trade in products of animal origin. Most countries report some regulation (or at least institutions or programmes) related to animal health. However, some countries explicitly state that they do not yet have adequate regulation in place. Some of these countries mention the difficulties that they face in generating the necessary political will to ensure adequate regulation. Specific reference to the management of AnGR within national-level animal health legislation is rare in most parts of the world.

Legislation in this field may address disease surveillance and reporting, vaccination or vector control programmes, emergency measures to be taken in the event of epidemics, food hygiene and traceability of livestock products, inspection of livestock holdings and food processing establishments, production of livestock feed and veterinary products, and regulation of the qualifications, competences and duties of the veterinary profession. A country may have broad laws that regulate many aspects of animal health (Box 66), or there may be specific legislation related to a particular aspect of animal health or to a specific disease.

Table 96
Regulations in the field of animal health

| Types of measures | Africa | Near & Middle East | Southwest Pacific | Europe & the Caucasus | Asia | Latin America & the Caribbean | North America |
|--------------------------------|--------|--------------------|-------------------|-----------------------|--------|-------------------------------|---------------|
| Legislation or policy in place | 23 [2] | 4 [2] | 10 | 32 [1] | 18 [4] | 13 [1] | 1 |
| Vet. Services | 8 [4] | 2 | 0 | 10 [9] | 7 [6] | 0 | |
| Epidemics general | 0 | 1 | 3 | 5 | 3 | 1 | |
| Epidemics specific | 5 | 0 | 1 | 9 | 5 | 7 | |
| Number of CRs | 42 | 7 | 11 | 39 | 25 | 22 | 2 |

[n] = policies

It can probably be assumed that nearly every country has some laws on animal health in place. Differences exist with regard to the comprehensiveness of the legal provision, and whether the issue is handled within a regional-level framework.

Box 66**The Islamic Republic of Iran's Act of National Veterinary System (1971)**

The act encompasses overall sanitary regulations, and regulates quarantine measures and transboundary movement of animals. The act also covers the following measures:

- prevention and control of animal diseases;
- hygiene certificates for animals and animal products for export;
- hygienic supervision of pastures, watering places, stables and other breeding establishments;
- monitoring of feed plants, slaughterhouses and processing units; and
- control of the production, import, export and marketing of various biological materials (e.g. drugs, vaccines and serums).

Source: CR Islamic Republic of Iran (2004)

Measures to be implemented in the event of epidemics

A number of countries report general legislation outlining response measures to be taken in the event of an epidemic. One such example is Denmark's Infectious Animal Diseases Control Act¹³⁴ (Legal Questionnaire, 2003). Legislation of this type may specify a list of notifiable diseases. Responses to epidemics may include the declaration and designation of epidemic-free zones and establishments – countries reporting such legislation include Viet Nam¹³⁵ and Zambia¹³⁶. Eradication and control zones may be declared – countries reporting such legislation include El Salvador,¹³⁷ Australia¹³⁸ and the United Kingdom¹³⁹. Uruguay, in its efforts to combat scabies in sheep obliges farmers to declare outbreaks or even the suspicion of an outbreak, and to contribute to the control of the disease¹⁴⁰.

Measures may include quarantine – examples include Zambia's Livestock Diseases Act (Legal Questionnaire, 2003). There may also be regulations regarding the disposal of infected animals – countries reporting such measures include Malawi¹⁴¹, Zambia¹⁴², the Netherlands¹⁴³ and Chile¹⁴⁴. There may be payment of compensation for losses – reported, for example, by Estonia¹⁴⁵ and Switzerland¹⁴⁶. Strategies to safeguard valuable AnGR in the event of eradication measures are rare, but have begun to be put in place in Europe for some diseases (see Section E: 3.2).

Regional cooperation

There tends to be a greater amount of regional or bilateral cooperation in the field of animal health than in other areas of AnGR-related legislation. Reported examples of cooperation agreements between neighbouring states, include those existing between Egypt and Algeria,¹⁴⁷ Turkey and Kazakhstan,¹⁴⁸ members of the Commonwealth of Independent States,¹⁴⁹ and Lusophone countries in

¹³⁴ Other reported examples include Australia, China, Costa Rica, Ecuador, El Salvador, Estonia, Fiji, Germany, Guatemala, Honduras, Iraq, Ireland, Jamaica, the Philippines, the Republic of Korea, Serbia and Montenegro, Switzerland, the United Kingdom, Vanuatu.

¹³⁵ Regulation on animal epidemic-free zones and establishments 2002 (FAOLEX)

¹³⁶ Cattle Cleansing Act of 1930 amended 1994 (Legal Questionnaire, 2003)

¹³⁷ Accord 194, declaring the geographical areas of the departments Usulután, San Miguel, Morazán and La Unión as control and eradication zones for bovine tuberculosis and brucellosis (CR El Salvador, 2003)

¹³⁸ Animal Health Act, 1995 (Legal Questionnaire, 2003)

¹³⁹ Diseases of Poultry (England) Order, 2003 (S.I. No. 1078 of 2003); Disease Control (England) Order, 2003 (S.I. No. 1729 of 2003) (Legal Questionnaire, 2003)

¹⁴⁰ Law No. 16.339 – declaring sheep scab a plague and making efforts to eradicate it compulsory (FAOLEX)

¹⁴¹ Control and Diseases of Animals Act 2000 (Legal Questionnaire, 2003)

¹⁴² Stock Diseases Act 1963 (amended 1994) (Legal Questionnaire, 2003)

¹⁴³ Decree No. 403 of 2001 to amend the Decree implementing provisions of the Animal Destruction Act, 16 July 2001 (Legal Questionnaire, 2003)

¹⁴⁴ Ley N° 18.617 – norms for compensation for the slaughter of animals for the control of foot-and-mouth disease (Legal Questionnaire, 2003)

¹⁴⁵ Infectious Animal Disease Control Act, 16 June 1999 (Legal Questionnaire, 2003)

¹⁴⁶ Law on Epizootics, 1966 (amended 2002) (Legal Questionnaire, 2003)

¹⁴⁷ Algeria: Official Gazette No. 14, 5 April 2001 (FAOLEX)

¹⁴⁸ Agreement between the Government of Kazakhstan and the Government of Turkey on cooperation in the sphere of animal health, 1995 (FAOLEX)

¹⁴⁹ Russian Federation, Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Uzbekistan, Ukraine; Agreement on cooperation of CIS member-states in the veterinary sphere (FAOLEX)

Africa.¹⁵⁰ There are also examples of bilateral international cooperation agreements between more distant countries – for example between Argentina and Hungary¹⁵¹.

Institutions and animal health services

A number of countries report legislation related to institutional aspects of the delivery of veterinary services. There may be laws defining the roles, responsibilities and obligations of veterinarians. These measures may include licensing requirements for veterinary practice – an example being reported by Kazakhstan¹⁵², or define the duties and powers¹⁵³, or responsibilities and obligations of veterinarians¹⁵⁴. CR India (2004) reports the existence of veterinary councils established by a Veterinary Council Act; similar measures are reported from Nepal¹⁵⁵.

A number of countries report legislation defining their animal health systems. Examples include the Act of Veterinary System mentioned in CR Islamic Republic of Iran (2004), and the Russian Federation's Federal Law on Veterinary Service, which involves a scheme for state veterinary inspection of collective farms, state agricultural enterprises, and big livestock farms and complexes (Legal Questionnaire, 2003). Some countries have decentralized institutions – Peru, for example, reports local committees for animal health (CR Peru, 2004). Brazil reports regional Animal Health Inspectorates within the Ministry of Agriculture to carry out control of animal health at regional level.¹⁵⁶

4.5 Conclusions

The analysis presented above clearly indicates that AnGR management is a complex matter, comprising a wide range of technical, policy and logistical operations. Many policy areas are involved – including agricultural and rural development, animal health, environmental and landscape conservation, culture, trade, research and education. Cooperation between many diverse stakeholders is required.

The decline of traditional livestock production systems is significant threat to many livestock breeds. Legislative and policy measures that, for whatever motivation, seek to support this type of production are potentially of importance to the maintenance of AnGR diversity. Countries in industrialized parts of the world are increasingly concerned about the conservation of rural environments and landscapes. There is a trend towards the introduction of regulations and policies aimed at the promotion of extensive farming practices – which tend to require breeds that are well adapted to local conditions. Conversely, in developing countries, food security and poverty alleviation are key objectives. Although there is often considerable focus on promoting intensive production, a number of countries, particularly in Africa, report measures to regulate and support the sustainability of extensive grazing systems. Given the unique adaptive traits of many dryland breeds and the many pressures faced by these production systems, effective policy and legislation in this field are of great importance. Nonetheless, devising measures that are appropriate to the needs of pastoral groups, who are often politically marginalized, remains a major challenge. Other reported legislative measures that have been put in place to support small-scale livestock production include those related to the provision of credit and the establishment of producer organizations and cooperative groups.

The implementation of specific measures aimed at the conservation of AnGR is greatly dependent on the economic means of the country in question, and this is reflected in the greater density of legislation and policy in the more developed areas of the world. However, it is also clear that the importance of

¹⁵⁰ Angola, Cape Verde, Guinea-Bissau, Mozambique, Sao Tome and Principe; Guinea-Bissau's Decree No 351/73, Boletim Oficial No. 89 (FAOLEX)

¹⁵¹ Governmental Decree No. 4 of 2002 ratifying and publishing the Agreement stipulated on 10 December 1999 in Budapest between Hungary and Argentina on animal health (FAOLEX)

¹⁵² Ministerial Decree No. 1972 of 1997 regarding the validation for the regulation on licensing of veterinary practice, 20 August 1997 (Legal Questionnaire, 2003)

¹⁵³ Georgia's Veterinary Act (CR Georgia, 2004)

¹⁵⁴ Estonia's Veterinary Activities Organization Act, 1999 (Legal Questionnaire, 2003)

¹⁵⁵ Nepal's Veterinary Council Act, 2055 (1999) (FAOLEX)

¹⁵⁶ Law No. 1.052 creating the Animal Health Inspectorate within the Ministry of Agriculture (1950) (Legal Questionnaire, 2003)

sustainable use and conservation of AnGR has in many cases not been adequately accommodated in the development of legal and policy frameworks at the national level. Inventory and registration systems, for example, are of great importance for the planning and implementation of conservation measures, but many countries report that policy and legislation in this field remains weak. A further step that can facilitate the administration of conservation schemes is the legal definition of criteria for the inclusion of breeds in such programmes, but measures of this type remain rare.

Where regulations related to conservation exist, they are often isolated, and not integrated into a strategy which takes account of the cross-cutting character of the issue. For example, measures aimed at increasing food security often focus almost exclusively on high-output breeds, without an adequate assessment of the potential contribution of local breeds, and without a strategy for their conservation. Another example is the field of animal health, which is the most highly regulated aspect of livestock management on a global scale. While effective disease control is essential for the use and development of AnGR, restrictions on movement and trade can present problems for AnGR management. Slaughter policies implemented in the event of epidemics pose a potential threat to rare breed populations. It is a matter of concern that throughout most of the world, very little attention has been paid to this threat in the development of legal frameworks and policies for disease control.

The extent to which legal frameworks for the management of AnGR have been put in place at the national level varies greatly. Many countries in Europe have extensive legislation. Conversely, in other regions, in particular in Africa, countries generally seem to rely on policy measures, which may be backed by legal mandates for the implementing institutions. This contrast raises the question of whether the establishment of elaborate legislative instruments regulating AnGR management is the most appropriate objective in developing countries. In some cases, countries clearly indicate that improved legislation is considered necessary. CR Kenya (2004), for example, states that “a suitable legal framework is ... required for operationalization of the [existing] policies. Once the right policies and legislation have been formulated, it will be necessary to review and revise them regularly to make them respond to the changes that occur with time.” Some countries are increasingly relying on market mechanisms or on private institutions for specific aspects of AnGR management, but have only limited legislation in place to regulate the field. It is possible that this could give rise to problems with regards to public goods aspects of AnGR management, and a close evaluation of the need for improved regulation is likely to be necessary. The decision, as to the appropriate solution for a given situation will depend on the political and legislative culture of the country in question, and on the structures available for implementation. In some circumstances, sound policy decisions and strategies, complemented by a clear legal definition of the competences and duties of institutions, and a well-organized monitoring and evaluation system, might be more effective than an elaborate legal framework.

4.6 References

CR (Country name). year. *Country report on the state of animal genetic resources.* (available in DAD-IS library at <http://www.fao.org/dad-is/>)

E-mail Consultation (Country name). 2005. E-mail consultation with National Coordinators during the preparation of this chapter. (unpublished)

FAO. 2005, *The legal framework for the management of animal genetic resources*, by A. Ingrassia, D. Manzella & E. Martynuik, for the Development Law Service, FAO Legal Office. FAO Legislative study No 89. Rome.

FAOLEX. (available at <http://faolex.fao.org/faolex/index.htm>)

Legal Questionnaire. 2003. Questionnaire survey conducted by FAO in 2003, (see FAO, 2005 for details).

Part 4

State of the art in the management of animal genetic resources

Introduction

This part of the Report gives an overview of the state of the art in methodologies and techniques for the management of animal genetic resources for food and agriculture (AnGR). As AnGR management is not an established scientific discipline, Section A outlines basic concepts that underlie FAO's understanding of the term. These concepts are the outcome of a series of expert meetings. Methodological developments in relevant fields of research are then highlighted, and important findings are illustrated through case studies. Finally, gaps in current knowledge are identified, and priorities for future research are proposed.

SECTION A: BASIC CONCEPTS

1 Animal genetic resources and breeds

AnGR are here defined as those animal species that are used, or may be used, for food production and agriculture,¹ and the populations within each. Distinct populations within species are usually referred to as breeds. The broad definition of the term “breed” used by FAO (Box 67) is a reflection of the difficulties involved in establishing a strict definition of the term.

Box 67

Definition of breed adopted by FAO

Either a subspecific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity.

Source: FAO (1999)

In developed countries, breeds are relatively clearly delineated. The role of breed societies, normally voluntary organizations, which supervise breeding standards, provide for the registration of animals, and promote the utilization of the breed, is important in this respect. A pattern of breed development based on recorded breeding and shared pedigrees emerged in western Europe during the late eighteenth century, with the first breed societies being established in England during the nineteenth century. Under the auspices of such organizations, a breed has come to be distinguished as a population sharing common ancestry, which has been subjected to similar selection objectives, and which conforms to certain established “breed standards”.

Breeds are generally not completely isolated in genetic terms. They are constantly required to change in response to changes in market demand, and will at times be supplemented with bloodlines from other breeds (FAO, 2003). Moreover, despite the existence of societies ostensibly associated with specific breeds, the precepts to be followed when establishing criteria for the delineation of a breed remain vague. Definitions of breeds within a developed-country context have included “animals which share a common pattern of use in agriculture, a degree of uniformity of phenotype, and a common gene pool” (FAO, 1995) and “distinct intraspecific groups, the members of which share particular characteristics that distinguish them from other such groups” (FAO, 2003). Discussing the situation in the United States of America, Hammak (2003) notes that all that is required to start a breed registry is “to adopt specific requirements for eligibility and start to record ancestry.” Similarly, under European Union (EU) legislation, there is no definition of a “breed” beyond the requirement that in order to be registered as a pure-bred animal, an animal's pedigree should be traceable to “parents and grandparents ... which are entered or registered in a herd-book of the same breed ... [and the animal itself should be] ... either entered or registered and eligible for entry in such a herd-book” (the

¹ Fish are excluded as management requirements and breeding techniques are very different. The term “farm animal genetic resources”, which had been used by FAO in relation to the Global Strategy for the Management of Farm Animal Genetic Resources, has been criticized on the grounds that it appeared to exclude animals not kept on farms, but in mobile systems.

quotation, from Council Directive 77/504/EEC, relates to bovine animals, but similar rules apply to other species).

There may, indeed, be little benefit in seeking a perfect definition. In the words of Jay Lush, a prominent figure in the field of animal breeding and genetics, “A breed is a group of domestic animals, termed such by common consent of the breeders, ... a term which arose among breeders of livestock, created one might say, for their own use, and no one is warranted in assigning to this word a scientific definition and in calling the breeders wrong when they deviate from the formulated definition. It is their word and the breeders’ common usage is what we must accept as the correct definition” (Lush, 1994).

In the developing regions of the world, the situation is even more complex, and the term “breed” often has little meaning. Populations that are isolated from others, whether on geographical, ecological or cultural grounds, will tend to become distinct as a result of natural and artificial selection, and genetic drift (FAO, 2003). However, the names used to distinguish livestock populations do not necessarily correspond to the underlying genetic diversity. In many cases, animals will not correspond to any recognized breed, although there may be local terms referring to different populations.

Where distinguishing genetically diverse populations is difficult, molecular studies may contribute to the delineation of separate breeds and breed groups. Studying the cultural and ecological aspects of livestock keeping also serves as a means of identifying populations that merit being treated as separate breeds. The following definition is an example of such an approach: “A domestic animal population may be regarded as a breed, if the animals fulfil the criteria of (i) being subjected to a common utilization pattern, (ii) sharing a common habitat/distribution area, (iii) representing largely a closed gene pool, and (iv) being regarded as distinct by their breeders” (Köhler-Rollefson, 1997). Thus, in the absence of breed association records or molecular studies, the views of the livestock keepers themselves perhaps provide the best indicator of breed identity. It may be possible to identify groups of farmers who claim to be raising an animal of a distinct type; can reliably recognize the type; exchange germplasm only with other breeders dedicated to holding the same type; and indicate that such breeding practices have been ongoing for many generations (FAO, 2003).

Within a breed there may be “stocks”, “strains”, “varieties”, or “lines”; these terms which are often used interchangeably describe populations within breeds that are phenotypically distinct as a result of human selection. The term “ecotype” refers to a population within a breed that is genetically adapted to a specific habitat.

2 Management of animal genetic resources

Management of AnGR focuses on maintaining genetic diversity. However, most scientific methods and techniques within the animal sciences (e.g. animal husbandry, animal breeding or genetics) have not been developed with this focus. Thus, there is no well-defined set of methodologies encompassed by the phrase “management of AnGR”. The overview presented here, therefore, selects the methodologies most relevant to the topic, guided by FAO’s definition:

“AnGR management encompasses all technical, policy, and logistical operations involved in understanding (characterization), using and developing (utilization), maintaining (conservation), accessing, and sharing the benefits of animal genetic resources” (FAO, 2001).

As such, this part of the Report includes descriptions of methodologies for characterization and conservation (Sections B and F); because of their increasing importance, methods for molecular characterization are presented separately from other aspects of characterization (Section C). However, when it comes to utilization – using and developing AnGR for agriculture and food production – no clear concept has emerged. It is, therefore, not possible to present a comprehensive description of the state of the art in utilization. Nonetheless, FAO has started to identify key elements of such a concept, using as a starting point the definition of sustainable use proposed by the Convention on Biological Diversity (CBD):

“Sustainable use is the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations” (Article 2 of the CBD).

To meet this objective FAO has proposed that:

- wise use of AnGR is possible without depleting domestic animal diversity;
- AnGR with high levels of adaptive fitness to the environment concerned should be used, and sound genetic principles deployed; and
- development of AnGR includes a broad mix of ongoing activities that must be well planned and executed for success, and compounded over time.

Thus, an important element of (sustainable) use of AnGR is to ensure that locally adapted breeds remain a functional part of production systems. Adaptive fitness traits, some of which may not yet have been discovered, are of particular importance, as they are genetically complex and cannot easily be achieved by selection over a short period of time. Use of AnGR inevitably includes development – AnGR are dynamic resources, changing with each generation in interaction with the physical environment and according to the selection criteria of their keepers. The proposed approach for genetic improvement is to base breeding efforts on locally adapted genetic resources. This will help to avoid the loss of breeds with unique attributes. Existing genetic variation in animals’ ability to use locally available resources, survive, produce and reproduce under the conditions of medium-to-low input farming should be exploited by well-designed breeding programmes. Complementary measures such as improvement in the provision of feed and water, treatment of diseases and parasites, and the management of reproduction will also need to be considered in strategies to improve the performance of these breeds.

Thus, genetic improvement methods are central to the development of breeds. Scientific methods for breeding programmes have, however, been developed mainly in higher-input production systems, and under favourable infrastructural conditions. Breeding programmes do not usually include maintaining genetic diversity within and between breeds as an explicit goal. The state of knowledge in the field of genetic improvement is described in Section D.

Ideally, breeding programmes should be part of a holistic strategy with the goal of sustainably intensifying production systems to improve the livelihoods of the producers. Sustainable intensification has been put forward as the ideal way of improving production systems, and is defined as follows:

“Sustainable intensification of production systems is the manipulation of inputs to, and outputs from, livestock production systems aimed at increasing production and/or productivity and/or changing product quality, while maintaining the long-term integrity of the systems and their surrounding environment, so as to meet the needs of both present and future human generations. Sustainable agricultural intensification respects the needs and aspirations of local and indigenous people, takes into account the roles and values of their locally adapted genetic resources, and considers the need to achieve long-term environmental sustainability within and beyond the agro-ecosystem” (FAO, 2001).

Addressing these general principles for the use and development of AnGR is not merely a matter of scientific methodology, but requires an effective combination of methodologies and techniques with appropriate development policies. To support policy development, economic analyses are needed to describe the economic importance of locally adapted breeds, in particular from the perspective of the smallholder; to define the value of livestock genetic diversity; and to compare different management strategies. An overview of economic valuation methods is presented in Section E.

Another difficulty related to the concept of utilization, is that of clearly distinguishing it from *in vivo* conservation. This problem arises due to the fact that sustainable use is considered the preferred method of maintaining AnGR. Thus, when conservation is defined in the broad sense of ensuring maintenance of all relevant AnGR, it includes sustainable use. However, a more operational definition, which allows a clearer delineation of the subject, and which is used in Section F on methods for conservation, is that conservation comprises actions that are required because the continued use of a particular genetic resource is threatened. The role of conservation is to ensure that unique genetic

resources are available to farmers and breeders in the future, and consequently, conservation can be considered as part of an overall strategy to use AnGR in a sustainable manner to meet current and future human needs. To inform decisions regarding conservation strategies, it is important to have an estimate of current risk status (see below), and also to identify threats likely to affect the breed in the near future. The latter allows interventions, such as any breed development necessary to maintain the breed, to take place at a sufficiently early stage.

Accessing and sharing the benefits of AnGR (also components of FAO's definition of AnGR management) are key areas for policy development. Interdependencies among regions in terms of their access to AnGR, and past and present patterns of exchange are described in Part 1 – Section C. Developments in biotechnology (described in Sections C and F) have facilitated exchange and use of genetic resources, have begun to detect genes regulating functional traits, and present new opportunities for the use of genetic material. Thus, they will play an important role in future patterns of access and benefit sharing (ABS). The contribution that methodologies developed in the social and political sciences can make to the formulation of adequate policies for ABS is, however, beyond the scope of this discussion.

3 Risk status classification

An assessment of the risk status of livestock breeds or populations is an important element in national planning of AnGR management. The risk status of a breed informs stakeholders whether, and how urgently, actions need to be taken. Gandini *et al.* (2004) define “degree of endangerment” as “a measure of the likelihood that, under current circumstances and expectations, the breed will become extinct.” Accurately estimating degrees of risk is a difficult undertaking and incorporates both demographic and genetic factors.

Clearly, current population size is an important factor in determining risk status. A small population is at greater risk of being wiped out by natural disasters, disease or inappropriate management. However, a mere headcount of animals, or even of animals of breeding age, does not give the whole picture with regard to risk status.

Breeding between individuals sharing common ancestors tends to reduce the rate of allelic variation in the next generation. The genetic diversity of the population is, thus, reduced. The accumulation of deleterious recessive alleles may threaten the fitness of the population and negatively affect reproductive rates, thereby increasing the risk of extinction (Gandini *et al.*, 2004; Woolliams, 2004). The extent of the risk is commonly expressed in terms of the rate of inbreeding (ΔF) in the population, which is a measure of the expected changes in gene frequencies in the population due to genetic drift (Woolliams, 2004). The rate of inbreeding is often inferred from the effective population size (N_e). As N_e goes up ΔF decreases, or more formally, $N_e = 1/(2 \Delta F)$.

The value of N_e in a population is often approximated on the basis of the equation $N_e = 4MF/(M+F)$ where M and F are number of reproducing males and females. The method is based on the assumption that matings between these breeding animals are random. However, this assumption is rarely applicable in livestock populations, as some individuals contribute disproportionate numbers of progeny to the next generation. The way in which breeding is managed, for example the implementation of selective breeding programmes, influences the effective population size. Various techniques for adjusting the calculation to account for such factors have been developed, but require further data inputs (Gandini *et al.*, 2004). Collecting the demographic data needed to calculate N_e is often problematic: there may be inconsistencies in census data and registration of females and offspring, some females may be used in crossing programmes, and not all females may be bred each year (Alderson, 2003). Another element that can influence the outcome of risk status estimations is the time interval over which risk is calculated. Because of the different generation intervals in different livestock species, calculations performed on the basis of the number of generations will produce different priorities from those calculated on the basis of years (*ibid.*).

Some implications of changes to the effective population size are important to note. At low levels of N_e , particularly below 100, the rate of loss of genetic diversity increases dramatically (FAO, 1992a).

For example, approximately 18, 10, 4, 1.6 and 0.8 percent of genetic diversity is lost in ten generations, when N_e is equal to 25, 50, 125, 250 and 500, respectively (ibid.). Additionally, it can be seen from the above equation that the value of N_e is far more readily influenced by changes affecting the male (smaller) breeding population than the female. This underlines the importance of considering the number of breeding males in any assessment of risk status.

In addition to the current effective population size, degree of risk is related to population growth trends. As noted above, where populations are small there is a greater likelihood that adverse events or trends will lead rapidly to extinction. Above a certain population size the risk of such an outcome can be regarded as small (see below for discussion of the thresholds used in various risk status classifications). The more rapidly a population builds up to reach the critical size, the less it is exposed to the risk of extinction. Obviously, if population figures are low and the growth trend is negative, the prospects for the breed are not good. A complicating factor is that breed population growth rates often show considerable fluctuations over time, particularly where production conditions cannot be strictly controlled (Gandini *et al.*, 2004). Factors which may influence the variance of the population growth rate include the variability of market demand, patterns of disease, the existence of programmes for and awareness of AnGR conservation, the general economic stability of the agricultural sector, and the spatial distribution and density of the population (ibid.). Calculating the probability that the population size will lie within a given range at a given time in the future is, thus, fraught with theoretical and data-related difficulties. Despite such problems, current population trends are clearly a factor to be considered in assessing risk status. In addition to overall population size and growth rates, the risk status of a population is affected by other factors such as the number of herds, and the geographical concentration of the population, which influence exposure to threats such as disease epidemics; and by sociological factors such as the age of the farmers keeping the breed (Woolliams, 2004).

In 1992, FAO convened an Expert Consultation to develop recommendations for the assessment of risk status. The preference was for a breed risk status classification based on the concept of N_e , adjusted by trends in population size, extent of cross-breeding, extent of cryoconservation, and variability of family size. It was also suggested that the number of herds and trends in the number of herds should be included (FAO, 1992a). However, data limitations and the necessity of a consistent approach on a global scale meant that a simpler approach was adopted, based on the number of breeding females and males, and trends in population size (see below for details). In the future, as more complete data become available it may be possible to refine the method of calculation to account for the above factors, and also to adapt it to account for the different generation intervals of different species.

For planning and prioritization purposes, it is useful to classify breeds into risk status categories. The numerical boundaries between the different risk status categories used by FAO are intended to be indicators of the need to take action. A paper presented at the Expert Consultation in 1992 argued that a population size between 100 and 1 000 breeding females “implies that the breed is in danger of extinction. Without action its effective population size is inadequate in most cases to prevent continuing genetic loss in future generations. An increase in the degree of inbreeding is unavoidable and threatens the vitality of animals. There is a real danger either of spontaneous loss for example by sudden disease, or due to neglect by man” (FAO 1992b). Further, a population size of less than 100 breeding females indicates that “The population is close to extinction. The first action must be to increase the population size. At this level of threat, the genetic variability is often already reduced so that the population cannot be considered the same as the ancient breed” (ibid.).

As such, the following classification is used by FAO to describe the degrees of risk faced by livestock breeds:

- Extinct breed: The case when it is no longer possible to recreate a population of the breed. Extinction is absolute when there are no breeding males (semen), breeding females (oocytes), nor embryos remaining.
- Critical breed: A breed where the total number of breeding females is less than 100 or the total number of breeding males is less than or equal to five; or the overall population size is close

to, but slightly above 100 and decreasing, and the percentage of pure-bred females is below 80 percent.

- Endangered breed: A breed where the total number of breeding females is between 100 and 1000 or the total number of breeding males is less than or equal to 20 and greater than five; or the overall population size is close to, but slightly above 100 and increasing and the percentage of pure-bred females is above 80 percent; or the overall population size is close to, but slightly above 1 000 and decreasing and the percentage of pure-bred females is below 80 percent.
- Critical–maintained breed and endangered–maintained breed: Critical or endangered breeds that are being maintained by an active public conservation programme or within a commercial or research facility.
- Breed not at risk: A breed where the total number of breeding females and males is greater than 1 000 and 20 respectively; or the population size approaches 1 000 and the percentage of pure-bred females is close to 100 percent, and the overall population size is increasing.

The FAO system outlined above is not the only existing classification of risk status. Another classification was developed for the European Association of Animal Production–Animal Genetic Data Bank (EAAP–AGDB), and is now used by the European Farm Animal Biodiversity Information System (EFABIS) (<http://efabis.tzv.fal.de/>). It covers breeds of buffalo, cattle, goat, sheep, horse, donkey, pig and rabbit in 46 European countries, and is based on genetic risk – as represented by expected cumulative rates of inbreeding in 50 years ($\Delta F-50$). Calculations are based on the familiar equation $N_e = 4MF/(M+F)$ (see above) with its inherent assumptions (EAAP–AGDB, 2005). Breeds are classified into one of five categories according to $\Delta F-50$: not endangered, <5 percent; potentially endangered, 5–15 percent; minimally endangered, 16–25 percent; endangered, 26–40 percent; and critically endangered, >40 percent. Breeds may be shifted to a higher risk class based on a set of additional risk factors: a high rate of incrossing with other breeds; a downward trend in the number of breeding females; or a low number of breeding herds (*ibid.*).

The EU, under Commission Regulation (EC) No. 817/2004, sets out risk status thresholds for the purposes of providing incentive payments to farmers keeping threatened breeds. Calculations are based on the number of breeding females summed across all EU countries. Separate thresholds are established for each species: cattle – 7 500, sheep – 10 000, goats – 10 000, equidae – 5 000, pigs – 15 000 and avian species – 25 000. Some arguments can be put forward in support of these rather high thresholds. Gandini *et al.* (2004) note that while in the European context a breed with 1000 or more breeding females can generally be self-sustainable, this is not always the case, and that it is easier to prevent a population from losing self-sustainability than to restore it.

The NGO Rare Breeds International has also developed a system based on the number of registered pure-bred breeding females, which classifies priority breeds into four categories: critical, endangered, vulnerable and at risk (Alderson, 2003). Other factors (number of breeding units, number of unrelated sire lines, population trends, distance between major breeding units), which would ideally be included in an estimation of risk status, are disregarded in the interests of avoiding excessive complexity in the calculations (*ibid.*).

4 References

Alderson, L. 2003. Criteria for the recognition and prioritisation of breeds of special genetic importance. *Animal Genetic Resources Information*, 33: 1–9.

Convention on Biological Diversity (CBD). Convention Text. Article 2. Use of Terms. Concluded at Rio de Janeiro, 5 June 1992. (available at <http://www.biodiv.org/convention/convention.shtml>).

EAAP–AGDB. 2005. *Factors used for assessing the status of endangerment of a breed*. European Association of Animal Production – Animal Genetic Data Bank. (available at <http://www.tiho-hannover.de/einricht/zucht/eaap/>).

- FAO.** 1992a. Monitoring animal genetic resources and criteria for prioritization of breeds, by K. Maijala. In J. Hodges, ed. *The management of global animal genetic resources*, Proceedings of an FAO Expert Consultation, Rome, Italy, April 1992, Animal Production and Health Paper No. 104. Rome.
- FAO.** 1992b. The minimum number of preserved populations, by I. Bodó, In J. Hodges, ed. *The management of global animal genetic resources*, Proceedings of an FAO Expert Consultation, Rome, Italy, April 1992, Animal Production and Health Paper No. 104. Rome.
- FAO.** 1995. *Global impact domain – animal genetic resources*, by E.P. Cunningham. Rome.
- FAO.** 1999. *The global strategy for the management of farm animal genetic resources*. Executive Brief. Rome.
- FAO.** 2001. *Preparation of the first report on the state of the world's animal genetic resources. Guidelines for the development of country reports*. Rome.
- FAO.** 2003. Defining livestock breeds in the context of community-based management of farm animal genetic resources, by J.E.O. Rege, In *Community-based management of farm animal genetic resources*. Proceedings of the workshop held in Mbabane, Swaziland, 7–11 May 2001. Rome.
- Gandini, G.C., Ollivier, L., Danell, B., Distl, O., Georgoudis, A., Groeneveld, E., Martyniuk, E., van Arendonk, J.A.M., & Woolliams, J.A.** 2004. Criteria to assess the degree of endangerment of livestock breeds in Europe. *Livestock Production Science*, 91(1-2): 173–182.
- Hammak, S.P.** 2003. *Creating cattle breeds and composites*. College Station Texas. Texas Cooperative Extension, Texas A & M University.
- Köhler-Rollefson, I.** 1997. Indigenous practices of animal genetic resource management and their relevance for the conservation of domestic animal diversity in developing countries. *Journal of Animal Breeding and Genetics*, 114: 231–238.
- Lush, J.L.** 1994. *The genetics of populations*. Iowa Agriculture and Home Economics Experiment Station. Special Report 94. Ames, Iowa. Iowa State University.
- Woolliams, J.A.** 2004. Managing populations at risk. In G. Simm, B. Villanueva, K.D. Sinclair & S. Townsend, eds. *Farm animal genetic resources*, pp. 85–106. British Society for Animal Science, Publication 30. Nottingham, UK. Nottingham University Press.

European legislation cited

COMMISSION REGULATION (EC) No 817/2004 of 29 April 2004 laying down detailed rules for the application of Council Regulation (EC) No 1257/1999 on support for rural development from the European Agricultural Guidance and Guarantee Fund (EAGGF). http://europa.eu.int/eur-lex/pri/en/oj/dat/2004/l_153/l_15320040430en00300081.pdf

COUNCIL DIRECTIVE 77/504/EEC of 25 July 1977 on pure- bred breeding animals of the bovine species. http://europa.eu.int/smartapi/cgi/sga_doc?smartapi!celexapi!prod!CELEXnumdoc&lg=EN&numdoc=31977L0504&model=guichett

SECTION B: METHODS FOR CHARACTERIZATION

1 Introduction

Characterization of AnGR encompasses all activities associated with the identification, quantitative and qualitative description, and documentation of breed populations and the natural habitats and production systems to which they are or are not adapted. The aim is to obtain better knowledge of AnGR, of their present and potential future uses for food and agriculture in defined environments, and their current state as distinct breed populations (FAO, 1984; Rege, 1992). National-level characterization comprises the identification of the country's AnGR and the surveying of these resources. The process also includes the systematic documentation of the information gathered so as to allow easy access. Characterization activities should contribute to objective and reliable prediction of animal performance in defined environments, so as to allow a comparison of potential performance within the various major production systems found in a country or region. It is, therefore, more than the mere accumulation of existing reports.

The information provided through the characterization process enables a range of interest groups, including farmers, national governments and regional as well as global bodies to make informed decisions on priorities for the management of AnGR (FAO, 1992; FAO/UNEP, 1998). Such policy decisions aim to promote further development of AnGR while ensuring that these resources are conserved for the needs of present and future generations.

2 Characterization – as the basis for decision-making

A key consideration for the management of AnGR at the national level is whether, at a given point in time, a particular breed population is self-sustainable or whether it is at risk. This primary assessment (baseline survey²) of breed/population status is based on information on:

- the population size and structure;
- geographical distribution;
- within-breed genetic diversity; and
- the genetic connectedness of breeds when populations are found in more than one country (e.g. the Djallonke sheep of West Africa).

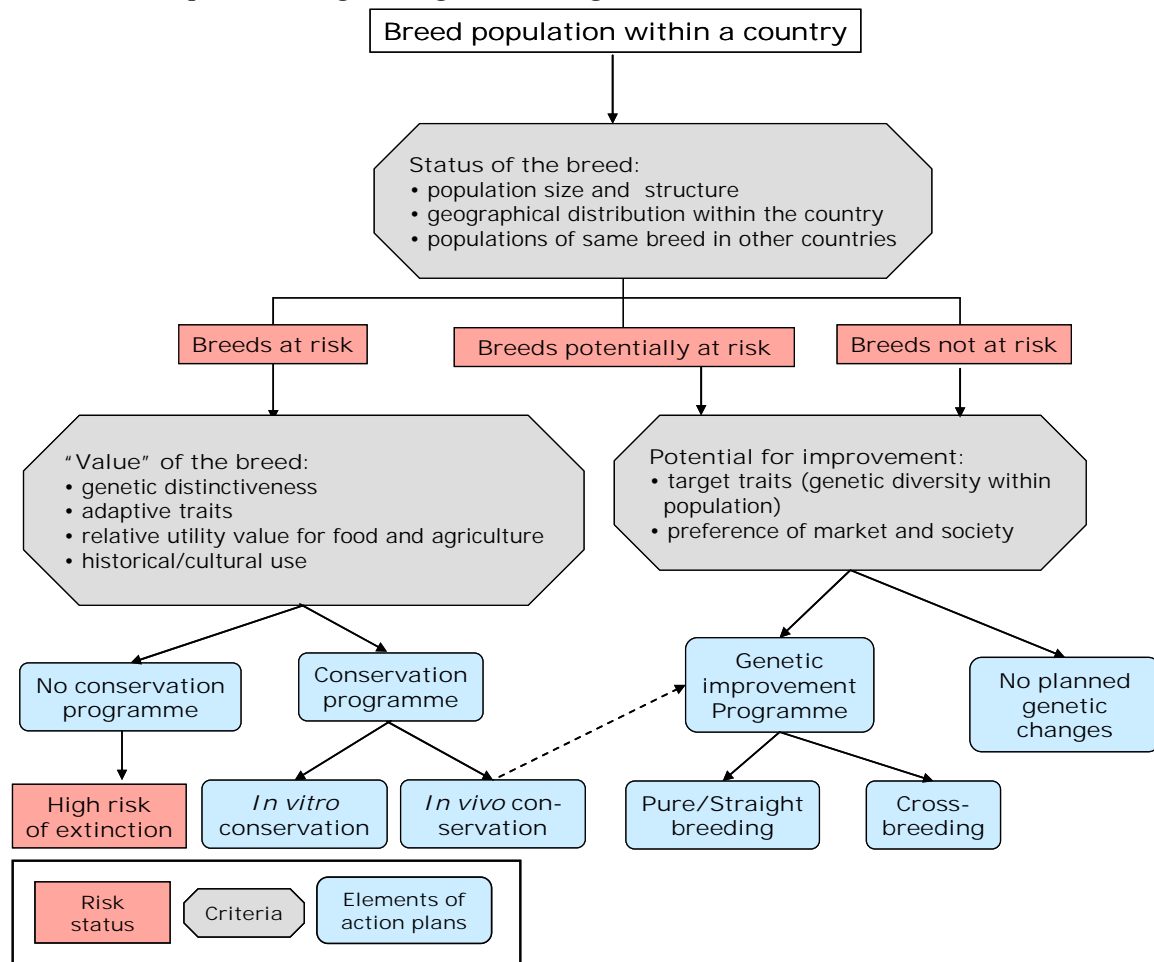
If a breed/population is not at risk, no immediate steps to implement conservation measures are necessary. Nevertheless, as part of national livestock development plans, decisions have to be taken as to whether a genetic improvement programme is needed – in response, for example, to changing market conditions. Decisions regarding such improvement programmes are mainly guided by information on long-term benefits to livestock keepers and society.

When a breed/population is found to be at risk, active conservation strategies have to be implemented or the potential loss of the breed must be accepted. To allocate the limited resources that are available for conservation programmes, breeds need to be prioritized. These decisions may be based on the genetic distinctiveness, adaptive traits, relative value for food and agriculture or historical/cultural values of the breeds in question. This information is also needed to decide, whether *in vivo* or *in vitro* strategies or a combination of both appears to be the most promising approach. If the breeds to be conserved are found in more than one country, decisions should be taken at the regional level. Thus,

² Baseline information is related to a particular target animal population at a given time and within a given production environment. Depending on the degree of change, these descriptions may need to be updated about once a generation. The baseline study should characterize phenotypic and molecular attributes of the breeding females and males in the population. About 100 adult females and about 30 adult males are needed for phenotypic characterization, but about a third of this size may be sufficient for molecular diversity estimation.

regional coordinating institutions/organizations, and supporting national policies, are required to facilitate such decisions and to implement actions. To date, only a few examples of multi-country actions in AnGR management have been reported.

Figure 47
Information required to design management strategies



For decisions on conservation strategies and on development programmes for self-sustainable breeds, comprehensive characterization information is needed, and should include:

- description of the typical phenotypic characteristics of the breed population, including physical features and appearance, economic traits (e.g. growth, reproduction and product yield/quality) and some measures (e.g. range) of variation in these traits – the focus is generally on the productive and adaptive attributes of the breed;
- description of the production environments (Box 68), both the original habitat and the current production system in which the population is kept – some breeds are kept in more than one production environment, in a number of countries, and sometimes outside their original geographical area;
- documentation of any special characteristics (unique features) of the population in terms of adaptation and production – including responses to environmental stressors (disease and parasite challenge, extremes of climate, poor feed quality etc.);
- images of typical adult males and females in their typical production environment;
- relevant indigenous knowledge (including but not limited to gender-specific knowledge) of traditional management strategies used by communities to utilize the genetic diversity of their livestock;

- description of ongoing management (utilization and conservation) actions and the stakeholders involved; and
- description of any known genetic relationships between breeds within or outside the country.

In addition to the information listed for both pathways (conservation and development), the following supplementary information is useful to guide the choice of priority breeds and geographic areas for conservation programmes:

- genetic distinctiveness of the breeds and their significance with respect to the total genetic diversity among the breeds under consideration (in order to maximize the diversity conserved for the benefit of future human generations);
- origin and development of the breeds; and
- unique genetic (or phenotypic if genetic attributes are not known) characteristics and their significance in current or anticipated production settings.

National decision-makers need to identify the breeds in which genetic improvement programmes would be most beneficial. Such programmes could include breeds classified as at risk, and form part of a conservation programme. Investments in breed improvement should be justified by adequate returns to investment. These are determined by performance levels, special adaptive characteristics and/or specific uses and values of the breeds in a given production environment or in relation to anticipated changes in the production environment (including market conditions). Thus, performance data, description of particularly useful attributes and values, and a detailed description of the general production environment are essential to guide decisions on breed development programmes.

The set of information needed for the development of appropriate breeding programmes also allows the choice of breed to be reconsidered as the production environment evolves, whether through changes to husbandry practices, market conditions, cultural preferences, or biophysical (e.g. climatic stress or disease challenge) factors. Similarly, this information is needed in the design of AnGR restocking schemes undertaken following natural disasters (drought, floods etc.), disease outbreaks or civil unrest. Restocking may be based on AnGR available within the country, from other countries in the region, or from another region of the world. In all cases, restocking schemes should seek to obtain the animals that are best adapted to the production environment into which they will be introduced.

Management decisions may differ in type and scope at subnational, national, regional and international levels. It is, therefore, important that relevant information on breed characteristics is made accessible to decision-makers at all levels. For example, it may happen that a country decides not to invest in the conservation of a specific local breed, but a regional or international organization decides that the breed is a unique genetic resource, and that it is in the global interest to conserve it.

Box 68**Production environment descriptors for animal genetic resources**

A comprehensive description of the production environment is essential to make use of performance data and to understand the special adaptations of breeds/populations. Adaptive fitness of breeds is complex and difficult to measure directly, but can be characterized indirectly by describing the primary variables (criteria) which have affected an animal gene pool (breed) over time, and have probably maximized its adaptive fitness for that environment. Thus, an (improved) description of production environments would be extremely valuable, in order to better understand the comparative adaptive fitness of specific AnGR.

In January 1998, an expert group met in Armidale, Australia, and devised a very detailed and well-structured approach, using five main criteria to characterize most, if not all, production environments, for all animal species used for food and agriculture. The five criteria were: climate; terrain; disease, disease complexes and parasites; resource availability; and management interventions (FAO, 1998). At a second level of hierarchy three to seven indicators for each criterion were formulated to characterize (i.e. describe and measure variables in) the production environments. For each indicator two or more verifiers were identified to specify or measure each indicator. The workshop noted that many developing countries had very little capacity to collect and analyse production environment variables, and that, a less complex descriptive system would, therefore, be preferable as it would be more likely to be used. Despite these concerns, the system proposed required very detailed information. A less detailed and more pragmatic approach to describing production systems would probably facilitate efforts to begin to fill the current large gaps in breed documentation. However, a detailed approach should be encouraged whenever this is possible.

The system devised at the meeting in Armidale appears to be the first attempt to develop a structured set of production environment descriptors (PEDs) for use in the characterization of livestock breeds. The Domestic Animal Genetic Resources Information System (DAGRIS) database, developed by the International Livestock Research Institute (ILRI) includes a field devoted to the "habitat" of each breed, but there is no set structure to the entries, and the information provided to date is quite limited. Oklahoma State University's "Breeds of Livestock" database provides some information on production environments, but this is again not based on a systematic set of descriptors.

3 Tools for characterization

3.1 Surveying

Surveys are undertaken to systematically collect data needed to identify breed populations and describe their observable characteristics, geographical distribution, uses and general husbandry, as well as their production environments. Full baseline surveys need to be undertaken once; some elements of the survey may be repeated when significant changes are observed in the livestock sector.

As part of the effort to develop global databanks for the management of AnGR, FAO developed a comprehensive list of animal and environment descriptors to serve as a guide for standardized characterization activities at various levels (FAO, 1986a,b,c). However, these descriptors were far too complex for universal application. In recognition of this fact, FAO developed simplified formats for data collection for mammalian and avian species (see summary of data items in Tables 97 and 99). This was based on the experience of the EAAP, which started collecting data in the 1980s and later built the first computer-based information system known as EAAP-AGDB. ILRI, in collaboration with FAO (Rowlands *et al.*, 2003) has developed and tested an approach for collecting and analysing on-farm breed-level information in Zimbabwe. The same approach has been applied in Ethiopia. A key lesson from this work was that logistic and time requirements for extensive livestock surveys, data management and analysis, can be grossly underestimated. It was also found that the outcomes of multivariate survey techniques need to be verified by complementary molecular genetic studies (Ayalew *et al.*, 2004).

Table 97
Information recorded for mammalian species in the Global Databank for Animal Genetic Resources

| | |
|---|---|
| <p>☐ GENERAL INFORMATION</p> <ul style="list-style-type: none"> Species Breed name (most common name and other local names) Distribution <p>☐ POPULATION DATA</p> <p>Basic Population Information:</p> <ul style="list-style-type: none"> Year of data collection Total population size (range or exact figure) Reliability of population data Population trend (increasing, stable, decreasing) Population figures based on (census/survey at species/breed level or estimate) <p>Advanced Population Information:</p> <ul style="list-style-type: none"> Number of breeding females and males Percentage of females bred to males of the same breed and percentage of males used for breeding Number of females registered in herd book/register Artificial Insemination usage and storage of semen and embryos Number of herds and average herd size <p>☐ MAIN USES</p> <ul style="list-style-type: none"> Listed in order of importance <p>☐ ORIGIN AND DEVELOPMENT</p> <ul style="list-style-type: none"> Current domestication status (domestic/wild/feral) Taxonomic classification (breed/variety/strain/line) Origin (description and year) Import Year of herd book establishment Organization monitoring breed (address) <p>☐ MORPHOLOGY</p> <ul style="list-style-type: none"> Adult height and weight Number and shape/size of horns Colour Specific visible traits Hair and/or wool type | <p>☐ SPECIAL QUALITIES</p> <ul style="list-style-type: none"> Specific quality of products Specific health characteristics Adaptability to specific environment Special reproductive characteristics Other special qualities <p>☐ MANAGEMENT CONDITIONS</p> <ul style="list-style-type: none"> Management system Mobility Feeding of adults Housing period Specific management conditions <p>☐ <i>IN SITU</i> CONSERVATION</p> <ul style="list-style-type: none"> Description of <i>in situ</i> conservation programmes <p>☐ <i>EX SITU</i> CONSERVATION</p> <ul style="list-style-type: none"> Semen stored and number of sires represented Embryos stored and number of dams and sires represented in embryos Description of <i>ex situ</i> conservation programmes <p>☐ PERFORMANCE</p> <ul style="list-style-type: none"> Birth weight Age at sexual maturity Average age of breeding males Age at first parturition and parturition interval Length of productive life Milk yield and lactation length (mammals) Milk fat Lean meat Daily gain Carcass Weight Dressing percentage Management conditions under which performance was measured |
|---|---|

Source: FAO/UNEP (2000)

Table 98
Information recorded for avian species in the Global Databank for Animal Genetic Resources

| | |
|---|---|
| <p>▣ GENERAL INFORMATION</p> <ul style="list-style-type: none"> Species Breed name (most common name and other local names) Distribution <p>▣ POPULATION DATA</p> <p>Basic Population Information:</p> <ul style="list-style-type: none"> Year of data collection Total population size (range or exact figure) Reliability of population data Population trend (increasing, stable, decreasing) Population figures based on (census/survey at species/breed level or estimate) <p>Advanced Population Information:</p> <ul style="list-style-type: none"> Number of breeding females and males Percentage of females bred to males of the same breed and percentage of males used for breeding Number of females registered in herd book/register Artificial Insemination usage and storage of semen and embryos Number of herds and average herd size <p>▣ MAIN USES</p> <ul style="list-style-type: none"> Listed in order of importance <p>▣ ORIGIN AND DEVELOPMENT</p> <ul style="list-style-type: none"> Current domestication status (domestic/wild/feral) Taxonomic classification (breed/variety/strain/line) Origin (description and year) Import Year of herd book establishment Organization monitoring breed (address) | <p>▣ MORPHOLOGY</p> <ul style="list-style-type: none"> Adult live weight Patterns within feathers Plumage pattern Skin colour Shank and foot colour Comb type Egg shell colour Specific visible traits <p>▣ SPECIAL QUALITIES</p> <ul style="list-style-type: none"> Specific quality of products Specific health characteristics Adaptability to specific environment Special reproductive characteristics Other special qualities <p>▣ MANAGEMENT CONDITIONS</p> <ul style="list-style-type: none"> Management system Mobility Feeding of adults Housing period Specific management conditions <p>▣ <i>IN SITU</i> CONSERVATION</p> <ul style="list-style-type: none"> Description of <i>in situ</i> conservation programmes <p>▣ <i>EX SITU</i> CONSERVATION</p> <ul style="list-style-type: none"> Semen stored and number of sires represented Description of <i>ex situ</i> conservation programmes <p>▣ PERFORMANCE</p> <ul style="list-style-type: none"> Age at sexual maturity Age at first egg and clutch interval Length of productive life Number of eggs per year Daily gain Carcass Weight Dressing percentage Management conditions under which performance was measured |
|---|---|

Source: FAO/UNEP (2000)

Based on the Global Strategy for the Management of AnGR, ten categories of variables are covered in AnGR surveys, including basic and advanced breed population information, main uses of the breed, origin and development/evolution of the breed, typical morphological features, average performance levels, special characteristics, and ongoing conservation activities.

3.2 Monitoring

Changes in population size and structure need to be documented regularly for all breeds. This should be carried out on a yearly or biennial basis, as the application of modern reproductive technologies, global trade, market demands, and policies favouring particular breeds, can lead to rapid changes in the size and structure of breed populations.

Monitoring should be conducted at least once per generation of the species, particularly for breeds classified as at risk or potentially at risk. This requires surveys at intervals of about eight years for horses and donkeys, five years for cattle, buffalo, sheep and goats, three years for pigs and two years for poultry species.

At present, most national livestock censuses do not contain breed-level data, and so regular reporting of breed population numbers does not take place. Species and breeds that have been classified as at risk should be monitored on a regular basis. This monitoring should serve as the basis for national early warning.

Information collected during monitoring activities enables adjustments to be made to management plans for AnGR. Monitoring programmes need to be carefully designed so that they provide feedback to farmers, managers and other stakeholders. Monitoring approaches need to be flexible, and activities by different players need to be well coordinated, as different groups will monitor different parameters. For example, farmers may wish to monitor production parameters; resource managers may wish to monitor completion of breed inventories; and administrators may wish to monitor the cost-effectiveness of various programmes. Monitoring is also necessary to evaluate progress in the implementation of action plans, and to identify new priorities, issues and opportunities.

Monitoring can be an extremely expensive aspect of AnGR management. However, if countries are strategic in their approaches to monitoring, and take advantage of existing resources, it can be cost effective. For managing genetic resources at high risk, data on current population size and geographic location are required. For such populations, regular and simple quantification and reporting of actual population sizes by those directly involved may be adequate and achievable. Large and widely dispersed populations may require the establishment of stratified samples, where a portion of the population in each major geographical region of the country is monitored. Lack of easy-to-apply tools for collecting such data, general lack of trained persons to undertake assessments, and lack of awareness on the part of policy-makers and implementers regarding the importance of such information, represent important challenges.

In every country there may be opportunities to monitor AnGR by taking advantage of existing activities, and thereby avoiding significant additional costs. National livestock censuses offer good opportunities. It may also be possible to set up effective monitoring stations in locations where livestock are sold or traded, such as auctions and local markets. This approach can greatly reduce costs by bringing the livestock to the monitors. However, a focus on traded animals may not accurately reflect the structure of the target populations on the farms. In countries where farmer groups, breed societies, or herd or stud books exist, tracking registrations can be a very effective means to monitor particular breeds. There may also be opportunities to combine monitoring activities with the tasks of existing government offices. For example, wildlife biologists could assist in monitoring livestock populations as part of wildlife surveys. Health officials could record livestock population numbers by breed when conducting food-processing inspections or delivering veterinary services. All these options, however, have to be treated with caution and potential biases need to be considered. The value of the information obtainable on the basis of existing activities has to be weighed against the additional information, but also greater costs, associated with surveys specifically designed and conducted to monitor AnGR.

As a step towards the inclusion of breed-level data in national livestock censuses, the next World Programme for Census of Agriculture (produced by FAO every ten years to guide countries in conducting of their agricultural census) (FAO, 2006) encourages countries to collect and report livestock data at breed level.

3.3 Molecular genetic characterization

Molecular genetic characterization explores polymorphism in selected protein molecules and DNA markers in order to measure genetic variation at the population level. Because of the low level of polymorphism observed in proteins, and hence limited applicability in diversity studies, DNA-level polymorphisms are the markers of choice for molecular genetic characterization (see Section C).

The process of molecular genetic characterization comprises field sampling of biological material (often blood or hair root samples), laboratory extraction of DNA from the samples, DNA storage, laboratory assaying (e.g. genotyping or sequencing), data analysis, report writing, and maintenance of a molecular genetic information database. Sampling for molecular analysis may be combined with surveying and/or monitoring, as molecular information on its own cannot be used for utilization and conservation decisions.

Characterization at the molecular genetic level is undertaken mainly to explore genetic diversity within and between animal populations, and to determine genetic relationships among such populations. More specifically, the results from the laboratory work are used to:

- determine within and between-breed diversity parameters;
- identify the geographical locations of particular populations, and/or of admixture among populations of different genetic origins;
- provide information on evolutionary relationships (phylogenetic trees) and clarify centres of origin and migration routes;
- implement gene mapping activities, including identification of carriers of known genes;
- identify parentage and genetic relationships (e.g. DNA fingerprinting) within populations;
- support marker assisted genetic improvement of animal populations; and
- develop DNA repositories for research and development (Hanotte and Jianlin, 2005).
- In populations with limited or no information on pedigrees and population structure, molecular markers can also be used to estimate the effective population size (N_e).

In the absence of comprehensive breed characterization data and documentation of the origin of breeding populations, molecular marker information may provide the most easily obtainable estimates of genetic diversity within and between a given set of populations.

3.4 Information systems

Information systems or databases can serve a variety of different purposes, but collectively they contain important information for decision-making, research, training, planning and evaluation of programmes, progress reporting and public awareness. An information system normally includes hardware, software (applications), organized data (information) and facilities for communication. It can be operated either manually, electronically using computers, or through a combination of both. The information may be on a single desktop machine, or a network of computers. Alternatively, it may be on the Internet, allowing external access to view or, in case of interactive dynamic systems, update the information.

The overall purpose of information systems is to enable and support decision-making regarding the present value and potential future uses of AnGR, by a range of stakeholders, including policy-makers, development practitioners, farmers and researchers. Thus, they need to incorporate essential decision-support tools to meet the needs of stakeholders at subnational, national, subregional, regional and global levels. However, users operating at these different hierarchies or levels will each have different objectives, and be interested in different aspects of the data contained within the information system. For instance, users operating at regional or global levels will be more interested in the cross-border distribution of breeds, cross-border livestock markets, transboundary disease risks, and germplasm exchange across borders. Conversely, more relevant issues for users at national and subnational (local)

levels are breed population size, herd/flock structures, production levels, and stressors associated with local environments. Linkages and information exchange between the hierarchies, as well as with external information sources can add value to information systems. Complementary databases may exchange information through a system of data transfer, or can serve as “gateways” to each other through electronic links via the Internet. For instance, national and subnational AnGR databases could be linked to geophysical databases (climate, soils, water or landscape). Functional linkages between these sets of data could lead to the generation of animal disease risk maps, and information on specific adaptations of particular breeds to stressful environments.

National databases of domestic animal diversity are essential planning tools. They present the current state of knowledge on the size, distribution, status, and utility value of AnGR. They allow access to information on planned and ongoing management activities. Moreover, they facilitate the identification of gaps in existing information.

At present, a number of public-domain electronic information systems for animal genetic diversity are globally accessible and contain data from more than one country. Two of these – DAD-IS and EFABIS (previously EAAP-AGDB) are related to the FAO global information system for AnGR. The Domestic Animal Genetic Resources Information System (DAGRIS), managed by ILRI is a database of synthesized research information from published and grey literature. Oklahoma State University’s Breeds of Livestock information system provides brief summaries of breed origins, characteristics and uses. The content of these information systems is described in Box 69.

Currently, the information resources have facilities for simple searches by country or breed only. Ideally, they should have as much research information as is available, and enable users to make informed judgements about the value of each item of information. If researchers and decision-makers are to have the information they require, the functionality of the existing information systems will need to be greatly increased, to allow extraction and customized analysis of various categories of information within and between data sources. The scope of data acquisition also needs to be expanded so that breed information can be linked to geographical information system (GIS)-based environment and production system mapping. This will allow poorly documented adaptation traits such as disease resistance to be predicted from past and current breed distribution and use (Gibson *et al.*, 2007).

Information systems for AnGR have been developed and administered as global public goods, and have limited ability to attract investment from the private sector or major funding agencies. This explains the very limited information that the systems contain compared to that which is potentially possible and which would be necessary for them to effectively achieve their stated purposes. One possibility to circumvent such limitations is to establish functionalities for interconnectivity and interoperability between information systems. This has been achieved with FABISnet (a distributed information system for AnGR) which enables countries to set up national Web-based information systems that can exchange core data with the higher levels of the network – regional systems (such as EFABIS) and the global system (DAD-IS).

Box 69**Information systems at global level**

DAD-IS [<http://www.fao.org/dad-is>]

The Domestic Animal Diversity Information System (DAD-IS) developed by FAO is the first globally accessible dynamic multilingual database of AnGR. It was initiated as a key communication and information tool for implementing the Global Strategy for the Management of AnGR, to assist countries and country networks in their respective programmes (FAO, 1999). Apart from country-level breed information and images, DAD-IS provides a virtual library containing a large number of selected technical and policy documents, including tools and guidelines for research related to AnGR. It offers Web-links to relevant electronic information resources. It also has a facility for the exchange of views and for addressing specific information requests, by linking a range of stakeholders: farmers, scientists, researchers, development practitioners and policy-makers.

DAD-IS provides a summary of national breed-level information on the origin, population, risk status, special characteristics, morphology and performance of breeds, as provided by FAO member countries. Currently, the database contains more than 14 000 national breed populations from 35 species and 181 countries. A key feature of DAD-IS is that it provides a country-secure information storage and communication tool. Each country decides when and what breed data are released through their officially designated contact person (the National Coordinator (NC) for the Management of AnGR). See Tables 97 and 98 for a summary of information recorded, stored and disseminated in the global breeds database contained in DAD-IS.

DAD-IS:3 has been rebuilt based on the same software and functionality as EFABIS (European Farm Animal Biodiversity Information System – <http://efabis-eaap.tzv.fal.de>), and with a similar interface. The software was developed within a European Union project in order to overcome the problem of incompatibility between EAAP-AGDB and DAD-IS. The new system allows for the creation of a network of distributed information systems with automatic data synchronization. Countries and regions are provided with tools to set up their own Web-based information systems. Information content and interface can be translated to any local language. The appearance of the interface can be adapted to reflect local flavours. Outside the core data structure, countries and regions may further define data structures that specifically reflect their needs. These specificities would not be synchronized with the higher-level information systems. Poland set up the first national information system under this new framework (<http://efabis.izoo.krakow.pl>), and defined additional structures to accommodate data on farmed fish and bees. NCs can enter breed information, images, publications, links to external Web sites, contact addresses and news into the system.

DAGRIS [<http://dagris.ilri.cgiar.org/>]

The Domestic Animal Genetic Resources Information System (DAGRIS) is developed and managed by the International Livestock Research Institute (ILRI). It was initiated in 1999 as a tool to collate research information available on global AnGR. In addition to containing information, obtained from a synthesis of the literature, on the origin, distribution, diversity, characteristics, present uses and status of indigenous breeds, DAGRIS is unique in that it includes complete references and abstracts of published or unpublished scientific literature pertaining to the breeds in the system. DAGRIS is designed to support research, training, public awareness, genetic improvement and conservation. Version I of the database was released on the Web in April 2003, and is also available on CD-ROM. Currently, the database contains over 19 200 trait records on 154 cattle, 98 sheep, and 62 goat breeds of Africa, plus 129 chicken ecotypes/breeds and 165 pig breeds of Africa and some Asian countries. The breed information pages in DAGRIS provide a Web link to the page for the corresponding breed in the FAO's DAD-IS system and vice versa.

The scope of DAGRIS is being expanded so that it will, in the near future, cover more species (turkeys, geese and ducks) and countries in Asia (Ayalew *et al.*, 2003). The priority next-steps for DAGRIS are: 1) development of a new module to allow all users to upload relevant research information into the database so that database administrators can capture and collate otherwise unavailable breed-level information; 2) development of GIS linkages in the database to allow georeferencing of as much of the breed-level information as possible; and 3) development of a template for a country module of DAGRIS to assist interested countries to further develop and customize the database.

Breeds of Livestock – Oklahoma State University [<http://www.ansi.okstate.edu/breeds>]

The Department of Animal Science of Oklahoma State University, in the United States of America, manages this information resource established in 1995. It provides a brief description of breeds in terms of origin, distribution, typical features, uses, and population status, along with photographs/images and key references for breed information. It presents a list of breeds from all over the world, with options to sort by region. As of January 2006, the database displayed a total of 1 063 breeds including 280 sheep, 262 cattle, 217 horse, 100 goat, 72 pig, 8 donkey, 8 buffalo, 6 camel, 4 reindeer, 1 llama, 1 yak, 64 chicken, 10 duck, 7 turkey, 7 goose, 1 guinea fowl and 1 black swan breeds. It also provides links to relevant information in its virtual livestock library. The aim is to expand the scope of the system, in terms of the number of breeds and the educational and scientific information it contains, through collaboration with individuals and universities from around the world. The submission of information (written material or images) on breeds not included in the list, or additional information on those already included, is welcome.

4 Conclusions

Adequate characterization of AnGR is a prerequisite for successful management programmes and for informed decision-making in national livestock development. Tools developed in the field of characterization should allow a strategic and coherent approach to identification, description and documentation of breed populations. Interest in such an approach is slowly emerging. Some aspects of characterization are increasingly being addressed. Molecular characterization has received particular attention. However, there is still a need for methods and tools to organize surveying and monitoring.

An important missing element in breed descriptions in many countries/regions, is a clear definition of the respective breeds to give them unique identity, and a description of the production environments to which they are adapted. A basic structure for the definition of production environments has been proposed, but needs to be reviewed and implemented. The existing breed-related information systems need to be further developed to allow easy information capture, processing, accessibility and interconnectivity.

Ideally, tools and methods for decision-making on AnGR management, as well as early warning and response tools, would be based on comprehensive information obtained using the methods described above. However, given that immediate action is required, there is a need for tools and methods that make effective use of incomplete information.

5 References

- Ayalew, W., Rege, J.E.O., Getahun, E., Tibbo, M. & Mamo, Y.** 2003. Delivering systematic information on indigenous animal genetic resources – the development and prospects of DAGRIS. In *Proceedings of the Deutscher Tropentag 2003, Technological and Institutional Innovations for Sustainable Rural Development*, held 8–10 October 2003. Göttingen, Germany. (also available at <http://www.tropentag.de/2003/abstracts/full/28.pdf>).
- Ayalew, W., van Dorland, A. & Rowlands, J.** 2004. *Design, execution and analysis of the livestock breed survey in Oromia Regional State, Ethiopia*. Addis Ababa and Nairobi. OADB (Oromia Agricultural Development Bureau) and ILRI (International Livestock Research Institute).
- DAGRIS.** 2004. *Domestic Animal Genetic Resources Information System (DAGRIS)*. J.E.O. Rege, W. Ayalew & E. Getahun, eds. Addis Ababa. International Livestock Research Institute.
- FAO.** 1984. *Animal genetic resource conservation by management, databanks and training*. Animal Production and Health Paper No. 44/1. Rome.
- FAO.** 1986a. *Animal genetic resources data banks - 1. Computer systems study for regional data banks*. Animal Production and Health Paper No. 59, Volume 1. Rome.
- FAO.** 1986b. *Animal genetic resources data banks - 2. Descriptor lists for cattle, buffalo, pigs, sheep and goats*. Animal Production and Health Paper No. 59, Volume 2. Rome.
- FAO.** 1986c. *Animal genetic resources data banks - 3. Descriptor lists for poultry*. Animal Production and Health Paper No. 59, Volume 3. Rome.
- FAO.** 1992. *The management of global animal genetic resources. Proceedings of an Expert Consultation*, Rome, Italy, April 1992. Edited by J. Hodges, Animal Production and Health Paper No.104. Rome.
- FAO.** 1998. *Report: Working group on production environment descriptors for farm animal genetic resources*. Report of a Working Group, held in Armidale, Australia, 19 – 21 January 1998. Rome.
- FAO.** 2006. *A system of integrated agricultural censuses and surveys, volume 1, World Programme for the Census of Agriculture 2010*. Statistical Development Series No. 11. (also available at <http://www.fao.org/es/ess/census/default.asp>).
- FAO/UNEP.** 1998. *Primary guidelines for development of national farm animal genetic resources management plans*. Rome.

FAO/UNEP. 2000. *World watch list for domestic animal diversity*, 3rd edition. Edited by B.D. Scherf. Rome.

Gibson, J.P., Ayalew, W. & Hanotte, O. 2007. Measures of diversity as inputs for decisions in conservation of livestock genetic resources. In D.I. Jarvis, C. Padoch & D. Cooper, eds. *Managing biodiversity in agroecosystems*. New York. Columbia University Press.

Hanotte, O. & Jianlin, H. 2005. Genetic characterization of livestock populations and its use in conservation decision-making. In *The role of biotechnology for the characterisation and conservation of crop, forestry, animal and fishery genetic resources*. Proceedings of the International Workshop, held 5-7 March 2005, Turin, Italy, Session IV, Electronic Forum on Biotechnology in Food and Agriculture, pp. 131–136. (also available at <http://www.fao.org/biotech/torino05.htm>).

Oklahoma State University. 2005. *Breeds of livestock*. Department of Animal Science, Oklahoma State University. (available at <http://www.ansi.okstate.edu/breeds/>).

Rege, J.E.O. 1992. Background to ILCA's animal genetic resources characterization project, objectives and agenda for the research planning workshop. In J.E.O. Rege & M.E. Lipner, eds. *Animal genetic resources: their characterization, conservation and utilization*. Research planning workshop, ILCA, Addis Ababa, Ethiopia, 19-21 February, 1992, pp. 55–59. Addis Ababa. International Livestock Centre for Africa.

Rowlands, J., Nagda, S., Rege, E., Mhlanga, F., Dzama, K., Gandiya, F., Hamudikwanda, H., Makuza, S., Moyo, S., Matika, O., Nangomasha, E. & Sikosana, J. 2003. *The design, execution and analysis of livestock breed surveys - a case study in Zimbabwe*. A report to FAO. Nairobi. International Livestock Research Institute.

SECTION C: MOLECULAR MARKERS – A TOOL FOR EXPLORING GENETIC DIVERSITY

DNA markers are useful in both basic (e.g. phylogenetic analysis and search for useful genes) and applied research (e.g. marker assisted selection, paternity testing and food traceability). This section focuses mainly on their application in characterization of AnGR diversity, and in the search for functional variants of relevant genes. It is important to note that RNA and proteins also contain key information, and therefore deserve parallel study; their role in the search for functional variants is also explored below.

1 Introduction

Diversity among organisms is a result of variations in DNA sequences and of environmental effects. Genetic variation is substantial, and each individual of a species, with the exception of monozygotic twins, possesses a unique DNA sequence. DNA variations are mutations resulting from substitution of single nucleotides (single nucleotide polymorphisms – SNPs), insertion or deletion of DNA fragments of various lengths (from a single to several thousand nucleotides), or duplication or inversion of DNA fragments. DNA variations are classified as “neutral” when they cause no change in metabolic or phenotypic traits, and hence are not subjected to positive, negative, or balancing selection; otherwise, they are referred to as “functional”. Mutations in key nucleotides of a coding sequence may change the amino acid composition of a protein, and lead to new functional variants. Such variants may have an increased or decreased metabolic efficiency compared to the original “wild type”, may lose their functionality completely, or even gain a novel function. Mutations in regulatory regions may affect levels and patterns of gene expression; for example, turning genes on/off or under/over-expressing proteins in specific tissues at different development or physiological stages.

Box 70 DNA, RNA and protein

DNA (deoxyribonucleic acid) is organized in pairs of chromosomes, each inherited from one of the parents. Each gene in an individual, therefore, has two copies, called alleles, one on each chromosome of a pair. In mammals, genes are scattered along chromosomes, separated by long, mainly repetitive, DNA sequences. Genes are formed by coding sequences (exons) separated by introns. The latter carry no protein coding information, but sometimes play a role in the regulation of gene expression. The instruction encoded by genes is put into action through two processes. The first is transcription (copy) of genetic information into another type of nucleic acid, RNA (ribonucleic acid). Both exons and introns are transcribed into a primary messenger RNA (mRNA) molecule. This molecule is then edited, a process which involves removing the introns, joining the exons together, and adding unique features to each end of the mRNA. A mature mRNA molecule is, thereby, created, which is then transported to structures known as ribosomes located in the cell cytoplasm. Ribosomes are made of ribosomal RNA (rRNA) and proteins, and provide sites for the second process – translation of the genetic information, previously copied to the mRNA, into a polypeptide (an entire protein or one of the chains of a protein complex). The mRNA molecule is read or translated three nucleotides (a codon) at a time. Complementarity between the mRNA codon and the anticodon of a transfer RNA (tRNA) molecule which carries the corresponding amino acid to the ribosome ensures that the newly formed polypeptide contains the specific sequence of amino acids required.

Not all genes are translated into proteins; some express their function as RNA molecules (such as the rRNA and tRNA involved in translation). Recently, new roles of RNA in the process of mRNA editing and in the regulation of gene expression have been discovered (Storz *et al.*, 2005; Aravin and Tuschl, 2005; Wienholds and Plasterk 2005). Indeed, non-coding RNAs appear to be key players in various regulatory processes (Bertone *et al.*, 2004; Clop *et al.*, 2006). Thus, three types of molecules are available for investigating genetic characteristics at cellular, tissue and whole organism levels: the DNA which contains the encoded instruction; the RNA which transfers the instructions to the cell “factory”; and the proteins which are built according to the instructions, and make functioning cells and organisms.

Although analysis of single types of biomolecules has proven extremely useful in understanding biological phenomena, the parallel large-scale investigation of DNA, RNA and proteins opens up new perspectives in the interpretation and modelling of the complexity of living organisms. New scientific disciplines with the suffix “-omics” are coming into existence. In these fields, recent advances in the preparation, identification and sequencing of DNA, RNA and proteins, and in large-scale data storage

and analysis, are bringing about a revolution in our understanding. A global, integrated view of an entire set of biological molecules involved in complex biological processes is emerging. Structural genomics, transcriptomics and proteomics are followed by metabolomics, and interactomics among others, and at a still higher level of complexity, systems biology (Hood *et al.*, 2004; Box 71).

Box 71

The new “-omics” scientific disciplines

Genomics charts genes and the genetic variations among individuals and groups. It provides an insight into the translation of genetic information to metabolic functions and phenotypic traits. It unveils biological processes and their interactions with environmental factors. Genomics involves the combination of a set of high-throughput technologies, such as proteomics and metabolomics, with the bioinformatic techniques that enable the processing, analysis and integration of large amounts of data.

Investigation of biological complexity is a new frontier which requires high-throughput molecular technology, high computer speed and memory, new approaches to data analysis, and integration of interdisciplinary expertise (Box 72).

Box 72

Recent developments in molecular biology

Current revolutionary developments in molecular biological research relevant to livestock breeding and genetic diversity conservation include: 1. establishment of the entire genome sequence of the most important livestock species; 2. development of technology to measure polymorphisms at loci spread all over the genome (e.g. methods to detect SNPs); and 3. development of microarray technology to measure gene transcription at a large scale. Information obtained through the sequencing of the entire genome (achieved for chickens and almost complete for pigs and cattle), integrated with SNP technology, will speed up the search for genes. Quantitative trait loci (QTL) mapping to identify chromosome regions influencing a target trait, the presence of candidate genes located in the same region, and investigation of their patterns of expression (e.g. by microarray and proteomic analyses) and their function across species, will come together to identify key genes and to unravel the complexity of physiological regulation for target traits.

See below for further discussion of these developments

2 The roles of molecular technologies in characterization

Information on genetic diversity is essential in optimizing both conservation and utilization strategies for AnGR. As resources for conservation are limited, prioritization is often necessary. New molecular tools hold the promise of allowing the identification of genes involved in a number of traits, including adaptive traits, and polymorphisms causing functional genetic variation (QTN – Quantitative Trait Nucleotides). However, we do not have sufficient knowledge to prioritize conservation choices on the basis of functional molecular diversity, and alternative measures are still needed. Phenotypic characterization provides a crude estimate of the average of the functional variants of genes carried by a given individual or population. However, the majority of phenotypes of the majority of livestock species are not recorded.

First role: In the absence of reliable phenotype and QTN data, or to complement the existing data, the most rapid and cost-effective measures of genetic diversity are obtained from the assay of polymorphisms using anonymous molecular genetic markers. Anonymous markers are likely to provide indirect information on functional genes for important traits, assuming that unique populations that have had a particular evolutionary history at the neutral markers (e.g. because of ancient isolation or independent domestication) are likely to carry unique variants of functional variations. Molecular techniques have also proved useful in the investigation of the origin and domestication of livestock species, and their subsequent migrations, as well as providing information on evolutionary relationships (phylogenetic trees), and identifying geographical areas of admixture among populations of different genetic origins. Subchapter 3.1 presents an outline of molecular techniques for the assessment of genetic diversity within and between breeds.

Second role: Effective population size (N_e) is an index that estimates the effective number of animals in a population that reproduce and contribute genes to the next generation. N_e is closely linked to the level of inbreeding and genetic drift in a population, and therefore is a critical indicator for assessing

the degree of endangerment of populations (see Sections A and F). Traditional approaches to obtaining reliable estimates of N_e for breeding populations are based on pedigree data or censuses. The necessary data on variability of reproductive success and generation intervals are often not reliably available for populations in developing countries. Molecular approaches may, therefore, be a promising alternative (see subchapter 3.2 for further details).

Third role: A top priority in the management of AnGR is the conservation of breeds that have unique traits. Among these, the ability to live and produce in challenging conditions, and to resist infectious diseases are of major importance, particularly for developing countries. Complex traits, such as adaptation and disease resistance, are not visible or easily measurable. They can be investigated in experiments in which the animals are submitted to the specific environmental conditions or are infected with the relevant agent. However, such experiments are difficult and expensive to perform, and raise concerns about animal welfare. This is the reason why researchers are extremely interested in identifying genes controlling complex traits. Such genes can be sought by a number of different approaches. Tools being developed by modern research are described in subchapter 3.3.

3 Overview of molecular techniques

This section describes the most important molecular techniques currently being utilized and developed for the assessment of genetic diversity, and for targeting functional variation. Box 73 describes how DNA and RNA are extracted from biological material and prepared for analysis. The attributes of commonly used molecular markers are outlined in Box 74, and sampling (a very important aspect of molecular studies) is discussed in Box 75.

Box 73

Extraction and multiplication of DNA and RNA

The first step in DNA, RNA and protein analysis is extraction and purification from biological specimens. Several protocols and commercial kits are available. The strategies applied depend on the source material and the target molecule. For example, DNA extraction from whole blood or white cells is relatively easy, while its extraction from processed food is rather difficult. RNA extraction from pancreatic tissue is difficult because of very rapid post-mortem degradation in this organ. Purity of DNA, RNA and proteins is often a key neglected factor in obtaining reliable results. After isolating DNA (or RNA) from cells, the next step is to obtain thousands or millions of copies of a particular gene or piece of DNA. DNA fragment multiplication can be delegated to micro-organisms, typically *E. coli*, or accomplished *in vitro* using a polymerase chain reaction (PCR). This technique, which won the Nobel Prize for its inventor, Cary Mullis, exponentially amplifies any DNA segment of known sequence. The key component in a PCR reaction is the DNA polymerase isolated from *Thermus aquaticus*, a micro-organism adapted to live and multiply at very high temperature. This thermostable *Taq*- (after *Thermus aquaticus*) polymerase permits chain replication in cycles and produces a geometric growth in the number of copies of the target DNA. A PCR cycle includes three steps: i) DNA denaturation at 90–95 °C to separate the DNA into two single strands to serve as a template; ii) annealing of a pair of short single-strand oligonucleotides (primers) complementary to the target regions flanking the fragment of interest, at 45–65 °C; iii) extension or elongation of newly synthesized DNA strands led by primers and facilitated by the *Taq*-polymerase, at 72 °C. This cycle can be repeated, normally 25 to 45 times, to enable amplification of enough amplicons (a fragment of a gene or DNA synthesized using PCR) to be detected.

Protein polymorphisms were the first markers used for genetic studies in livestock. However, the number of polymorphic loci that can be assayed, and the level of polymorphisms observed at the loci are often low, which greatly limits their application in genetic diversity studies. With the development of new technologies, DNA polymorphisms have become the markers of choice for molecular-based surveys of genetic variation (Box 74).

Box 74**Commonly used DNA markers**

Restriction fragment length polymorphisms (RFLPs) are identified using restriction enzymes that cleave the DNA only at precise “restriction sites” (e.g. EcoRI cleaves at the site defined by the palindrome sequence GAATTC). At present, the most frequent use of RFLPs is downstream of PCR (PCR–RFLP), to detect alleles that differ in sequence at a given restriction site. A gene fragment is first amplified using PCR, and then exposed to a specific restriction enzyme that cleaves only one of the allelic forms. The digested amplicons are generally resolved by electrophoresis.

Microsatellites or SSR (Simple Sequence Repeats) or STR (Simple Tandem Repeats) consist of a stretch of DNA a few nucleotides long –2 to 6 base pairs (bp) – repeated several times in tandem (e.g. CACACACACACACACA). They are spread over a eukaryote genome. Microsatellites are of relatively small size, and can, therefore, be easily amplified using PCR from DNA extracted from a variety of sources including blood, hair, skin or even faeces. Polymorphisms can be visualized on a sequencing gel, and the availability of automatic DNA sequencers allows high-throughput analysis of a large number of samples (Goldstein and Schlötterer, 1999; Jarne and Lagoda, 1996). Microsatellites are hypervariable; they often show tens of alleles at a locus that differ from each other in the numbers of the repeats. They are still the markers of choice for diversity studies as well as for parentage analysis and Quantitative Trait Loci (QTL) mapping, although this might be challenged in the near future with the development of cheap methods for the assay of SNPs. FAO has published recommendations for sets of microsatellite loci to be used for diversity studies for major livestock species, which were developed by the ISAG–AO Advisory Group on Animal Genetic Diversity (see DAD-IS library <http://www.fao.org/dad-is/>).

Minisatellites share the same characteristics as microsatellites, but the repeats are ten to a few hundreds bp long. Micro and minisatellites are also known as VNTRs (Variable Number of Tandem Repeats) polymorphisms.

Amplified fragment length polymorphisms (AFLPs) are a DNA fingerprinting technique which detects DNA restriction fragments by means of PCR amplification.

STS (Sequence Tagged Site) are DNA sequences that occur only once in a genome, in a known position. They needn't be polymorphic and are used to build physical maps.

SNPs are variations at single nucleotides which do not change the overall length of the DNA sequence in the region. SNPs occur throughout the genome. They are highly abundant and are present at one SNP in every 1000 bp in the human genome (Sachinadam *et al.*, 2001). Most SNPs are located in non-coding regions, and have no direct impact on the phenotype of an individual. However, some introduce mutations in expressed sequences or regions influencing gene expression (promoters, enhancers), and may induce changes in protein structure or regulation. These SNPs have the potential to detect functional genetic variation.

Box 75**Sampling genetic material**

Sample collection is the first and the most important step in any diversity study. Ideally, samples should be unrelated and representative of the populations under investigation. Generally, the sampling of 30 to 50 well-chosen individuals per breed is considered sufficient to provide a first clue as to breed distinctiveness and within-breed diversity, if a sufficient number of independent markers is assayed (e.g. 20–30 microsatellites; Nei and Roychoudhury, 1974; Nei, 1978). However, the actual numbers required may vary from case to case, and may be even lower in the case of a highly inbred local population, and higher in a widely spread population divided into different ecotypes.

The choice of unrelated samples is quite straightforward in a well-defined breed, where it can be based on the herd book or pedigree record. Conversely, it can be rather difficult in a semi-feral population for which no written record is available. In this case, the use of a geographic criterion is highly recommendable, i.e. to collect a single or very few (unrelated) animals per flock from a number of flocks spread over a wide geographic area. The record of geographical coordinates, and photo-documentation of sampling sites, animals and flocks is extremely valuable – to check for cross-breeding in the case of unexpected outliers, or for identifying interesting geographic patterns of genetic diversity. A well-chosen set of samples is a long-lasting valuable resource, which can be used to produce meaningful results even with poor technology. Conversely, a biased sample will produce results that are distorted or difficult to understand even if the most advanced molecular tools are applied.

3.1 Techniques using DNA markers to assess genetic diversity

Nuclear DNA markers

A number of markers are now available to detect polymorphisms in nuclear DNA. In genetic diversity studies, the most frequently used markers are microsatellites.

Microsatellites

Currently, microsatellites (Box 74) are the most popular markers in livestock genetic characterization studies (Sunnucks, 2001). Their high mutation rate and codominant nature permit the estimation of within and between-breed genetic diversity, and genetic admixture among breeds even if they are closely related.

Some controversy has surrounded the choice of a mutation model – infinite allele or step-wise mutation model (Goldstein *et al.*, 1995) – for microsatellite data analysis. However, simulation studies have shown that the infinite allele mutation model is generally valid for assessment of within-species diversity (Takezaki and Nei, 1996).

The mean number of alleles (MNA) per population, and observed and expected heterozygosity (H_o and H_e), are the most common parameters for assessing within-breed diversity. The simplest parameters for assessing diversity among breeds are the genetic differentiation or fixation indices. Several estimators have been proposed (e.g. F_{ST} and G_{ST}), the most widely used being F_{ST} (Weir and Basten, 1990), which measure the degree of genetic differentiation of subpopulations through calculation of the standardized variances in allele frequencies among populations. Statistical significance can be calculated for the F_{ST} values between pairs of populations (Weir and Cockerham, 1984) to test the null hypothesis of a lack of genetic differentiation between populations and, therefore, the partitioning of genetic diversity (e.g. Mburu *et al.*, 2003). Hierarchical analysis of molecular variance (AMOVA) (Excoffier *et al.*, 1992) can be performed to assess the distribution of diversity within and among groups of breeds.

Microsatellite data are also commonly used to assess genetic relationships between populations and individuals through the estimation of genetic distances (e.g. Beja-Pereira *et al.*, 2003; Ibeagha-Awemu *et al.*, 2004; Joshi *et al.*, 2004; Sodhi *et al.*, 2005; Tapio *et al.*, 2005). The most commonly used measure of genetic distances is Nei's standard genetic distance (D_S) (Nei, 1972). However, for closely related populations, where genetic drift is the main factor of genetic differentiation, as is often the case in livestock breeds, particularly in the developing world, the modified Cavalli-Sforza distance (D_A) is recommended (Nei *et al.*, 1983). Genetic relationship between breeds is often visualized through the reconstruction of a phylogeny, most often using the neighbour-joining (N-J) method (Saitou and Nei, 1987). However, a major drawback of phylogenetic tree reconstruction is that the evolution of lineages is assumed to be non-reticulate, i.e. lineages can diverge, but can never result from crosses between lineages. This assumption will rarely hold for livestock, where new breeds often originate from cross-breeding between two or more ancestral breeds. The visualization of the evolution of breeds provided by phylogenetic reconstruction must, therefore, be interpreted cautiously.

Multivariate analysis, and more recently Bayesian clustering approaches, have been suggested for admixture analysis of microsatellite data from different populations (Pritchard *et al.*, 2000). Probably the most comprehensive study of this type in livestock is a continent-wide study of African cattle (Hanotte *et al.*, 2002), which reveals the genetic signatures of the origins, secondary movements, and differentiation of African cattle pastoralism.

Molecular genetic data, in conjunction with, and complemented by, other sources such as archaeological evidence and written records, provide useful information on the origins and subsequent movements and developments of genetic diversity in livestock species. Mapping the origin of current genetic diversity potentially allows inferences to be made about where functional genetic variation might be found within a species for which only limited data on phenotypic variation exist.

Combined analysis of microsatellite data obtained in separate studies is highly desirable, but has rarely been possible. This is because most population genetic studies using DNA markers are limited to small

numbers of breeds, often from a single country (Baumung *et al.*, 2004). Often, different subsets of the FAO-recommended markers are used, and no standard samples are genotyped across projects. The application of different microsatellite genotyping systems causes variation between studies in the estimated size of alleles at the same loci. To promote the use of common markers, FAO is now proposing an updated, ranked list of microsatellite loci for the major livestock species.³ FAO recommends the use of the markers in the order of ranking, to maximize the number of markers overlapping among independent investigations. For some species, DNA from standard animals is available. For example, aliquots of sheep and goat standard DNA used in the European Union (EU) Econogene project have been distributed to other large-scale projects in Asia and Africa, and can be requested through the Econogene Website (<http://www.econogene.eu>).

There are only a few examples of large-scale analyses of the genetic diversity of livestock species. Hillel *et al.* (2003) and SanCristobal *et al.* (2006a) investigated, respectively, chicken and pig diversity throughout Europe; Hanotte *et al.* (2002) obtained data on cattle at the scale of almost the entire African continent; Tapio *et al.* (2005) assessed sheep diversity at a large regional scale in northern European countries; and Cañon *et al.* (2006) studied goat diversity in Europe and the Near and Middle East. However, for most species, a comprehensive review is still lacking. Ongoing close coordination between large-scale projects promises the delivery of a global estimate of genetic diversity in the near future for some species such as sheep and goats. In the meantime, new methods of data analysis are being developed to permit the meta-analysis of datasets that have only a few breeds and no, or only a few, markers in common (Freeman *et al.*, 2006). This global perspective on livestock diversity will be extremely valuable to reconstruct the origin and history of domestic animal populations and, indirectly, of human populations. It will also highlight regional and local hotspots of genetic diversity which may be targeted by conservation efforts.

SNPs

SNPs (Box 74) are used as an alternative to microsatellites in genetic diversity studies. Several technologies are available to detect and type SNP markers (see Syvänen, 2001, for a review). Being biallelic markers, SNPs have rather low information content, and larger numbers have to be used to reach the level of information obtained from a standard panel of 30 microsatellite loci. However, ever-evolving molecular technologies are increasing automation and decreasing the cost of SNP typing. This is likely, in the near future, to permit the parallel analysis of a large number of markers at a lower cost. With this perspective, large-scale projects are ongoing in several livestock species to identify millions (e.g. Wong *et al.*, 2004) and validate several thousands of SNPs, and identify haplotype blocks in the genome. Like sequence information, SNPs permit a direct comparison and joint analysis of different experiments.

SNPs seem to be appealing markers to apply in the future for genetic diversity studies because they can easily be used in assessing either functional or neutral variation. However, the preliminary phase of SNP discovery or SNP selection from databases is critical. SNPs can be generated through various experimental protocols, such as sequencing, single-stranded conformational polymorphism (SSCP) or denaturing high-performance liquid chromatography (DHPLC), or *in silico*, aligning and comparing multiple sequences of the same region from public genome and expressed sequence (EST) databases. When data have not been obtained randomly, standard estimators of population-genetic parameters cannot be applied. A frequent example is when SNPs initially identified in a small sample (panel) of individuals are then typed in a larger sample of chromosomes. By preferentially sampling SNPs at intermediate frequencies, such a protocol will bias the distribution of allelic frequencies compared to the expectation for a random sample. SNPs do hold promise for future application in population genetic analyses; however, statistical methods that can explicitly take into account each method of SNP discovery have to be developed (Nielsen and Signorovitch, 2003; Clark *et al.*, 2005).

AFLPs

AFLPs are dominant biallelic markers (Vos *et al.*, 1995). Variations at many loci can be arrayed simultaneously to detect single nucleotide variations of unknown genomic regions, in which a given

³ Lists and guidelines can be found in the DAD-IS library at <http://fao.org/dad-is>.

mutation may be frequently present in undetermined functional genes. However, a disadvantage is that they show a dominant mode of inheritance; this reduces their power in population-genetic analyses of within-breed diversity and inbreeding. Nevertheless, AFLP profiles are highly informative in assessing the relationship between breeds (Ajmone-Marsan *et al.*, 2002; Negrini *et al.*, 2006; De Marchi *et al.*, 2006; SanCristobal *et al.*, 2006b) and related species (Buntjer *et al.*, 2002).

Mitochondrial DNA markers

Mitochondrial DNA (mtDNA) polymorphisms have been extensively used in phylogenetic and genetic diversity analyses. The haploid mtDNA, carried by the mitochondria in the cell cytoplasm, has a maternal mode of inheritance (individuals inherit the mtDNA from their dams and not from their sires) and a high mutation rate; it does not recombine. These characteristics enable evolutionary biologists to reconstruct evolutionary relationships between and within species by assessing the patterns of mutations in mtDNA. MtDNA markers may also provide a rapid way of detecting hybridization between livestock species or subspecies (e.g. Nijman *et al.*, 2003).

The polymorphisms in the sequence of the hypervariable region of the D-loop or control region of mtDNA have contributed greatly to the identification of the wild progenitors of domestic species, the establishment of geographic patterns of genetic diversity, and the understanding of livestock domestication (see Bruford *et al.*, 2003, for a review). For example, the Middle Eastern origin of modern European cattle was recently demonstrated by Troy *et al.* (2001). The study identified four maternal lineages in *Bos taurus* and also demonstrated the loss of bovine genetic variability during the human Neolithic migration out of the Fertile Crescent. In the same way, multiple maternal origins with three mtDNA lineages were highlighted in goats (Luikart *et al.*, 2001), with Asia and the Fertile Crescent as possible centres of origin. Recently, a third mtDNA lineage was discovered in native Chinese sheep (Guo *et al.*, 2005), a fourth in native Chinese goats (Chen *et al.*, 2005), and a fifth in Chinese cattle (Lai *et al.*, 2006). In Asian chickens, nine different mtDNA clades have been found (Liu *et al.*, 2006), suggesting multiple origins in South and Southeast Asia. All these results indicate that our current knowledge of livestock domestication and genetic diversity remains far from complete. For further discussion of the origins of domestic livestock species see Part 1 – Section A.

3.2 Using markers to estimate effective population size

Hill (1981) suggested using gametic phase disequilibrium of DNA polymorphisms to estimate effective population size (N_e). This estimation can be based on genotypes for linked markers (microsatellites or SNPs). The expected correlation of allele frequencies at linked loci is a function of N_e and the recombination rate. N_e can, therefore, be estimated from the observed disequilibrium. Hayes *et al.* (2003) suggested a similar approach based on chromosome segment homozygosity, which, in addition, has the potential to estimate N_e for earlier generations, and therefore allows a judgement of whether an existing population was of increasing or decreasing size in the past. The study demonstrated, with example data sets, that the Holstein-Friesian cattle breed underwent a substantial reduction of N_e in the past, while the effective population size of the human population is increasing, which is in agreement with both census and pedigree studies.

3.3 Molecular tools for targeting functional variation

Approaches based on map position: quantitative trait loci (QTL) mapping

Genetic markers behave as Mendelian traits; in other words, they follow the laws of segregation and independent assortment first described by Mendel. Two genes that are located on the same chromosome are physically linked and tend to be inherited together. During meiosis, recombination between homologous chromosomes may break this linkage. The frequency of recombination between two genes located on the same chromosome depends of the distance between them. Recombination rate between markers is, therefore, an indication of their degree of linkage: the lower the recombination rate, the closer the markers. The construction of genetic maps exploits this characteristic to infer the likely order of markers and the distance between them.

Mapping exercises are generally accomplished following the co-segregation of polymorphic markers in structured experimental populations (e.g. F2 or backcross) or existing populations under selection programmes (families of full siblings or half siblings). Medium to high density genetic maps of a few hundred to a few thousand markers are available for most livestock species.

To identify a QTL for a given trait, a family segregating for the trait is genotyped with a set of mapped molecular markers evenly spread over the genome (Box 76). A number of statistical methods exist to infer the presence of a significant QTL at a given marker interval, but all rely on the fact that families possess a high level of linkage disequilibrium, i.e. large segments of chromosomes are transmitted without recombination from parents to progeny.

Box 76 **QTL mapping**

If a QTL for a target trait exists, the plus- and minus- variant allele of the unknown responsible gene (Q and q) will co-segregate with the alleles at a nearby M1 marker (M1 and m1) that we are able to genotype in the laboratory. Let us, for instance, hypothesize that M1 co-segregates with Q and m1 with q, that is M1 and Q are nearby on a same chromosome and m1 and q on the homologous chromosome (M1Q and m1q).

Let us also assume that an F2 population derived by the mating of heterozygous F1 individuals is genotyped. Following the genotyping, F2 progenies are grouped on the base of their marker genotype (M1M1 and m1m1; M2M2 and m2m2; ... MnMn and mnmn), and afterwards the average phenotype of the groups is compared. If no QTL is linked to a given marker (e.g. M2), then no significant difference will be detected between the average phenotypic value of the M2M2 and m2m2 progenies for the target trait. Conversely, when progenies are grouped by their genotype at the marker M1, then the group M1M1 will mostly be QQ at the QTL, and the group m1m1 will mostly be qq. In this case, a significant difference is observed between progeny averages, and therefore the presence of a QTL is detected. In species, such as poultry and pigs, where lines and breeds are commonly interbred commercially, this exercise can be accomplished in experimental populations (F2, BC) while in ruminants two (daughter design – DD) or three (grand-daughter design – GDD) generation pedigrees are generally used. In DD the segregation of markers heterozygous in a sire (generation I) is followed in the daughters (generation II) on which phenotypic data are collected. In GDD, the segregation of markers heterozygous in a grand-sire (generation I) are followed in his half-sib sons (generation II), whose phenotype is inferred from those of the grand-daughters (generation III).

The result of a QTL mapping experiment is the identification of a chromosome region, often spanning half of a chromosome, in which a significant effect is detected for the target trait. Modern research is actively using mapping to identify QTL influencing adaptive traits. Examples of such traits include, in chickens, increased resistance to *Salmonella* colonization and excretion (Tilquin *et al.*, 2005), and susceptibility to develop pulmonary hypertension syndrome (Rabie *et al.*, 2005); and in cattle, trypanotolerance (Hanotte *et al.*, 2002).

The QTL mapping phase is generally followed by the refinement of the map position of the QTL (QTL fine mapping). To accomplish this task, additional markers, and above all additional recombination events in the target area, are analysed. A clever approach has recently been designed and applied to the fine mapping of a chromosome region on BTA14 carrying a significant QTL for milk fat percentage and other traits (Farnir *et al.*, 2002). This approach exploits historical recombination in past generations to restrict the map position to a relatively small 3.8 cM (centimorgan) region, a size that has permitted the positional cloning of the gene (DGAT1) (Grisart *et al.*, 2002).

Following fine mapping, the genes determining the performance trait can be sought among the genes that are located in the regions identified. Candidate genes may be sought in the same species (e.g. when a rich EST map is available or when the genome is fully sequenced) or in orthologous regions of a model organism for which complete genome information is available.

Occasionally, key information on gene function arrives from an unexpected source. This was the case with the myostatin gene, the function of which was first discovered in mice and then found to be located in cattle in the chromosomal region where the double-muscling gene had previously been mapped (McPherron and Lee, 1997).

It is clear that identifying the responsible gene (quantitative trait genes – QTG) and the functional mutation (QTN) of a complex trait is still a substantial task, and several approaches are needed to decrease the number of positional candidate genes. Information on gene function is fundamental in

this respect. However, we are still ignorant about the possible function(s) of the majority of genes identified by genome and cDNA (complementary DNA) sequencing. This is why the investigation of patterns of gene expression may provide useful information, in combination with the positional approach previously described, to identify candidate genes for complex traits. This combined approach is referred to as genetical genomics (Haley and de Koning, 2006). New advances in the investigation of patterns of gene expression are described in the next section.

Alternative approaches are presently being investigated to detect adaptive genes using genetic markers (Box 77). They are now at the experimental stage, and only further research will permit an evaluation of their efficacy.

Box 77

The population genomics approach

An alternative approach to the identification of genome regions carrying relevant genes has recently been proposed. It consists of the detection of “selection signatures” via a “population genomics” approach (Black *et al.*, 2001; Luikart *et al.*, 2003). Three main principles of the population genomics approach to QTL mapping are that (1) neutral loci across the genome will be similarly affected by genetic drift, demography, and evolutionary history of populations; (2) loci under selection will often behave differently and, therefore, reveal “outlier” patterns of variation, loss of diversity (increase of diversity if the loci were under a balanced selection), linkage disequilibrium, and increased/decreased G_{st}/F_{st} indices; and (3) through hitchhiking effects selection will also influence linked markers, allowing the detection of a “selection signature” (outlier effects), which can often be detected by genotyping a large number of markers along a chromosome and identifying clusters of outliers. This approach utilizes phenotypic data at the breed level (or subpopulations within a breed), rather than at the individual level, and thereby nicely complements classical QTL mapping approaches within pedigrees.

The population genomics approach can also identify genes subjected to strong selection pressure and eventually fixed within breeds, and in particular, genes involved in adaptation to extreme environments, disease resistance etc. Many of these traits, which are of great importance to the sustainability of animal breeding, are difficult or impossible to investigate by classic QTL mapping or association study approaches. The potential of population genomics has recently been investigated from a theoretical point of view (Beaumont and Balding, 2004; Bamshad and Wooding, 2003), and through experimental work with different types of markers in natural populations (AFLPs: Campbell and Bernatchez, 2004; microsatellites: Kayser *et al.*, 2003; SNPs: Akey *et al.*, 2002). The approach has recently been applied within the Econogene project (<http://lasig.epfl.ch/projets/econogene>). In preliminary analyses, three SNPs in MYH1 (myosin 1), MEG3 (callypige), and CTSB (cathepsin B) genes in sheep have shown significant outlier behaviour (Pariset *et al.*, 2006).

Within the same project, a novel approach based on Spatial Analysis Method (SAM) has been designed to detect signatures of natural selection within the genome of domestic and wild animals (Joost, 2006). Preliminary results obtained with this method are in agreement with those obtained by the application of theoretical models in population genetics, such as those developed by Beaumont and Balding (2004). SAM goes a step further compared to classical approaches, since it is designed to identify environmental parameters associated with selected markers.

The ultimate goal of QTL mapping is to identify the QTG, and eventually the QTN. Although only a few examples exist to date in livestock, these are the kind of mutations that could have a direct impact on marker assisted breeding and on conservation decision-making. Conservation models considering functional traits and mutation need to be developed, as an increasing number of QTG and QTN will be uncovered in the near future.

Investigating patterns of gene expression

In the past, the expression of specific traits, such as adaptation and resistance, could only be measured at the phenotypic level. Nowadays, the transcriptome (the ensemble of all transcripts in a cell or tissue), and the proteome (the ensemble of all proteins) can be directly investigated by high-throughput techniques, such as differential display (DD) (Liang and Pardee, 1992), cDNA-AFLP (Bachem *et al.*, 1996), serial analysis of gene expression (SAGE) (Velculescu *et al.*, 1995; 2000), mass spectrometry, and protein and DNA microarrays. These techniques represent a breakthrough in RNA and protein analysis, permitting the parallel analysis of virtually all genes expressed in a tissue at a given time. Thus, the techniques contribute to the decoding of the networks that are likely to underlie many complex traits.

-Omics technologies are often compared to turning on the light in front of a Michelangelo fresco rather than using a torch that permits a view only of parts of the whole. The overall view allows the meaning of the representation to be understood and its beauty to be appreciated. In reality, the power of these techniques is paralleled at present by the difficulty and cost involved in applying them and in

analyzing the data produced. The isolation of homogeneous cell samples is rather difficult, and is an important prerequisite in many gene expression profiling studies. The large number of parallel assays results in low cost per assay, but at a high cost per experiment. Equipment is expensive, and high technical skill is needed in all experimental phases. This is in addition to the general difficulty in analysing RNA compared to DNA. RNA is very sensitive to degradation, and particular care has to be taken while extracting it from tissues that have a very active metabolism. Indeed, sample conservation and manipulation is one of the keys to success in RNA analysis experiments. The application of nanotechnologies to the analysis of biological molecules is opening up very promising perspectives in solving these problems (Sauer *et al.*, 2005).

Data handling is a further problem. Molecular datasets such as gene expression profiles can be produced in a relatively short time. However, the standardization of data between laboratories is needed for consistent analysis of different biological datasets. Agreements on standardization, as well as the creation of interconnected databases, are essential for the efficient analysis of molecular networks.

Transcript profiling

This section briefly describes SAGE and microarray techniques. Descriptions of other techniques may be found in a number of recent reviews (e.g. Donson *et al.*, 2002). SAGE generates complete expression profiles of tissues or cell lines. It involves the construction of total mRNA libraries which enable a quantitative analysis of the whole transcripts expressed or inactivated at particular steps of a cellular activation. It is based on three principles: (i) a short sequence tag (9–14 bp) obtained from a defined region within each mRNA transcript contains sufficient information to uniquely identify one specific transcript; (ii) sequence tags can be linked together to form long DNA molecules (concatemers) which can be cloned and sequenced – sequencing of the concatemer clones results in the quick identification of numerous individual tags; (iii) the expression level of the transcript is quantified by the number of times a particular tag is observed.

Microarrays can be used to compare, in a single experiment, the mRNA expression levels of several thousands of genes between two biological systems, for example, between animals in a normal and animals in a challenging environment. Microarray technology can also provide an understanding of the temporal and spatial patterns of expression of genes in response to a vast range of factors to which the organism is exposed.

Very small volumes of DNA solution are printed on a slide made of a non-porous material such as glass, creating spots that range from 100 to 150 μm in diameter. Currently, about 50 000 complementary DNAs (cDNAs) can be robotically spotted onto a microscope slide. DNA microarrays contain several hundreds of known genes, and a few thousands of unknown genes. The microarray is spotted with cDNA fragments or with prefabricated oligonucleotides. The latter option has the advantage of a higher specificity and reproducibility, but can be designed only when the sequence is known. Microarray use is based on the principle of “hybridization”, i.e. the exposure of two single-stranded DNA, or one DNA and one RNA, sequences to each other, followed by the measurement of the amount of double-stranded molecule formed. The expression of mRNA can be measured qualitatively and quantitatively. It indicates gene activity in a tissue, and is usually directly related to the protein production induced by this mRNA.

Gene expression profiling contributes to the understanding of biological mechanisms, and hence facilitates the identification of candidate genes. The pool of genes involved in the expression of trypanotolerance in cattle, for example, has been characterized by SAGE (Berthier *et al.*, 2003), and by cDNA microarray analysis (Hill *et al.*, 2005). The parallel investigation of the expression of many genes may permit the identification of master genes responsible for phenotypic traits that remain undetected by differential expression analysis. These master genes may, for instance, possess different alleles all expressed at the same level, which promote the expression of downstream genes with different efficiency. In this case, the master gene can be sought either by exploiting current knowledge of metabolic pathways, or via an expression QTL (eQTL) approach (Lan *et al.*, 2006). In this approach, the level of expression of the downstream genes is measured in a segregating population. The amount of transcript of each gene is treated as a phenotypic trait, and QTL that influence the gene

expression can be sought using methodologies described above. It is worth noting that data analysis for the detection of QTL is still quite difficult to master. This is also true for transcript profiling techniques because of the many false signals that occur.

Protein profiling

The systematic study of protein structures, post-translational modifications, protein profiles, protein–protein, protein–nucleic acid, and protein–small molecule interactions, and the spatial and temporal expression of proteins in eukaryotic cells, are crucial to understanding complex biological phenomena. Proteins are essential to the structure of living cells and their functions.

The structure of a protein can be revealed by the diffraction of x-rays or by nuclear magnetic resonance spectroscopy. The first requires a large amount of crystalline protein, and this is often restrictive. In order to understand protein function and protein–protein interactions at the molecular level, it would be useful to determine the structure of all the proteins in a cell or organism. At present, however, this has not been achieved. Interestingly, the number of different protein variants arising from protein synthesis (alternative splicing and/or post-translational modifications) is significantly greater than the number of genes in a genome.

Mass spectrometry (an analytical technique for the determination of molecular mass) in combination with chromatographic or electrophoretic separation techniques, is currently the method of choice for identifying endogenous proteins in cells, characterizing post-translational modifications and determining protein abundance (Zhu *et al.*, 2003). Two-dimensional gel electrophoresis is unique with respect to the large number of proteins (>10 000) that can be separated and visualized in a single experiment. Protein spots are cut from the gel, followed by proteolytic digestion, and proteins are then identified using mass spectrometry (Aebersold and Mann, 2003). However, standardization and automation of two-dimensional gel electrophoresis has proved difficult, and the use of the resulting protein patterns as proteomic reference maps has only been successful in a few cases. A complementary technique, liquid chromatography, is easier to automate, and it can be directly coupled to mass spectrometry. Affinity-based proteomic methods that are based on microarrays are an alternative approach to protein profiling (Lueking *et al.*, 2003), and can also be used to detect protein–protein interactions. Such information is essential for algorithmic modelling of biological pathways. However, binding specificity remains a problem in the application of protein microarrays, because cross-reactivity cannot accurately be predicted. Alternative approaches exist for detecting protein–protein interactions such as the two hybrid system (Fields and Song, 1989). However, none of the currently used methods allow the quantitative detection of binding proteins, and it remains unclear to what extent the observed interactions are likely to represent the physiological protein–protein interactions.

Array-based methods have also been developed for detecting DNA–protein interaction *in vitro* and *in vivo* (see Sauer *et al.*, 2005, for a review), and identifying unknown proteins binding to gene regulatory sequences. DNA microarrays are employed effectively for screening nuclear extracts for DNA-binding complexes, whereas protein microarrays are mainly used for identifying unknown DNA-binding proteins at proteome-wide level. In the future, these two techniques will reveal detailed insights into transcriptional regulatory networks.

Many methods of predicting the function of a protein are based on its homology to other proteins and its location inside the cell. Predictions of protein functions are rather complicated, and also require techniques to detect protein–protein interactions, and to detect the binding of proteins to other molecules, because proteins fulfil their functions in these binding processes.

4 The role of bioinformatics

Developing high-throughput technologies would be useless without the capacity to analyse the exponentially growing amount of biological data. These need to be stored in electronic databases (Box 78) associated with specific software designed to permit data update, interrogation and retrieval. Information must be easily accessible and interrogation-flexible, to allow the retrieval of information, that can be analysed to unravel metabolic pathways and the role of the proteins and genes involved.

Box 78

Databases of biological molecules

A number of databases exist which collect information on biological molecules:

DNA sequence databases:

- European Molecular Biology Lab (EMBL): <http://www.ebi.ac.uk/embl/index.html>
- GenBank: <http://www.ncbi.nlm.nih.gov/>
- DNA Data Bank of Japan (DDBJ): <http://www.ddbj.nig.ac.jp>

Protein databases:

- SWISS-PROT: <http://www.expasy.ch/sprot/sprot-top.html>
- Protein Information Resource (PIR): <http://pir.georgetown.edu/pirwww/>
- Protein Data Bank (PDB): <http://www.rcsb.org/pdb/>

Gene identification utility sites Bio-Portal

- GenomeWeb: <http://www.hgmp.mrc.ac.uk/GenomeWeb/nuc-geneid.html>
- BCM Search Launcher: <http://searchlauncher.bcm.tmc.edu/>
- MOLBIOL: <http://www.molbiol.net/>
- Pedro's BioMolecular Research tools: http://www.biophys.uni-duesseldorf.de/BioNet/Pedro/research_tools.html
- ExPASy Molecular Biology Server: <http://www.expasy.ch/>

Databases of particular interest for domestic animals:

- <http://locus.jouy.inra.fr/cgi-bin/bovmap/intro.pl>
- <http://www.cgd.csiro.au/cgd.html>
- <http://www.ri.bbsrc.ac.uk/cgi-bin/arkdb/browsers/>
- <http://www.marc.usda.gov/genome/genome.html>
- <http://www.ncbi.nlm.nih.gov/genome/guide/pig/>
- <http://www.ensembl.org/index.html>
- <http://www.tigr.org/>
- <http://omia.angis.org.au/>
- <http://www.livestockgenomics.csiro.au/ibiss/>
- <http://www.thearkdb.org/>
- <http://www.hgsc.bcm.tmc.edu/projects/bovine/>

Bioinformatics is crucial to combine information from different sources and generate new knowledge from existing data. It also has the potential to simulate the structure, function and dynamics of molecular systems, and is therefore helpful in formulating hypotheses and driving experimental work.

5 Conclusions

Molecular characterization can play a role in uncovering the history, and estimating the diversity, distinctiveness and population structure of AnGR. It can also serve as an aid in the genetic management of small populations, to avoid excessive inbreeding. A number of investigations have described within and between-population diversity – some at quite a large scale. However, these studies are fragmented and difficult to compare and integrate. Moreover, a comprehensive worldwide survey of relevant species has not been carried out. As such, it is of strategic importance to develop methods for combining existing, partially overlapping datasets, and to ensure the provision of standard samples and markers for future use as worldwide references. A network of facilities collecting samples of autochthonous germplasm, to be made available to the scientific community under appropriate regulation, would facilitate the implementation of a global survey.

Marker technologies are evolving, and it is likely that microsatellites will increasingly be complemented by SNPs. These markers hold great promise because of their large numbers in the genome, and their suitability for automation in production and scoring. However, the efficiency of SNPs for the investigation of diversity in animal species remains to be thoroughly explored. The subject should be approached with sufficient critical detachment to avoid the production of biased results.

Methods of data analysis are also evolving. New methods allow the study of diversity without *a priori* assumptions regarding the structure of the populations under investigation; the exploration of diversity to identify adaptive genes (e.g. using population genomics, see Box 77); and the integration of information from different sources, including socio-economic and environmental parameters, for setting conservation priorities (see Section F). The adoption of a correct sampling strategy and the systematic collection of phenotypic and environmental data, remain key requirements for exploiting the full potential of new technologies and approaches.

In addition to neutral variation, research is actively seeking genes that influence key traits. Disease resistance, production efficiency, and product quality are among the traits having high priority. A number of strategies and new high-throughput –omics technologies are used to this end. The identification of QTN offers new opportunities and challenges for AnGR management. Information on adaptive diversity complements that on phenotypic and neutral genetic diversity, and can be integrated into AnGR management and conservation decision-tools. The identification of unique alleles or combinations of alleles for adaptive traits in specific populations may reinforce the justification for their conservation and targeted utilization. Gene assisted selection also has the potential to decrease the selection efficiency gap currently existing between large populations raised in industrial production systems, and small local populations, where population genetic evaluation systems and breeding schemes cannot be effectively applied. Marker and gene assisted selection may not, however, always represent the best solution. These options need to be evaluated and optimized on a case-by-case basis, taking into account short and long-term effects on population structure and rates of inbreeding, and cost and benefits in environmental and socio-economic terms – in particular impacts on people's livelihoods.

As in the case of other advanced technologies, it is highly desirable that benefits of scientific advances in the field of molecular characterization are shared across the globe, thereby contributing to an improved understanding, utilization and conservation of the world's AnGR for the good of present and future human generations.

Box 79**Glossary: molecular markers**

For the purpose of this section the following definitions are used:

Candidate gene: any gene that could plausibly cause differences in the observable characteristics of an animal (e.g. in disease resistance, milk protein production or growth). The gene may be a candidate because it is located in a particular chromosome region suspected of being involved in the control of the trait, or its protein product may suggest that it could be involved in controlling the trait (e.g. milk protein genes in milk protein production).

DNA: the genetic information in a genome is encoded in deoxyribonucleic acid (DNA), which is stored in the nucleus of a cell. DNA has two strands structured in a double helix which is made of a sugar (deoxyribose), phosphate, and four chemical bases – the nucleotides: adenine (A), guanine (G), cytosine (C) and thymine (T). An A on one strand always pairs with a T on the other through two hydrogen bonds, while a C always pairs with a G through three hydrogen bonds. The two strands are, therefore, complementary to each other.

Complementary DNA (cDNA): DNA sequences generated from the reverse transcription of mRNA sequences. This type of DNA includes exons and untranslated regions at the 5' and 3' ends of genes, but does not include intron DNA.

Genetic marker: a DNA polymorphism that can be easily detected by molecular or phenotypic analysis. The marker can be within a gene or in DNA with no known function. Because DNA segments that lie near each other on a chromosome tend to be inherited together, markers are often used as indirect ways of tracking the inheritance pattern of a gene that has not yet been identified, but whose approximate location is known.

Haplotype: a contraction of the phrase “haploid genotype”, is the genetic constitution of an individual chromosome. In the case of diploid organisms, the haplotype will contain one member of the pair of alleles for each site. It may refer to a set of markers (e.g. single nucleotide polymorphisms – SNPs) found to be statistically associated on a single chromosome. With this knowledge, it is thought that the identification of a few alleles of a haplotype block can unambiguously identify all other polymorphic sites in this region. Such information is very valuable for investigating the genetics behind complex traits.

Linkage: The association of genes and/or markers that lie near each other on a chromosome. Linked genes and markers tend to be inherited together.

Linkage disequilibrium (LD): is a term used in the study of population genetics for the non-random association of alleles at two or more loci, not necessarily on the same chromosome. It is not the same as linkage, which describes the association of two or more loci on a chromosome with limited recombination between them. LD describes a situation in which some combinations of alleles or genetic markers occur more or less frequently in a population than would be expected from a random formation of haplotypes from alleles based on their frequencies. Linkage disequilibrium is caused by fitness interactions between genes or by such non-adaptive processes as population structure, inbreeding, and stochastic effects. In population genetics, linkage disequilibrium is said to characterize the haplotype distribution at two or more loci.

Microarray technology: a new way of studying how large numbers of genes interact with each other and how a cell's regulatory networks control vast batteries of genes simultaneously. The method uses a robot to precisely apply tiny droplets containing functional DNA to glass slides. Researchers then attach fluorescent labels to mRNA or cDNA from the cell they are studying. The labelled probes are allowed to bind to cDNA strands on the slides. The slides are put into a scanning microscope that can measure the brightness of each fluorescent dot; brightness reveals how much of a specific mRNA is present, an indicator of how active it is.

Primer: a short (single strand) oligonucleotide sequence used in a polymerase chain reaction (PCR)

RNA: Ribonucleic acid is a single stranded nucleic acid consisting of three of the four bases present in DNA (A, C and G). T is, however, replaced by uracil (U).

6 References

- Aebersold, R. & Mann, M.** 2003. Mass spectrometry-based proteomics. *Nature*, 422 (6928): 198–207. Review.
- Ajmone-Marsan, P., Negrini, R., Milanesi, E., Bozzi, R., Nijman, I.J., Buntjer, J.B., Valentini, A. & Lenstra, J.A.** 2002. Genetic distances within and across cattle breeds as indicated by biallelic AFLP markers. *Animal Genetics*, 33: 280–286.
- Akey, J.M., Zhang, G., Zhang, K., Jin, L. & Shriver, M.D.** 2002. Interrogating a high-density SNP map for signatures of natural selection. *Genome Research*, 12(12): 1805–14.
- Aravin, A. & Tuschl, T.** 2005. Identification and characterization of small RNAs involved in RNA silencing. *Febs Letters*, 579(26): 5830–40.
- Bachem, C.W.B., Van der Hoeven, R.S., De Bruijn, S.M., Vreugdenhil, D., Zabeau, M. & Visser, R.G.F.** 1996. Visualization of differential gene expression using a novel method of RNA fingerprinting based on AFLP: analyses of gene expression during potato tuber development. *The Plant Journal*, 9: 745–753.
- Bamshad, M. & Wooding, S.P.** 2003. Signatures of natural selection in the human genome. *Nature Reviews Genetics*, 4(2): 99–111. Review.
- Baumung, R., Simianer, H. & Hoffmann, I.** 2004. Genetic diversity studies in farm animals – a survey. *Journal of Animal Breeding and Genetics*, 121: 361–373.
- Beaumont, M.A. & Balding, D.J.** 2004. Identifying adaptive genetic divergence among populations from genome scans. *Molecular Ecology*, 13(4): 969–80.
- Beja-Pereira, A., Alexandrino, P., Bessa, I., Carretero, Y., Dunner, S., Ferrand, N., Jordana, J., Laloe, D., Moazami-Goudarzi, K., Sanchez, A. & Cañon, J.** 2003. Genetic characterization of southwestern European bovine breeds: a historical and biogeographical reassessment with a set of 16 microsatellites. *Journal of Heredity*, 94: 243–50.
- Berthier, D., Quere, R., Thevenon, S., Belemsaga, D., Piquemal, D., Marti, J. & Maillard, J.C.** 2003. Serial analysis of gene expression (SAGE) in bovine trypanotolerance: preliminary results. *Genetics Selection Evolution*, 35 (Suppl. 1): S35–47.
- Bertone, P., Stolc, V., Royce, T.E., Rozowsky, J.S., Urban, A.E., Zhu, X., Rinn, J.L., Tongprasit, W., Samanta, M., Weissman, S., Gerstein, M. & Snyder, M.** 2004. Global identification of human transcribed sequences with genome tiling arrays. *Science*, 306: 2242–2246.
- Black, W.C., Baer, C.F., Antolin, M.F. & DuTeau, N.M.** 2001. Population genomics: genome-wide sampling of insect populations. *Annual Review of Entomology*, 46: 441–469.
- Bruford, M.W., Bradley, D.G. & Luikart, G.** 2003. DNA markers reveal the complexity of livestock domestication. *Nature Reviews Genetics*, 4: 900–910.
- Buntjer, J.B., Otsen, M., Nijman, I.J., Kuiper, M.T. & Lenstra, J.A.** 2002. Phylogeny of bovine species based on AFLP fingerprinting. *Heredity*, 88: 46–51.
- Campbell, D. & Bernatchez, L.** 2004. Generic scan using AFLP markers as a means to assess the role of directional selection in the divergence of sympatric whitefish ecotypes. *Molecular Biology and Evolution*, 21(5): 945–56.
- Cañon, J., Garcia, D., Garcia-Atance, M.A., Obexer-Ruff, G., Lenstra, J.A., Ajmone-Marsan, P., Dunner, S. & The ECONOGENE Consortium.** 2006. Geographical partitioning of goat diversity in Europe and the Middle East. *Animal Genetics*, 37: 327–334.
- Chen, S.Y., Su, Y.H., Wu, S.F., Sha, T. & Zhang, Y.P.** 2005. Mitochondrial diversity and phylogeographic structure of Chinese domestic goats. *Molecular Phylogenetics and Evolution*, 37: 804–814.
- Clark, A.G., Hubisz, M.J., Bustamante, C.D., Williamson, S.H. & Nielsen, R.** 2005. Ascertainment bias in studies of human genome-wide polymorphism. *Genome Research*, 15: 1496–1502.
- Clop, A., Marcq, F., Takeda, H., Pirottin, D., Tordoir, X., Bibe, B., Bouix, J., Caiment, F., Elsen, J.M., Eychenne, F., Larzul, C., Laville, E., Meish, F., Milenkovic, D., Tobin, J., Charlier, C. &**

- Georges, M.** 2006. A mutation creating a potential illegitimate microRNA target site in the myostatin gene affects muscularity in sheep. *Nature Genetics*, 38: 813–818.
- De Marchi, M., Dalvit, C., Targhetta, C. & Cassandro, M.** 2006. Assessing genetic diversity in indigenous Veneto chicken breeds using AFLP markers. *Animal Genetics*, 37: 101–105.
- Donson, J., Fang, Y., Espiritu-Santo, G., Xing, W., Salazar, A., Miyamoto, S., Armendarez, V. & Volkmuth, W.** 2002. Comprehensive gene expression analysis by transcript profiling. *Plant Molecular Biology*, 48: 75–97.
- Excoffier, L., Smouse, P.E. & Quattro, J.M.** 1992. Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. *Genetics*, 131: 479–491.
- Farnir, F., Grisart, B., Coppieters, W., Riquet, J., Berzi, P., Cambisano, N., Karim, L., Mni, M., Moisisio, S., Simon, P., Wagenaar, D., Vilkki, J. & Georges, M.** 2002. Simultaneous mining of linkage and linkage disequilibrium to fine map quantitative trait loci in outbred half-sib pedigrees: revisiting the location of a quantitative trait locus with major effect on milk production on bovine chromosome 14. *Genetics*, 161: 275–287.
- Fields, S. & Song, O.** 1989. A novel genetic system to detect protein–protein interactions. *Nature*, 340: 245–246.
- Freeman, A.R., Bradley, D.G., Nagda, S., Gibson, J.P. & Hanotte, O.** 2006. Combination of multiple microsatellite data sets to investigate genetic diversity and admixture of domestic cattle. *Animal Genetics*, 37: 1–9.
- Goldstein, D.B., Linares, A.R., Cavalli-Sforza, L.L. & Feldman, M.W.** 1995. An evaluation of genetic distances for use with microsatellite loci. *Genetics*, 139: 463–471.
- Goldstein, D.B. & Schlotterer, C.** 1999. *Microsatellites: evolution and applications*. New York. Oxford University Press.
- Grisart, B., Coppieters, W., Farnir, F., Karim, L., Ford, C., Berzi, P., Cambisano, N., Mni, M., Reid, S., Simon, P., Spelman, R., Georges, M. & Snell, R.** 2002. Positional candidate cloning of a QTL in dairy cattle: identification of a missense mutation in the bovine DGAT1 gene with major effect on milk yield and composition. *Genome Research*, 12: 222–231.
- Guo, J., Du, L.X., Ma, Y.H., Guan, W.J., Li, H.B., Zhao, Q.J., Li, X. & Rao, S.Q.** 2005. A novel maternal lineage revealed in sheep (*Ovis aries*). *Animal Genetics*, 36: 331–336.
- Haley, C. & de Koning, D.J.** 2006. Genetical genomics in livestock: potentials and pitfalls. *Animal Genetics*, 37(Suppl 1): 10–12.
- Hanotte, O., Bradley, D.G., Ochieng, J.W., Verjee, Y. & Hill, E.W.** 2002. African pastoralism: genetic imprints of origins and migrations. *Science*, 296: 336–339.
- Hayes, B.J., Visscher, P.M., McPartlan, H.C. & Goddard, M.E.** 2003. A novel multilocus measure of linkage disequilibrium to estimate past effective population size. *Genome Research*, 13: 635–643.
- Hill, E.W., O’Gorman, G.M., Agaba, M., Gibson, J.P., Hanotte, O., Kemp, S.J., Naessens, J., Coussens, P.M. & MacHugh, D.E.** 2005. Understanding bovine trypanosomiasis and trypanotolerance: the promise of functional genomics. *Veterinary Immunology and Immunopathology*, 105: 247–258.
- Hill, W.G.** 1981. Estimation of effective population size from data on linkage disequilibrium. *Genetics Research*, 38: 209–216.
- Hillel, J., Groenen, M.A., Tixier-Boichard, M., Korol, A.B., David, L., Kirzhner, V.M., Burke, T., Barre-Dirie, A., Crooijmans, R.P., Elo, K., Feldman, M.W., Freidlin, P.J., Maki-Tanila, A., Oortwijn, M., Thomson, P., Vignal, A., Wimmers, K. & Weigend, S.** 2003. Biodiversity of 52 chicken populations assessed by microsatellite typing of DNA pools. *Genetics Selection Evolution*, 35: 533–557.
- Hood, L., Heath, J.R., Phelps, M.E. & Lin, B.** 2004. Systems biology and new technologies enable predictive and preventative medicine. *Science*, 306: 640–643.

- Ibeagha-Awemu, E.M., Jann, O.C., Weimann, C. & Erhardt, G.** 2004. Genetic diversity, introgression and relationships among West/Central African cattle breeds. *Genetics Selection Evolution*, 36: 673–690.
- Jarne, P. & Lagoda, P.J.L.** 1996. Microsatellites, from molecules to populations and back. *Tree*, 11: 424–429.
- Joshi, M.B., Rout, P.K., Mandal, A.K., Tyler-Smith, C., Singh, L. & Thangaraj, K.** 2004. Phylogeography and origin of Indian domestic goats. *Molecular Biology and Evolution*, 21: 454–462.
- Joost, S.** 2006. *The geographical dimension of genetic diversity*. A GIScience contribution for the conservation of animal genetic resources. École Polytechnique Fédérale de Lausanne, Switzerland. (PhD thesis)
- Kayser, M., Brauer, S. & Stoneking, M.** 2003. A genome scan to detect candidate regions influenced by local natural selection in human populations. *Molecular Biology and Evolution*, 20: 893–900.
- Lai, S.J., Liu, Y.P., Liu, Y.X., Li, X.W. & Yao, Y.G.** 2006. Genetic diversity and origin of Chinese cattle revealed by mtDNA D-loop sequence variation. *Molecular Phylogenetics and Evolution*, 38: 146–54.
- Lan, L., Chen, M., Flowers, J.B., Yandell, B.S., Stapleton, D.S., Mata, C.M., Ton-Keen Mui, E., Flowers, M.T., Schueler, K.L., Manly, K.F., Williams, R.W., Kendziorski, C. & Attie, A.D.** 2006. Combined expression trait correlations and expression quantitative trait locus mapping. *PLoS Genetics*, 2: 51–61.
- Liang, P. & Pardee, A.B.** 1992. Differential display of eukaryotic messenger RNA by means of the polymerase chain reaction. *Science*, 257: 967–997.
- Liu, Y.P., Wu, G.S., Yao, Y.G., Miao, Y.W., Luikart, G., Baig, M., Beja-Pereira, A., Ding, Z.L., Palanichamy, M.G. & Zhang, Y.P.** 2006. Multiple maternal origins of chickens: out of the Asian jungles. *Molecular Phylogenetics and Evolution*, 38: 12–19.
- Lueking, A., Possling, A., Huber, O., Beveridge, A., Horn, M., Eickhoff, H., Schuchardt, J., Lehrach, H. & Cahill, D.J.** 2003. A nonredundant human protein chip for antibody screening and serum profiling. *Mol. Cell Proteomics*, 2: 1342–1349.
- Luikart, G., England, P.R., Tallmon, D., Jordan, S. & Taberlet, P.** 2003. The power and promise of population genomics: from genotyping to genome typing. *Nature Genetics Rev.*, 4: 981–994.
- Luikart, G., Gielly, L., Excoffier, L., Vigne, J.D., Bouvet, J. & Taberlet, P.** 2001. Multiple maternal origins and weak phylogeographic structure in domestic goats. *Proceedings of the National Academy of Science USA*, 98: 5927–5932.
- Mburu, D.N., Ochieng, J.W., Kuria, S.G., Jianlin, H. & Kaufmann, B.** 2003. Genetic diversity and relationships of indigenous Kenyan camel (*Camelus dromedarius*) populations: implications for their classification. *Animal Genetics*, 34(1): 26–32.
- McPherron, A.C. & Lee, S.J.** 1997. Double muscling in cattle due to mutations in the myostatin gene. *Proceedings of the National Academy of Science USA*, 94: 12457–12461.
- Negrini, R., Milanesi, E., Bozzi, R., Pellicchia, M. & Ajmone-Marsan, P.** 2006. Tuscany autochthonous cattle breeds: an original genetic resource investigated by AFLP markers. *Journal of Animal Breeding and Genetics*, 123: 10–16.
- Nei, M.** 1972. Genetic distance between populations. *The American Naturalist*, 106: 283–292.
- Nei, M.** 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. *Genetics*, 89: 583–590.
- Nei, M. & Roychoudhury, A.K.** 1974. Sampling variances of heterozygosity and genetic distance. *Genetics*, 76: 379–390.
- Nei, M., Tajima, F. & Tateno, Y.** 1983. Accuracy of estimated phylogenetic trees from molecular data. II. Gene frequency data. *Journal of Molecular Evolution*, 19: 153–170.
- Nielsen, R. & Signorovitch, J.** 2003. Correcting for ascertainment biases when analyzing SNP data: applications to the estimation of linkage disequilibrium. *Theoretical Population Biology*, 63: 245–55.

- Nijman, I.J., Otsen, M., Verkaar, E.L., de Ruijter, C. & Hanekamp, E.** 2003. Hybridization of banteng (*Bos javanicus*) and zebu (*Bos indicus*) revealed by mitochondrial DNA, satellite DNA, AFLP and microsatellites. *Heredity*, 90: 10–16.
- Pariset, L., Cappuccio, I., Joost, S., D'Andrea, M.S., Marletta, D., Ajmone Marsan, P., Valentini A. & ECONOGENE Consortium** 2006. Characterization of single nucleotide polymorphisms in sheep and their variation as an evidence of selection. *Animal Genetics*, 37: 290–292.
- Pritchard, J.K., Stephens, M. & Donnelly, P.** 2000. Inference of population structure using multilocus genotype data. *Genetics*, 155: 945–959.
- Rabie, T.S., Crooijmans, R.P., Bovenhuis, H., Vereijken, A.L., Veenendaal, T., van der Poel, J.J., Van Arendonk, J.A., Pakdel, A. & Groenen, M.A.** 2005. Genetic mapping of quantitative trait loci affecting susceptibility in chicken to develop pulmonary hypertension syndrome. *Animal Genetics*, 36: 468–476.
- Saitou, N. & Nei, M.** 1987. The neighbor-joining method: a new method for reconstructing phylogenetic trees. *Molecular Biology and Evolution*, 4: 406–425.
- Sachidanandam, R., Weissman, D., Schmidt, S.C., Kakol, J.M., Stein, L.D., Marth, G., Sherry, S., Mullikin, J.C., Mortimore, B.J., Willey, D.L., Hunt, S.E., Cole, C.G., Coggill, P.C., Rice, C.M., Ning, Z., Rogers, J., Bentley, D.R., Kwok, P.Y., Mardis, E.R., Yeh, R.T., Schultz, B., Cook, L., Davenport, R., Dante, M., Fulton, L., Hillier, L., Waterston, R.H., McPherson, J.D., Gilman, B., Schaffner, S., Van Etten, W.J., Reich, D., Higgins, J., Daly, M.J., Blumenstiel, B., Baldwin, J., Stange-Thomann, N., Zody, M.C., Linton, L., Lander, E.S. & Altshuler, D.; International SNP Map Working Group.** 2001. A map of human genome sequence variation containing 1.42 million single nucleotide polymorphisms. *Nature*, 409: 928–933.
- SanCristobal, M., Chevalet, C., Haley, C.S., Joosten, R., Rattink, A.P., Harlizius, B., Groenen, M.A., Amigues, Y., Boscher, M.Y., Russell, G., Law, A., Davoli, R., Russo, V., Desautes, C., Alderson, L., Fimland, E., Bagga, M., Delgado, J.V., Vega-Pla, J.L., Martinez, A.M., Ramos, M., Glodek, P., Meyer, J.N., Gandini, G.C., Matassino, D., Plastow, G.S., Siggens, K.W., Laval, G., Archibald, A.L., Milan, D., Hammond, K. & Cardellino, R.** 2006a. Genetic diversity within and between European pig breeds using microsatellite markers. *Animal Genetics*, 37: 189–198.
- SanCristobal, M., Chevalet, C., Peleman, J., Heuven, H., Brugmans, B., van Schriek, M., Joosten, R., Rattink, A.P., Harlizius, B., Groenen, M.A., Amigues, Y., Boscher, M.Y., Russell, G., Law, A., Davoli, R., Russo, V., Desautes, C., Alderson, L., Fimland, E., Bagga, M., Delgado, J.V., Vega-Pla, J.L., Martinez, A.M., Ramos, M., Glodek, P., Meyer, J.N., Gandini, G., Matassino, D., Siggens, K., Laval, G., Archibald, A., Milan, D., Hammond, K., Cardellino, R., Haley, C. & Plastow, G.** 2006b. Genetic diversity in European pigs utilizing amplified fragment length polymorphism markers. *Animal Genetics*, 37: 232–238.
- Sauer, S., Lange, B.M.H., Gobom, J., Nyarsik, L., Seitz, H. & Lehrach, H.** 2005. Miniaturization in functional genomics and proteomics. *Nature Reviews Genetics*, 6: 465–476.
- Sodhi, M., Mukesh, M., Mishra, B.P., Mitkari, K.R., Prakash, B. & Ahlawat, S.P.** 2005. Evaluation of genetic differentiation in *Bos indicus* cattle breeds from Marathwada region of India using microsatellite polymorphism. *Animal Biotechnology*, 16: 127–137.
- Storz, G., Altuvia, S. & Wassarman, K.M.** 2005. An abundance of RNA regulators. *Annual Review of Biochemistry*, 74: 199–217.
- Sunnucks, P.** 2001. Efficient genetic markers for population biology. *Tree*, 15: 199–203.
- Syvänen, A.C.** 2001. Accessing genetic variation genotyping single nucleotide polymorphisms. *Nature Reviews Genetics*, 2: 930–941.
- Takezaki, N. & Nei, M.** 1996. Genetic distances and reconstruction of phylogenetic trees from microsatellite DNA. *Genetics*, 144: 389–399.
- Tapio, M., Tapio, I., Grislis, Z., Holm, L.E., Jeppsson, S., Kantanen, J., Miceikiene, I., Olsaker, I., Viinalass, H. & Eythorsdottir, E.** 2005. Native breeds demonstrate high contributions to the molecular variation in northern European sheep. *Molecular Ecology*, 14: 3951–3963.

- Tilquin, P., Barrow, P.A., Marly, J., Pitel, F., Plisson-Petit, F., Velge, P., Vignal, A., Baret, P.V., Bumstead, N. & Beaumont, C. 2005. A genome scan for quantitative trait loci affecting the Salmonella carrier-state in the chicken. *Genetics Selection Evolution*, 37: 539–61.
- Troy, C.S., MacHugh, D., Bailey, J.F., Magee, D.A., Loftus, R.T., Cunningham, P., Chamberlain, A.T., Sykes, B.C. & Bradley D.G. 2001. Genetic evidence for Near-Eastern origins of European cattle. *Nature*, 410: 1088–1091.
- Velculescu, V.E., Vogelstein, B. & Kinzler, K.W. 2000. Analyzing uncharted transcriptomes with SAGE. *Trends in Genetics*, 16: 423–425.
- Velculescu, V.E., Zhang, L., Vogelstein, B. & Kinzler, K.W. 1995. Serial analysis of gene expression. *Science*, 270: 484–487.
- Vos, P., Hogers, R., Bleeker, M., Reijans, M., van de Lee, T., Hornes, M., Frijters, A., Pot, J., Peleman, J. & Kuiper, M. 1995. AFLP: a new technique for DNA fingerprinting. *Nucleic Acids Research*, 23: 4407–1444.
- Weir, B.S. & Basten, C.J. 1990. Sampling strategies for distances between DNA sequences. *Biometrics*, 46: 551–582.
- Weir, B.S. & Cockerham, C.C. 1984. Estimating F-statistics for the analysis of population structure. *Evolution*, 38: 1358–1370.
- Wienholds, E. & Plasterk, R.H. 2005. MicroRNA function in animal development. *FEBS Letters*, 579: 5911–5922.
- Wong, G.K., Liu, B., Wang, J., Zhang, Y., Yang, X., Zhang, Z., Meng, Q., Zhou, J., Li, D., Zhang, J., Ni, P., Li, S., Ran, L., Li, H., Zhang, J., Li, R., Li, S., Zheng, H., Lin, W., Li, G., Wang, X., Zhao, W., Li, J., Ye, C., Dai, M., Ruan, J., Zhou, Y., Li, Y., He, X., Zhang, Y., Wang, J., Huang, X., Tong, W., Chen, J., Ye, J., Chen, C., Wei, N., Li, G., Dong, L., Lan, F., Sun, Y., Zhang, Z., Yang, Z., Yu, Y., Huang, Y., He, D., Xi, Y., Wei, D., Qi, Q., Li, W., Shi, J., Wang, M., Xie, F., Wang, J., Zhang, X., Wang, P., Zhao, Y., Li, N., Yang, N., Dong, W., Hu, S., Zeng, C., Zheng, W., Hao, B., Hillier, L.W., Yang, S.P., Warren, W.C., Wilson, R.K., Brandstrom, M., Ellegren, H., Crooijmans, R.P., van der Poel, J.J., Bovenhuis, H., Groenen, M.A., Ovcharenko, I., Gordon, L., Stubbs, L., Lucas, S., Glavina, T., Aerts, A., Kaiser, P., Rothwell, L., Young, J.R., Rogers, S., Walker, B.A., van Hateren, A., Kaufman, J., Bumstead, N., Lamont, S.J., Zhou, H., Hocking, P.M., Morrice, D., de Koning, D.J., Law, A., Bartley, N., Burt, D.W., Hunt, H., Cheng, H.H., Gunnarsson, U., Wahlberg, P., Andersson, L., Kindlund, E., Tammi, M.T., Andersson, B., Webber, C., Ponting, C.P., Overton, I.M., Boardman, P.E., Tang, H., Hubbard, S.J., Wilson, S.A., Yu, J., Wang, J., Yang, H.; International Chicken Polymorphism Map Consortium. 2004. A genetic variation map for chicken with 2.8 million single-nucleotide polymorphisms. *Nature*, 432: 717–722.
- Zhu, H., Bilgin, M. & Snyder, M. 2003. Proteomics. *Annual Review of Biochemistry*, 72: 783–812.

SECTION D: GENETIC IMPROVEMENT METHODS TO SUPPORT SUSTAINABLE UTILIZATION

1 Introduction

This section gives an overview of genetic improvement methods for sustainable use of AnGR. The first chapter describes the contexts for genetic improvement. As social and economic contexts are discussed extensively in other parts of the Report, they are only briefly described here. The scientific and technology-related context is described in greater detail. The second chapter discusses breeding strategies for genetic improvement, along with the elements of a straight-breeding programme. These elements involve planning, implementation and evaluation, and constitute a continuous and interactive process. Breeding programmes for the main livestock species in high-input systems are then reviewed. This includes a description not only of the breeding goals and the traits making up the selection criteria, but also the organization and the evolution of the breeding sector. This is followed by a description of breeding strategies for low-input systems, and those utilized in the context of breed conservation. This distinction is somewhat artificial as the situations and strategies sometimes overlap. Finally, some general conclusions are drawn.

2 The context for genetic improvement

Genetic improvement implies change. For a change to be an improvement, the overall effects of the change must bring positive benefits to the owners of the animals in question or to the owners' community. Moreover, to be an improvement, the effects of the change should bring positive benefits in both the short and the long term, or at minimum a short-term benefit should not result in long-term harm. As such, it is vital that the planning of genetic-improvement programmes takes careful account of the social, economic and environmental context in which they will operate. This can best be achieved by making these programmes an integral part of national livestock development plans, which should establish broad development objectives for each production environment.

2.1 Changing demand

Traditionally, livestock breeding has been of interest only to a small number of professionals: breeding company employees, farmers, and some animal scientists. However, food production is changing from being producer driven to consumer driven. Consumer confidence in the livestock industry has broken down in many countries (Lamb, 2001). Fears about the quality and safety, of animal products have been heightened in recent years by various crises: bovine spongiform encephalopathy (BSE), dioxin, and more recently, highly pathogenic avian influenza (HPAI). Welfare has also become an important element in consumers' perception of product quality especially in Europe (organic products and free-range animals). At the same time, the majority of consumers have become less connected to the countryside, and know less about farming. There is a growing demand for "natural" production, but often without a clear understanding of what this should encompass.

2.2 Diverse production environments

Sustainable production systems need to be tailored to account for physical, social and market conditions. For breeding organizations this raises the question of whether they should diversify their breeding objectives, or whether they should breed an animal that can do well under a wide range of environments (physical environment, management system and market conditions). To date, however, only limited insights into the underlying genetics of phenotypic adaptation to the environment have been achieved.

2.3 Increasing recognition of the importance of genetic diversity

Livestock breeding requires variability within and between populations if it is to improve the traits of interest. Genetic diversity is important to meet present requirements, but is especially important to meet future requirements. For example, a change of emphasis from high-input to low-input production systems will favour different breeds and different characteristics within breeds. More generally, the increasing importance given to factors such as animal welfare, environmental protection, distinctive product quality, human health and climate change, will require a wider range of criteria to be included in breeding programmes. These criteria are often met by local breeds. Thus, it is possible that the most appropriate strategies for managing these breeds may involve only limited genetic change. For example, it may be wise to maintain adaptation to the local environment and disease challenges – and even to maintain the level of a production trait, such as body size or milk production, if this is currently at or near an optimum level.

2.4 Scientific and technological advances

Developments in genetic improvement methods

Quantitative genetics

A breeding scheme aims to achieve genetic improvement in the breeding goal through the selection of the animals that will produce the next generation. The breeding goal reflects the traits that the breeder aims to improve through selection. The rate of genetic improvement (ΔG) with respect to the breeding goal (and the underlying traits) depends on the amount of genetic variability in the population, the accuracy of the selection criteria, the intensity of selection, and the generation interval.

Maintenance of genetic variation is a condition for continuous genetic improvement. Genetic variation is lost by genetic drift and gained by mutation. Therefore, the minimum population size to maintain genetic variation is a function of the mutation rate (Hill, 2000). Selection experiments in laboratory animals have shown that substantial progress can be maintained for many generations, even in populations with an effective size well under 100, but that responses increase with population size (*ibid.*).

The loss of genetic variation within a breed is related to the rate of inbreeding (ΔF). In the absence of selection, ΔF is related directly to the number of sires and dams. In populations undergoing selection, this assumption is no longer valid because parents contribute unequally to the next generation. A general theory to predict rates of inbreeding in populations undergoing selection has recently been developed (Woolliams *et al.*, 1999; Woolliams and Bijma, 2000). This approach facilitates a deterministic optimization of short and long-term response in breeding schemes.

Research on the optimization of breeding schemes initially focused on genetic gain, while little attention was paid to inbreeding. It is now well accepted that constraining inbreeding is an important element of breeding schemes. Meuwissen (1997) developed a dynamic selection tool which maximizes genetic gain while restricting the rate of inbreeding. From a given set of selection candidates, the method allows the selection of a group of parents in which the genetic merit is maximized while the average coefficient of co-ancestry is constrained. Implementation of this method results in a dynamic breeding programme, in which the number of parents and the number of offspring per parent may vary, depending on the candidates available in a particular generation.

The accuracy of selection depends largely on the quality and the quantity of the performance records that are available. Genetic improvement can only be made if performance and pedigree are recorded. Based on these observations, the genetic merit of an individual is predicted and the animals with the highest predicted merit can be selected as parents.

It is well established that the method of choice for the genetic evaluation of linear traits (e.g. milk and egg production, body size and feed efficiency) is best linear unbiased prediction based on an animal model (BLUP-AM) (Simianer, 1994). The development of algorithms and software has meant that by today, in most countries and for most species, BLUP-AM is routinely used by breeding companies or

in national-level breeding programmes. The limitations associated with applying simplistic single-trait models has led to the development of multiple-trait BLUP-AM evaluations based on sophisticated models (including, for example, maternal effects, herd \times sire interactions or dominance genetic effects). This has been greatly facilitated by the increasing power of computers, and major advances in computational methods. The tendency now is to use all available information, including single test day records, records from cross-bred animals, and a wide geographical range (across countries). Significant difficulties associated with the use of increasingly complex models are a lack of robustness (especially when population size is limited) and computational problems. The challenge today is to develop tools to systematically validate the models used.

BLUP is optimum only when the true genetic parameters are known. Methods for unbiased estimation of (heterogeneous) variance components with large data sets have been developed. Restricted Maximum Likelihood (REML) applied to animal models is the method of preference. Quite a few important traits are not correctly described by linear models (e.g. traits based on scoring and survival). A wide variety of nonlinear mixed models have, therefore, been proposed: threshold models, survival models, models based on ranks, Poisson models etc. However, the benefits of using these nonlinear models remain to be proven.

The selection intensity reflects the proportion of animals that are needed as parents for the next generation. Reproductive capacity and techniques have an important influence on the number of parents that are needed for the production of the next generation, and thereby on the rate of genetic improvement. In poultry, high reproductive capacity means that about 2 and 10 percent of the male and female candidates, respectively, are retained as parents. In cattle, the introduction of AI has resulted in an enormous reduction in the number of sires. In dairy and beef cattle, the bulls used for AI and the cows with high genetic merit are the nucleus animals, and form less than 1 percent of the entire population.

The generation interval is the average time between two generations. In most populations, a number of age classes can be distinguished. The amount of information available differs between classes. In general, there is less information about the younger age classes than about older age classes. Consequently, the accuracy of estimates of breeding value is lower in the younger generations. However, the mean level of the estimated breeding value (EBV) of young age classes is higher than that of older age classes because of continuous genetic improvement in the population. Selection across age classes to obtain the highest selection differential is recommended (James, 1972). The fraction of animals selected from each age class depends on the differences in accuracy of the EBV between the age classes (Ducrocq and Quaas, 1988; Bijma *et al.*, 2001). The use of reproductive technologies may increase the amount of sib information available, and thereby increase the accuracy of the EBV of younger age classes (van Arendonk and Bijma, 2003). This will change the proportion of parents selected from the younger age classes, and therefore also influence the average generation interval. Thus, generation interval is primarily a result of selection among the available age classes.

Molecular genetics

Molecular genetics in livestock has been subject to extensive study during the last two decades. These studies are related to gene-based selection of Mendelian traits (mainly diseases and genetic defects), marker assisted selection and introgression. Furthermore, molecular information is increasingly used to assist breed conservation programmes and to improve understanding of the origin and domestication of livestock.

Gene-based selection. Increasing knowledge of the animals' genome increases the prospects for applying this technology and provides new tools with which to select for healthy animals. Initial applications are related to Mendelian traits. In cattle for example, DNA diagnosis is routinely utilized to eliminate genetic disorders such as bovine leukocyte adhesion deficiency (BLAD), deficiency of uridine monophosphate synthase (DUMPS) and complex vertebral malformation (CVM), as well as in selection for traits such as milk kappa-casein and double muscling.

In pigs, the best-known gene which has so far been used in commercial breeding is the "halothane" gene. It was known that a number of pigs could not handle stressful situations (e.g. transportation to the slaughterhouse). A (recessive) gene – a natural mutation, called the "halothane" gene – was found

to be responsible for this defect. Using a DNA test that detects whether a pig has the “defective form” of the gene, it has been possible to eliminate this gene completely from several breeds (Fuji *et al.*, 1991).

Scrapie, the prion disease of sheep, is the most common natural form of transmissible spongiform encephalopathy (TSE), a group of diseases which also include Creutzfeldt-Jakob disease in humans and BSE in cattle. Genetic susceptibility to scrapie is strongly modulated by allelic variations at three different codons in the sheep PrP gene (Hunter, 1997). Breeding for scrapie resistance has, therefore, been considered an attractive option for the control of this disease (Dawson *et al.*, 1998; Smits *et al.*, 2000). This can be done by selecting for the allele that is associated with the greatest degree of resistance to scrapie (the ARR allele). As described in Part 1 – Section F: 4, breeding programmes to eliminate scrapie can pose a threat to rare breeds that have a low frequency of the resistant genotype.

Marker assisted selection. Most economically important traits in animal production are of a quantitative nature and are affected by a large number of genes (loci), a few of which have major effects, while the majority have small effects (Le Roy *et al.*, 1990; Andersson *et al.*, 1994). If a gene (locus) with a major effect can be identified, and if a molecular test can be designed, animals’ genotypes at the locus can be used for selection. In other cases, a chromosomal region close to the gene of interest may be identified and used as a marker.

Mixed models of inheritance, which assume one or several identified segregating loci, and an additional polygenic component, have been developed. When genotypes at each identified locus are known, they can be treated as fixed effects in standard mixed-model techniques (Kennedy *et al.*, 1992). When only genotypes at linked markers are known, the uncertainty resulting from unknown haplotypes and recombination events has to be taken into account (Fernando and Grossman, 1989).

Extra genetic gain is usually to be expected if information on genes with medium to large effects is included in the genetic evaluation process. Numerous studies have investigated this problem in recent years. Results are not always comparable, because selection criteria differed between studies (i.e. from an index based on individual information to animal models), but they all indicate that knowledge of genotypes at quantitative trait loci generally improves short-term response to selection (Larzul *et al.*, 1997). Conversely, some discrepancies have been obtained for long-term response to selection – see Larzul *et al.* (1997). In less favourable situations where only genotypes at linked markers are known, results largely depend on the particular circumstances. Large gains can be expected when linkage disequilibrium exists at the population level (Lande and Thompson, 1990), and when traits are difficult to measure (e.g. disease resistance), sex limited (e.g. traits related to egg or milk production), expressed late in the lifespan of the animals (e.g. longevity and persistency in litter size), or measured after slaughtering (e.g. meat quality traits). In other cases, the advantage of marker assisted selection may be questionable.

Genes at the same or at different loci interact with each other in producing a phenotypic effect. It is seldom known how this occurs. When, by using statistical models, an apparent effect is assigned to a particular gene, such interaction is not taken into account. This explains, at least partly, why even when genes with major effects are identified, incorporating them (or their markers) into a selection programme may not achieve the desired results. Because of such interactions, there is often an apparent lack of consistency between different studies related to the use of genetic markers (Rocha *et al.*, 1998). To correctly assess the effect of a gene, the average effect over the possible genotypes in the population where the information is to be applied (weighted according to their frequencies) has to be considered.

Introgression is advocated mainly to improve disease resistance in a given population. If markers for the resistance gene(s) (or probe for the gene) are available, marker assisted selection may be used to simplify the process of introgression. Dekkers and Hospital (2002) discuss the use of repeated backcrosses to introgress a gene into a population. If the non-resistant breed is considered the recipient breed, and the breed that carries the resistance gene is considered the donor breed, introgression of the desirable gene from the donor breed to the recipient breed is accomplished by multiple backcrosses to the recipient breed, followed by one or more generations of intercrossing. The aim of the backcross generations is to generate individuals that carry one copy of the donor gene, but that are similar to the

recipient breed for the rest of the genome. The aim of the intercrossing phase is to fix the donor gene. Marker information can enhance the effectiveness of the backcrossing phase of gene introgression strategies by identifying carriers of the target gene (foreground selection), and by enhancing recovery of the recipient genetic background (background selection). Generally, it is more feasible and economically sound to mate, in successive generations, pure-bred females of the recipient breed to cross-bred males that carry the desired gene, than to carry out the reverse process.

If the gene for resistance is dominant, its introgression into a population may be effective even without a molecular marker for the gene. If the gene for resistance is recessive (or co-dominant), markers are necessary. In cases where resistance is polygenic, introgression without genetic markers is not likely to be effective; by the time the genetic influence of the donor breed is high enough to give high levels of resistance, the desired characteristics of the recipient breed will probably have been lost. In fact, the development of a composite breed would be easier than the introgression of numerous genes into a recipient breed by backcrossing, even when genetic markers are available. Hanotte *et al.* (2003) mapped QTLs affecting trypanotolerance in a cross between the “tolerant” N’Dama and “non-tolerant” Boran cattle breeds. Results showed that at some of the putative QTLs associated with trypanotolerance, the allele associated with tolerance came from the non-tolerant cattle. It was concluded that “selection for trypanotolerance within an F2 cross between N’Dama and Boran cattle could produce a synthetic breed with higher trypanotolerance levels than currently exist in the parental breeds.”

Conceptually, introgression through marker assisted selection could be accomplished even without exposure to the disease agent. It is, however, wise to test the resistance of animals with the desired genotype.

Molecular characterization of genetic diversity is helpful in the planning of conservation programmes and to develop understanding of the origin and domestication of livestock species. Better knowledge of genomic variation, together with the development of new quantitative genetic methods, may provide the means to link marker information to functional variation. For example, combination of molecular methods and pedigree analysis has been used to estimate the degree of genetic diversity in founder populations in thoroughbred horses (Cunningham *et al.*, 2001).

Developments in reproductive technologies

Reproductive technology has a direct effect on the rate of genetic improvement. For a given population size, a higher reproduction rate implies a lower number of breeding animals and, therefore, a higher intensity of selection. More offspring per breeding animal also allows more accurate estimation of breeding values. Another advantage of increasing reproductive rates is to disseminate superior genetic stock more quickly.

As reproductive technologies are extensively discussed elsewhere in the Report, this chapter focuses only on the use of AI and multiple ovulation and embryo transfer (MOET) in breeding programmes. For other techniques, only a brief description is provided here.

Artificial insemination The use of AI results in higher selection intensity, more accurate selection of males based on progeny testing and more accurate estimation of breeding value across herds. The latter is a result of exchange of semen between different nucleus herds, which facilitates the establishment of genetic links between them. AI is used by breeding organizations for most species. For species such as cattle that have low reproductive rates, progeny testing based on AI is a prerequisite for an accurate estimation of breeding values for traits of low heritability such as functional traits. AI allows faster dissemination of genetic superiority to the commercial population. Sixty to eighty percent of all the AI performed is carried out in cattle. A male identified as superior can leave thousands of progeny in different populations all over the world.

AI requires technical skills both at the AI centre and on the farm, as well as effective lines of communication between the two. However, in many countries, the majority of producers are smallholder farmers, and existing skills and infrastructure may be insufficient to allow the successful operation of AI services. The farmer has to be able to detect heat and have a means to contact the semen distribution centre, which then has to be able to serve within few hours. For extensive

production systems, this is a labour-intensive process. Consequently, AI is unlikely to be used in extensive grazing systems for beef production. Similarly, AI is difficult to perform in sheep, and natural mating using superior males is still the dominant means of diffusing genetic improvement.

Use of AI affects the ownership structure of the breeding sector. Where AI is used, the ownership of the breeding animals is usually transferred to larger breeding organizations, such as cooperatives or private breeding companies. For the last twenty years in the developed world, AI centres have been responsible for the identification of young bulls for progeny testing, and for the marketing of semen from proven sires.

Multiple ovulation and embryo transfer Increasing the reproductive rate of females by MOET is mainly useful in species with low reproductive rates such as cattle. The benefits are higher selection intensity on the female side, and more accurate estimation of breeding values. As family sizes are larger, there is more information available on animals' sibs. This allows reasonably reliable breeding values to be obtained at a younger age, particularly when the traits are only recorded for one sex (female). In practice, this means that there is no need to wait for a progeny test to select males – they can be selected at younger age based on information on their half-sib sisters. The gain in generation interval is large, and compensates for the loss of selection accuracy that results from replacing a progeny test by a sib test. The ability to select at a young age, even among embryos, is the main reason of the application of MOET in pig breeding. Embryo transfer is also used to disseminate desirable genes from superior female animals with minimum disease risks, as animals do not need to be transported.

The use of MOET is costly and requires highly developed technical skills. The logistical challenge is that at the time of embryo transfer, a group of recipient cows needs to be available and synchronized. This can be done only in large centralized nucleus herds. In many cases, it may be better to invest resources in more basic prerequisites – performance and trait recording, extension and dissemination. This is all the more true as MOET seems less efficient than AI in enhancing genetic progress. In all cases, the introduction of AI and/or MOET has to be cost effective and accepted by the local farmers.

Semen and embryo freezing gives breeding organizations the opportunity to create genebanks as a back-up store of genetic diversity in breeding programmes. Moreover, cryopreservation of gametes and embryos facilitates international exchange and transport of genetic material in ruminants, and is a prerequisite for routine use of AI and ET on a world scale.

Cloning (somatic cells) is a new technology which is currently not being used commercially. This is partly for technical and economic reasons, and partly because there is no public desire for such developments at present. Cloning has potential application in the field of conservation, as other tissues may be easier to preserve than embryos.

Sexing of embryos or semen enables the production of larger numbers of animals of a particular sex. For example, preferences for male or female offspring are obvious in cattle – females for milk production, and males for beef production. Numerous attempts have been made to develop a reliable technology. Currently, it is possible to identify male and female embryos by various methods. However, with a few exceptions, this technology has not yet been widely used by breeders or farmers. Various attempts have been made to separate sperm based on their sex-determining characteristics. However, further advances are required before the technology can be applied on a large scale.

The use of the above-described reproductive and conservation techniques means that there is less need for the transportation of breeding animals. Furthermore, these technologies offer an opportunity to safeguard the health status of flocks and herds even when embryos originate from countries with a radically different health status.

2.5 Economic considerations

Any economic evaluation should consider both returns and costs. As animal breeding is a long-term process, returns on breeding decisions may be realized many years later. This is the case in dairy cattle for example. Furthermore, different costs and returns are realized at different times with different probabilities, and a number of considerations that may not be important for relatively short-term processes are sometimes of major importance in the longer term.

Until the advent of reproductive biotechnologies, the main cost elements of breeding programmes were trait measurement and recording, progeny testing and maintaining the breeding stock. Although the main objective of most recording systems is breeding, it should be noted that once available, the information is useful for other farm management decisions such as culling and predicting future production.

Animal breeding in the developed world has become more and more sophisticated and professionalized, and hence costly. Economic considerations are, therefore, driving most if not all breeding-related activities, and economic theory has been incorporated into this area. The bases for economic evaluation are profit, economic efficiency, or return on investment. When breeding goals have been developed by and for (groups of) producers, emphasis is put on profit maximization. In developing countries, markets are generally more local, but the same mechanism will apply. It is, therefore, advisable to opt for profit maximization, unless there are clear reasons to deviate from this strategy.

A critical economic consideration is: who will pay for the genetic improvement? This question is not particularly important when breeding nuclei, multipliers and commercial herds/flocks are fully integrated. However, in all other situations, where vertical integration does not exist, it is not unusual that those who invested in breeding activities are unable to adequately recoup their investment. This commonly provides justification for public sector involvement in one or more facets of genetic improvement.

Under a free market system, breeding organizations have to adapt to the demands of their customers – the commercial producers, who are normally only prepared to pay for improved breeding animals or semen if this will enhance their profits. However, it is interesting to note that even if a trend in breeding does not appear to be economically justified, it may continue for an extended period of time (Box 80). Under a government subsidized system, all or part of the costs of genetic efforts are paid for by taxpayers. In this case, breeding programmes should be subject to scrutiny to ensure that they truly produce some social benefits. Such benefits could include, for example, providing safer, more nutritious or less expensive products for the consumer, or reducing the negative environmental impacts of livestock production.

3 Elements of a breeding programme

The elements required in a breeding programme depend on the choice of the general breeding strategy. Thus, the first decision is which of the three main genetic improvement strategies should be applied: selection between breeds, selection within breeds or lines, or cross-breeding (Simm, 1998).

- Selection between breeds, the most radical option, is the substitution of a genetically inferior breed by a superior one. This can be done at once (when as in poultry the cost is not prohibitive) or gradually by repeated backcrossing with the superior breed (in large animals).
- Cross-breeding, the second fastest method, capitalizes on heterosis and complementarity between breeds' characteristics. Conventional cross-breeding systems (rotational systems and terminal sire-based systems) have been widely discussed (e.g. Gregory and Cundiff, 1980). The *inter se* mating of animals of newly developed composites has been suggested as an alternative form of cross-breeding (Dickerson, 1969; 1972).

- The third method, within-breed selection, gives the slowest genetic improvement, especially if the generation interval is long. However, this improvement is permanent and cumulative, which is not the case for cross-breeding programmes.

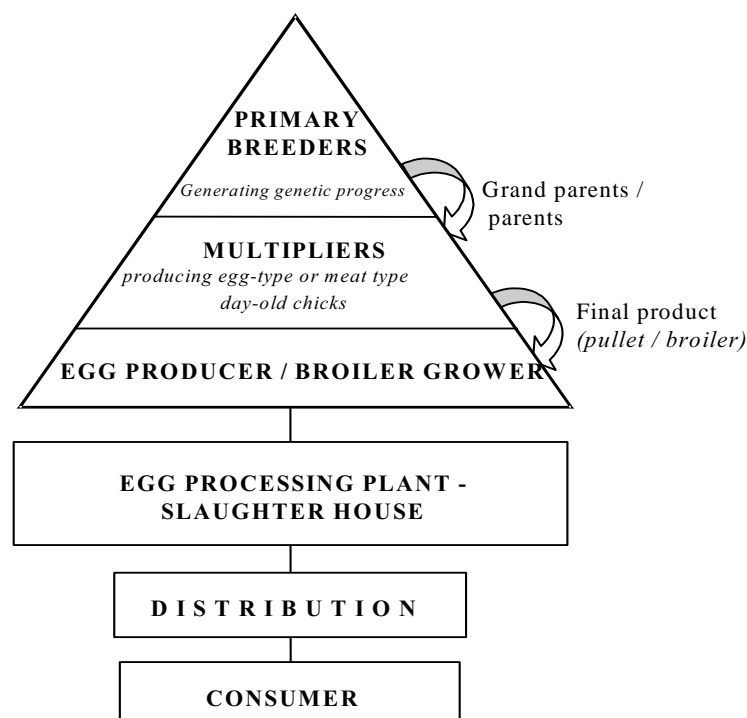
Gradual genetic improvement is the most sustainable form of improvement, as it gives the stakeholders time to adapt the production system to the intended change. When the traits of interest are numerous and/or some of them are antagonistic, different lines may be created, and maintained by within-line selection. These lines can then be crossed to produce commercial animals. This strategy is used in pig and poultry breeding.

Setting up a breeding programme involves the definition of a breeding goal (Groen, 2000) and the design of a scheme that is able to deliver genetic progress in line with this goal. In practice, it involves the management of people and resources as well as the application of the principles of genetics and animal breeding (Falconer and Mackay, 1996). Each aspect of the breeding programme involves many processes, individuals and sometimes institutions. Success depends on how well the available resources are harnessed and managed to achieve the goals of the stakeholders.

The stakeholders of a breeding programme are all those who are affected, in one way or another, by its success. These include the end users of the products of the programme (i.e. livestock producers), commercial companies and others who directly or indirectly invest in the scheme, government departments, breed societies, and those employed to implement the programme. Other stakeholders include ancillary beneficiaries such as suppliers, distributors, and sellers of by-products of the scheme.

Most programmes have a pyramidal structure (Simm, 1998), with varying number of tiers depending on the sophistication of the programme. At the apex of the pyramid is the nucleus where selection and breeding of the elite pedigree animals is concentrated. The multiplication of stock happens in the middle tiers. This is required when the number of nucleus animals is insufficient to satisfy the demands of commercial farmers. The bottom tier comprises the commercial units where the final product is disseminated. The pyramidal structure of the poultry breeding industry is illustrated in Figure 48.

Figure 48
Structure of the poultry breeding industry



The activities that constitute a breeding programme can be summarized in eight major steps (Simm, 1998):

- choice of breeding goal;
- choice of selection criteria;
- design of the breeding scheme;
- recording of the animals;
- genetic evaluation of the animals;
- selection and breeding;
- progress monitoring; and
- dissemination of genetic improvement.

These steps will be described in the following subchapters. However, the reader should be aware that planning, implementation and evaluation form a continuous process – the elements should be approached interactively rather than step-by-step. A further critical element is the need to document in detail all areas of the breeding plan and its execution over time.

3.1 Breeding goals

The breeding goal is a list of traits to be improved genetically. It should be in line with national agricultural development objectives, and appropriate for the production system for which it is defined and the breeds suited to the production system. A country's development objectives for agricultural production traditionally include economic variables, but should be extended to accommodate ethics, and other social aspects of human well-being. These objectives are used to formulate the breeding goals. Different tools are available to achieve this. The most common is the profit function. In theory, setting up a profit function is straightforward, especially in the case of within-breed selection programmes, as it is a linear function of the relative economic values of the traits to be improved. In practice, however, it is not easy to obtain these economic values, partly because they may vary in time and in space, and partly because of a lack of time, expertise, knowledge, resources etc. Thus, breeders manipulate the direction of change through trial and error based on perceived market demand and preference. Amer (2006) discusses other tools for formulating breeding goals such as the bio-economic model and the geneflow model.

Livestock improvement is measured relative to a given set of traits, generally referred to as “traits of economic importance”. In reality, the traits and their economic importance vary as widely as the breeding programmes. For many livestock species, the traits of economic importance are those that affect the productivity, longevity, health and reproductive ability of the animals.

For most of the traits, the objective is a continuous improvement, but for some traits the goal is to reach intermediate values. Pharo and Pharo (2005) term these alternatives, respectively, breeding for a “direction” and for a “destination”. An example of the latter is egg weight in laying hens. The market values eggs within a particular range of weights – for example, between 55 and 70 grams. Smaller eggs are not saleable and there is no premium for bigger ones. Given that egg size is correlated negatively to egg number, shell strength and hatchability, selecting for bigger eggs is not only a waste of selection intensity, it is also counter productive. Another example is body size. For meat animals, size at slaughter is an important determinant of value. Body size has a major effect on nutritional requirements, through its effect on maintenance requirements. It may also affect fertility. The latter (net fertility such as calf crop or lamb crop weaned) is a major determinant of biological efficiency and profitability. Since body size is associated with both costs and benefits, it is difficult to determine an optimum value, especially under grazing systems, because of the difficulty involved in adequately describing forage intake. Another consideration is that most slaughter markets discriminate against animals that fall outside a desired range of carcass (or live) weights. For example, the European market requires a minimum carcass weight, which cannot be met by some breeds (e.g. Sanga breeds

from Namibia). Even if the current body size of these cattle is optimum with regard to biological efficiency, larger cattle may be more profitable.

The choice of the breeding goal may be a one-off activity, or one that is revised from time to time. The decision is taken by the breeders, with feedback from all tiers of the breeding pyramid. In poultry and pig breeding, this decision is taken by the top management of the breeding companies (research and development managers in agreement with technical and marketing or sales managers). In cattle breeding, the decision is taken at the apex nucleus, but usually in consultation with people in all other tiers including the commercial tier, in a way that reflects the ownership pattern of the programme.

The outcome of breeding programmes, particularly in dairy and beef cattle, is realized many years after selection decisions are made. Even in poultry, where the generation interval is shorter, a genetic change implemented in the nucleus will not be noticed at the commercial level in less than three years, at the earliest. This underlines the need to anticipate future demands when defining breeding goals.

In a competitive market like the poultry breeding industry, the identification of traits of interest and the focus of selection efforts is not only highly dependent on signals from the market place (i.e. the commercial producers), but also on the performance of the products of competing programmes.

3.2 Selection criteria

The breeding goal is distinct from the selection criteria that are used to take the decision as to which animals are to become the parents of the next generation. Usually, the decision involves the construction of a “selection index”. Measurements are taken in the candidate animals and their relatives, and are weighted according to index coefficients calculated to maximize the correlation between the selection index and the breeding goal. It should be emphasized that some of the breeding goal traits may differ from those used to construct the selection index. For example, pigs are selected for the fatness of their carcass – this is a breeding goal trait. However, it cannot be observed in selection candidates, as this would mean that they would have to be slaughtered. A predictor trait, the subcutaneous fat thickness measured ultrasonically, is therefore recorded. Where it is difficult or expensive to acquire information on the relationships between animals, and the traits are sufficiently heritable, selection can be based on individual performance (mass selection). The construction of the selection index is a technical issue, and requires personnel with the necessary expertise.

There are numerous circumstances in which at the moment of selection many traits that are not relevant to breeding goal trait list are considered. This can seriously decrease the actual selection intensity and, therefore, limits the genetic improvement. Sometimes this is acceptable (e.g. a genetic defect is a valid reason for culling). In other cases such criteria are doubtful (e.g. “body volume” as an indicator of productivity) or not recommendable (e.g. frame size or “dairyness”).

Box 80**The changing body size of beef cattle in United States of America**

In 1900 the vast majority of beef cattle in the United States of America were Shorthorn, Hereford, or Angus. The cattle at the time were fairly large. Bulls of 1 100 kg and cows of 730 kg were common. Cattle were finished (fattened) primarily on grass, and there was some interest in producing cattle that would finish at a younger age and lighter weight. A trend developed for selecting for smaller-framed cattle that had greater apparent ability to fatten. Much of the selection was actually based on attempts to win in the show ring. Selection was effective, and major changes were achieved in the cattle population. After a few generations (the late 1920s and early 1930s) the cattle were probably of a more appropriate size for the production conditions under which they were kept. However, selection continued in the same direction, and by the 1950s the cattle in most highly regarded herds were much too small and predisposed to fattening to be profitable under any commercial management programme.

A major change in the United States beef industry began in the mid-1950s, with the development of large feedlots in the Great Plains states. To be profitable in these new feedlots, cattle had to be able to grow at a fairly high rate for a long feeding period (four or five months) without getting too fat. The small early fattening cattle which had previously been popular were not acceptable to the feedlot industry. Charolais and other continental European breeds became popular, and cattle of the British beef breeds were selected for increased size and growth. From the mid-1950s to the late 1960s, larger cattle were favoured as long as they were fairly compact in their conformation. However, by the late 1960s, larger cattle were favoured, even if they were taller and very different in their conformation from the popular cattle of the earlier period. Within a few years, cattle were being selected for larger frame size, even in the continental European breeds. This selection was also quite effective, and extremely large animals were produced.

In the mid to late 1980s, several of the major breeding organizations realized that the trend had gone too far, and moves were made to produce more moderate sized animals. In the last ten years, more breeders have recognized that intermediate size is preferable to extremes in any direction. However, they continue to be in the minority, and extremely large cattle have continued to be favoured in many major herds.

3.3 Design of the breeding schemes

Designing a breeding programme requires taking a range of decisions in a logical order. The designer of the programme should be aware that such a process evolves over time – from the simple to increasing levels of sophistication as organization and capacity develop. Most of the decisions involve determining how best to utilize present population structure to reliably generate the improvement and/or restructuring that is needed. Economic evaluation is an integral part of this process, and should be carried out both for the pre-implementation phase and for evaluating the change being realized when the programme is underway.

Investment decisions in the breeding programme should be assessed with respect to the three components contributing to the rate of genetic change: selection intensity, selection accuracy and generation interval. Based on these components, alternative scenarios are assessed. Theoretical knowledge of quantitative genetics is used to predict the gains to be expected from different scenarios (Falconer and Mackay, 1996). For this purpose, population genetic parameters such as heritability and phenotypic variation of the traits are needed to build up the selection index (reasonable assumptions can also be made) (Jiang *et al.*, 1999). A suitable mating plan is then outlined. It must allow sufficient records to be obtained for genetic evaluation, and sufficient elite animals to be produced for the nucleus and for multiplication in the lower levels of the breeding pyramid. Note that in performing these activities, the designer of the programme is already in the optimization phase.

When designing the breeding programme, it should not be forgotten that most aspects are directly influenced by the reproductive rate of the breeding animals. A higher reproductive rate means that fewer breeding animals are needed. More offspring per breeding animal allows more accurate estimation of breeding value.

3.4 Data recording and management

Recording of performance data and pedigrees is the main driving force for genetic improvement. Abundant and accurate measurements lead to efficient selection. In practice, however, resources are limited. The question then is: which traits should be measured and on which animals? Preferably, the traits included in the breeding objective should be measured, but this will depend on the ease and cost of measurement. The nucleus animals, at least, should be measured for performance and pedigree.

The collection of performance data on which to base selection decisions is a vital component of any breeding programme, and it should be regarded as such, rather than as a by-product of recording systems primarily designed to assist short-term management (Bichard, 2002). The task of collecting, collating and using data in genetic evaluation requires good organization and considerable resources (Wickham, 2005; Olori *et al.*, 2005). In many instances, special schemes may need to be put in place to generate and record the required data. The cost and complexity of these schemes vary depending on the type of breeding organization, the type of traits, and the method of testing.

Type of breeding organization: pig and poultry breeding companies have in-house facilities for the collection and storage of all required data, whereas other breeding organizations may rely on resources owned by more than one stakeholder. For example, this is the case in a typical dairy cattle breeding programme (see subchapter 4.1).

Type of trait: when body weight of live animals is the trait of interest, all that is needed is a weighing scale. However, to measure feed efficiency in individual animals, more sophisticated equipment may be needed to allow the recording of individual feed intake.

Performance versus progeny or sib testing: in a performance-testing scheme, the traits of interest are recorded directly in every individual. For example, body weight and growth are often recorded over a fixed period during the lifespan of beef cattle, pigs, broiler chickens or turkeys. Basically, a cohort of animals is managed together under similar conditions over a period of time during which individual performance is measured. This can be done on the farm, or at a performance test station where cattle or pigs from different herds or farms are brought together for a direct comparison under the same conditions.

Sometimes, the information of interest may not be measurable directly in the selection candidate, either because the expression of the trait is sex-limited as in the case of milk and egg production, or because the traits can only be recorded after the death of the animal (e.g. carcass composition). In these circumstances, indirect recording by progeny and/or sib testing is required. This is also useful for traits with low heritability which may require several records to accurately evaluate an individual. Progeny testing refers to a scheme in which an individual is evaluated on the basis of performance records obtained from its progeny. It is mainly associated with males (Willis, 1991), as it is easier to generate large numbers of progeny from a single male than from a single female. Typically, not all males are progeny tested, but only the males born from “elite matings”. Progeny testing is very useful to increase selection accuracy for species with low reproductive rates, and to test genotype–environment interactions.

For many ruminant species, the cost of a central progeny testing facility may be prohibitive. It is, therefore, a common practice to involve as many farmers or commercial producers as possible. The farmers are encouraged to accept semen from a group of young sires to be used on a proportion of their female animals. Because the young sires are not of proven genetic merit, farmers involved in progeny testing often require good incentives to participate (Olori *et al.*, 2005). In these circumstances, the total costs (several hundred thousand US Dollars) are often borne by the owners of the young sire under test.

In addition to performance records, genetic evaluation in a breeding programme requires pedigree information. The quality of pedigree information depends on its depth and completeness. Whether the breeding objective involves genetic improvement or the prevention of extinction resulting from a loss of genetic variation, the pedigree of all breeding animals must be recorded and maintained.

When the resources are available, a centralized database with shared access has been shown to be beneficial and cost effective (Wickham, 2005; Olori *et al.*, 2005). The provision of comprehensive management-related information from such a system often serves as a stimulus for further participation in data recording schemes. The requirement for small breeding programmes may simply be a single personal computer with adequate spreadsheet, data management and reporting software, while national-level programmes may require a specialized department utilizing modern information technology (Grogan, 2005; Olori *et al.*, 2005).

3.5 Genetic evaluation

Progress in a breeding programme requires that animals of superior genotypes for the traits of interest are identified and selected to breed the next generation. Identifying these animals requires disentangling the environmental contribution from the phenotypic observation. This is accomplished by breeding value prediction or genetic evaluation. This is a core activity in every breeding programme.

The genetic evaluation should be reliable. BLUP methodology, applied to a variety of models depending on the traits and data available, has become the standard method for nearly all species. The evaluation should also be available in time to make the best use of the investment in data collection and database management. A genetic evaluation system using BLUP relies on good data measurement and structure. If these prerequisites are in place, investment in BLUP is usually highly cost effective.

Across-herd evaluation has the advantage of allowing fair comparisons of predicted breeding values (PBVs) of animals in different herds, which leads to selection of more animals from the genetically superior herds. To do this, genetic links (usage of animals across herds and across years) are critical. In order to use the information from different herds, an adequate organizational structure is needed. This can be achieved through close collaboration between breeders, their associations, and universities or research centres. Unique identification for all animals that supply data for the breeding scheme is essential. The data analysts, with guidance and assistance from breed association personnel, assign animals to contemporary groups (groups of animals of about the same age that are raised together with the same treatment). This assignment may be critical for accurate genetic evaluation. The breeders submit data to the association, and after checking for obvious errors, the information is forwarded to the evaluation team for analysis. For ruminants, the evaluations are performed once or twice a year, but for pig and poultry meat programmes, where the selection is performed on a monthly, weekly or bi-weekly basis, evaluations are run continuously.

The results of the genetic predictions (PBV and aggregate indices) are typically printed on the animals' registration certificates. It is common to print PBVs in sale and semen catalogues. This means that the end users (farmers) have to understand and accept the EBVs that are produced, and know how to use them. There is no sense in running a genetic evaluation if the results are left untouched by the end users.

A typical genetic evaluation unit requires both qualified staff, and adequate material resources to carry out data analysis and produce suitable reports to facilitate selection decisions. Many large-scale breeding programmes have a dedicated genetic evaluation unit in-house. However, it is also easy to contract this evaluation out to an external institution. Many universities and research centres provide a genetic evaluation service for national and non-national breeding programmes. Such services can cover several different breeds or species, as the principle of genetic evaluation and the software involved will be similar in each case. Perhaps, the most popular genetic evaluation unit with international reputation is the International Bull Evaluation Service (INTERBULL). The centre, which is based at the Swedish Agricultural University in Uppsala, was set up as a permanent subcommittee of the International Committee for Animal Recording (ICAR), and provides international genetic evaluation to facilitate the comparison and selection of dairy bulls on an international scale. Another example is BREEDPLAN, a commercial beef cattle genetic evaluation service with an operational base in Australia, which has clients in many countries.

3.6 Selection and mating

Selection should predominantly be based on the selection criterion. From each sex, as few breeding animals as possible should be selected to maximize selection intensity, with the only restrictions being the number of animals required for a minimum population size, and the number needed for reproductive purposes. As reproductive rates of males are generally much higher than those of females, far fewer breeding males than females are normally selected.

Selection candidates may be of different ages, and thus unequal amounts of information may be available about them. For example, older males may have a progeny test, while for younger ones, their own performance, or that of their dam or sibs, will be the only information available. If BLUP is used, such candidates can be easily and fairly compared. Selecting more animals with accurate EBVs, and only the very best animals with less accurate EBVs, is probably the best approach.

It is widely accepted that the use of family information, as occurs in BLUP, increases the probability of co-selection of close relatives, which in turn leads to increased inbreeding. Various methods are used to reduce inbreeding while maintaining high rates of genetic gain. All these methods are based on the same principle – reducing the average relationship between the individuals selected. Computer programmes have been developed to optimize selection decisions for a given list of candidates for which pedigree information and EBVs are available. Ad hoc methods to control inbreeding include selecting a sufficient number of males, as the rate of inbreeding depends on effective population size; not overusing the males within the nucleus; restricting the number of close relatives selected, especially the number of males selected per family; limiting the number of females mated to each male; and avoiding mating between full and half sibs. These simple rules have been quite effective in maintaining a low level of inbreeding in commercial poultry and pig breeding.

Mating of selected animals may or may not be at random. In the latter case, the very best of the selected males are mated to the very best of the selected females – this is known as assortative mating. The average genetic value of the progeny born in the next generation does not change, but there will be more variance among the progeny. When multiple traits are included in the breeding objective, assortative mating may be useful – matching qualities in different parents for different traits.

Any mating strategy will require sufficient facilities. For natural mating, animals to be mated have to be put together in the same paddock, but separated from other animals of reproductive age. AI can be used, but also requires a range of resources and expertise (semen collection, freezing and/or storing, and insemination).

3.7 Progress monitoring

This involves the periodic evaluation of the programme with respect to progress towards the desired goal. If necessary, it leads to a reassessment of the goal and/or the breeding strategy. Monitoring is also important to ensure early detection of undesired effects of the selection process, such as increased susceptibility to diseases or a reduction in genetic variation.

To assess progress, phenotypic and genetic trends are usually obtained by regressing average annual phenotypic and breeding values on year of birth. In addition to this information, breeders run regular internal and external performance testing. An external testing scheme needs to cover a wide range of production environments to ensure that selected animals can perform well under a wide range of conditions. Other sources of information, and probably the most important, are field results and feedback from customers. Ultimately, the customer is the best judge of the work done.

3.8 Dissemination of genetic progress

The value of superior individuals is limited if they do not efficiently contribute to the improvement of the gene pool of the whole target population. The wide impact of genetic improvement depends on the dissemination of genetic material. Reproductive technologies, especially AI, are very important in this respect. However, their impact varies between species. In sheep and goat breeding, the exchange of genetic material largely depends on trade in live animals. In the case of cattle, AI allows bulls selected

in the nucleus to be used across the whole population. In principle, there is no problem in allowing an exceptional bull to have many progeny throughout the population. However, performing AI using semen from bulls from the same family very intensively will ultimately lead to inbreeding.

It should be possible to apply the elements described above even under basic conditions. Breeding structures do not necessarily require sophisticated systems of data recording and genetic evaluation, nor do they initially require use of reproductive technologies. The breeding structure should be determined in accordance with what is possible and what is optimum. Environmental or infrastructure restrictions, tradition, and socio-economic conditions have to be considered when planning breeding programmes.

4 Breeding programmes in high-input systems

In high-input systems, continuous genetic improvement is generated mainly by straight-breeding within a breed or line. In the case of ruminants, this is largely a result of the strong position and active work of breeding associations, and of the spectacular results obtained by this method. Cross-breeding is used to realize the benefits of hybrid vigour (heterosis) and complementarity. In poultry and pigs, breeders concentrate their efforts on within-breed or line selection, and use cross-breeding to capitalize on heterosis for fitness traits and on complementarity for other traits.

The number of livestock breeding companies in the world is relatively low, but they are of great economic significance. They increasingly operate on a global scale. As the following subchapters will illustrate, the structure, including the ownership, of breeding organizations differs greatly between species.

4.1 Dairy and beef cattle breeding

Selection criteria

In dairy cattle, the average milk, fat and protein production per cow per year has increased enormously in the past decades as a result of the widespread use of breeds such as the Holstein-Friesian and intensive within-breed selection. This increase is also a reflection of the fact that productivity has for many years been an important selection objective, with selection mainly being based on production and morphological traits.

Recent years have seen a growing concern on the part of consumers about animal welfare issues, and about the use of antibiotics in livestock production. Breeding organizations have also realized that selecting solely for product output per animal leads to a deterioration of animals' health and reproductive performance, increased metabolic stress and reduced longevity (Rauw *et al.*, 1998). As a result, emphasis on functional traits has increased, and less attention is paid to product output. Selection for functional traits is now based on direct recording of these traits rather than through type traits. Breeding values for a wide range of functional traits have been developed and applied in most countries. This enables breeding organizations and farmers to pay direct attention to these traits in their selection decisions.

Box 81

Calving problems in Belgian White Blue cattle

In beef cattle, the demand for high-quality meat has led to the use of breeds, such as the Belgian White Blue, that have extreme phenotypes. However, this breed has an extremely high rate of caesarean sections (Lips *et al.*, 2001). In the short term, this rate cannot be significantly reduced. The extreme muscularity of the Belgian White Blue is mainly caused by the myostatin gene, a single autosomal recessive gene which is located on chromosome 2. It is, therefore, questionable whether a reduction in calving difficulties can be realized while maintaining the extreme muscularity. Because of this, as well as the obvious animal welfare concerns, the future of the breed is questionable.

Breeders face difficulties in two areas – breeding (including recording) and marketing. With regard to breeding, there are problems associated with correlated responses to selection. In most cattle breeding programmes, an aggregate index is constructed that includes traits such as growth, milk yield, fertility,

conformation, number of somatic cells in the milk, calving ease and duration of productive lifespan (for more details see Table 99). In dairy cattle, the main focus has been (and is still) put on milk yield, despite the negative genetic correlations between milk yield and reproduction and health-related traits. Undesired side-effects have, therefore, been observed – including lower fertility, and greater susceptibility to mastitis, leg problems and ketosis.

In beef cattle and in sheep, selection for growth has led to higher birth weights and increasing risk of birth problems. Higher growth rates can also be expected to increase the mature size of breeding females. This may result in lower reproductive rates if larger animals are unable to meet their nutritional requirements because of limitations in the quantity or quality of the available forage. These undesired effects can be avoided, or at least reduced, by increasing the weight of functional traits within selection indices. This supposes that these traits can be directly measured. Recording of functional traits often remains an important bottleneck hindering their inclusion in breeding schemes. This is illustrated by the example of efficiency of feed utilization. Recording feed intake in a large number of animals is currently impossible – preventing efficient selection for this trait.

Box 82

Cross-breeding to address inbreeding-related problems in Holstein cattle

The Holstein breed, which is composed almost completely of American Holstein genes, has largely replaced other breeds of dairy cattle throughout much of the world. Production and conformation traits have been emphasized in the breeding of Holsteins because of moderately high heritability and ease of data collection. However, female fertility, calving ease, calf mortality, health and survival have been ignored until very recently. Problems related to functional traits, coupled with increased inbreeding on an international scale, have resulted in tremendous interest in cross-breeding among commercial dairy producers. Pure-bred sires will continue to be sought to breed almost all dairy heifers and cows for cross-breeding. Most cross-breeding systems with dairy cattle will make use of three breeds to optimize the average level of heterosis across generations.

For further information see Hansen (2006)

There are also problems related to marketing. For milk, good management practices have been in place in many countries for a long time, and product quality has a direct impact on the price paid to producers. In the case of meat, however, traceability and organization in the production chain has traditionally been poor. This limits opportunities to improve quality. In general, farmers are not rewarded for meat quality, and often only poorly rewarded for carcass quality.

Table 99
Breeding objectives in ruminants

| Objectives/product | Criteria | Further specification |
|-------------------------|--|--|
| Production traits | | |
| Milk | Quantity Contents/quality | Milk carrier production % protein, % fat, somatic cell count, milk coagulation |
| Beef | Growth rate Carcass quality Meat quality | At different ages Fat content, bone/meat ratio Tenderness, juiciness |
| Wool | Quantity Fibre quality | Length, diameter |
| Functional traits | | |
| Health and welfare | Genetic defects Mastitis incidence Udder conformation Feet and leg problems Locomotion | BLAD, MF and CVM Udder attachment, udder depth and teat traits Indicator of hoof disorders |
| Reproduction efficiency | Female fertility Male fertility Calving ease Number of live offspring | Showing heat, pregnancy rate Non-return rate Direct and maternal effects, still births |
| Feed Efficiency | Feed conversion efficiency Milk production persistency | |
| Workability | Milkability Behaviour | Milking speed |
| Longevity | Functional herd life | |

Box 83**Norwegian Red Cattle - selection for functional traits**

The Norwegian Red (NRF) is a high-producing dairy cattle breed in which fertility and health have been included in a selection index (known as the Total Merit Index) which has been in operation since the 1970s. The case of the NRF provides a practical illustration that production and functional traits can be successfully balanced in a sustainable breeding programme. This achievement has been based on an effective recording system and a willingness to place sufficient weight on the functional traits. The programme is run by GENO, a cooperative owned and managed by Norwegian dairy farmers. Currently, ten traits are included in the Total Merit Index. The following list shows the relative weight given to each:

| | |
|---------------------|------|
| Milk index | 0.24 |
| Mastitis resistance | 0.22 |
| Fertility | 0.15 |
| Udder | 0.15 |
| Beef (growth rate) | 0.09 |
| Legs | 0.06 |
| Temperament | 0.04 |
| Other diseases | 0.03 |
| Stillbirths | 0.01 |
| Calving ease | 0.01 |



Photo credit: Erling Fimland

Key features of the programme include the fact that more than 95 percent of herds participate in the recording system and are on a computerized mating plan, 90 percent of matings are carried out using AI, and there is 40 percent use of test bulls. All diagnosis and health registration is carried out by veterinarians, and databases are maintained for pedigree and AI-related information. About 120 young bulls are tested annually with progeny groups of 250 to 300 daughters – thus enabling the inclusion of traits with low heritability (such as mastitis with a heritability of 0.03 and other diseases with 0.01) while still providing a selection index with high accuracy.

Milk production per lactation in the best herds exceeds 10 000 kg, with the top cows producing more than 16 000 kg. The genetic trend is positive with respect to fertility – the average 60 day non-return rate in the population is 73.4 percent. Between 1999 and 2005 incidence of mastitis in NRF cows was reduced from 28 percent to 21 percent, and it is estimated that of this reduction 0.35 percent per year was the result of genetic improvement. Major calving difficulties are reported in less than 2 percent of calvings, and less than 3 percent of calves are stillborn.

The sustainability of the breeding programme is promoted by a number of factors:

Both production and function are expressed by many traits, and they are both strongly weighted in the breeding strategy.

Many different combinations can result in a high total breeding value. This allows for the selection of animals from different breeding lines and, thus, automatically reduces the risk of inbreeding.

The breeding work is based on data from ordinary dairy herds, which guarantees that the breeding programme produces animals that are well adapted to normal production conditions.

Provided by Erling Fimland

For further information, see: http://www.geno.no/genonett/presentasjonsdel/engelsk/default.asp?menyvalg_id=418

Organization and evolution of the breeding sector

Because of the low reproductive rate, the long generation interval and the large amount of space required to house each animal, cattle breeding has a more complex and more open organizational structure than poultry or pig breeding. Gene flow can occur both from the breeder to the producer and vice versa. Information resources are shared between players at different levels. In a typical dairy cattle breeding programme, pedigree information is often recorded, owned and managed by breed societies, while milk production records are owned by farmers, but collected and managed by milk recording organizations. Information on fertility and reproductive performance are kept by companies that provide AI services, while health information generally resides with veterinarians. Often, these organizations are in decentralized locations and may store information in different systems.

Because cattle production is a major traditional agricultural enterprise and because breeding has a major impact on this enterprise, cattle breeding programmes have more input from government agencies than do poultry or pig breeding, and therefore have a country-specific outlook. Most programmes were either initiated or sustained with support or grants from national government agencies (Wickham, 2005). Organizations such as the Animal Improvement Programs Laboratory (AIPL) of the United States Department of Agriculture (USDA), Canadian Dairy Network (CDN), Cr-Delta in the Netherlands, and l'Institut de l'Élevage (IE) in France, play major roles in cattle breeding

programmes in their respective countries, especially in data management and genetic evaluation. This is also the case for breed societies, which have played a major role in maintaining and enhancing the integrity of their respective breeds. The success of the Holstein-Friesian, which is by far the dominant sire breed in most dairy herds in the Western world, is testimony to the activities of the World Holstein-Friesian Federation (WHFF). The formation of herd books with dedicated members and the importance of show ring performance (which are strictly within-breed affairs) have helped sustain pure-breed development and the maintenance of all major breeds of dairy and beef cattle.

The selection programmes conducted by AI centres have developed from local to national schemes, and are increasingly operating internationally. The dissemination of genetic material from “superior” animals is now global. It is predicted that within the next ten to 15 years AI centres will become unified into a few worldwide breeding companies, such as now exist in the pig and poultry sectors. For example, in the early 1990s the “Genus” breeding programme was the major cattle programme in the United Kingdom. Over the years, Genus has merged with ABS genetics from the United States of America to form a global company, which now supplies bovine genetics from a variety of dairy and beef cattle breeds to over 70 countries. More recently, Genus bought Sygen, a biotech company.

Breeding programmes in cattle rely on commercial producers to generate sufficient data for genetic evaluation. Data recording, therefore, takes place in all tiers of the breeding pyramid. This requirement is greatest in the case of dairy programmes, which require large progeny groups for the accurate evaluation of bulls (especially for traits with low heritability), or in beef cattle to be able to estimate direct and maternal effects. The use of AI to disseminate semen across many herds is prevalent, and this helps to facilitate the comparison of animals raised in different environments. AI also enables higher intensity in the selection of males.

Successful selection within dairy cattle breeds is the result of well-organized programmes for the measurement of production, testing of young bulls and effective genetic evaluation. The high level of feeding in commercial dairy production allows a high proportion of a cow’s genetic potential to be expressed, which in turn allows selection to be particularly effective.

Cross-breeding studies with dairy cattle have consistently found significant levels of heterosis between dairy breeds for milk production, fertility and survival traits. However, successful long-term selection for high levels of milk production in the Holstein-Friesian has led to the widespread use of straight-bred animals of this breed. However, increasing pressure from commercial producers, who are suffering losses related to poor fertility and longevity, and the need for flexibility in product development is likely in the future to lead to increased development of hybrid cattle at the breeding programme level.

Cross-breeding applied to beef cattle is often undertaken without a well-designed programme. In beef cattle, cross-breeding programmes are difficult to implement in herds that use fewer than four bulls. Even for larger operations, managing the herds separately, as is required in organized cross-breeding programmes, can be difficult (Gregory *et al.*, 1999).

In cattle, the introduction of AI has resulted in an enormous reduction of the number of sires and contributed to the exchange of genetic material between regions and countries. Through AI, bulls selected in the nucleus are used in the general population. As a result of the high reproductive rate of sires, the selection of bulls contributes 70 percent to total genetic change in dairy and beef cattle populations.

4.2 Sheep and goat breeding

Selection criteria

Sheep and goats are kept for meat, milk, and wool or fibre (see Table 99 for corresponding breeding goals). Sheep milk is an important product in Mediterranean countries. It is mainly transformed into a variety of cheeses (e.g. Roquefort, Fiore Sardo, Pecorino Romano and Feta). Milk production and quality are important breeding criteria. Milk sheep may also be bred for growth rate, reproductive traits such as twinning rate, and type traits such as udder shape (Mavrogenis, 2000). Conversely, in northwestern Europe, meat is the most significant product obtained from sheep. Specific breeding objectives will depend on the production environment (e.g. mountain vs. lowland), and may include growth rates, carcass quality, reproductive performance and maternal abilities. Commercial wool production is dominated by Australia and New Zealand with their specialized flocks of straight-bred fine-wool sheep of the Merino type. Although the animals all descend from the Merino sheep of Spain, different strains have been developed over the years. The need for animals adapted to specific environmental conditions has shaped breed development. In Australia, for example, different strains of Merino have been bred for their adaptation to the environment in different parts of the country. With respect to wool production, criteria for selection normally include clean fleece weight and fibre diameter. Increasing economic importance of meat relative to wool has led to a shifting of breeding objectives towards criteria such as reproduction rate and sale weight.

In Mediterranean countries, in South Asia, and in parts of Latin America and Africa, goats are mainly kept for their milk. In Mediterranean countries and in Latin America, goat milk is often used for cheese production, whereas in Africa and South Asia, it is consumed raw or acidified. In other parts of Asia and Africa, goats are kept mainly for meat production. In these regions very little supplemental feeding is provided, and browse provides a significant amount of the nutritional requirements. The animals are of moderate to small size, and of moderate to light muscling. An exception is the development of the Boer goat for meat production in South Africa. The breed has been introduced to other countries in Africa and to other parts of the world such as Australia.

Organization of the breeding sector

Major breeding programmes for fine-wool sheep are based in the southern hemisphere (Australia and New Zealand). These programmes are based on straight-breeding. However, in fine-wool sheep operations where a significant part of the income is from lambs (for slaughter), self-contained F1 production has been used. Under this type of programme, all ewes are straight-bred for fine wool. A large fraction of the selected ewes are mated to fine-wool rams to produce replacement females. The remaining ewes are mated to terminal sires and all the lambs are sold.

In the case of meat sheep breeding, the average size of flocks is generally too small to allow intensive within-flock selection. This problem has been overcome through cooperative breeding schemes. Nucleus breeding schemes are well established (e.g. James, 1977), but sire-referencing schemes (SRS) have recently gained popularity. In SRS, genetic links are created between flocks by mutual use of specific rams (reference sires). These connections allow comparable across-flock genetic evaluation, offering a larger pool of candidates for selection for collective goals. About two-thirds of performance-recorded sheep in the United Kingdom, including all of the major specialized meat breeds, now belong to these schemes (Lewis and Simm, 2002).

Cross-breeding is the basis of the stratified sheep industry of the United Kingdom (Simm, 1998). The system functions on the basis of a loose structure involving several breed societies, government agencies and other institutions. Traditional hill breeds such as the Scottish Blackface are straight-bred under the harsh production conditions of the hills. Ewes from these pure breeds are sold to farmers in “upland” areas (where the climate is less harsh and there is better grazing). Here, they are crossed with rams from intermediate crossing breeds such as the Blueface Leicester. F1 Females are sold for breeding in lowland flocks where they are mated to terminal-sire breeds such as the Suffolk and the Texel. Most data recording and genetic evaluation aim at improving the terminal-sire breeds to produce rams of

superior genetic quality. Data recording and genetic evaluations are carried out by commercial operations such as Signet or by research institutions supported by public funds.

Most dairy goats are in developing countries. However, breeding programmes are concentrated mainly in Europe and North America. The French selection programme, based on AI with frozen semen and oestrus synchronization (60 000 goats inseminated/year), and the Norwegian programme, based on rotation of sires in several herds (buck circles), are examples of organized progeny testing programmes. They include a formal definition of selection objectives and organized mating to produce young sires and their progeny. Probably, the best example of a structured meat goat breeding programme is that run by the Boer Goat Breeders' Association of Australia. Cashmere and mohair production is based on straight-breeding of the respective breeds. There is almost no cross-breeding involving Angoras.

4.3 Pig and poultry breeding

Selection criteria in pigs

As in the case of ruminants, pig breeding programmes have been very successful in achieving genetic improvement of economically important traits, especially daily gain, backfat thickness, feed efficiency and, during the last decade, litter size (for more details see Table 100). At present, the goal is to breed for more robust and efficient animals to meet different environmental conditions. This implies finding an adequate strategy to deal with genotype \times environment interaction, and the placing of more emphasis on secondary traits which have up to the present been of negligible economic importance. Secondary traits include piglet survival, interval between weaning and first oestrus, longevity of sows, conformation (especially legs), vitality of pigs until slaughter weight, meat colour and drip loss. The health of the pigs is becoming more important. This means not only improving the sanitary status in breeding farms, but also selecting for general disease resistance under commercial conditions.

Table 100
Breeding objectives in pigs

| Objectives | Criteria | Further specification |
|--------------------|----------------------------|--|
| Production traits | | |
| | Growth rate | At different ages |
| | Carcass weight | |
| | Carcass quality | Uniformity, leanness of carcass |
| | Meat quality | Water holding capacity, colour, flavour |
| Functional traits | | |
| Health and welfare | | |
| | General resistance | Robustness |
| | Vital piglets | Maternal ability, Teat number |
| | Survival of pigs | |
| | Stress | Elimination of stress (halothane) gene in dam lines, and where possible, in male lines |
| | Congenital effects | Example: Atresia Ani, Cryptorchism, Splay leg, Hermaphrodism and Hernia |
| | Leg problems | Leg weakness and lameness. |
| Efficiency | | |
| | Litter size | Number of slaughter pigs per sow per year |
| | Feed conversion efficiency | |
| Longevity | | |
| | Functional herd life | Lifetime production with minimal health problems |

As in the case of ruminants, there are some difficulties involved in implementing efficient selection for “functional” traits. There are still no appropriate tools to select for better resistance to diseases or to reduce metabolic disorders. Sufficient knowledge of the genetic aspects of welfare is lacking. Stress recording methods need to be improved – for example, through the use of non-invasive methods for measuring stress-indicating parameters, determination of catecholamine levels, and heart-rate recording on under-skin chips. Improved knowledge of the cognitive abilities and coping strategies of pigs might enable individual characteristics to become indicative of ability to adapt to various housing conditions and social challenges, and could be included in selection criteria. Additionally, there is a need for further assessment of the impact of selection for specific disease resistance and welfare objectives.

Selection criteria in poultry

Laying hens have been selected mainly for productivity. Over several decades, breeding programmes were refined, and more and more traits were included in the selection objectives. Today, the main selection objectives are: the number of saleable eggs per hen housed per year, efficiency of converting feed into eggs, external and internal egg quality, and adaptability to different environments (for more details see Table 101).

Table 101
Breeding objectives in poultry

| Objectives/product | Criteria | Further specification |
|--------------------|--|---|
| Production traits | | |
| Egg | Egg number External egg quality Internal egg quality | Number of saleable eggs per hen Average egg weight, shell strength and colour Egg composition (yolk/albumen ratio), firmness of albumen and freedom from inclusions (blood and meat spots). |
| Meat | Growth rate Carcass quality | Weight gain; age at market weight “Yield” in terms of valuable parts, especially breast meat; select against breast blisters and other defects to reduce condemnation rate |
| Functional traits | | |
| Health and welfare | Disease resistance Monofactorial genetic defects Leg problems in broilers and turkeys Osteoporosis in laying hens Heart and lung insufficiency Cannibalism, feather pecking | Not routinely used Incidence of “sudden death syndrome” and ascites in broilers and “round heart” in turkeys |
| Feed efficiency | Feed consumption per – kg egg mass in laying hens, – kg weight gain in broilers and turkeys Residual feed consumption | |
| Longevity | Length of productive life | |

For poultry meat, substantial genetic improvements in terms of market weight at a younger age and correlated feed efficiency have been achieved by simple mass selection for juvenile growth rate and “conformation”. During the 1970s, direct selection for efficient feed conversion was introduced. During the last two decades, the emphasis of selection has shifted increasingly to traits that are of primary importance to processing plants – breast meat yield, total carcass value, efficiency of lean meat production, uniformity of product, and low mortality and condemnation rates. The development of specialized male and female lines, and the introduction of controlled feeding of parents, are effective tools to overcome the negative correlation between juvenile growth rate and reproductive traits.

The most obvious challenges for the poultry industry are related to diseases. Primary breeding companies have eliminated egg-transmitted disease agents such as leucosis virus, mycoplasmas and salmonella from their elite stock, and continue to monitor freedom from these problems. Other diseases such as Marek’s disease, *E. coli*, *Campylobacter coli*, and highly pathogenic avian influenza are more difficult to control.

In the field of animal welfare, the main challenges for breeders are to adapt laying hens to alternative management systems – for example, to reduce feather pecking and cannibalism in non-cage systems (pecking and cannibalism are also serious problems for turkeys and waterfowl), and to reduce the incidence of cardio-vascular insufficiencies (sudden death syndrome and ascites) and leg problems in broilers and turkeys. However, the causes of these problems are probably multifactorial, and further research is required.

Organization and evolution of pig and poultry breeding sectors

The modern poultry industry has a typical hierarchical structure with several distinct tiers. Breeding companies, based mainly in Europe and North America with subsidiaries in major production regions, own the pure lines. They have to keep the whole production chain in mind – hatcheries, egg and meat poultry growers, processing plants, retailers and consumers. Hatcheries (multipliers) are located near population centres around the world. They receive either parents or grandparents from the breeders as day-old chicks, and produce the final crosses for egg producers and broiler, turkey or duck growers. Today, egg processing plants, slaughterhouses and feed suppliers have developed contractual relationships with egg producers and poultry growers, which provide the latter with better financial security, but at the cost of reduced initiative and freedom.

The pig sector has a similar pyramidal structure, which is largely the result of the introduction of cross-breeding, AI and specialized breeding farms. However, some differences exist between the pig and the poultry sectors. For example, a pig producer will typically obtain the “commercial” animals by mating sows from a specialized dam line and boars from a specialized sire line – both genders being bought from the breeding company (and not from a multiplier as in poultry).

In contrast to poultry, there are still breeding associations for pigs, and national genetic evaluation is performed. While genetic evaluations for the large breeding companies may be performed in-house, genetic evaluations at the pure-breed level are conducted by governmental institutions (e.g. by the National Swine Registry in the United States of America) or breed associations.

Pig and poultry breeding schemes are sometimes referred to as “commercial” breeding programmes because of the corporate ownership structure of these companies. Over the years, these programmes have amalgamated to become large corporations. In poultry, for example, only two to three groups of primary breeders account for about 90 percent of the layers, broilers and turkeys produced annually. Furthermore, some of these companies are owned by the same group. The pig breeding industry has more breeding companies and fewer large ones (such as PIC and Monsanto), but is following the same trend. The recent entry of the giant Monsanto into this sector is a clear indication of this tendency. Because of the competitive nature of the business and the high level of investment, “commercial” breeding companies are usually at the forefront in the application of technologies. These leading companies are on the verge of incorporating genomic information in their breeding programmes, at a time when many breeders are merely discussing the feasibility of the approach.

The activities of these commercial breeding companies are characterized by the following features:

- Pedigree selection occurs in the nucleus only.
- Selection is strictly within specialized lines (or breeds). These lines are designated as sire and dam lines and are selected with different intensities. In poultry bred for meat and in pigs, male lines are selected for growth and lean meat production, while female lines are selected for reproduction. New lines are constantly developed either by crossing between existing lines or by further selection in a given direction.
- The final product is a cross between two or more pure-bred lines.

For economic reasons, each breeding company will sell under several trademarks (accumulated through acquisitions and fusions), but will in fact only have a limited number of differentiated products. Indeed, pig or poultry breeding companies develop lines to meet few (two or three) breeding goals, which vary depending on the extent of their global market share and the degree of variation in the production environments in which the clients operate. For example, a breeder may develop a high-yielding, fast-growing line for use under high-input conditions where superior-quality feed allows the expression of the animals' full genetic potential, and a line for more challenging environments that is more "robust", but has lower performance for production traits.

5 Breeding programmes in low-input systems

5.1 Description of low-input systems

Many of the world's livestock will continue to be kept by smallholders and pastoralists. These producers often have limited access to external inputs and to commodity markets. Even if external inputs are locally available, there is usually little cash available for their purchase. To quote LPPS and Köhler-Rollefson (2005), "Cash products are often of secondary importance, especially in marginal and remote areas. Traditional breeds generate an array of benefits that are more difficult to grasp and to quantify than outputs of meat, milk, eggs or wool. These include their contribution to social cohesion and identity, their fulfilment of ritual and religious needs, their role in nutrient recycling and as providers of energy, and their capacity to serve as savings bank and insurance against droughts and other natural calamities."

The livestock owned by smallholders and pastoralists may be autochthonous or originate from early introductions of exotic breeds to the area. Traditional livestock keepers have no technical training in genetics and many are illiterate. However, they possess valuable local knowledge about breeds and their management. They have breeding goals and strategies even if they are not "formalized" or written down. For example, they may share breeding males (they seldom have more than one of a given species) with their neighbours or the entire community.

In conclusion, formalizing genetic improvement in these conditions is a challenging, but definitely not an impossible or inappropriate, task.

Box 84**Community-based sheep management in the Peruvian Andes**

Agriculture in the central Andes of Peru is severely limited by low temperatures and drought, and most rural households depend on livestock for their income. Rangeland sheep are economically the most important species, and are used as a source of food, as a means of obtaining goods through exchange, and to generate cash through the sale of live animals or wool. To a lesser extent they are also used for cultural activities, recreation and tourism. Criollo sheep represent 60 percent of the Peruvian sheep population. They are mainly raised on family farms and by individual farmers, who value the local breed highly. A dual-purpose breed, developed from a cross between Criollo sheep and Corriedale sheep imported from Argentina, Australia, Chile, New Zealand and Uruguay between 1935 and 1954, is also available. Peasant farmers maintain both the Criollo and the composite breed.

In this part of Peru, peasant communities have organized themselves independently to improve the management of their sheep, with little support from the government. Multicommunal and communal enterprises, cooperatives, as well as family and individual farms, are common. Farmers exchange genetic material, experiences and technologies. Multicommunal and communal enterprises have far higher production rates than individual farmers. They have successfully set up participatory breed improvement programmes based on open-nucleus schemes, are technically efficient, keep their pastures in good condition, and use some of their profits to improve the social well-being of their members – for example, by buying school materials, selling milk and meat at reduced prices, and providing assistance to the elderly.

Provided by Kim-Ahn Tempelman

For further information see FAO (2007)

Box 85**Genetic improvement of an indigenous livestock breed – Boran cattle in Kenya**

The Boran, a medium-sized cattle breed of East African origin, is the breed most widely kept primarily for beef production in the semi-arid zones of Kenya. Commercial ranchers prefer the Boran to *Bos taurus* breeds because of their relative adaptability to the local environment – achieved through generations of natural and artificial selection in conditions of high ambient temperature, poor feed quality, and high disease and parasite challenge. Boran genetic material is recommended as a means of improving beef production in other indigenous and exotic breeds in the tropics. Genetic exports to Zambia, the United Republic of Tanzania, Uganda, Australia and the United States of America occurred from the 1970s to the 1990s. Export of Boran embryos to Zimbabwe and South Africa took place during 1994 and 2000.

This market potential has been an incentive for farmers to improve the breed. By the 1970s, the Boran had undergone cross-breeding with *B. taurus* types, backcrossing, and within-breed selection (which was mainly based on visual appraisal guided by experience). During the 1970s a recording scheme was initiated. Producers sent animal performance records routinely to the Livestock Recording Centre (LRC) for genetic evaluation. However, because of inconsistency and delays in the release of evaluation results, and the expenses associated with recording, most producers opted out of the scheme. In 1998, a bull performance testing project was implemented by the National Beef Research Centre in an attempt to evaluate bulls across various herds. However, the performance testing could not be sustained because of a lack of funds.

Recently, breeding objectives for Boran production systems have been developed. Systems are classified according to the sale age of the animals (24 or 36 months), levels of input (low, medium or high), and final goal (beef or dual purpose). Traits of economic importance have been identified, and genetic parameters have been estimated for some of them. These traits include sale weight for steers and heifers, dressing percentage, consumable meat percentage, milk yield in dual purpose production systems, cow weight, cow weaning rate, cow survival rate, post-weaning survival rate, and feed intake of steers, heifers and cows.

Genetic improvement of the Boran in Kenya is facilitated by the Boran Cattle Breeders' Society (BCBS). Membership of the society is restricted to farmers keeping Boran cattle, and other interested stakeholders. At present, the activities of the society focus on administration, maintaining breed standards, and searching for new markets for both beef and genetic material. Farmers are still independent with respect to selection and genetic improvement. Occasional exchange of genetic material between herds as a means of preventing inbreeding is probably the only form of interaction between farms. On most farms, selection focuses largely on weaning weights and calving interval. To evaluate their animals, some farmers have purchased various computer programmes to enable them to re-orientate on-farm performance recording to suit their management purposes.

The BCBS is among the most active breeders' associations in Kenya. It is not at present subsidized financially, but is involved in strategic cooperation with the LRC which stores and evaluates performance records for those producers still participating in the recording scheme. The BCBS also cooperates with the National Agricultural Research System in the exchange of information – especially on nutrition and breeding. Research aimed at developing appropriate genetic improvement programmes for the Boran and updating the current ones is ongoing.

Provided by Alexander Kahi

For more information on the Boran cattle and BCBS, see <http://www.borankenya.org>

5.2 Breeding strategies

It is important to keep in mind that whatever strategy is considered, it will be successful only if certain conditions are met. Meeting these conditions does not guarantee success, but neglecting them will certainly lead to failure. The owners of the livestock should be involved as much as possible, and preferably from the very beginning of the programme. The social structure of the region and the objectives of the producers should be carefully taken into consideration. The whole system, and not only one element of it, needs to be considered. For example, when considering a cross-breeding scheme in a remote area, it is necessary to ensure that the progeny of cross-bred animals are viable in these conditions.

The programme should be as simple as possible. In some cases it may be feasible to cross-breed individual females to males from other breeds that are available in the vicinity, but programmes that require continuous use of males of more than one breed are not feasible under low-input systems.

Box 86**A llama breeding programme in Ayopaya, Bolivia**

In the high Andes of Bolivia, llama keeping is an important and integral part of the mixed farming practised by rural households. Llamas provide smallholders with dung, meat and fibre; they are used as pack animals and also play an important social role. Llamas, as an autochthonous species, contribute to maintaining the ecological balance of the fragile local ecosystem. There are two main types of llama – the “Kh’ara” type and the wool type known as “Th’ampulli”.

The region of Ayopaya (department of Cochabamba) where the breeding programme takes place is situated at 4 000 to 5 000 metres above sea level in the eastern Cordillera of the Andes. Because of the geographical conditions and very basic infrastructure, the region is difficult to access.

In 1998, a breeding programme for llamas was jointly initiated by the 120-member local producers association ORPACA (Organización de Productores Agropecuarios de Calientes), the NGO ASAR (Asociación de Servicios Rurales y Artesanales) and two universities (University Mayor de San Simón, Cochabamba, and University of Hohenheim, Germany). Initial funding was assured by the above-mentioned institutions. Continuation of the programme critically depends on securing external funding.

As a first step, the production system was studied by participative observation and the use of questionnaires. The phenotype of 2 183 llamas, of the Th’ampulli type, was also characterized. The process revealed that the llamas possess fibre of extraordinarily high quality – 91.7 percent fine fibres and a fibre diameter averaging 21.08 μm . This fibre quality is unmatched by other llama populations in Bolivia. The animals, therefore, constitute a unique genetic resource. Interviews with representatives of the textile industry and traders provided information on the economic potential of the fleece. The performance of identified llamas was recorded and breeding parameters estimated. A mating centre run by ASAR to which members of ORPACA bring their females for service was established in Calientes in 1999. Selected males are kept at the centre during the mating season. The phenotypic evaluation of the males aims to identify animals with uniform fleece colour; a straight back, legs and neck; testicles that are of equal size and not too small; and no congenital defects. Six communities within a radius of about 15 km are served by the mating centre. Performance data for the offspring are recorded by trained farmers.

Llamas in Ayopaya region



Photo credit: Michaela Nürnberg

Restraining llamas for transport



Photo credit: Michaela Nürnberg

Functions of llamas and breeding objectives are being recorded, ranked and valued jointly with the llama keepers. In a stepwise procedure, the breeding programme is being adapted to meet the breeders' preferences, the market conditions, and the biological constraints. Genetic progress has not yet been evaluated because of the llama's long generation interval.

Linear measurements on llamas



Photo credit: Javier Delgado

Deworming during sire selection at Milluni



Photo credit: André Markemann

Llama herd (of Emeterio Campos) in Ayopaya region



Photo credit: André Markemann

*Provided by: Angelika Stemmer, André Markemann, Marianna Siegmund-Schultze, Anne Valle Zárate
Further information can be obtained from the following sources: Alandia (2003); Delgado Santivañez (2003); Markemann (forthcoming); Nürnberg, M. (2005); Wurzinger (2005), or from: Prof. Dr Anne Valle Zárate, Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, 70593 Stuttgart, Germany. E-mail: inst480a@uni-hohenheim.de*

Breeding strategies

Determining the breeding objectives is the most important and difficult task in any genetic improvement programme, and there is even less margin for error in low-input systems. The questions that need to be considered under these conditions include: what (if anything) should be changed, and what would actually be an improvement in these conditions?

A low-input system is also a low-output system, but this does not necessarily mean low productivity. For the low-input system, it is inadequate to think of genetic improvement only in terms of increases in output traits, such as body weight, milk or egg production, or fleece weight. Efficiency is also a key criterion. Unfortunately, very little is known about the genetic improvement of intrinsic efficiency. Increased efficiency is usually measured in terms of increased gross efficiency. The increased gross efficiency observed in high-producing animals results from the fact that a lower proportion of the animals' nutrient intake is used for maintenance, and a correspondingly higher proportion is used for production. This does not mean that the animal needs less feed to achieve a given level of performance.

Box 87

Pastoralists' breeding criteria – insights from a community member

The East African pastoralists of the Karamoja cluster⁴ keep a range of livestock including Zebu cattle, Small East African goats, Persian Black Head sheep, grey donkeys and light brown dromedaries. Some also keep indigenous chickens. Uses of livestock are diverse, and include food; a store of wealth, and a currency against which other commodities can be valued; a source of recreation and prestige; a means for the payment of debts, fines and compensations; a means of transport and agricultural traction; a source of skins and fibres; and a source of dung for fuel, fertilizer or building. Livestock also have many cultural roles such as being given to the bride's family at the time of marriage. They are also slaughtered at the time of rituals associated with births; funerals; the onset of transhumance; rain-making; averting bad omens, epidemics or enemy attack; cleansing ceremonies; or curing an ailment on the prescription of a village herbalist.

Criteria for breeding decisions are multifaceted, and reflect the interaction of social, economic and ecological factors. They include not only productivity, but also the taste of meat, blood, and milk; agreeable temperament; coat colour; religious requirements; disease and parasite resistance; mothering instincts; walking ability; tolerance of droughts; survival on meagre feed; and tolerance of extremes of temperature or precipitation.

Criteria for breeding decisions (in order of importance)

A breeding bull should:

be active and agile – so as to serve all the females in the herd in a given breeding period (it is considered that such bulls are tolerant of diseases and parasites, and that diseases in them are easily detected);

produce offspring that can maintain their body weight (and milk yield in the case of females) even during periods of feed shortage;

have large body size and weight – important for marketability and status, but be not too heavy to perform its breeding functions;

be tall, with a wide chest and straight back – again to meet breeding functions;

have the coat colour or horn configuration identified with the owner⁵ or the community;

have a coat colour and quality suitable for marketing or other uses;

have good temperament – aggressive⁶ towards predators, but not towards other livestock or humans;

bulls kept to breed offspring for draught purposes should have large body weight, and be strong and tractable;

breeding bulls should stay in the owner's herd, graze well, and not be fond of roaming or fighting other bulls.

⁴“Karamoja Cluster”: The entire Ateker people in Uganda, Kenya, Ethiopia and the Sudan who generally share a common livelihood. “Ateker” people: (variously called “Ngitunga/Itunga” = the people). The people with a common origin living in Uganda (NgiKarimojong including Pokot, Iteso), Kenya (NgiTurukana; Itesio, Pokot); Ethiopia (NgiNyangatom/NgiDongiro) and in the Sudan (NgiToposa) and their neighbours; who speak similar languages and refer to their clans as Ateker (pl. Ngatekerin / Atekerin). Some clans of Ateker people are spread all over Karamoja cluster.

⁵ Pastoralists also base their own name on the colour or horn configuration of their favorite bulls. This is typical in the Karamoja Cluster. Such names have the prefix Apa- which means “the owner of the bull with a ... coat colour/horn configuration”. For instance, the name “ApaLongor” means “the man with a bull with a brownish coat colour”. The favourite breeding bull receives many privileges from the owner such as being adorned with a bell, or prompt treatment when ill.

⁶ Indiscriminate aggression is unacceptable in livestock, even if other traits are favourable.

Female breeding animals should:

have a stable high milk yield that is not only tasty and has ample butterfat content, but is also able to maintain healthy and quick growth of the offspring;

be able to calve regularly and produce quick-growing offspring;

be tolerant of disease, heat, cold and long droughts;

survive on little feed and maintain high milk yield, particularly in the dry season when the feed quantity and quality is low;

the udder should be wide and the teats always complete;

cows should be docile to humans and other livestock, but aggressive towards predators;

small stock (goats, sheep) should regularly give birth to twins.⁷

The world should appreciate the role pastoralists play in sustainably utilizing their uniquely adapted breeds. Not only do these animals provide food and income security for their keepers, but they also contribute to the maintenance of genetic diversity, thereby providing a resource for future genetic improvement programmes. In this regard, pastoralists need appropriate support from livestock services provided by national governments, civil society organizations and the international community.

Provided by Thomas Loquang (member of the Karimojong pastoralist community)

For further information see: Loquang (2003); Loquang (2006a); Loquang (2006b); Loquang and Köhler-Rollefson (2005)

Selection based on residual feed intake (RFI) has been proposed as a means of improving intrinsic efficiency. This is an important criterion for all species and all production systems. Genetic selection to reduce RFI can result in animals that eat less without sacrificing growth or production performance (Herd *et al.*, 1997; Richardson *et al.*, 1998). For example, in contrast to the ratio of weight gain/feed intake, residual feed consumption is relatively independent of growth. RFI is therefore a more sensitive and precise measurement of feed utilization (Sainz and Paulino, 2004).

Box 88

The Bororo Zebu of the WoDaaBe in Niger – selection for reliability in an extreme environment

This example refers to cattle breeding in a specialized pastoral system in Niger. The WoDaaBe are full-time cattle keepers. Marketing livestock is the cornerstone of their livelihood strategy. Their herds contribute a substantial proportion of national cattle exports, particularly to the large markets of Nigeria where Bororo animals sell at a premium.

“Extreme environment” here refers to a combination of a harsh ecosystem characterized by stochastic events, and comparatively poor access to both primary resources and external inputs. WoDaaBe herders exploit a semi-arid territory characterized by erratic and unpredictable rainfall. In an ordinary year, fresh grass is available for only two to three months at any given location. Access to forage, water and services requires a degree of purchasing power and negotiation with neighbouring economic actors competing for these resources. The WoDaaBe are usually on the weaker side in these transactions.

It has been proposed that the concept of “reliability” is key to understanding the management strategies of pastoralists under such conditions (Roe *et al.*, 1998). “High-reliability” pastoral systems are geared to the active management of hazards rather than their avoidance, with the aim of ensuring a steady flow of livestock production. In these systems, breeding has to be closely interconnected with the environment and the production strategy. The main goal of the WoDaaBe is to maximize the health and reproductive capacity of the herd throughout the year. Their management system aims to ensure that the animals eat the highest possible amount of the richest possible diet all year round (cf. Schareika, 2003). This involves specialized labour, focusing on managing the diversity and variability of both grazing resources and livestock capabilities.

./..

⁷ Please note that it is a taboo for small ruminants to deliver twins at the first delivery. It is allowed only in the subsequent births. Similarly, it is a taboo for cattle to deliver twins whether at the first or subsequent delivery. Any such situations (births of twins) would lead to the animals concerned being slaughtered by stoning or beating. An animal in this situation is said to have become a witch and as such should be promptly eliminated!

/..



photos provided by Saverio Krätli

The nutritional value of the range is maximized by moving the herd across zones that show spatially and temporally heterogeneous distribution of fodder. Additionally, the animals' capacity as feeders is stretched beyond the natural level. While feeding capacity has in part a genetic base (for example the enzymatic system or the size and conformation of the mouth), it can also be greatly affected by learning, based on individual experience and imitation between social partners (for example efficient trekking and grazing behaviour and diet preferences). Animals' feeding motivation is manipulated through optimizing their digestive feedback, and ensuring best fodder quality and preferred foraging conditions. A carefully diversified diet of grasses and browses is favoured, in order to correct nutritional imbalances which, particularly during the dry season, could keep feeding motivation low by triggering negative digestive feedback. The dry-season watering regime is also tailored in order to hone cattle's digestive performance to meet the herders' long-term strategic goal of maximizing reproduction.

The production strategy is very demanding on both people and the herd. With the onset of the dry season, while other pastoral groups sharing the same ecosystem move closer to water points, where water is more accessible but pasture is poor, the WoDaaBe move in the opposite direction, trying to keep their camps close to prime fodder. This results in long-distance mobility and a watering regime which, at the peak of the hot season, often involves journeys of 25–30 kilometres to reach the well, with the herd drinking every third day.

It is, therefore, essential to the WoDaaBe's production strategy that functional behavioural patterns are maintained within the herd. Consequently, their breeding system focuses on fostering social organization and interaction within the herd. It encourages sharing of animals' feeding competence across the breeding network, and tries to guarantee the genetic and "cultural" continuity of successful cattle lineages within the network. These lineages have proved capable of prospering under the WoDaaBe's herd management system, and over a long enough period to have included episodes of severe stress. The breeding strategy focuses on ensuring the reliability of the herd's reproductive performance, more than on maximizing individual performance in specific traits.

Breeding involves selective mating of cows with matched sires, and a marketing policy that targets unproductive cows. Less than 2 percent of the males are used for reproduction. Close monitoring of the herd allows early detection of oestrus and ensures that more than 95 percent of births result from match-making with selected males. A different sire is used for almost every oestrus of a particular cow, with an overall ratio of about one sire every four births. Pedigree sires are borrowed across large networks of (often related) breeders. Sire borrowing remains frequent (affecting about half the births) even when a breeder owns pedigree sires of his own. Match-making with non-pedigree sires, owned or borrowed, affects about 12 percent of births. Both practices are maintained explicitly in order to preserve variability. Matrilineal genealogies and the sire of each animal in the herd are usually remembered, together with pedigrees of special sires, and the identity and owner of all borrowed sires.

A cow's productivity depends heavily on how well the animal responds to the management system. By adopting a production strategy that manipulates the animals' experience of the ecosystem, the herder exposes his animals to diverse natural environments involving particular combinations of favourable and unfavourable foraging and watering conditions. Over the years, some cows prosper and produce a numerous progeny while others die, or struggle and are sold. In this way, the WoDaaBe are able to harness natural selection pressure for their breeding purposes.

Provided by Saverio Krätli

For more information see: Krätli (2007)

Data recording in low-input systems

The absence of a credible recording scheme and resources for adequate data storage and management hinder the development of sustainable breeding programmes in low-input systems. Running a computerized database can be expensive and may require specialized skills. The absence of technical skills and financial resources has been identified as the main obstacle to the establishment of sustainable animal recording systems in many African countries (Djemali, 2005). Continuous advances in information technology mean that data recording devices are becoming cheaper and offer greater potential for recording in low-input systems. The use of hand-held devices, laptops and the

Internet could make it easier for small numbers of people to gather and transmit large amounts of data from remote locations to a central database. Such a database could be based in a university or a government department. Provision of facilities of this type is one way in which governments or donor agencies could facilitate the development of breeding programmes for low-input systems in developing countries.

Box 89

Community-driven breeding programmes for local pig breeds in north Viet Nam

In the mountainous areas of Northwest Viet Nam, livestock breeding and management programmes, can contribute to improving rural livelihoods if they respect the production objectives, intensity and resource-availability of the area's resource-poor smallholder mixed farming systems. The local Ban pig which shows considerable hardiness, but has a low reproductive and growth performance is increasingly being replaced by higher-yielding Vietnamese Mong Cai sows from the Red River Delta.

In a collaborative project between the National Institute of Animal Husbandry (NIAH) Hanoi and the University of Hohenheim, Germany⁸, community-based pig breeding programmes have been established in seven villages, differing in terms of their remoteness and market access.

A total of 176 households currently participate in the programmes. On-farm performance testing schemes have been developed. Farmers are provided with data sheets on which they record the performance of their pigs (mainly date of farrowing and number of piglets). Vietnamese and German researchers cross-check data and collect additional data by weighing and identifying animals when they visit the villages. Specially trained farmers enter the data into the project databank using the PigChamp® software and researchers analyse the data.

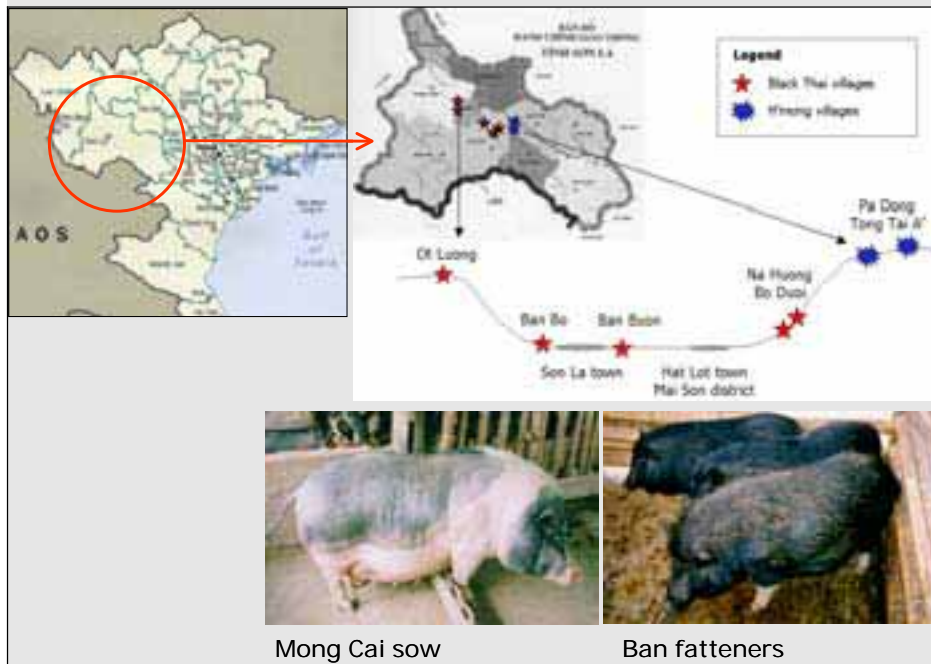
Farmers in Viet Nam often receive money for their participation in projects; in the case of this project, compensations are gradually being reduced. Results are fed back to farmers at seminars/training modules, and are further used to optimize breeding (gilt selection and optimization of mating plans). In order to ensure long-term sustainability, local partners such as the province Department of Agriculture and Rural Development (DARD) and the sub-Department of Animal Health of Son La province, are actively involved and trained. Cooperation with provincial extension services will be strengthened in the current project phase. In earlier phases, the service's strong orientation towards intensive management in favoured regions meant that exchanges were limited. Financial support for the future of the project seems to be available thanks to NIAH's official mandate to carry out projects on AnGR conservation. Moreover, the marketing element of the current project is aimed at ensuring long-term economic viability.

Initial performance testing results indicate that Mong Cai and their cross-bred offspring (sired by exotic boars) are more suited to semi-intensive, market-oriented production conditions, where the higher levels of inputs needed to achieve higher production can be provided. They seem to be less robust in the harsh upland climates and under conditions of low and varying input intensity. Ban pigs are only suited for the extensive conditions of subsistence-oriented resource-poor farming. As the project continues, efforts are being made to further develop breeding goals, to optimize stratified breeding programmes, and to implement marketing programmes. Close to town, lean meat is produced from the cross-bred offspring of Mong Cai sows. Production of Ban pigs continues in remote locations with pure or cross-bred animals marketed as a branded speciality – contributing to the “conservation through use” of this local breed.

./..

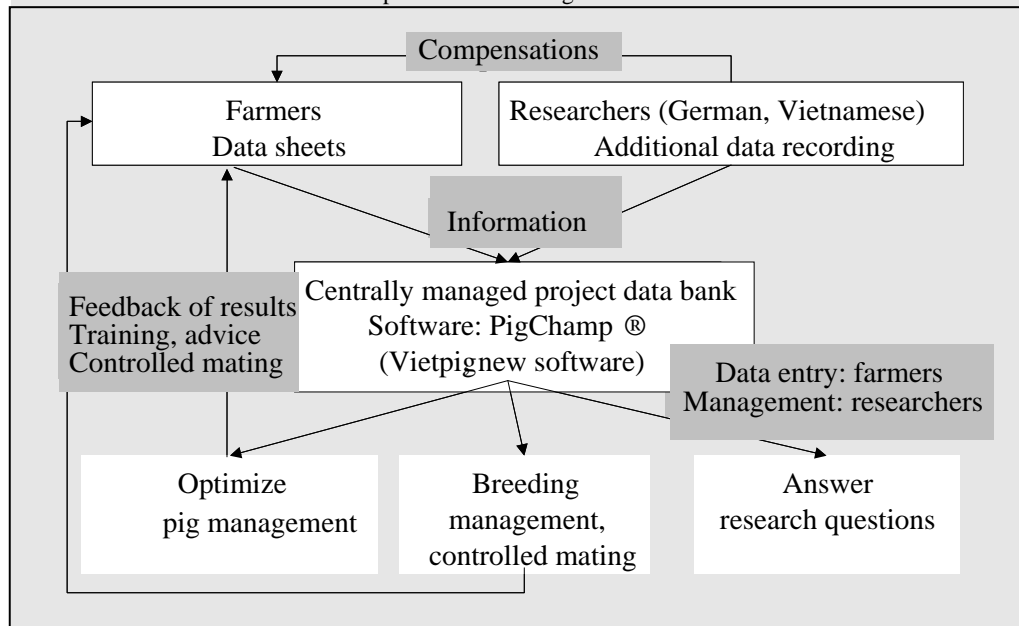
⁸Funded by the German Research Association (DFG) in the frame of the Thai-Vietnamese-German collaborative research programme SFB 564 and by the Ministry of Science and Technology, Viet Nam.

Schematic view of the study region



photos provided by Ute Lemke

Data and resource flow in the on-farm performance testing schemes



Weighing of pigs in Pa Dong, Mai Son district



Photo credit: Regina Rößler

Pigs in Song Ma district



Photo credit: Pham Thi Thanh Hoa

Provided by Ute Lemke and Anne Valle Zárate

Further information can be obtained from the following sources: Huyen, et al. (2005); Lemke, (2006); Rößler. (2005), or from: Prof Dr Anne Valle Zárate, Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, 70593 Stuttgart, Germany. E-mail: inst480a@uni-hohenheim.de

Breeding schemes

If genetic change is justified, how can it be achieved? The choice is between straight or cross-breeding, but choosing the appropriate option is far from simple.

In low-input systems, adaptation to the environment is a prerequisite for improved efficiency. This is a matter of great importance, as intervention to reduce environmental stresses (supplementary feeding, parasite treatments or other management inputs) is often unaffordable. In these circumstances, straight-breeding to improve well-adapted indigenous breeds may be an option. Implementing a straight-breeding programme is a long-term undertaking, requiring considerable resources, good organization, and (most of all) commitment of all stakeholders. These requirements tend to be lacking under low-input systems in the developing world, and programmes that do exist are only of a very limited scope. For example, most controlled breeding of the West African Dwarf Goat has been in research institutions (especially in those in Nigeria) (Odubote, 1992).

Cross-breeding with an exotic breed may appear to be a more rapid means to improve performance with a minimal increase in inputs. However, the higher performance of the cross-breeds is accompanied by higher nutritional and management requirements (disease control, housing etc.).

Therefore, any system that incorporates higher-performing cross-bred animals will require (among other needs) more feed resources – which in many cases can only be achieved by maintaining a smaller number of animals.

If, after careful analysis, cross-breeding is considered to be a better option than straight-breeding the local breed, the programme should be developed in a way that can be sustained with locally available inputs. Cross-breeding with an exotic (non-adapted) breed presents particular difficulties. Even if the F1 animals are sufficiently adapted, the pure-bred exotic males will usually be under environmental stress, and this will often result in a reduced reproductive life. Even if the male of the exotic breed can be successfully maintained, the backcross resulting from mating F1 females with the exotic males will almost always lack adequate adaptation to the area. Therefore, the F1 females should preferably be mated to adapted-breed sires.

One option under these conditions is to use F1 males, generation after generation. Under such a system, the original local females are mated to F1 males, resulting in offspring that are 1/4 exotic. These quarter-blood females are, in turn, mated to F1 males, resulting in females that are 3/8 exotic. After a few generations the animals would be very close to half exotic. This system introduces exotic influence into the population, but never uses or produces any animals that are more than half exotic.

Box 90

The cost of heterosis

Heterosis has sometimes been referred to as a free opportunity for increased profitability. Although it may be worth more than it costs, heterosis is not free. It involves at least two types of costs.

First, there is the cost involved in meeting the nutritional requirement for the additional performance. The higher performance of the cross-bred animal tends to reduce the cost per unit of production, because the cost for maintenance becomes a smaller fraction of the total requirement, but there is a cost for the extra production.

A second type of cost is associated with potential changes in population structure. These costs may include (1) reductions in the size (and a corresponding increase in the level of inbreeding) of an original pure-bred population which occurs because of the need to accommodate the cross-bred population, and (2) a reduced opportunity to select for female productivity in a population where some of the cross-bred females are not considered to be candidates for selection (as in any terminal-sire system).

Another option for cross-breeding under low-input systems is to cross different breeds that are well adapted to the production conditions. The obvious advantage of such programmes is the ability to maintain and produce the breeding stock in the area without additional inputs. It would be logical to assume that such crosses would produce less-productive animals and/or exhibit less heterosis than crosses between a local and an exotic breed. However, Gregory *et al.* (1985) report estimates of heterosis for weight of calf weaned per cow of 24 percent between Boran and Ankole cattle, and 25 percent between Boran and Small East African Zebu.

With any cross-breeding scheme it is important to consider the whole system and all outputs produced. Commenting the value of the European dairy–Zebu F1 cow for milk production in the tropics, LPPS and Köhler-Rollefson (2005) write “in India, many owners of cross-bred cows cannot see a use for male calves, so let them die.”

Box 91

Nigeria’s Village Poultry Improvement Scheme

A Village Poultry Improvement Scheme aimed at upgrading the indigenous breed of chicken with improved exotic breeds (Rhode Island Red, Light Sussex and Australorp) was initiated in Nigeria around 1950 (Anwo, 1989). The strategy was to cull all indigenous males and replace them with improved imported breeds in a “cockerel exchange programme” (Bessei, 1987). This scheme failed because the cross-bred chicks, though better in performance, could not survive in the semi-wild extensive backyard production system under which the indigenous chickens were raised. Another major drawback was that breed replacement resulted in a rapid loss in genetic variation and narrowing of the available AnGR.

Box 92**A community-based and participatory dairy goat cross-breeding programme in a low-input smallholder system in the eastern highlands of Kenya**

FARM Africa's Meru project in Kenya provides an example of a comprehensive and flexible cross-breeding programme. Improved goat genotypes accompanied by improved husbandry practices have been adopted by very poor farmers with incomes well below US\$1 per person per day. The local goats (Galla and East African) were proving difficult to maintain on small and declining farm sizes (0.25 to 1.5 acres), and the farmers had started to abandon goat production. Consequently, the cross-breeding programme aimed to provide more docile and productive animals. Sixty-eight female and 62 male British Toggenburg goats were imported from the United Kingdom and crossed with indigenous goats: the Toggenburgs providing the dairy potential and the local goats providing adaptability. Previous introductions and trials had indicated that Toggenburgs were better adapted than other exotic dairy breeds such as Saanens or Anglo-Nubians.

The project adopted a group and community-based approach. The farmers established the project's rules, by-laws and mechanisms. It was linked to the government, NARS, and international research institutes, which provided training in husbandry (housing, nutrition, fodder production, record keeping and healthcare), group dynamics, marketing and entrepreneurship.

Farmer groups initially comprised 20 to 25 members, but some lost members over time while others grew. Four such groups were linked in a unit (mainly for administrative and monitoring purposes), with representatives being elected to a larger body the Meru Goat Breeders' Association (MGBA). Small (one buck and four does) breeder units were provided (as a loan to be paid back in kind) to one group member, who produced the Toggenburgs (T) needed for breeding stock. One pure-bred Toggenburg buck was provided to each farmer group and kept in a buck station, maintained by another group member. Local does were brought to the buck station for service. The resulting F1 female cross-breeds were backcrossed to unrelated Toggenburg bucks to produce $\frac{3}{4}$ Toggenburg and $\frac{1}{4}$ Local (L) animals. These were evaluated, and superior males selected to start new buck stations, where they were used to serve unrelated females of similar genetic composition ($\frac{3}{4}$ T and $\frac{1}{4}$ L). Initial trials had shown that such does produced adequate amounts of both milk and meat, and were reasonably adapted to the local conditions. Through the MGBA, which also registered the cross-breeds with the Kenya Stud Book, groups rotated the bucks every 1 to 1.5 years to avoid inbreeding. Farmers who wished to further upgrade towards the Toggenburg had the opportunity to do so by further backcrossing the $\frac{3}{4}$ T females to unrelated pure T bucks.

Project statistics 1996 to 2004

| | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 |
|------------------------|------|------|------|------|------|------|------|------|------|
| New farmer groups | 10 | 34 | 20 | 6 | 12 | 10 | 7 | 18 | 8 |
| New buck stations | 10 | 34 | 10 | 11 | 6 | 16 | 14 | 3 | 22 |
| New breeders units | 5 | 20 | 25 | 10 | 12 | 6 | 2 | 4 | 7 |
| Buck services | | 809 | 1994 | 3376 | 3936 | 3892 | 3253 | 5660 | 6500 |
| Families participating | 250 | 1100 | 1125 | 1400 | 1550 | 1700 | 2050 | 2050 | 2650 |
| Cross-breeds produced | | 990 | 2894 | 3241 | 3817 | 3736 | 4187 | 5865 | 7200 |

Source: FARM-Africa Dairy Goat and Animal Healthcare Project; six-monthly reports January 1996–June 2004.

Two years after FARM Africa's pull-out the number of operating groups has continued to increase. In 2006 the MGBA has 3 450 members, all of whom keep improved goats which produce between 1.5 and 3.5 litres of milk per day. The group produces about 3 500 litres of milk daily, some of which is processed and packaged for sale. Member families own more than 35 000 improved goats of which 30 percent have reliable pedigree and performance records. The performance records are used for calculating growth rates and milk yields. These data were formerly processed by FARM-Africa. After the phasing out of the project, MGBA has been encouraged to establish collaboration with universities and research institutions to support them in data processing. Most of the owners of the improved goats are no longer "poor". Some have used profits from goat production to purchase one or two dairy cows, build better houses and educate their children. Production of yoghurt and fresh pasteurized milk (adding value) is indicative of scope for further developments.

./...

.../.

The features that made the scheme successful include:

- a farmer-based approach since its inception;
- an emphasis on capacity building so that farmers can manage the programme;
- availability of locally produced breeding material;
- a group approach – farmers train each other and share experiences;
- capacity building for extension staff, farmer-centred extension messages, and participatory approaches; and
- the community-based establishment of breeder units and buck stations.

The scheme has ensured that after the end of “the project”, farmers are not reliant on government services. Breeding stock is supplied by farmers themselves, and a parallel animal healthcare service has also been established by training community-based animal health workers, with links to more qualified paraveterinarians and veterinarians. An integrated fodder and reforestation programme was also established.

Provided by Okeyo Mwai and Camillus O. Ahuya

For further reading see: Ahuya et al. (2004); Ahuya et al. (2005); Okeyo (1997)

6 Breeding in the context of conservation

Conservation programmes for AnGR are discussed in greater detail elsewhere in this Report. The following discussion, therefore, focuses on aspects of breeding that need to be considered when implementing conservation measures. A conservation programme may simply aim at ensuring the survival of a population through monitoring and maintaining its integrity, or a programme may also have the objective of improving the performance of the population.

6.1 Methods for monitoring small populations

FAO has produced several publications on the management of at-risk small populations. These documents provide a more extensive review of the subject. Where the objective is merely to ensure the survival of the population and the maintenance of its integrity (as a pure population), the conservation strategy is limited to monitoring the population, and ensuring that the following criteria are within acceptable limits:

Inbreeding: is the result of mating related animals. In a small population, all animals in future generations will come to be related to each other, and mating among these animals will result in inbreeding. The genetic effect of inbreeding is increased homozygosity – the animal receives the same alleles from both its parents. The degree of inbreeding and homozygosity in future generations can be predicted from the population size.

Effective population size: As there is almost always a much smaller number of breeding males than breeding females, the number of breeding males is the more important factor determining the amount of inbreeding. The effective population size (N_e) is a function of the number of breeding males and breeding females. If N_m represents the number of breeding males and N_f represents the number of breeding females, effective population size can be calculated as:

$$N_e = (4N_m N_f) / (N_m + N_f)$$

If the number of breeding males is the same as the number of breeding females, the effective population size is the same as the actual population size; if the numbers of males and females are different, the effective population size is less than the actual population size. If the number of breeding females is much larger than the number of males, the effective population size will be slightly less than four times the number of males.

A decrease in effective population size in livestock populations can be observed in two situations. The first and most obvious case is when the actual population size decreases. This can result from the replacement of a significant proportion of a breed with breeding animals of another breed, or from cross-breeding a significant fraction of the breed.

The second situation is when a particularly popular sire and his sons and other descendents are heavily used. From the time of the first establishment of breed societies up to the mid-1900s, much of the popularity of particular sires came about as a result of success in the show ring. In more recent times, predicted genetic value for particular traits has been the decisive factor. In dairy cattle, selection was for many years almost entirely focused on milk yield. Hansen (2001) reports that although over 300 000 head were registered by the Holstein Association USA Inc. in 2000, the effective population size was only 37 head. Using pedigree records of cattle born in 2001, Cleveland *et al.* (2005) report an estimated effective population size in the American Hereford of 85 head. The American Hereford Association registered over 75 000 head in 2001.

Relationship between the rate of inbreeding (ΔF) and effective population size (N_e) The level of inbreeding in a given population is dependent on effective population size rather than actual population size. The increase in the level of inbreeding per generation is expected to be $1/2N_e$. This is the increase expected per generation if each animal produces an equal number of offspring, and the animals in the initial population are not related to each other. If these assumptions are not met, the degree of inbreeding will be higher. Based on this relationship, Gregory *et al.* (1999) recommend that at least 20 to 25 sires be used per generation. This would also be a reasonable number to be used in the conservation of a breed. The use of 25 sires per generation would result in a rate of increase in inbreeding of about 0.5 percent per generation.

While the loss of effective population size is an important issue in the conservation of AnGR, it is interesting to note that successful breeders have always accepted some level of inbreeding in their programmes. These breeders established herds or flocks that met their standards – the animals produced in these closed herds or flocks inevitably came to be closely related, and inbreeding resulted (Hazelton, 1939).

6.2 Conservation through breeding

The objectives of a conservation programme may include not only ensuring the survival and integrity of the target population, but also improving its reproductive rate and performance while maintaining its specific adaptive features. Much of the above discussion of breeding strategy for low-input systems is likely to be applicable in these circumstances. This subchapter focuses on the potential risks associated with cross-breeding in the context of breed conservation.

One option to safeguard a breed is to use it as one of the components of a cross-breeding programme. However, any use of pure-bred females to produce cross-breeds will reduce the population size unless there is a reproductive surplus of females. In many cases, the environmental and management conditions do not allow for much reproductive surplus – especially in cattle, which have low reproductive rates. As such, most of the females that are raised must be retained as breeding animals in order to maintain the size of the population. In fact, the largest effect comes from the requirement for a smaller number of indigenous breeding males, brought about by the smaller number of indigenous females that are being used to produce pure-bred offspring. A logical starting point for consideration of a cross-breeding programme is, therefore, to estimate the amount of reproductive surplus in females. This can be measured in terms of the fraction of young females that are available for slaughter or for sale out of the programme (or region). As an example, for fairly well-managed beef herds in temperate areas, about 40 percent of the heifer calves are needed for replacements in order to maintain the size of the herd.

With knowledge of the reproductive surplus of females, and knowledge of the fraction of the total population that is currently made up of cross-breeds, the fraction of pure-breeds that can be utilized to produce F1s without further decreasing the population size of the pure breed can be calculated. As an example, if there is a 20 percent reproductive surplus of females and the current population is composed of 50 percent pure-breeds and 50 percent cross-breeds (includes any pure-bred females that are currently being used for cross-breeding), the population could move towards a composition of slightly more than 50 percent pure-breeds producing pure-breeds, slightly more than 20 percent pure-breeds producing F1s, and slightly less than 30 percent F1 females, without any further reduction in the size of the pure-bred population that is producing pure-breeds. These values assume that none of

the females produced by the F1 females are retained as breeding females; in reality, this would probably never occur.

7 Conclusions

Breeding methods and organization vary greatly between industrialized commercial production systems and subsistence-oriented low external input systems. The current organization of the breeding sector is a result of a long evolutionary process. The latest development is the spread of the industrialized breeding model, characteristic of the poultry sector, to other species.

The industrialized breeding model uses state of the art techniques for genetic improvement. Breeding programmes are based mainly on straight-breeding and vary according to the characteristics of the species. Breeding companies market their animals worldwide. This tendency, which is well established among “commercial” pig and poultry breeders, is increasingly the case for beef and dairy cattle. To select for robust animals that are able to cope with different environments, breeders run selection programmes across different environments and management systems. However, it is not possible to have animals that produce well everywhere and under all conditions. As such, different breeds or lines may be developed to meet demands in high-input systems. To date, little is known about the genetic aspects of adaptation. Scientists and breeding companies are expected to explore these matters further in their research and their breeding programmes in the coming years.

In low external input production systems, animals kept by smallholders represent an important element of household food security and of the social fabric of village communities. To a large extent, smallholders and pastoralists keep local breeds. Genetic improvement in these conditions is a challenging, but not impossible, task. Detailed guidelines for the design and execution of sustainable breed utilization and improvement programmes for low external input systems are being developed and validated. Straight-breeding to adjust a local breed to the changing needs of producers is the most viable option not only to keep it in production and hence safeguard it, but also to improve food security and alleviate poverty. Another option is to use it as a component of a well-planned cross-breeding programme. In conjunction with the introduction of a breeding programme, attention should be given to the improvement of management conditions and husbandry practices.

A common tendency in research related to breeding programmes for all species is an increasing focus on functional traits – in response to the growing importance given to factors such as animal welfare, environmental protection, distinctive product qualities and human health. Examples of functional traits include robustness, disease resistance and behavioural traits, fertility, efficiency of feed utilization, calving ease and milkability. Generally, considered as secondary traits in high-input systems, functional traits are of great importance in low-input systems. Recording of functional traits, however, still remains an important bottleneck which hinders their inclusion in breeding schemes. Information is lacking on the genetic basis of disease resistance, welfare, robustness and adaptation to different environments. Nevertheless, the dairy cattle and pig industries have started to use DNA typing of single genes and genomics (SNPs) to screen breeding animals. This will support the expected shift towards breeding for functional and lifetime productivity traits.

Because of the tendency for reduced use of chemical medications in the developed world, animals are required to have better resistance, or at least tolerance, to particular diseases and parasites. However, for economic and animal welfare reasons, it is very difficult to select for such animals using classical quantitative genetic approaches. High expectations are therefore placed on genomics. Some applications are already in use to eliminate genetic disorders with Mendelian inheritance. In the case of the more complex resistance traits for which genetic markers have been identified, such as Marek’s disease in poultry and *E. coli* in pigs, few if any breeding companies have implemented DNA-based selection.

Welfare has become an important element in consumers’ perception of product quality, especially in Europe. The main challenges for breeders are to select for better temperament, and reduce foot and leg problems and the incidence of cardio-vascular problems (in poultry kept for meat production). The causes of these problems are multifactorial.

The increasing importance of functional traits will require inclusion of a wider range of criteria in breeding programmes. Some of these criteria may be best met by local breeds. Characterization (phenotypic and molecular) and assessment of these breeds for important traits may allow the detection of some that have unique features. Their further development through breeding programmes would ensure that they remain available for future generations. Unfortunately, the reality is a continuous loss of breeds and lines. The developed world (where the majority of concerted genetic improvement efforts are occurring) contributes directly or indirectly to this loss by concentrating on a very small number of breeds. The deletion of genetic lines that accompanies the worldwide reduction in the number of breeding companies via buy-outs has also played a major role.

8 References

- Ahuya, C.O., Okeyo, A.M., Mosi, R.O. & Murithi, F.M.** 2004. Growth, survival and milk breeds in the eastern slopes of Mount Kenya. *In* T. Smith, S.H. Godfrey, P.J. Buttery, & E. Owen, eds. *The contribution of small ruminants in alleviating poverty: communicating messages from research*. Proceedings of the third DFID Livestock Production Programme Link Project (R7798) workshop for small livestock keepers. Izaak Walton Inn, Embu, Kenya, 4–7 February 2003, pp. 40–47. Aylesford, Kent, UK. Natural Resources International Ltd.
- Ahuya, C.O., Okeyo, A.M., Mwangi, N. & Peacock, C.** 2005. Developmental challenges and opportunities in the goat industry: The Kenyan experience. *Small Ruminant Research*, 60: 197–206.
- Alandia, E.R.** 2003. *Animal health management in a llama breeding project in Ayopaya, Bolivia: parasitological survey*. Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Stuttgart, Germany. (MSc thesis)
- Amer, P.R.** 2006. Approaches to formulating breeding objectives. *In* Proceedings of the 8th World Congress on Genetics Applied to Livestock Production, August 13–18. 2006. Belo Horizonte, MG, Brazil.
- Andersson, L., Haley, C.S., Ellegren, H., Knott, S.A., Johansson, M., Andersson, K., Andersson-Eklund, L., Edfors-Lilja, I., Fredholm, M., Hansson, I., Hakansson, J. & Lundstrom, K.** 1994. Genetic mapping of quantitative trait loci for growth and fatness in pigs. *Science*, 263: 1771–1774.
- Anwo, A.** 1989. Ministerial speech. *In* E.B. Sonaiya, ed. *Rural Poultry in Africa: proceedings of an international workshop*, pp 8–9. Ile-Ife, Nigeria. Thelia House Ltd.
- Bessei, W.** 1987. International poultry development. *In* Proceedings, 3rd International DLG symposium on poultry production in hot climates. June 20–24 1987. Hamelin, Germany
- Bichard, M.** 2002. Genetic improvement in dairy cattle – an outsider’s perspective. *Livestock Production Science*, 75: 1–10.
- Bijma, P., Van Arendonk, J.A. & Woolliams, J.A.** 2001. Predicting rates of inbreeding for livestock improvement schemes. *Journal of Animal Science*, 79: 840–853.
- Cleveland, M.A., Blackburn, H.D., Enns, R.M. & Garrick, D.J.** 2005. Changes in inbreeding of U.S. Herefords during the twentieth century. *Journal of Animal Science*, 83: 992–1001.
- Cunningham, E.P., Dooley, J.J., Splan, R.K. & Bradley, D.G.** 2001. Microsatellite diversity, pedigree relatedness and the contribution of founder lineages to thoroughbred horses. *Animal Genetics*, 32: 360–364.
- Dawson, M., Hoinville, L., Hosie, B.D. & Hunter, N.** 1998. Guidance on the use of PrP genotyping as an aid to the control of clinical scrapie. Scrapie Information Group. *Veterinary Record*, 142: 623–625.
- Dekkers, J.C.M. & Hospital, F.** 2002. The use of molecular genetics in the improvement of agricultural populations. *Nature*, 3: 22–32.
- Delgado Santivañez, J.** 2003. *Perspectivas de la producción de fibra de llama en Bolivia. Potencial y desarrollo de estrategias para mejorar la calidad de la fibra y su aptitud para la comercialización*. Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Cuvillier, Göttingen, Germany. (PhD thesis)

- Dickerson, G.E.** 1969. Experimental approaches in utilizing breed resources. *Animal Breeding Abstracts*, 37: 191–202.
- Dickerson, G.E.** 1972. Inbreeding and heterosis in animals. In *Proceedings of Animal Breeding and Genetics Symposium in honor of Dr. J.L. Lush*, pp. 54–77. Blacksburg, Virginia. ASAS, ADSA.
- Djemali, M.** 2005. Animal recording for low to medium input production systems. In M. Guellouz, A. Dimitriadou & C. Mosconi, eds. *Performance recording of animals, state of the art, 2004*. EAAP Publication No. 113, pp. 41–47. Wageningen, the Netherlands. Wageningen Academic Publishers.
- Ducrocq, V. & Quaas, R.L.** 1988. Prediction of genetic response to truncation selection across generations. *Journal of Dairy Science*, 71: 2543–2553.
- Falconer, D.S. & Mackay, T.F.C.** 1996. *Introduction to quantitative genetics*. 4th Edition. London. Longman.
- FAO.** 2007. Management of sheep genetic resources in the central Andes of Peru, by E.R. Flores, J.A. Cruz & M. López. In K-A. Tempelman & R.A. Cardellino eds. *People and animals. Traditional livestock keepers: guardians of domestic animal diversity*, pp. 47–57. FAO Interdepartmental Working Group on Biological Diversity for Food and Agriculture. Rome.
- Fernando, R.L. & Grossman, M.** 1989. Marker-assisted selection using best linear unbiased prediction. *Genetics Selection and Evolution*, 21: 467–477.
- Fuji, J., Otsu, K. & De Zozzato, F.** 1991. Identification of a mutation in porcine cyanodine receptor associated with malignant hyperthermia. *Science*, 253: 448–451.
- Gregory, K.E. & Cundiff, L.V.** 1980 Cross-breeding in beef cattle: evaluation of systems. *Journal of Animal Science*, 51: 1224–1242
- Gregory, K.E., Trail, J.C.M., Marples, H.J.S. & Kakonge, J.** 1985. Heterosis and breed effects on maternal and individual traits of *Bos indicus* breeds of cattle. *Journal of Animal Science*, 60: 1175–1180.
- Gregory, K.E., Cundiff, L.V. & Koch, R.M.** 1999. *Composite breeds to use heterosis and breed differences to improve efficiency of beef production*. Technical Bulletin. No. 1875. Springfield, Virginia. USDA Agricultural Research Service, National Technical Information Service.
- Groen, A.F.** 2000. Breeding goal definition. In S. Galal, J. Boyazoglu & K. Hammond, eds. *Developing breeding strategies for lower input animal production environments*. Rome. ICAR.
- Grogan, A.** 2005. Implementing a PDA based field recording system for beef cattle in Ireland. In M. Guellouz, A. Dimitriadou & C. Mosconi, eds. *Performance recording of animals, State of the art, 2004*. EAAP Publication No. 113, pp. 133–140. Wageningen, the Netherlands. Wageningen Academic Publishers.
- Hanotte, O., Ronin, Y., Agaba, M., Nilsson, P., Gelhaus, A., Horstmann, R., Sugimoto, Y., Kemp, S., Gibson, J., Korol, A., Soller, M. & Teale, A.** 2003. Mapping of quantitative trait loci controlling trypanotolerance in a cross of tolerant West African N'Dama and susceptible East African Boran cattle. *Proceedings of the National Academy of Science USA*, 100(13): 7443–7448.
- Hansen, L.B.** 2001. Dairy cattle contributions to the National Animal Germplasm Program. *Journal of Dairy Science*, 84(Suppl. 1): 13.
- Hansen, L.B.** 2006. Monitoring the worldwide genetic supply for cattle with emphasis on managing crossbreeding and inbreeding. In *Proceedings of the 8th World Congress on Genetics Applied to Livestock Production*, August 13–18. 2006. Belo Horizonte, MG, Brazil.
- Hazelton, J.** 1939. *A history of linebred Anxiety 4th Herefords of straight Gudgeon & Simpson breeding*. Kansas City, MO. George W. Gates Printing Co.
- Herd, R.M., Arthur, P.F., Archer, J.A., Richardson, E.C., Wright, J.H., Dibley, K.C.P. & Burton, D.A.** 1997. Performance of progeny of high vs. low net feed conversion efficiency cattle. In *Proceedings of the 12th Conference of the Association for the Advancement of Animal Breeding and Genetics*, Dubbo, Australia, pp. 742–745.
- Hill, W.G.** 2000. Maintenance of quantitative genetic variation in animal breeding programmes. *Livestock Production Science*, 63: 99–109.

- Hunter, N.** 1997. Molecular biology and genetics of scrapie in sheep. *In* L. Piper & A. Ruvinsky, eds. *The genetics of sheep*, pp. 225–240. Oxon, UK. CAB International,
- Huyen, L.T.T., Rößler, R., Lemke, U. & Valle Zárate, A.** 2005. *Impact of the use of exotic compared to local pig breeds on socio-economic development and biodiversity in Vietnam*. Stuttgart, Beuren, Germany.
- James, J.W.** 1972. Optimum selection intensity in breeding programmes. *Animal Production*, 14: 1–9.
- James, J.W.** 1977. Open nucleus breeding systems. *Animal Production*, 24: 287–305.
- Jiang, X, Groen, A.F. & Brascamp, E.W.** 1999. Discounted expressions of traits in broiler breeding programs. *Poultry Science*, 78: 307–316.
- Kennedy, B.W., Quinton, M. & van Arendonk, J.A.** 1992. Estimation of effects of single genes on quantitative traits. *Journal of Animal Science*, 70: 2000–2012.
- Krätli, S.** 2007. *Cows who choose domestication. Cattle breeding amongst the WoDaaBe of central Niger*. Institute of Development Studies, University of Sussex, Brighton, UK. (PhD thesis)
- Lamb, C.** 2001. Understanding the consumer. *In* Proceedings of the British Society of Animal Science, 2001, pp. 237–238.
- Lande, R. & Thompson, R.** 1990 Efficiency of marker-assisted selection in the improvement of quantitative traits. *Genetics*, 124: 743–756.
- Larzul, C., Manfke, E. & Elsen, J.M.** 1997. Potential gain from including major gene information in breeding value estimation. *Genetics Selection Evolution*, 29: 161–184.
- Lemke, U.** 2006. *Characterisation of smallholder pig production systems in mountainous areas of North Vietnam*. Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Germany. (PhD thesis)
- Le Roy, P., Naveau, J., Elsen, J.M. & Sellier, P.** 1990. Evidence for a new major gene influencing meat quality in pigs. *Genetical Research*, 55: 33–40.
- Lewis, R.M. & Simm, G.** 2002. Small ruminant breeding programmes for meat: progress and prospects. *In* Proceedings of the Seventh World Congress on Genetics Applied to Livestock Production, held August 19–23, 2002, Montpellier, France.
- Lips, D., De Tavernier, J., Decuypere, E. & van Outryve, J.** 2001. Ethical objections to caesareans: implications on the future of the Belgian White Blue. *In* Proceedings of the Third Congress of the European Society for Agricultural and Food Ethics, Florence, Italy, October 3–5 2001, pp. 291–294.
- Loquang, T.M.** 2003. The Karamojong. *In* I. Köhler-Rollefson & J. Wanyama, eds. *The Karen Commitment: Part 2. The role of livestock and breeding; community presentations*. Proceedings of a Conference of Indigenous Communities on Animal Genetic Resources. League for Pastoral Peoples and Endogenous Development and Intermediate Technology Development Group Eastern-Africa, Karen, Nairobi, Kenya, 27–30 October 2003. Bonn, Germany. German Non-Governmental Organisations Forum on Environment and Development.
- Loquang, T.M.** 2006a. *Livestock Keepers' Rights*. Paper presented at the side event during the Fourth Ad Hoc Open-Ended Intercessional Working Group on Article 8(j) and Related Provisions of the Convention on Biological Diversity, COP 8, Granada, Spain, 23–27 January 2006.
- Loquang, T.M.** 2006b. *The role of pastoralists in the conservation and sustainable use of animal genetic resources*. Paper presented at the International Conference on Livestock Biodiversity, Indigenous Knowledge and Intellectual Property Rights; League for Pastoral Peoples and Endogenous Development, Rockefeller Study and Conference Centre, Bellagio, Italy, 27 March–2 April 2006.
- Loquang, T.M. & Köhler-Rollefson, I.** 2005. *The potential benefits and challenges of agricultural animal biotechnology to pastoralists*. Paper presented at the Fourth All Africa Conference on Animal Agriculture, Arusha, Tanzania, 19–26 September 2005.
- LPPS (Lokhit Pashu-Palak Sanstham) & Koehler-Rollefson, I.** 2005. *Indigenous breeds, local communities: Documenting animal breeds and breeding from a community perspective*. Sadri, Rajasthan, India. Lokhit Pashu-Palak Sanstham.

- Markemann, A.** (forthcoming). *Development of a selection programme in a llama population of Ayopaya region*. Department Cochabamba, Bolivia, Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Germany. (PhD thesis)
- Mavrogenis, A.P.** 2000. Analysis of genetic improvement objectives for sheep in Cyprus. In D. Gabiña, ed. *Analysis and definition of the objectives in genetic improvement programmes in sheep and goats. An economic approach to increase their profitability*, pp. 33–36. Zaragoza, CIHEAM–IAMZ.
- Meuwissen, T.H.E.** 1997. Maximizing response to selection with a predefined rate of inbreeding. *Journal of Animal Science*, 75: 934–940.
- Nürnberg, M.** 2005. *Evaluierung von Produktionssystemen der Lamahaltung in bäuerlichen Gemeinden der Hochanden Boliviens*. Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim. Cuvillier, Göttingen, Germany. (PhD thesis)
- Odubote, I.K.** 1992. *Genetic and non-genetic sources of variation in litter size, kidding interval and body weight at various ages in West African Dwarf Goats*. Obafemi Awolowo University, Ile-Ife, Nigeria. (PhD thesis)
- Okeyo, A.M.** 1997. Challenges in goat improvement in developing rural economies of Eastern Africa, with special reference to Kenya. In C.O. Ahuya & H. van Houton, eds. *Goat development in East Africa*. Proceedings of a workshop held at Izaak Walton Inn, Embu, Kenya, 8–11 December 1997, pp. 55–66. Nairobi. FARM-Africa.
- Olori, V.E., Cromie, A.R., Grogan, A. & Wickham, B.** 2005. *Practical aspects in setting up a National cattle breeding program for Ireland*. Invited paper presented at the 2005 EAAP meeting in Uppsala, Sweden.
- Pharo, K. & Pharo, D.** 2005. *Direction vs. destination*. Pharo Cattle Co. Spring 2005 Sale Catalog, pp. 72–73. Cheyenne Wells, Colorado. Pharo Cattle Co.
- Rauw, W.M., Kanis, E., Noordhuizen-Stassen, E.N. & Grommers, F.J.** 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livestock Production Science*, 56: 15–33.
- Richardson, E.C., Herd, R.M., Archer, J.A., Woodgate, R.T. & Arthur, P.F.** 1998. Steers bred for improved net feed efficiency eat less for the same feedlot performance. *Animal Production Australia*, 22: 213–216.
- Rößler, R.** 2005. *Determining selection traits for local pig breeds in Northern Vietnam: smallholders' breeding practices and trait preferences*. Institute of Animal Production in the Tropics and Subtropics, University of Hohenheim, Germany. (MSc thesis).
- Rocha, J.L., Sanders, J.O., Cherbonnier, D.M., Lawlor, T.J. & Taylor, J.F.** 1998. Blood groups and milk and type traits in dairy cattle: After forty years of research. *Journal of Dairy Science*, 81: 1663.
- Roe E., Huntsinger, L. & Labnow, K.** 1998. High reliability pastoralism. *Journal of Arid Environments*, 39(1): 39–55.
- Sainz, R.D. & Paulino, P.V.** 2004. *Residual feed intake*. Agriculture & Natural Resources Research & Extension Centers Papers, University of California.
- Schareika, N.** 2003. *Know to move, move to know. ecological knowledge among the WoDaaBe of south eastern Niger*. Rome. FAO.
- Simianer, H.** 1994. Current and future developments in applications of animal models. In Proceedings of the 5th World Congress on Genetics Applied to Livestock Production. Guelph, Canada. Vol. 18, pp. 435–442.
- Simm, G.** 1998. *Genetic improvement of cattle and sheep*. Tonbridge, UK. Farming Press, Miller Freeman UK Limited.
- Smits, M.A., Barillet, F., Harders, F., Boscher, M.Y., Vellema, P., Aguerre, X., Hellings, M., McLean, A.R., Baylis, M. & Elsen, J.M.** 2000. Genetics of scrapie susceptibility and selection for resistance. In Proceedings of the 51st Meeting of the European Association for Animal Production (EAAP). 21–24 August, The Hague, Paper S.4.4. EAAP. Rome

- van Arendonk, J.A.M. & Bijma, P.** 2003. Factors affecting commercial application of embryo technologies in dairy cattle in Europe- a modelling approach. *Theriogenology*, 59: 635–649.
- Wickham, B.W.** 2005. Establishing a shared cattle breeding database: Recent experience from Ireland. In M. Guellouz, A. Dimitriadou & C. Mosconi, eds. *Performance recording of animals, State of the art, 2004*. EAAP Publication No. 113, pp. 339–342. Wageningen, the Netherlands. Wageningen Academic Publishers.
- Willis, M.B.** 1991. *Dalton's introduction to practical animal breeding*. 3rd ed. Oxford, UK. Blackwell Science Ltd.
- Woolliams, J.W. & Bijma, P.** 2000. Predicting rates of inbreeding in populations undergoing selection. *Genetics*, 154: 1851–1864.
- Woolliams, J.W., Bijma, P. & Villanueva, B.** 1999. Expected genetic contributions and their impact on gene flow and genetic gain. *Genetics*, 153: 1009–1020.
- Wurzinger, M.** 2005. *Populationsgenetische analysen in Lamapopulationen zur implementierung von leistungsprüfung und selektion*. University of Natural Resources and Applied Life Sciences (BOKU), Vienna, Austria. (PhD thesis)

SECTION E: METHODS FOR ECONOMIC VALUATION

1 Introduction

The large number of AnGR at risk in developing countries, together with the limited financial resources available for conservation and sustainable use, means that economic analysis can play an important role in ensuring an appropriate focus for conservation and genetic improvement efforts. In this regard, important tasks include, *inter alia*:

- determining the economic contribution that AnGR make to various sectors of society;
- supporting the assessment of priorities through the identification of cost-effective measures which might be taken to conserve livestock diversity; and
- assisting in the design of economic incentives and institutional arrangements for the promotion of AnGR conservation by individual farmers or communities.

Swanson (1997) notes that human societies have been expanding and developing over time through a process involving biodiversity depletion. This process can be understood in terms of a trade-off between maintaining the stock of diverse biological resources, and the benefits to human society derived from the depletion of this stock. AnGR erosion can, thus, be seen in terms of the replacement of the existing slate of livestock with a small range of specialized “improved” breeds. Such replacement occurs not only through substitution, but also through cross-breeding and the elimination of livestock because of production system changes. Genotype choices and threats to AnGR, therefore, need to be understood in the context of the evolution of production systems (including biophysical, socio-economic and markets changes). See Part 2 for a further discussion of trends in livestock production systems.

From an economic point of view, AnGR erosion can be seen as a result of drivers generating a bias towards investment in specialized genotypes, which in turn results in under-investment in a more diverse set of breeds. Economic rationality suggests that investment decisions will be determined by the relative profitability of the two options (assuming risk neutrality and well-functioning markets). However, from a farmer’s perspective, the relevant rates of return are those that accrue to him/her rather than to society or the world as a whole. To the farmer, the loss of a local breed will appear to be economically rational in a situation where the returns from the activities that lead to the loss are higher than those from activities compatible with genetic resource conservation – especially as returns from the latter may consist of non-market benefits that accrue to people other than the farmer. This divergence will be further compounded by the existence of distortions in the values of inputs and outputs such that they do not reflect their economic scarcity.

The above-described divergence between private and public returns is important. As Pearce and Moran (1994) note, the recognition of the broader total economic value (TEV – see Box 93) of natural assets can be instrumental in altering decisions about their use, particularly in investment decisions that present a clear choice between erosion/destruction or conservation. When the activity of biodiversity (and genetic resource) conservation generates economic values that are not captured in the market place, the result of this “failure” is a distortion in which the incentives are against genetic resource conservation, and in favour of the economic activities that erode such resources. Such outcomes are, from an economic viewpoint, associated with market failure (i.e. distortions arising from the “missing markets” in the external benefits generated by biodiversity conservation); intervention failure (i.e. distortions caused by government actions in intervening in the workings of the market place, even where those appear to serve some social purpose); and/or global appropriation failures (i.e. the absence of markets/mechanisms to capture globally important external values). Note that global missing markets can co-exist with local market failure and intervention failure. The loss of biodiversity and genetic resources is a case in point.

Box 93**Economic values**

Livestock keepers benefit from the conservation of livestock diversity because of their need for animals that are able to produce in diverse agro-ecosystems, and fulfil a range of functions. In addition to supplying products for sale or home consumption, livestock provide input functions related to other farm/household activities. Livestock provide manure to enhance crop yields, transport for inputs and products, and also serve for traction. Where rural financial and insurance markets are not well developed, they enable farm families to smooth variation in income and consumption levels over time. Livestock constitute savings and insurance, buffering against crop failure and cyclical patterns in crop-related income. They enable families to accumulate capital and diversify, and serve a range of sociocultural roles related to the status and the obligations of their owners (Jahnke, 1982; Anderson, 2003). Livestock also play a role in the maintenance of ecosystems; for example, managed grazing is increasingly viewed as an important tool for conservation.

The values mentioned in the above paragraph are components of direct or indirect use value. Other values are not related to use, but simply to the existence of the breeds (existence and bequest values). Another type of value arises from the notion of uncertainty about the future. The latter result from the motivation to avert risk (option value), and from the irreversibility of the loss of a breed and the related loss of information.

The “Total Economic Value” (TEV) is formally equal to the sum of all direct and indirect use values plus non-use and option values: $TEV = DUV + IUV + OV + BV + XV$ where:

Direct Use Values (DUV) are the benefits resulting from, *inter alia*, actual uses, such as for food, fertilizer and hides, as well as cultural/ritual uses.

Indirect Use Values (IUV) are the benefits deriving from ecosystem functions. For example, some animals play a key role in the dispersion of certain plant species.

Option Values (OV) are derived from the value given to safeguarding an asset for the option of using it at a future date. It is a kind of insurance value (given uncertainty about the future and risk aversion) against the occurrence of, for example, a new animal disease or drought/climate change. Subtly different from, but related to, option values are quasi-option values. The latter relates to the extra value attached to future information made available through the preservation of a resource. Quasi-option values arise from the irreversible nature of breed loss (after which no further learning can take place); they are not related to the risk aversion of the decision makers.

Bequest Values (BV) measure the benefit accruing to any individual from the knowledge that others might benefit from a resource in the future; and

Existence Values (XV) are derived simply from the satisfaction of knowing that a particular asset exists (e.g. blue whales, capybaras or N'Dama cattle).

Some asset values may overlap between these categories, and double counting has to be avoided. Attempts to isolate option, bequest and existence values can be problematic. Underlying principles and procedures for such valuation are still debated.

Sources: adapted from Arrow and Fisher (1974); Jahnke, (1982); Pearce and Moran, (1994); Anderson, (2003); Roosen et al., (2005)

It is apparent from the above typology of values that current economic decisions are largely based on the first category, direct use values, although the other categories may be of equal or greater importance. For example, it has been estimated that approximately 80 percent of the value of livestock in low-input developing-country systems can be attributed to non-market roles, while only 20 percent is attributable to direct production outputs. By contrast, over 90 percent of the value of livestock in high-input developed-country production systems is attributable to the latter (Gibson and Pullin, 2005). By focusing exclusively on direct use values, biodiversity and genetic resource conservation are likely to be consistently undervalued, resulting in a bias towards activities that are incompatible with their conservation.

2 Development of methodologies for economic analysis

Although there is a large body of literature on the economic benefits of improved breeds in intensive (largely developed-country) commercial agriculture, the importance of indigenous breeds and trait values in the subsistence production systems typical of developing countries have been much less studied. There is an extensive amount of conceptual and theoretical literature concerning sources of value arising from genetic resources and biodiversity in general (usually referring to plants and wild animals). However, it is only since an FAO/ILRI workshop (ILRI, 1999) identified potential AnGR valuation methodologies, and subsequent initiatives by ILRI (Economics of AnGR Conservation and

Sustainable Use Programme) and its partners to test these methodologies, that significant research into the matter has been carried out.

Such tools and their findings have, as yet, rarely been put to use in situations that influence policy-making and farmer livelihoods. Further research is urgently needed to better understand implications for genotype preferences of an increasingly dynamic context characterized by, *inter alia*:

- globalization of markets;
- climate change and environmental degradation;
- the occurrence of new epidemic animal diseases;
- developments in the field of biotechnology; and
- policy developments related to the Convention on Biological Diversity.

Global efforts to eradicate poverty, as embodied in the Millennium Development Goals, also require an improved understanding of the potential contributions of alternative genotypes to poverty alleviation, in order to improve pro-poor targeting of AnGR programmes. In this context, research supporting institutional innovations and technology-adoption also play an important role. Such areas are critical for the management of AnGR and have important socio-economic dimensions.

There are a number of reasons for the relatively slow development of the economics of AnGR, including: the fact that the measurement of the benefits of germplasm diversity to livestock development is difficult; the limited availability of the data required to carry out economic analysis; and the importance of considering non-market values of livestock – obtaining such data frequently requires the modification of economic techniques for use in conjunction with participatory and rapid rural appraisal methods.

Despite the difficulties, there are a range of analytical techniques from other areas of economics that can be adapted for carrying out such analyses. These methodologies are reviewed by Drucker *et al.* (2001) who broadly categorize them into three (non-mutually exclusive) groups on the basis of the practical purpose for which they may be used (see Table 102):

- group 1) determining the actual economic importance of the breed at risk;
- group 2) determining the costs and benefits of AnGR conservation programmes, and targeting farmers for participation; and
- group 3) priority setting in AnGR breeding programmes.

A number of these methodologies have significant conceptual shortcomings and intensive data requirements (see Drucker *et al.*, 2001 for a detailed description). However, they have been shown to produce useful estimates of the values that are placed on market, non-market and potential breed attributes of the type useful for designing breeding and conservation strategies. The following section presents an overview of the methodologies. The objective is both to show the potential usefulness of the methodologies, as well as to provide information (inevitably location-specific) on the economic importance of indigenous AnGR. To this end, a number of specific studies are presented as illustrative examples of the application of the various tools. Many of the findings give useful insights into the value of particular indigenous livestock breeds within the production systems studied. Salient conclusions are highlighted at the start of each subsection. A more detailed overview can be found in Drucker *et al.* (2005), and an annotated bibliography of literature in this field is provided by Zambrano *et al.* (2005).

Table 102
Overview of valuation methodologies

| Valuation methodology | Purpose | Contribution to conservation and sustainable use of AnGR |
|--|---|--|
| Group 1: Methodologies for determining the actual economic importance of the breed (mostly of interest to policy makers and breeders, as well as some farmers) | | |
| Aggregate Demand & Supply | Identify value of breed to society. | Value potential losses associated with AnGR loss. |
| Cross-sectional Farm and Household | Identify value of breed to society. | Value potential losses associated with AnGR loss. |
| Aggregated Productivity Model | Determine farmer net returns by breed. | Justify economic importance of given breed in the context of multiple limiting inputs. |
| IPR and Contracts | Market creation and support for “fair and equitable” sharing of AnGR benefits. | Generate funds and incentives for AnGR conservation. |
| Contingent Valuation Methodologies I (e.g. dichotomous choice, contingent ranking, choice experiments) | Determine farmer trait value preferences and net returns by breed. | Justify economic importance of given breed. |
| Market Share I | Indicate current market value of a given breed. | Justify economic importance of given breed. |
| Group 2: Methodologies for determining the costs and benefits of AnGR conservation programmes and for targeting farmers for participation (mostly of interest to policy makers and farmers) | | |
| Contingent Valuation Methodologies II (e.g. dichotomous choice, contingent ranking, choice experiments) | Identify society’s willingness to pay (WTP) for the conservation of AnGR. Identify farmer willingness to accept (WTA) compensation for raising indigenous AnGR instead of exotics. | Define maximum economically justified conservation costs. |
| Production Loss Averted | Indicate magnitude of potential production losses in the absence of AnGR conservation. | Justify conservation programme costs of at least this magnitude. |
| Opportunity Cost | Identify cost of maintaining AnGR diversity. | Define opportunity cost of AnGR conservation programme. |
| Market Share II | Indication of current market value of a given breed. | Justify conservation programme costs. |
| Least Cost | Identify cost-efficient programme for the conservation of AnGR. | Define minimum cost of conservation programme. |
| Safe Minimum Standard | Assess trade-offs involved in maintaining a minimum viable population. | Define opportunity cost of AnGR conservation programme. |
| Group 3: Methodologies for priority setting in AnGR breeding programmes (mostly of interest to farmers and breeders) | | |
| Evaluation of Breeding Programme | Identify net economic benefits of stock improvements. | Maximize economic benefits of conserved AnGR. |
| Genetic Production Function | Identify net economic benefits of stock improvements. | Maximize expected economic benefits of conserved AnGR. |
| Hedonic | Identify trait values. | Value potential losses associated with AnGR loss. Understand breed preferences. |
| Farm Simulation Model | Model improved animal characteristics on farm economics. | Maximize economic benefits of conserved AnGR. |

Source: adapted from Drucker et al. (2001)

3 Application of economic methodologies in AnGR management

The following examples are presented in the context of the classification presented in Table 102.

3.1 Value of livestock genetic resources to farmers⁹

- Adaptive traits and non-income functions form important components of the total value of indigenous-breed animals to livestock keepers.
- Conventional productivity evaluation criteria are inadequate to evaluate subsistence livestock production and have tended to overestimate the benefits of breed substitution.

Tano *et al.* (2003) and Scarpa *et al.* (2003a; 2003b) used stated preference choice experiments (CE) to value the phenotypic traits expressed in indigenous breeds of livestock. Adaptive traits and non-income functions are shown to form important components of the total value of the animals to livestock keepers. In the study carried out by Tano *et al.* (2003) in West Africa, for example, the most important traits for incorporation into the goals of breed improvement programme were found to be disease resistance, fitness for traction, and reproductive performance. Beef and milk production were less important. The results of these studies also show that it is possible to investigate values of genetically determined traits that are currently not widely recognized in livestock populations, but are desirable candidates for breeding or conservation programmes (e.g. disease resistance).

Karugia *et al.* (2001) used an aggregate demand and supply approach covering both national and farm levels. They argue that conventional economic evaluations of cross-breeding programmes have overestimated their benefits by ignoring subsidies, the increased costs of management such as veterinary support services, and the higher levels of risk and socio-environmental costs associated with the loss of the indigenous genotypes. Applied to dairy farming in Kenya, the results suggest that at the national-level, cross-breeding has had an overall positive impact on society's welfare (based on a consumer/producer surplus measure), although taking important social cost components into account substantially lowers the net benefits. Farm-level performance is, however, little improved under "traditional" production systems by replacing the indigenous Zebu with exotic breeds.

Comparing the performance of different genotypes (indigenous goats vs. exotic crosses), Ayalew *et al.* (2003) come to a similar conclusion. The secondary importance of meat and milk production traits in many production systems leads these authors to argue that conventional criteria for the evaluation of productivity are inadequate for subsistence livestock production systems, because:

- they fail to capture non-marketable benefits of the livestock; and
- the core concept of a single limiting input is inappropriate to subsistence production, as multiple limiting inputs (livestock, labour, land) are involved in the production process.

The study involved the use of an aggregated productivity model to evaluate subsistence goat production in the eastern Ethiopian highlands. The results show that indigenous goat flocks generated significantly higher net benefits under improved than under traditional management, which challenges the prevailing notion that indigenous livestock do not adequately respond to improvements in the level of management. Furthermore, it is shown that under the subsistence mode of production considered, the premise that cross-bred goats are more productive and beneficial than the indigenous goats is wrong. The model, thus, not only underlines the value of indigenous AnGR to farmers, but also provides a more realistic platform upon which to propose sound improvement interventions.

⁹ using Group 1 valuation methodologies (see Table 102)

3.2 Costs and benefits of conservation¹⁰

- The costs of implementing an *in situ* breed conservation programme may be relatively small, both when compared to the size of subsidies currently being provided to the commercial livestock sector, and with regard to the benefits of conservation. However, few such conservation initiatives exist, and even where the value of indigenous breeds has been recognized and support mechanisms implemented, significant shortcomings can be identified.
- Similar work regarding the costs and benefits of the *ex situ* (cryo)conservation of livestock remains limited. However, under the assumption that technical feasibility brings the cost of cryoconservation and regeneration of livestock species to within the same level of magnitude as that of plants, extensive conservation efforts would be justified on economic grounds.

In situ conservation

Cicia *et al.* (2003) show that a dichotomous choice stated preference approach can be used to estimate the benefits of establishing a conservation programme for the threatened Italian Pentro horse. A bio-economic model was used to estimate the costs associated with conservation, and a cost–benefit analysis was subsequently realized. Benefit estimates were based on society’s willingness to pay for conservation and, therefore, may be associated, in this particular case, with an existence value. The results not only show a large positive net present value associated with the proposed conservation activity (benefit/cost ratio > 2.9), but also show that this approach is a useful decision-support tool for policy-makers involved in allocating scarce funds to a growing number of animal breeds facing extinction.

A case study of the endangered Box Keken pig breed in Yucatan, Mexico revealed large net present values associated with conservation (Drucker and Anderson, 2004). Three methodologies for valuing the benefits of conservation and sustainable use of the breed – market share, production loss averted and contingent valuation (consumer taste test) – were tested and critically assessed. The costs of conservation were estimated with the use of contingent valuation (producer choice experiment) and least cost/opportunity cost approaches. A shortcoming of the first two techniques for valuing the benefits is that they are not based on consumer surplus measures, i.e. do not account for price changes and substitution possibilities should breed loss occur. Despite the identified shortcomings, and the fact that values can only be approximated, the study indicates that the benefits of conservation clearly outweigh the costs in this case (Table 103).

Table 103
Conservation benefits and costs under a range of valuation methodologies – the case of the Box Keken pig (Yucatan, Mexico)

| Valuation Methodologies* | Measure of Conservation and Sustainable Use Benefits US\$ <i>per annum</i> | Measure of Conservation Costs US\$ <i>per annum</i> |
|--|---|---|
| Market share | US\$490 000 | |
| Production loss averted (Yucatan State only) | US\$1.1 million | |
| Contingent valuation (consumer taste test) | US\$1.3 million | |
| Contingent valuation (producer choice experiment) and least cost/opportunity cost approach | | US\$2 500–3 500 |

Source: Drucker and Anderson (2004)

*See Table 102

Even where the value of indigenous breeds has been recognized and support mechanisms implemented, significant failings can be identified. Signorello and Pappalardo (2003), in an examination of livestock biodiversity conservation measures and their potential costs in the EU, report that many breeds at risk of extinction according to the FAO World Watch List are not covered by

¹⁰ using Group 2 valuation methodologies (see Table 102)

support payments as they do not appear in countries' Rural Development Plans. Furthermore, the results show that where payments are made, they do not take into account the different extinction risks faced by the different breeds. Moreover, payment levels are inadequate, meaning that it can still remain unprofitable to rear indigenous breeds. Ideally, support payments should be set at a level that reflects society's willingness to pay for conservation, but this is not usually the case and may not always be necessary to ensure profitability.

The lack of adequate incentives for the conservation of indigenous breeds is despite the fact that conservation costs have been shown, in a number of case studies described by Drucker (2006), to be relatively small. Drawing on the safe minimum standards (SMS) literature, the framework used in this study assumes that the benefits of indigenous livestock breed conservation can be maintained, as long as a minimum viable population of the breed is maintained. In general, the costs of implementing an SMS are made up of the opportunity cost differential (if any exists) of maintaining the indigenous breed rather than an exotic or cross-breed. In addition, the administrative and technical support costs of the conservation programme also need to be accounted for. Empirical cost estimates were obtained using data from economic case studies (Italy and Mexico), based on an SMS that is equivalent to the FAO measure of "not at risk", i.e. approximately 1 000 breeding animals. The results support the hypothesis that the costs of implementing an SMS are low (depending on the species/breed and location, these ranged from between approximately Euro 3 000 and 425 000 *per annum*), both when compared with the size of subsidies currently being provided to the livestock sector (less than 1 percent of the total subsidy) and with regard to the benefits of conservation (benefit/cost ratio greater than 2.9). The costs proved to be lowest in the developing country, which is encouraging given that an estimated 70 percent of the livestock breeds existing today are in developing countries, and that this is where the risk of loss is highest (Rege and Gibson, 2003).

More extensive quantification of the components required to determine SMS costs nevertheless needs to be undertaken before it can be applied in practice. Such economic valuation needs to cover both the full range of breeds/species being considered, and ensure that as many as possible of the elements making up their total economic value are accounted for.

Ex situ conservation

Similar work regarding the costs and benefits of the *ex situ* (cryo)conservation of livestock remains limited. Cryopreservation technologies for livestock, although advancing rapidly, are still well-developed only for a handful of species. Nevertheless, Gollin and Evenson (2003) argue that assuming that technical feasibility brings the cost of cryoconservation and regeneration of livestock species to within the same level of magnitude as that of plants, "there cannot be much doubt that the economics would justify extensive conservation efforts" (i.e. probable option values are likely to be much higher than conservation costs).

3.3 Targeting of farmers for participation in *in situ* breed conservation programmes¹¹

- *In situ* conservation programmes play a crucial role in the context of AnGR.
- Household characteristics play an important role in determining differences in farmers' breed preferences. This additional information can be of use in designing cost-effective conservation programmes.

Wollny (2003) argues that community-based management approaches are likely to be required to play an increasingly important role in strategies that aim to improve food security and to alleviate poverty through the conservation of AnGR. This is because the utilization of indigenous livestock populations depends, in large part, on the ability of communities to decide on and implement appropriate breeding strategies. The community-based management of AnGR is also considered to play a critical role in poverty alleviation (FAO, 2003).

¹¹ using Group 2 valuation methodologies (see Table 102)

In the context of crops (Meng 1997), proposed that conservation programmes should target those households that are the most likely to continue to maintain local varieties. As these households will be the least costly to incorporate into a conservation programme, a “least cost” programme can be identified. The cost of an *in situ* conservation programme can, thus, be expressed as the cost necessary to raise the comparative advantage of such breeds above that of competing breeds, species, or off-farm activities. A relatively small investment may suffice to maintain their advantage in a particular farming system.

This conceptual approach to identifying low-cost conservation strategies has recently been applied to estimate conservation costs for creole pigs in Mexico (Scarpa *et al.*, 2003b; Drucker and Anderson, 2004) and Boran cattle in Ethiopia (Zander *et al.*, forthcoming).

Scarpa *et al.* (2003b) show that for creole pigs in Mexico, the respondent’s age, years of schooling, size of the household, and the number of economically active members of the household, were important factors in explaining breed trait preferences. Younger, less-educated, and lower-income households placed relatively higher values on the attributes of indigenous piglets compared to exotics and their crosses (Drucker and Anderson, 2004). Pattison’s (2002) findings further corroborate these results. In the context of a ten-year conservation programme that would bring the creole pig population to a sustainable size considered “not at risk” under the FAO classification system; the findings indicate that small, less well-off households would require lower levels of compensation, or even (in 65 percent of cases) no compensation at all. The premise of this set of studies is that continued conservation of genetic resource diversity on-farm makes most economic sense in those locations where both society and the farmers who maintain it benefit the most.

Mendelsohn (2003) argues that where there is a divergence between private (farmer) and public values, conservationists must first make the case for why society should be willing to pay to protect apparently “unprofitable” AnGR, and then must design conservation programmes that will effectively protect what society treasures.

3.4 Priority setting in livestock conservation programmes¹²

- Conservation policy needs to promote cost-efficient strategies, and this can be achieved through the development of “Weitzman-type” decision-support tools. Such tools permit the allocation of a given budget among a set of breeds such that the expected amount of between-breed diversity conserved is maximized.

Simianer *et al.* (2003) and Reist-Marti *et al.* (2003) provide one of the few examples of the conceptual development of a decision-support tool in the field of AnGR. Recognizing the large number of indigenous livestock breeds that are currently threatened, and the fact that not all can be saved given limited conservation budgets, a framework is elaborated for the allocation of a given budget among a set of breeds so that the expected amount of between-breed diversity conserved is maximized. Drawing on Weitzman (1993) it is argued that the optimum criterion for a conservation scheme is to maximize the expected total utility of the set of breeds, which is a weighted sum of diversity, extinction probabilities and breed conservation costs (see Section F: 8.2 for further discussion of this approach). Drawing on Group 2 valuation methodologies (see Table 102) is currently postulated as a means of estimating conservation costs. However, Group 1 methodologies could be used should a livelihoods rather than a conservation cost approach be adopted. Both this, and the original Weitzman study, used measures of diversity based on genetic distances. Note, however, that alternative measures of diversity could also be used – for example, measures that include both between and within-breed diversity (Ollivier and Folly, 2005) or those drawing on functional diversity, based on the existence of unique attributes in certain breeds (see Brock and Xepapadeas (2003) for a plant genetic resource illustration). Implications for the choice of breeds for inclusion in conservation programmes may well differ depending on how the diversity index is constructed and the overall goal of the conservation programme (conservation of genetic diversity *per se*, maximizing the number of unique traits conserved, or maximizing the livelihood contribution of the livestock diversity conserved). Where

¹² using Group 2 valuation methodologies (see Table 102)

such models are sufficiently specified and essential data on key parameters are available (currently lacking for conservation costs and benefits or contribution to livelihoods), the framework can be used for rational decision-making on a global scale. See section F:8 for further discussion of methods for priority setting in conservation.

3.5 Priority setting in livestock-breeding strategies¹³

- Economic analysis has demonstrated the magnitude of the contribution of genetic selection, for example using selection indices, to increased production.
- Methods are needed not only to account for the current set of economic objectives, but also to include foreseeable and even unpredictable future needs.
- Hedonic¹⁴ approaches are useful to evaluate the importance of certain attributes or characteristics to the value of animals or animal products including their influence on selection strategies.

Breeding programmes have long used a selection index as a device for multiple-trait selection in livestock. For example, Mitchell *et al.* (1982) measured the value of genetic contributions to pig improvement in the United Kingdom by determining the heritability of important characteristics, and isolating the genetic contributions to improved performance. Using linear regression techniques to compare control and improved groups over time, they found that the returns were substantial, with costs in the region of £2 million *per annum* relative to benefits of £100 million *per annum*. The use of cross-breeding in commercial production was estimated to contribute approximately £16 million *per annum*. Farm-level simulation models have been built for several species under high-input management, and have also focused on valuing heritable trait gain.

Smith (1985), in the context of the importance of accounting for option values in genetic production function models, argues that genetic selection based on the current set of economic objectives is suboptimal in an intertemporal context. Instead, given uncertainty about future needs, selection should be “directed to cater for foreseeable and even unpredictable futures” (Smith, 1985, p. 411). In particular, Smith (1984) advocates the storage of stocks with traits that are currently not economically desirable because of temporary market demands and/or production conditions (e.g. market or grading requirements, carcass or product composition, special behavioural adaptations to current husbandry conditions).

Using hedonic approaches, Jabbar *et al.* (1998) show that in Nigeria, although there were some differences in prices that were solely because of breed, most variation in prices was because of such variables as wither height and girth circumference that vary from animal to animal within breeds. Variation because of type of animal or month of transaction was also greater than that because of breed. Jabbar and Diedhiou (2003) show that a hedonic approach used to determine livestock keepers’ breeding practices and breed preferences in southwest Nigeria, confirms a strong trend away from trypanotolerant breeds. Richards and Jeffrey (1995) identify the value of relevant production and type traits for dairy bulls in Alberta, Canada. A hedonic valuation model is estimated, which models semen price as a function of individual production and longevity characteristics for a sample of Holstein-Friesian bulls.

3.6 General policy analysis development¹⁵

The current rapid rate of loss of AnGR diversity is the result of a number of underlying factors. While, in some cases, changes in production systems and consumer preferences reflect the natural evolution of developing economies and markets, in other cases, production systems, breed choice and consumer

¹³ using Group 3 valuation methodologies (see Table 102)

¹⁴ Hedonic approaches are based on the idea that the total value of an animal can be decomposed into the values of individual characteristics. Statistical methods are used to estimate the contribution of each characteristic to the total value based on the market prices paid for animals with different combinations of characteristics

¹⁵ potentially using Group 2, as well as Group 1 valuation methodologies (see Table 102)

preferences have been distorted by local, national and international policy. Such distortions may arise from macroeconomic interventions (e.g. exchange and interest rates); regulatory and pricing policy (e.g. taxation, price controls, market and trade regulations); investment policy (e.g. infrastructure development); and institutional policy (e.g. land ownership and genetic resource property rights). While the impact of policy factors on AnGR is readily discernable in broad terms, little is known about their relative importance.

4 Implications for policies and future research

The above studies reveal not only that there are a range of methodologies that can be used to value livestock keeper breed/trait preferences, but that they can be of use in designing policies that counter the present trend towards marginalization of indigenous breeds. In particular, it becomes possible to, *inter alia* (Drucker and Anderson, 2004):

- recognize the importance that livestock keepers place on adaptive traits and non-income functions, and the need to consider these in breeding programme design;
- identify those breeds that are a priority for participation in cost-efficient diversity-maximizing conservation programmes; and
- contrast the costs involved with the large benefits non-livestock keepers place on breed conservation.

Nevertheless, as recent advances in economic valuation for livestock genetic resources have eased some (but by no means all) methodological/analytical constraints, the issue of data availability has become relatively more critical. Data requirements imply the need to *inter alia*:

- measure breed performance parameters;
- characterize actual and potential breeding systems;
- identify uses and farmers' trait preferences (including eliciting the values that farmers place on specific market/non-market traits and the trade-offs they are willing to make between traits) for local breeds under different production systems, as well as the forces influencing such factors and the use of alternative breeds;
- identify factors affecting livestock demand and prices, including the impact of policy-induced changes in agricultural commodity (e.g. forage/crop) prices and external (e.g. veterinary) input costs in the context of different breed use;
- carry out *ex ante* analysis of the effects on livelihoods of using alternative breeds, together with constraints to adoption and potential access/dissemination mechanisms;
- consider the role of such factors as land tenure, agricultural potential, population density, market access and integration, licensing requirements, tax regimes, credit and extension programmes and education; and
- improve understanding of the importance of continued access and trade in livestock germplasm for research and development purposes, together with the nature of the costs and benefits arising from AnGR research.

Despite a wealth of livestock production data at the national level, such information tends to be limited to the principal breeds and largely ignores important non-market contributions. Information on local breeds in developing countries is extremely limited. Initiatives such as FAO's DAD-IS and ILRI's DAGRIS systems are supporting national-level programmes.

The challenge is now to raise awareness regarding the important role of economic analysis in improving farm AnGR conservation and sustainable use. National capacities must also be strengthened in order to enable the application of the relevant methodologies/decision-support tools, and to integrate them into the wider national livestock development process. In this way, further work on the economics of AnGR (including in dynamic systems evolution contexts and integrated with

other components of agrobiodiversity), and the subsequent design of appropriate incentive mechanisms, can be applied in contexts where the results can be taken up so as to actively benefit farmers and support the work of national researchers and policy-makers.

5 References¹⁶

- Anderson, S.** 2003. Animal genetic resources and sustainable livelihoods. *Ecological Economics*, 45(3): 331–339.
- Arrow, K.J. & Fisher, A.C.** 1974. Environmental preservation, uncertainty, and irreversibility. *Quarterly Journal of Economics*, 88(2): 312–319.
- Ayalew, W., King, J.M., Bruns, E. & Rischkowsky, B.** 2003. Economic evaluation of smallholder subsistence livestock production: lessons from an Ethiopian goat development program. *Ecological Economics*, 45(3): 473–485.
- Brock, W. & Xepapadeas, A.** 2003. Valuing biodiversity from an economic perspective: a unified economic, ecological and genetic approach. *American Economic Review*, 93(5): 1597–1614.
- Cicia, G., D'Ercole, E. & Marino, D.** 2003. Costs and benefits of preserving farm animal genetic resources from extinction: CVM and bio-economic model for valuing a conservation program for the Italian Pentro horse. *Ecological Economics*, 45(3): 445–459.
- Drucker, A.G.** 2006. An application of the use of safe minimum standards in the conservation of livestock biodiversity. *Environment and Development Economics*, 11(1): 77–94.
- Drucker A.G. & Anderson, S.** 2004. Economic analysis of animal genetic resources and the use of rural appraisal methods: Lessons from South-East Mexico. *International Journal of Sustainable Agriculture*, 2(2): 77–97.
- Drucker, A.G., Gómez, V. & Anderson, S.** 2001. The economic valuation of farm animal genetic resources: a survey of available methods. *Ecological Economics*, 36(1): 1–18.
- Drucker, A.G., Smale, M. & Zambrano, P.** 2005. *Valuation and sustainable management of crop and livestock biodiversity: a review of applied economics literature*. SGRP/IFPRI/ILRI. (available at <http://www.ilri.org/>).
- FAO.** 2003. *Community-based management of animal genetic resources*. Proceedings of the workshop held in Mbabane, Swaziland, 7–11 May 2001. FAO/SADC/UNDP/GTZ/CTA. Rome.
- Gibson, J.P. & Pullin, R.S.V.** 2005. *Conservation of livestock and fish genetic resources*. Rome. CGIAR Science Council Secretariat.
- Gollin, D & Evenson, R.** 2003. Valuing animal genetic resources: lessons from plant genetic resources. *Ecological Economics*, 45(3): 353–363.
- ILRI.** 1999. *Economic valuation of animal genetic resources*. Proceedings of an FAO/ILRI workshop held at FAO Headquarters, Rome, Italy, 15–17 March 1999. Nairobi. International Livestock Research Institute.
- Jabbar, M.A. & Diedhiou, M.L.** 2003. Does breed matter to cattle farmers and buyers? Evidence from West Africa. *Ecological Economics*, 45(3): 461–472.
- Jabbar, M.A., Swallow, B.M., d'Ieteren, G.D.M. & Busari, A.A.** 1998. Farmer preferences and market values of cattle breeds of west and central Africa. *Journal of Sustainable Agriculture*, 12: 21–47.
- Jahnke, H.E.** 1982. *Livestock production systems and livestock development in Tropical Africa*. Kiel, Germany. Kieler Wissenschaftsverlag Vauk.
- Karugia, J., Mwai, O., Kaitho, R., Drucker, A., Wollny, C. & Rege, J.E.O.** 2001. Economic analysis of crossbreeding programmes in sub-Saharan Africa: a conceptual framework and Kenyan case study. *Animal Genetic Resources Research 2*. Nairobi. International Livestock Research Institute.

¹⁶ see <http://www.ilri.org/> for full text versions of a number of these papers

- Mendelsohn, R.** 2003. The challenge of conserving indigenous domesticated animals. *Ecological Economics*, 45(3): 501–510.
- Meng, E.C.H.** 1997. *Land allocation decisions and in situ conservation of crop genetic resources: The case of wheat landraces in Turkey*. University of California, Davis, California, USA. (PhD thesis)
- Mitchell, G., Smith, C., Makower, M. & Bird, P.J.W.N.** 1982. An economic appraisal of pig improvement in Great Britain. 1. Genetic and production aspects. *Animal Production*, 35(2): 215–224.
- Ollivier, L. & Foulley, J.** 2005. Aggregate diversity: new approach combining within- and between-breed diversity. *Livestock Production Science*, 95(3): 247–254.
- Pattison, J.** 2002. *Characterising backyard pig keeping households of rural Mexico and their willingness to accept compensation for maintaining the indigenous Creole breed: A Study of Incentive Measures and Conservation Options*. University of London. (MSc thesis).
- Pearce, D. & Moran, D.** 1994. *The economic value of biodiversity*. London. Earthscan.
- Rege, J.E.O. & Gibson, J.P.** 2003. Animal genetic resources and economic development: issues in relation to economic valuation. *Ecological Economics*, 45(3): 319–330.
- Reist-Marti, S., Simianer, H., Gibson, G., Hanotte, O. & Rege, J.E.O.** 2003. Weitzman's approach and breed diversity conservation: an application to African cattle breeds. *Conservation Biology*, 17(5): 1299–1311.
- Richards, T. & Jeffrey, S.** 1995. *Hedonic pricing of dairy bulls – an alternative index of genetic merit*. Department of Rural Economy. Project Report 95–04. Faculty of Agriculture, Forestry, and Home Economics. Edmonton, Canada. University of Alberta Edmonton.
- Roosen, J., Fadlaoui, A. & Bertaglia, M.** 2005. Economic evaluation for conservation of farm animal genetic resources. *Journal of Animal Breeding and Genetics*, 122(4): 217–228.
- Scarpa, R., Drucker, A.G., Anderson, S., Ferraes-Ehuan, N., Gómez, V., Risopatrón, C.R. & Rubio-Leonel, O.** 2003a. Valuing genetic resources in peasant economies: the case of 'hairless' Creole pigs in Yucatan. *Ecological Economics*, 45(3): 427–443.
- Scarpa, R., Ruto, E.S.K., Kristjanson, P., Radeny, M., Drucker, A.G. & Rege, J.E.O.** 2003b. Valuing indigenous cattle breeds in Kenya: an empirical comparison of stated and revealed preference value estimates. *Ecological Economics*, 45(3): 409–426.
- Signorello, G. & Pappalardo, G.** 2003. Domestic animal biodiversity conservation: a case study of rural development plans in the European Union. *Ecological Economics*, 45(3): 487–499.
- Simianer, H., Marti, S.B., Gibson, J., Hanotte, O. & Rege, J.E.O.** 2003. An approach to the optimal allocation of conservation funds to minimise loss of genetic diversity between livestock breeds. *Ecological Economics*, 45(3): 377–392.
- Smith, C.** 1984. Genetic aspects of conservation in farm livestock. *Livestock Production Science*, 11(1): 37–48.
- Smith, C.** 1985. Scope for selecting many breeding stocks of possible economic value in the future. *Animal Production*, 41: 403–412.
- Swanson, T.** 1997. *Global action for biodiversity*. London. Earthscan.
- Tano, K., Kamuanga, M., Faminow, M.D. & Swallow, B.** 2003. Using conjoint analysis to estimate farmer's preferences for cattle traits in West Africa. *Ecological Economics*, 45(3): 393–407.
- Weitzman, M.L.** 1993. What to preserve? An application of diversity theory to crane conservation. *The Quarterly Journal of Economics*, 108(1): 157–183.
- Wollny, C.** 2003. The need to conserve farm animal genetic resources through community based management in Africa: should policy-makers be concerned? *Ecological Economics*, 45(3): 341–351.
- Zander, K., Drucker, A.G., Holm-Muller, K. & Mburu, J.** (forthcoming). Costs and constraints of conserving animal genetic resources: The case of Borana cattle in Ethiopia.
- Zambrano, P., Smale, M. & Drucker, A.G.** 2005. *A selected bibliography of economics literature about valuing crop and livestock components of agricultural biodiversity*. SGRP/IFPRI/ILRI.

SECTION F: METHODS FOR CONSERVATION

1 Introduction

Breed development is a dynamic process of genetic change driven by environmental conditions and selection by humans, the latter being shaped by the culture and the economic situation. The fact that ecosystems are dynamic and complex and that human preferences change, has resulted in the evolution of breeds and, until recently, a net increase in diversity over time. However, in the past 100 years there has been a net loss of diversity resulting from an increase in the rate of extinction of breeds and varieties. In Europe and the Caucasus alone, 481 mammalian and 39 avian breeds have already become extinct, and another 624 mammalian and 481 avian breeds are at risk. Losses have been accelerated by rapid intensification of livestock production, a failure to evaluate local breeds, and inappropriate breed replacement or cross-breeding facilitated by the availability of high-performing breeds and reproductive biotechnologies (Box 95).

Box 94

Glossary: conservation

For the purpose of this Report, the following definitions are used:

Conservation of animal genetic resources: refers to all human activities including strategies, plans, policies and actions undertaken to ensure that the diversity of animal genetic resources being maintained to contribute to food and agricultural production and productivity, or to maintain other values of these resources (ecological, cultural) now and in the future.

***In situ* conservation:** refers to conservation of livestock through continued use by livestock keepers in the production system in which the livestock evolved or are now normally found and bred.

***Ex situ in vivo* conservation:** refers to conservation through maintenance of live animal populations not kept under normal management conditions (e.g. zoological parks and in some cases governmental farms) and/or outside of the area in which they evolved or are now normally found.

There is often no clear boundary between *in situ* and *ex situ in vivo* conservation and care must be taken to describe the conservation objectives and the nature of the conservation in each case.

***Ex situ in vitro* conservation:** refers to conservation external to the living animal in an artificial environment, under cryogenic conditions including, *inter alia*, the cryoconservation of embryos, semen, oocytes, somatic cells or tissues having the potential to reconstitute live animals (including animals for gene introgression and synthetic breeds) at a later date.

Box 95**Red Maasai sheep – accelerating threats**

The Red Maasai, renowned for its hardiness and disease resistance, especially its resistance to gastrointestinal parasites, is predominantly kept by Maasai pastoralists, as well as by the neighbouring tribes in the semi-arid regions of Kenya and the United Republic of Tanzania. A number of research projects have demonstrated the breed's resistance to diseases, and high productivity under extremely challenging environments, where other breeds, such as the introduced Dorper perform very poorly. Until the mid-1970s, pure-bred Red Maasai were ubiquitous throughout the pastoral lands of Kenya, probably numbering several million head. In the mid-1970s, a subsidized dissemination programme for Dorper rams was established in Kenya. Widespread indiscriminate cross-breeding followed. No instruction was provided to farmers about how to maintain a continuous cross-breeding programme and many farmers continued crossing their flocks to Dorsers, which subsequently proved unsuitable in many production areas. In 1992, and again more recently, the International Livestock Research Institute undertook an extensive search in Kenya and northern parts of the United Republic of Tanzania, but was only able to locate a very small number of pure-bred animals. The Institute was able to establish a small "pure-bred" flock, but this flock later showed some levels of genetic contamination. The Red Maasai breed is clearly threatened, but the livestock databases DAD-IS and DAGRIS do not identify the breed as threatened, and the breed does not appear in the World Watch List (FAO/UNEP 2000). This is related to the current inability of the systems to document the dilution of breeds.

Provided by John Gibson

While the loss of livestock genetic diversity has greatly increased in recent decades, the extent of the problem has still not been fully evaluated. Information on AnGR provided by FAO member countries is made available to the public in the DAD-IS database. Although a specific call for information on extinct breeds was made in 1999 before compiling the third edition of the World Watch List (FAO/UNEP, 2000), the lists of extinct breeds are probably not complete – uncharacterized local populations in rapidly developing regions of the world may have disappeared without being recorded. Reasons for extinction are either not documented or not readily accessible and, therefore, have not been thoroughly analysed. The risk status of many breeds can only be estimated, as breed population census data are often missing or unreliable. The lack of knowledge hinders concerted actions and the setting of conservation priorities.

2 Arguments for conservation

The ratification of the Convention on Biological Diversity (CBD) by 188 states indicates a growing international commitment to sustain and protect biodiversity. The CBD calls for conservation and sustainable use of all components of biological diversity including those used for agriculture and forestry. Recognizing the importance of genetic level diversity it provides a mandate to conserve genetic resources for food and agriculture. Article 2 specifically recognizes "domesticated and cultivated species" as an important component of global biological diversity.

However, it has been noted that "while a significant international consensus regarding policy has apparently emerged, this consensus is not grounded in a consensually accepted value theory to explain why biodiversity protection, however strongly supported, should be a top priority of environmental policy" (Norton, 2000 in FAO, 2003, p. 105). For example, the argument for maintaining biological diversity for its own sake can be contrasted with the view that in the absence of a clear case for the utility of a breed, its loss should not be of much concern. This chapter presents an overview of the different lines of argument put forward in favour of conservation. The rationale of a conservation programme may include a combination of the following arguments:

2.1 Arguments related to the past

Livestock breeds reflect the cultural and historical identity of the communities that developed them, and have been an integral part of the livelihood and traditions of many societies. Loss of typical breeds, therefore, means a loss of cultural identity for the communities concerned, and the loss of part of the heritage of humanity.

A further argument relates to the fact that breed development, especially in species with longer generation intervals, will often have involved considerable investments in terms of time, financial expenditure and/or institutional resources. Moreover, historical processes may have given rise to unique outputs that could not easily be recreated. According to this point of view, the decision to

abandon such breeds should, therefore, not be taken lightly. There is also a historical dimension to the development of adaptive traits – the longer an animal population has been exposed to an environmental challenge, the greater the possibility that specific adaptive traits have evolved. Areas with climatic extremes or particular disease conditions have given rise to genetically adapted and unique local stocks. These breeds have co-evolved with a particular environment and farming system, and represent an accumulation of both genetic stock, and associated husbandry practices and local knowledge.

2.2 Safeguarding for future needs

“Predicting the future is a risky business at best, particularly where human activities are involved” (Clark, 1995 in Tisdell, 2003, p. 369).

It is notoriously difficult to predict the future, and people’s expectations are highly diverse. Very negative expectations may at times be more related to unsubstantiated fears than to rational arguments. However, a strong case for concern about the loss of AnGR diversity can be put forward: “From a long-term point of view, it is possible that concentration on high yielding environmentally sensitive breeds will create a serious problem for the sustainability of livestock production ... it is possible that farmers will lose their ability to manipulate natural environmental conditions. If all environmentally tolerant breeds are lost in the interim, the level of livestock production could collapse.” (Tisdell, 2003, p. 373). Unforeseen developments may be brought about by changes in the ecosystem, in market demands and associated regulations, by changes in the availability of external inputs, by emerging disease challenges, or by a combination of these factors. Global climate change and the evolution of resistance in pathogens and parasites to chemical control are almost certain to affect future livestock production systems, though the nature of the changes remains unclear (FAO, 1992). The possibility of catastrophic losses of AnGR resulting from major disease epidemics, war, bioterrorism or civil unrest, indicates a need to have a secure reserve, such as a genebank, for breeds that are of great economic importance at present. The uncertainty of future needs, in combination with the irreversible nature of events such as species or breed extinction, highlights the need to safeguard the option value¹⁷ of diversity.

Examples of previously unforeseen needs include the trend among developed-world animal breeders away from production-oriented genetic improvement to focus more on adaptation, disease resistance and feed efficiency. In some developed countries, the importance of conservation grazing has reached an extent that few would have foreseen forty years ago when rare breeds began to be used for this purpose. In the United Kingdom, over 600 conservation sites are grazed (although not all with rare or traditional breeds) and as many as 1 000 sites would benefit from such grazing (Small, 2004). Specific breeds which were once under threat but have now proved to be of economic importance include the Piétrain pig. This very lean breed, which is now used in a large number of commercial cross-breeding programmes, was hardly known outside the Brabant province of Belgium prior to 1950. It almost became extinct during the Second World War when fat animals were in demand (Vergotte de Lantsheere *et al.*, 1974). Another example is the Lleyn sheep breed from Wales, which during the 1960s was in serious decline and had a population size of only 500 pure-bred ewes (Box 96). The breed has become increasingly popular among sheep farmers in the United Kingdom in recent years and its population has grown to over 230 000. The Wiltshire Horn, another British breed that was once in decline, is also attracting interest because of changing market conditions. The breed sheds its wool – a desirable characteristic when shearing costs can exceed the price obtained for the fleece.

Opportunities provided by future developments in biotechnology also need to be considered. Emerging reproductive and genetic technologies already provide greatly increased opportunities to identify and utilize the genetic variation of AnGR, and such technologies are expected to show major advances in future. If diverse AnGR remain available, such technologies should make it possible for developing countries to close the productivity gap with developed countries by selectively combining the best features of different breeds.

¹⁷ The option value of diversity is the value given to safeguarding an asset for the option of using it at a future date.

It is widely accepted that the future option value of AnGR provides a strong reason for conserving AnGR. It is reasonable to assume that changing circumstances and rapidly advancing technologies will require the use of conserved AnGR in the future.

Box 96

Lleyn sheep of Wales – revival in fortunes in tune with modern demands

In the course of the last half century the Lleyn sheep breed of northwest Wales has progressed from the brink of extinction to a breed of widespread national importance in the British sheep industry. Following the Second World War, the breed retreated from the considerable local importance that it had in the first half of the century, and by the 1960s there were a mere seven pure-bred flocks and 500 ewes. In contrast, by 2006 the number of pure breeders exceeds 1 000 spread throughout the United Kingdom, and regional Society sales involve the annual trading of many thousands of Lleyn sheep.

This revival was achieved through the determination and enthusiasm of an initially small group of twelve local breeders and supportive advisers. They set up a breed society in 1970 to coordinate breeding policy, register pure-bred flocks and grade up cross-bred sheep (by repeated backcrossing using Lleyn rams). The chief attributes of the breed from the start were its medium size, mothering ability (in its hey-day it was milked after weaning the lamb) and prolificacy, as well as meat and wool quality. An added attraction for flock biosecurity was the suitability of the Lleyn for “closed flock” operations in which the only animals purchased are top-quality rams.

These attributes were intensified by organized breeding, partly through the operation of a New Zealand-type nucleus group breeding scheme, involving objective recording (Meat and Livestock Commission) and fast generation turnover. The resulting wide appeal of easily handled ewes, convenient for large and small flock owners, coupled with efficient utilization of expensive land, was fostered by the support of the Breed Society. This involved shrewd marketing, with well-organized breed sales and information provision for prospective buyers and member breeders.

Another important element, as the breed rapidly extended its geographical coverage, was the encouragement given to local devolution. Groups or clubs have been formed on a countrywide basis, currently seven clubs in all, although the parent breed society has maintained its coordinating role and its link with the home base in northwest Wales.



Photo credit: David Cragg

Provided by J B Owen

For further information on the breed see: <http://www.lleynsheep.com>

2.3 Arguments related to the present situation

The importance of maintaining threatened AnGR does not necessarily relate only to their potential future use under changed circumstances. There are a number of reasons why the use of these resources may be sub-optimal at present. These reasons fall into three main categories: deficits in information,

market failures and policy distortions (Mendelsohn, 2003). There are large gaps in knowledge regarding the characteristics of local breeds and their traits or genes that may be important for production, research purposes or to meet other human needs (Oldenbroek, 1999). Imperfect information may lead to the overestimation of the performance of a breed within a particular production environment where its introduction is being considered, and hence an inappropriate decision regarding its adoption. It is, of course, also possible that imperfect information could lead to farmers unnecessarily retaining their indigenous breed and not adopting alternative breeds that would improve their livelihoods.

Policy distortions can put less intensive production systems at a disadvantage and provide disincentives for efficient resource allocation. A narrow focus on more productive breeds may be favoured by policies such as subsidized grain imports, free or subsidized support services (e.g. AI) or support prices for livestock products, which stimulate the intensification processes. For example, in some rapidly industrializing Asian countries important capital subsidies have clearly favoured an industrial mode of development; cheap capital has led to investments in large commercial units associated with high input use and uniform products. Furthermore, development or emergency programmes sometimes promote exotic breeds from donor countries. Finally, political instability and policies unfavourable to vulnerable livestock keeping populations may inhibit the efficient use of AnGR (Tisdell, 2003).

Markets may not accurately represent external costs or benefits. Examples of external costs include negative environmental impacts, and undesirable effects on income distribution and equity. External benefits associated with certain breeds may, for example, include their contribution to landscape management. Mendelsohn (2003, p. 10) suggests that: "Conservationists must focus on what the market will not do. They must identify and quantify the potential social benefits of AnGR that have been abandoned by the market."

The preservation of diversity, including within-breed diversity, serves to maintain stability in production systems. Diverse populations show greater ability to survive, produce and reproduce under conditions of fluctuating feed resources and water supply; extremes of temperature, humidity and other climatic factors; and low levels of management (FAO, 1992). There is evidence that they are also less susceptible to catastrophic epidemics (Springbett *et al.*, 2003). In general, genetically uniform populations are less able to respond to strong selection pressures resulting from environmental changes. Maintaining breed diversity enables people to exploit diverse ecological or economic niches. This is particularly the case in marginal and environmentally fragile areas, such as drylands, where most livestock kept by poor farmers are located, and which are characterized by great diversity and high levels of risk.

Arguments for existence and bequest values for AnGR,¹⁸ remove the need to identify tangible or non-tangible benefits as a justification for conservation. "Biological diversity has intrinsic value and should be conserved for its own sake to the maximum extent possible, regardless of whether any given component can be shown to produce tangible economic benefits" (FAO, 2003, p. 104). However, the development of breeds within domesticated species is primarily the product of human intervention to meet human objectives and values. The argument that the current diversity should be preserved on the grounds of its existence value is, therefore, perhaps more difficult to defend than in the case of the biodiversity of natural ecosystems.

Arguments and capacities for conservation vary from region to region. In Western societies, traditions and cultural values are important driving forces which ensure the development of conservation measures for rare breeds and promote the emergence of niche markets for livestock products. By contrast, in the developing world, the immediate concerns are for food security and economic development. However, most developing countries are already in a process of economic evolution, and their economies can be expected to become sufficiently developed to support conservation based on cultural heritage and other such drivers at some point in the future. There is a need to ensure that AnGR are not lost before this self-supporting stage is reached.

¹⁸ The existence value is derived from the satisfaction of knowing that a particular asset exists; a bequest value is the benefit accruing to any individual from the knowledge that others might benefit from the resource in the future.

3 The unit of conservation

A critical first step in the design of AnGR conservation programmes is to decide what is to be conserved. At the molecular genetic level, the genetic diversity present within a livestock species is a reflection of allelic diversity (i.e. differences in DNA sequences) across the 25 000 or so genes (i.e. functional DNA regions) affecting animal development and performance. Conceptually, therefore, the most basic unit of conservation is the allele. An objective might be to design conservation programmes that will both allow maintenance of a preponderance of the alleles that are currently present within a species, as well as providing for the normal accumulation and potential retention of the newly arising mutant alleles which are the fuel for continued animal evolution and improvement. Allelic diversity could, in theory, be quantified by enumeration of the number and frequencies of the various alleles, but for the moment this is an impossible task. In defining the unit of conservation, it must further be recognized that alleles do not act in isolation, and that animal performance in most cases is properly viewed as a result of the interactions of alleles present across the genome. Thus, the process of genetic resource development involves the creation of allelic combinations that support specific desired levels of animal performance and adaptation. Efficient genetic resource conservation, therefore, involves the creation of structures that allow for maintenance of existing genetic combinations of known adaptive or productive value, and for easy access to these combinations to support future animal production needs.

Existing livestock breeds are less genetically uniform than most varieties of crop plants, but nonetheless represent the realization of a diverse set of adaptive processes. The population structure of the major livestock species up to the mid-twentieth century conformed closely to the population structure predicted to maximize evolutionary potential. There were many partially isolated subpopulations (the breeds), maintained under diverse conditions, but with periodic exchange of animals among populations and periodic recombination of breeds to yield new genetic combinations. Thus, adoption of the breed as the unit of conservation is expected to maximize the maintenance of evolutionary potential within livestock species, and likewise to maximize access to a broad array of allelic combinations.

4 Conservation of plant versus animal genetic resources

Organization and implementation of the SoW-AnGR assessment process was based on the lessons learnt from the global assessment of plant genetic resources (PGR) and the resulting Report on the State of the World's Plant Genetic Resources (FAO, 1998a). Accordingly, the SoW-AnGR process focused on both the preparation of the first Report, and the initiation of actions at national level arising from the process of Country Report preparation. Nevertheless, approaches for conservation of PGR cannot be directly applied to AnGR.

In traditional production systems, plant and animal genetic resources are used in comparable ways. Locally adapted breeds and varieties predominate; seed for planting, and breeding animals are drawn from the farmers' fields, herds and flocks, and genetic diversity within resulting landraces is substantial. Most breeding and development activities are "participatory" (FAO, 1998a) in the sense that decisions regarding the seeds to save for planting and the animals to retain for breeding are made by farmers rather than professional plant and animal breeders. However, intensification of agriculture has resulted in important changes in patterns of genetic resource utilization and development. In plants, intensification of crop production has generally been accompanied by emergence of a strongly institutionalized and centralized seed production sector dominated by publicly funded national and international centres, and private firms. In contrast, the intensification of the livestock sector is currently much less advanced, and has been a result of, rather than a prerequisite for, economic development. The animal breeding sector is far less centralized and institutionalized than the plant seed sector, although there has been substantial movement towards centralization in the poultry, pig and, to a more limited extent, dairy cattle sectors. Direct involvement of farmers in animal breeding remains substantial for the other livestock sectors, and AnGR utilization and further development remains strongly "participatory" in certain production environments. The different structures of the

seed and seedstock sectors in plants and animals have important implications for the conservation of global genetic resources.

Table 104 compares a number of biological, operational, and institutional factors that influence conservation activities in plants and animals. Biological differences clearly require different approaches to conservation, but perhaps the most significant difference between the crop and livestock sectors involves institutional capacity for genetic resource management. Many of the institutions of the seed sector already maintain extensive collections of PGR, and actively contribute to the development and release of plant varieties. The databases of the World Information and Early Warning System on Plant Genetic Resources (WIEWS) record the location of over 5.5 million PGR accessions, in some 1 410 *ex situ* collections around the world (FAO, 2004).

Establishing a genebank for animals involves long-term storage of gametes, embryos or somatic cells in liquid nitrogen. Technical aspects of such *in vitro* conservation in animals are discussed in detail below, but costs to collect, cryoconserve and subsequently reconstitute animal germplasm are many times greater per preserved genome than costs to collect, store and subsequently utilize seeds. Moreover, funding to support the conservation of animal germplasm has been insufficient. As a result, AnGR conservation has much more heavily emphasized *in situ* approaches. However, with the exception of a small number of developed countries, there has been little action to establish *in situ* conservation programmes, and the long-term sustainability of such schemes remains uncertain.

DAD-IS lists 4 956 extant mammalian breeds and 1 970 extant avian breeds. Few of these are well represented in *in vitro* collections and almost none have been sampled at levels consistent with FAO (1998b) guidelines for *in vitro* sampling. Very substantial resources would be required to develop *in vitro* collections of even the most endangered of these nearly 7 000 livestock breeds. For example, the FAO (1998b) Guidelines for Management of Small Populations at Risk recommend collection of frozen semen from at least 25 males per breed, and use of semen from these males on an additional 25 females per breed to produce frozen embryos. For cattle, with 300 endangered breeds, cryoconservation of semen from 7 500 males and approximately 100 000 embryos would be required. Policy guidelines for ownership, use and management of *in vitro* collections are yet to be developed.

Table 104
Comparisons of biological, operational, and institutional factors influencing plant and animal genetic resources conservation

| Factor | Plants | Animals |
|---|---|--|
| Economic value of production per individual | Low to very low | Moderate to high |
| Reproductive rate (number of progeny per individual per generation) | High to very high (1000s) | Very low (<10) to moderate (<200) except for males of species (mainly cattle) where widespread use of artificial insemination is feasible (10 000s) |
| Generation interval | 0.25 to 1 year | 1 to 8 years |
| Within-line genetic diversity | Very limited in most plant varieties | Very substantial in most livestock breeds |
| Cost to record performance of an individual or family | Very low to low | High to very high |
| Cost to assess adaptation or disease resistance for an individual or family | Very low to moderate | Very high |
| Ability to conserve diversity of wild relatives under natural conditions | Common for plants | Rare in animal species |
| Ability to self-fertilize and develop inbred lines | Possible and routine in many species | Self-fertilization is not possible; due to depression, high levels of inbreeding have to be avoided; in specific cases inbred lines are used for crossing |
| Clonal propagation | Possible and routine for many species | Technically feasible but too inefficient even for most research purposes |
| Ability to collect germplasm | Simple in most cases | Technically feasible but requires facilities and trained personal |
| Ability to store germplasm <i>in vitro</i> | Seed storage in cool conditions is feasible for most species; a few species require tissue culture; in some cases cultures can be stored in liquid nitrogen | Feasible for male gametes of most species and female gametes of some species; storage of embryos is feasible for most mammalian species, but at much greater cost compared to spermatozoa; material from all species must be stored in liquid nitrogen |
| Requirements for regeneration of stored material | Most require periodic restoration to replenish stored material and maintain viability | Essentially permanent storage |
| Cost of extracting, regenerating, and testing material from a genebank | Relatively easy and with relatively low cost; tens of thousands of accessions are extracted and tested annually | Both regeneration and testing are difficult and time consuming; there has been little experience with the extraction and use of stored material |
| Status and scope of genebanks | Extensive collections at several locations globally include millions of accessions for hundreds of species mainly involving seed storage with relatively low collection and storage costs | Restricted to a small number of developed countries, mainly involving frozen semen |
| Ongoing collection of wild and indigenous germplasm | Lower levels than in past years, but still a significant effort, especially for neglected species | Very little activity, especially in the developing world |
| Institutional support for conservation | Substantial, well-organized, and stable | Limited, often poorly organized, some exception in developed countries |

In the table, “plants” refers specifically to the annual plants that dominate food and agricultural production, but it is recognized that long-lived perennial plants such as trees have significant elements in common with animals. Similarly, “animals” include both relatively fecund species such as chickens, which have some elements in common with plants (e.g. the potential for annual replacement of commercial flocks), and very extensively managed, long-lived species such as the dromedary.

Institutional capacity for AnGR conservation is limited, with only a few national *ex situ* collections existing, mainly in developed countries. Among the institutions of the Consultative Group on International Agricultural Research (CGIAR), only the International Livestock Research Institute (ILRI) and the International Center for Agricultural Research in the Dry Areas (ICARDA) actively address issues of better management of AnGR, and neither institution has an active programme for long-term storage of germplasm. Ownership of AnGR resides almost exclusively in the private sector. A substantial enhancement of global capacity for conservation and better use of AnGR, with new institutional models and collaboration among public institutions and between public institutions and private farmers, may therefore be required if the recommendations of the SoW-AnGR process are to be implemented.

5 Information for conservation decisions

Setting priorities for AnGR conservation requires a process that enables the identification of breeds that contribute most to global genetic diversity and have the greatest potential to contribute to efficient future utilization and further development of that diversity. Additional criteria, such as cultural or heritage values of a breed, will also affect priorities for conservation.

Assessing the likely genetic diversity present in a set of breeds may be based on a variety of criteria, including:

- trait diversity, which is diversity in the recognizable combinations of phenotypic characteristics that define breed identity;
- molecular genetic diversity, based on objective measurements of genetic relationships among breeds at the DNA level; and
- evidence for past genetic isolation as a result of either geographical isolation or of breeding policies and cultural preferences applied in the communities where the breeds were developed.

Trait diversity is based on heritable phenotypic differences among breeds. When breeds are compared under comparable environmental conditions, trait diversity is necessarily indicative of underlying functional genetic diversity. For this reason, breeds that possess unique or distinctive trait combinations should be given high priority for conservation, because their unique phenotypic characteristics necessarily reflect unique underlying genetic combinations. Trait diversity expressed at the level of complex quantitative traits such as disease resistance, milk production or growth rate is generally given higher priority in conservation decisions than trait diversity associated with simply inherited traits such as coat or plumage colour, horn shape or body type. These simply inherited traits can be changed rapidly in response to owner preferences, whereas differences in complex quantitative traits generally involve larger numbers of genes, take longer to change, and therefore have greater potential to reflect underlying genetic diversity.

Direct measures of molecular genetic relationships among breeds are increasingly becoming available and also provide an indication of genetic diversity. These measurements are based on variation in DNA sequences, usually in neutral regions of the DNA that are not thought to influence animal performance or phenotype. For this reason, molecular measures of genetic diversity reflect differences in evolutionary history, but provide only indirect indications of genetic diversity in functional or potentially functional regions of the DNA. Breeds that appear closely related based on allelic frequencies at neutral loci may nonetheless differ importantly at functional loci as a result of divergent selection histories. For example, genetic distance information, derived using few randomly selected genetic markers does not provide information on specific genetic variations such as the double-muscling allele in Belgian Blue cattle, or the dwarf gene in the Dexter (Williams, 2004). For this reason, trait diversity generally warrants first consideration in choosing candidates for conservation.

However, phenotypically similar breeds may evolve as a result of different genetic mechanisms, and measures of molecular genetic diversity can aid the identification of breeds that are superficially similar but genetically distinct. Conservation of genetically unique breeds is, likewise, justified because these breeds are more likely to exhibit functional genetic diversity for traits previously unmeasured or unexpressed, but that may be of future importance in new markets, with exposure to new diseases, or under different production conditions.

Box 97

Decision-making in conservation and utilization – use of genetic diversity data

It is only recently that the value of genetic diversity data in conservation and utilization of AnGR has been recognized and applied. The Global Environment Facility (GEF) is supporting a project on conservation of trypanotolerant cattle, sheep and goats in four West African countries, which started in 2005. In much of the region, the purity of trypanotolerant breeds has been diluted by past cross-breeding with non-trypanotolerant breeds. However, this lack of purity is not immediately obvious in the appearance of the animals. Molecular genetic markers are being used to map the diversity of these breeds and identify the most pure populations which will then be the focus of conservation and further development. Meanwhile, an ongoing International Atomic Energy Agency (IAEA) programme is mapping molecular genetic diversity among Asian sheep and goat breeds. The genetic diversity data will then be combined with phenotype data to identify breeds in which different mechanisms of resistance to the same disease have evolved. These breeds will then be crossed, and molecular genetic markers used to map the genes controlling resistance in order to confirm that different breeds have evolved different mechanisms of resistance. If this is confirmed, these different mechanisms can be used in further genetic improvement programmes.

Provided by John Gibson

Measures of molecular genetic diversity are attractive as a basis for conservation decisions because they yield quantitative measures of relatedness which can, in turn, be used to assess genetic diversity within a set of breeds. In contrast, trait diversity is more difficult to quantify objectively, especially for quantitative traits and for small groups of breeds. Past efforts to quantify phenotypic differences have focused mainly on morphological measures at species or subspecies levels in natural populations. In the absence of widespread access to molecular genetic information, results had value as indicators of evolutionary distance, but are less useful in domestic animals where artificial selection can lead to rapid morphological changes, such as those observed in domestic dogs or fancy poultry. Objective assessment of genetic diversity at functional or potentially functional sites will, thus, require further development of objective methods to combine information on trait and molecular genetic diversity (see Section F: 8).

Historical information or evidence of long-term genetic isolation can be used in the absence of information on trait or molecular genetic diversity, but can also be misleading. Population genetics theory shows that very low levels of movement of animals between seemingly isolated populations can effectively prevent meaningful genetic differentiation. Thus, breeds with a history of genetic isolation are important candidates for careful trait and molecular genetic characterization, but final decisions on genetic uniqueness are better made using more objective tools. It should be recognized, however, that livestock breeds developed as a result of cultural preferences in isolated rural communities may be an important part of community identity and heritage. Conservation of such breeds may merit consideration as part of broader community development efforts, regardless of their predicted value as a unique global genetic resource.

Box 98**Spatial analysis of genetic diversity**

The mapping of molecular genetic information in a Geographic Information System (GIS) allows a spatial analysis of the genetic information. GIS can be used to study spatial structures, distribution and distance of genetic data; to simulate animal population migrations in the landscape; to visualize and analyse geographic population structures; to define diversity zones; to detect areas of genetic differentiation; and to examine the interaction between environment and genetic variants.

The Econogene project (<http://lasig.epfl.ch/projets/econogene/>) was designed to combine molecular genetics with spatial analysis to document the spatial distribution and environmental correlates of genetic diversity among small ruminants in Europe. DNA was sampled from over 3 000 animals spread from Portugal to eastern Turkey. A set of 30 microsatellites, 100 AFLPs and 30 SNPs were assayed on these animals and more than 100 environmental variables were recorded. Geovisualization (GVIS) tools were then used to observe the patterns of physical association between various components of genetic variation and spatially varying environmental factors. Such visualizations led to the development of hypotheses for causative associations between environmental and anthropic factors and genetic variation. For example, the association of alleles of several molecular markers with selected environmental variables was tested. The testing included a set of AFLP molecular markers, which were not related to any specific trait, and a variety of environmental variables (mean temperature, diurnal temperature range, relative humidity, sunshine, ground frost frequency, wet day frequency, wind speed and precipitation). Three AFLP markers were found to be significantly associated with one or more variables, probably pointing to adaptation to a humid environment (e.g. coefficient of variation of precipitation, number of wet days, relative humidity, sunshine and mean diurnal temperature range).

The results were compared with those obtained with the application of a completely independent population genetics method. Two genetic markers were indicated to be under selection by both approaches, validating 31 percent of the significant associations identified by the spatial analysis. These results are particularly encouraging as they seem to validate an approach which is independent of any population genetics model (see Joost, 2005, for further details).

Provided by Paolo Ajmone Marsan and the ECONOGENE Consortium

6 *In vivo* conservation

The term “*in vivo* conservation” describes conservation of live animals and encompasses *in situ* and *ex situ in vivo* conservation methods.

6.1 Background

Conservation of AnGR takes place in a wide variety of contexts, varying in terms of species, breed, geographic region, and farming, social and economic systems. Conservation can also have a wide variety of objectives. Emphasis may be placed on the conservation of genetic resources or diversity *per se*; on the environmental services through which livestock contribute to the conservation of the wider ecosystem; on the socio-economic consequences of conservation; or on the cultural significance of maintaining particular livestock breeds. Approaches to the conservation of AnGR can differ significantly in their capacity to achieve the various conservation objectives, and in terms of their applicability in different contexts.

It is possible to view *in vivo* conservation techniques as subsuming a spectrum of different approaches: at the *in situ* end of the spectrum is the maintenance of breeds within their original production systems, while the extreme *ex situ in vivo* approach is to keep the breeds in zoos. Ranged between the two extremes are: maintaining the species under farm conditions but outside the environment in which they evolved; the maintenance of limited numbers of animals in special-purpose conservation farms, in experimental or educational herds; and keeping breeds for pasture or landscape management within protected areas. Faced with the diversity of potential conservation measures, it is sometimes difficult to make a clear distinction between *in situ* and *ex situ in vivo* approaches. For instance, governmental stations can be considered as applying *in situ* or *ex situ in vivo* conservation methods depending on location and husbandry practices.

There is no single prescription for a successful conservation programme. Numerous breed conservation activities have been undertaken, particularly since the 1980s. However, almost no attempts have been undertaken to analyse adequately the factors underlying the success or failure of *in vivo* conservation programmes. Such analyses are also constrained by the limited availability of data.

6.2 Genetic management of populations

Detailed discussions of many of the requirements for genetic management of populations can be found in Oldenbroek (1999).

Small populations and genetic variation

Whenever breeds are conserved *in vivo*, whether *in situ* or *ex situ*, they should be managed in ways that maintain their genetic variation in the long term. It is well known that a small population size may lead to loss of allelic diversity and an increase in inbreeding. Maintaining sufficient effective population sizes to preserve genetic variation is a central theme of long-term breed management. Apart from increasing the number of animals in the population, management techniques to maintain genetic diversity include maintaining a narrow sex-ratio. This is because even if the number of females in the population is large, high-intensity selection schemes can reduce the number of breeding males considerably, and result in a small effective population size and consequent high inbreeding increments. Another method is to minimize variance in the numbers of progeny produced by individual breeding animals, which reduces the average relationship among the animals available for breeding in the next generation.

The population should also be large enough to allow natural selection to purge deleterious mutations which could otherwise accumulate in the population as a result of genetic drift. It is significant for the management of small breeding populations that there is a threshold effective population size below which the fitness of the population decreases steadily. Based on the most recent estimates of mutation rates, this threshold of effective population size is considered to be between 50 and 100. The minimum population size required will therefore be above 50.

Another possible management technique is the use of cryoconserved genetic material in *in vivo* conservation schemes in order to increase the effective population size. The combined use of molecular genetic and pedigree information has also been proposed. Such techniques, however, require substantial expertise and expense, and may be too costly for many countries. Most of the theoretical and implementation models that have been developed refer to pedigree populations with a high degree of herd and animal management. Such models are likely only to be relevant for a limited number of species in a limited number of countries. Management schemes that can be implemented in populations with limited genealogical information have been developed (Raoul *et al.*, 2004). However, field testing and further methodological development is needed to adapt them to situations with limited organizational capacity and funding.

Selection in local breeds

Breeds are dynamic, undergoing continuous genetic change in response to environmental factors and active selection by livestock keepers. The indigenous breeds of the developing world are rarely subject to modern breeding techniques. However, selection programmes can increase the frequency of genes desirable for the productivity and profitability of local breeds. Such measures will undoubtedly be required if local breeds are to remain a viable livelihood option for the farmers who maintain them. Selection schemes need to take into account the maintenance of genetic variation within the breed and the risks associated with high rates of inbreeding. Traits under selection need to be accurately recorded, and the highest responses to selection result from the use of statistical genetic estimates of breeding value. Controlled breeding, based on estimates of breeding value, result in inbreeding rates two to four times higher than those that result from random selection of parents. However, techniques have been developed to optimize selection so that a suitable balance between inbreeding and genetic improvement can be achieved. Such methods should be of particular advantage in small populations, but there has been little work on how they should best be applied in developing-country situations. As a broad generalization, genetic improvement in local breeds will often involve a greater emphasis on characteristics contributing to low production costs, and the environmental and cultural values of the

associated farming systems.¹⁹ Traits proposed for selection will need to be accurately evaluated for their genetic relationships with traits that determine the conservation value of the breed, so that possible negative effects on key adaptation traits are avoided.

6.3 Self-sustaining strategies for local breeds

The sustainability of a given breed is affected by many factors including: cultural, social and food demand changes; transformation of the food production chain; changes to policies and national and international legal frameworks affecting the importation of germplasm and livestock products; economic development; and technological changes. In most cases, it is a combination of changes in production systems and lack of current economic profitability that plays the major role in the decline of a breed. The question arises: what options are available to halt and reverse the process of breed decline? Possible options for achieving self-sustainability are described below.

Identification and promotion of quality products

Many local breeds are able to provide unique products that may be of a higher quality than those obtained from high-output commercial breeds. Local breeds and their products may also be valued as a characteristic part of traditional farming systems. Moreover, many local breeds have long played a central role in the social and cultural life of rural populations – including religious and civic traditions, folklore, gastronomy, specialized products and handicrafts (Gandini and Villa, 2003).

These characteristics can potentially be a basis for diversified livestock production, and increased profitability for local breeds. Conservation objectives have been promoted both through direct subsidy (see below), and through the promotion of high-value specialized products. The latter approach has been particularly successful in Mediterranean areas, where the diversity of breeds and production systems is still associated with a variety of animal products, food preferences and cultural traditions. Unfortunately, even in this part of the world, it is probable that the majority of such relationships that were present in the mid-nineteenth century have been lost. The strategy is supported by current European certification systems for agricultural products, such as the PDO (Protected Designation of Origin) and the PGI (Protected Geographical Indication), and also by the development of specific commercial brands.

In case of Europe, these conservation efforts are implemented within a highly developed economy that can support diverse high-value products, and actions to support cultural and environmental goals. Opportunities to apply such approaches are likely to be more limited in less-developed economies; but examples do exist, such as the higher price achieved for meat from native Creole pigs in Yucatan, Mexico, and for native chicken meat in several Asian and African countries. As economies develop, the cultural identity of breeds is likely to become more important as an aspect of marketing and as a policy goal, and hence offer greater opportunities for the achievement of breed self-sustainability.

¹⁹ A greater focus on disease resistance, feed efficiency and general adaptation is also being applied to genetic improvement of more commercially oriented breeds, driven by concerns about possible failure of existing disease control measures, Legislated reduction or elimination of the use of antibiotics, and concerns about the costs of external inputs, particularly related to the use of fossil fuels.

Box 99***In situ* conservation of the Norwegian Feral Sheep**

The Norwegian Feral Sheep is a remnant of the sheep populations kept in Norway during the days of the Vikings. In 1995, it was confirmed that the breed was threatened with extinction. There were an estimated 2 000 animals in the country at that time, mostly kept in western Norway.

A few committed individuals, centred on an active and long-established sheep breeding community in Austevoll in the county of Hordaland, decided to try to save the Feral Sheep and develop a niche industry based on the breed. In June 1995, the Norwegian Feral Sheep Association was established. The association is a nationwide, cooperatively managed society with about 300 members. The objectives of the association are to conserve the breed and improve its profitability, by adapting production methods and products to market demands, and by raising public awareness.



Photo credit: Erling Fimland

The association quickly established a set of production standards which had to be met if products were to be certified under the “Feral Sheep” label. These standards include both a breed description, and certain requirements regarding production methods. An important aspect of the association’s producer standards is also to safeguard traditional farming methods, which are a continuation of the way in which Feral Sheep have been kept in Norway for centuries. Requirements specify that the sheep are kept outdoors all year round, and that they have access to a protective shed if there is no natural shelter available. As a rule, the use of feed concentrates is also prohibited. Meat from the Feral Sheep has been welcomed by consumers. The characterful, tasty meat is regarded as a fashionable niche product. Another important aim of the breeding association is to maintain the coastal heathlands and other cultural landscapes. These landscapes, with grazing Feral Sheep, are increasingly popular attractions for tourists.

In 2003, only eight years after the first conservation measures were introduced, the Feral Sheep population exceeded 20 000 animals. Most Feral Sheep are still found in western Norway, but there are initiatives to introduce this special form of sheep farming in the coastal regions of central and northern Norway, as part of the development of rural industries in these areas.

Provided by Erling Fimland

Ecological services

Breeds adapted to local production conditions are often the best suited to provide environmental services such as landscape management, including the stimulation of desired types of vegetation growth, fire or avalanche control, and keeping power line and wildlife corridors free of brush (thereby reducing herbicide use). There may be opportunities even in less-developed economies to sustain a variety of culturally important breeds through ecological and cultural tourism, or other novel approaches to income generation for livestock keepers. An example might be the use of local cattle to maintain healthy ecosystems that promote increased animal density and diversity in large wildlife parks. The challenge is to translate such breed services into economic rewards for the livestock keepers.

Incentive measures

A lack of profitability relative to other breeds, and hence a lack of popularity with farmers, is frequently a reason for the decline of a breed's population numbers. One potential approach to conservation is to offer farmers financial incentives to compensate them for income that they forgo by keeping the less profitable breed. This approach is only feasible where resources are sufficient and there is political will to expend public funds to meet conservation objectives; where breed characterization is sufficient to allow breed populations to be identified and classified according to their risk status; and where the institutional capacity is in place to allow eligible farmers to be identified, to monitor their activities, and to administer payments. It is perhaps not surprising that incentive schemes for breed conservation have largely been restricted to Europe. Schemes have been in place in the EU since 1992 (for a further discussion of EU legislation covering incentive payments see Part 3 – Section E: 3). Such incentives have halted the decline of some, but not all local breeds. A number of national-level schemes have also been put in place, again mostly in Europe (see Box 100 for examples). Even where successful, the longer-term sustainability of such incentive systems is questionable. It seems worthwhile to investigate the use of more specific incentives; in Europe for example, the elimination of milk production quotas for endangered breeds might promote their wider use. In general, economic incentives should be designed to accelerate the achievement of breed self-sustainability rather than merely to provide temporary economic support.

Box 100

Examples of incentive payment schemes at the national level

In the United Kingdom, the Traditional Breeds Incentive scheme run by English Nature (a government nature conservation agency) covers livestock kept at, or adjacent to, sites of special scientific interest (English Nature, 2004). The premise is that traditional breeds are often better adapted to grazing the herbage found at these sites, and thus do a better job where grazing is required for conservation purposes. Here, the objective is broader than simply preserving the breeds *per se*, and the incentive payments to the farmers can be regarded, in part, as payments for the broader environmental services provided.

In Croatia registered breeders of locally-adapted endangered breeds receive state subsidies totalling around US\$650 000 *per annum* (CR Croatia, 2003). Fourteen breeds including Istrian cattle, Slavonian-Podolian cattle, Posavina horse, Murinsulaner horse, Turopolje pig, Black Slavonian pig, Istrian sheep, Ruda sheep, Zagorje turkey and some donkey breeds are covered by the scheme. Similarly, in Serbia and Montenegro, the Department for Animal and Plant Genetic Resources of the Ministry of Agriculture operates a payment scheme for supporting the on-farm conservation of locally adapted breeds of horses, cattle, pigs and sheep (Marczin, 2005).

In Myanmar, population numbers of Shwe Ni Gyi cattle were increased through the provision of subsidized semen, and the payment of a small amount (equivalent to US\$1) to owners when they registered a pure-bred animal (Steane *et al.*, 2002).

Utilization in production systems

Higher productivity resulting from genetic improvement of local breeds can imply higher intensity of management and the need for supporting infrastructure. Conversely, improvement in production systems and infrastructure can stimulate improvement of the local breed and/or the importation of new breeds. Such development can be both an opportunity and threat to the maintenance of local breeds. For example, indiscriminate cross-breeding can be a major threat. However, if properly structured, cross-breeding can lead to maintenance of the local breed, for example, as a highly adapted and efficient dam breed in a recurrent cross-breeding programme. Unfortunately, little is known about how to improve production systems and infrastructure such that the livelihoods of local people are improved and food security is achieved while also conserving indigenous AnGR.

Box 101**An index of economic development potential for targeting *in situ* conservation investments**

The Econogene project combines molecular analysis of biodiversity, with socio-economics and geostatistics in order to address the conservation of sheep and goat genetic resources and rural development in marginal agrosystems across Europe. Samples of genetic material were collected in seventeen countries in Europe and the Near and Middle East. (<http://lasig.epfl.ch/projets/econogene/>)

One of the objectives was to help make expenditure of funds more effective. The project developed an index of development potential, provided as a simple tool that can be used to determine where public money can best be spent to maximize response. Application is possible at different levels: from a single farm up to a region. The index is a weighted sum of three sub-indexes that evaluate, (1) the economic characteristics of the firm/farm (single or average from a region), (2) the social characteristics of the firm/farm, (3) marketing strategies. Each sub-index is based on a variety of inputs. In the case of the Econogene study of EU sheep and goat breeds, the relative weights in the economic development index were 50 percent for the economic dimension, 30 percent for the social dimension, and the remaining 20 percent for marketing strategies. The index does not include environmental factors, such as climatic conditions, availability of agricultural land or pasture, or public administration factors. These factors can affect outcomes when the policy tools are applied, but the index evaluates only the economic potential resulting from the characteristics and behaviour of the private sector.

Provided by Paolo Ajmone Marsan and the ECONOGENE Consortium

6.4 *In situ* versus *ex situ* approaches to *in vivo* conservation

Given the intimate and complex relationships between indigenous communities, environments and livestock, and a widespread lack of breeding services and infrastructure, community-based management of AnGR is seen as a solution (Köhler-Rollefson, 2004), and is widely promoted by NGOs. Certainly, such community-based approaches to conservation seem the preferable option if they support further development of the breed and its ability to enhance livelihoods. Many of the conservation strategies based on high-value products or production services, discussed above, have been built around community-based, *in situ* conservation. It has to be ensured that maintaining local breeds will enhance the short and long-term livelihoods of the communities that keep them. If this is not the case, such strategies will prove unsustainable as the communities will eventually switch to alternative breeds that provide better livelihoods.

Community-based management approaches do exist in the developing world. The example described in Box 102 illustrates that even where traditional production systems are threatened, progress can be made towards the achievement of goals such as, managing communal grazing areas, improving genetic resources and strengthening social development. However, the example from Nepal (Box 103) shows that as production conditions change, the introduction of imported genetic resources can sometimes be a viable option for small-scale livestock keepers. While in this case the livelihoods of the farmers have been improved, the local buffalo genetic resources are no longer being utilized. The example illustrates that achieving strategies that simultaneously improve livelihoods and achieve conservation objectives will often be a challenge.

Box 102**Community-based *in situ* conservation programme – a case from Patagonia**

Photo credit: María Rosa Lanari

Neuquén criollo goats are the main source of income and animal protein for many households in the north of Neuquén province in Argentine Patagonia. The goats are well adapted to the transhumant movements which have traditionally shaped the lives of the goat keepers or *crianceros*. The sustainability of the system is, however, threatened by changes restricting livestock movements, notably the fencing of traditional grazing areas. Prospects of education, employment and better housing offered by more urbanized lives also promote sedentization. Attempts during the 1980s to introduce Angora and Anglo-Nubian goats for fibre and milk production proved unsuccessful because of the harsh environment. Nonetheless, indiscriminate cross-breeding poses a threat to the local genetic resources.

A programme for the conservation and improvement of the Neuquén criollo goat was established in 2001 under the auspices of the Instituto Nacional de Tecnología Agropecuaria (INTA) and the provincial Agricultural Bureau. Organizational and technological innovations which promote the continuance of the traditional system under changed circumstances have been introduced. The goat keepers have been involved in the programme since its inception through the establishment of producers' associations which play a leading role in the development and diffusion of new technologies.

./..

.../.

Genetic improvement work is oriented towards conserving the breed's genetic variability, hardiness and productive efficiency within the framework of the traditional system. The programme is developing a system for providing improved strains of local ecotypes based on selection criteria proposed by the *crianceros* themselves. Preferences are for large but compact animals that provide good meat yield and can withstand extreme environments. The *crianceros* also pay attention to does' suitability for breeding and kidding. A preference for white goats is related to the marketing of the hair. Conversely, goats with coloured coats are considered easier to manage in snow-covered pastures. This preference is strongest in areas where snow lies longest. Further developments include measures to increase the value of goat products. Kid meat is now sold under a distinct "geographical indication". This commercial-legal innovation enhances the profitability of the traditional product of the system. A newer undertaking for the goat keepers is the harvesting of cashmere. Recent studies of the fibre from the breed have revealed the potential of this product. The *crianceros* have been provided with combs and trained to harvest and classify the fibre.

The aim is, thus, to forestall the breed's genetic dilution as part of integrated efforts to preserve the underlying production system. The goat breed, the local environment, the culture and traditional practices of the *crianceros* are regarded as valuable assets that can be used to enhance the development of this rural area.

Provided by Maria Rosa Lanari

For further information see FAO (2007a)

Box 103

Changes in production systems leading to replacement of local buffaloes – a case from Nepal

Parcelling out of available grazing land as a result of population growth has had a large impact on traditional livestock farming systems in the Mid-Hills of Nepal. Rural households with access to growing urban markets have replaced low-yielding local cattle and buffaloes with high-yielding dairy buffaloes that can be stall-fed. In less than 30 years, more than 95 percent of farm households in the study area have replaced their local cattle and Lime buffaloes with one to three high-yielding Murah milk buffaloes from the Indian lowlands. About 65 percent of households buy new animals in lactation each year, selling the dry ones for rebreeding or meat. The imported buffaloes are bred in the Indian lowlands, and selected by Indian traders, who transport them to the highlands of Nepal and purchase the dry animals. These private traders have played a much more important part than the government in promoting the utilization of higher-yielding animals. The local buffalo and cattle breeds will remain important in more remote rural areas where they continue to provide draft power and give enough milk for family subsistence.

Initial obstacles to managing the newly introduced breed have been overcome, and farmers no longer wish to return to using the local animals. Farmers have kept improved buffaloes successfully on a prolonged basis, and have been rewarded with an improved standard of living. Their priority now is to further develop breeding strategies for the Murah buffaloes to achieve even better productivity. This requires collaboration between the breeders of Nepal and India.

Socio-economic changes led farmers to abandon traditional farming practices and to seek alternatives. The new management strategies have provided higher economic returns, and farmers have come to favour an introduced breed over their local animals. This case study shows that as production conditions change, new breeds with different characteristics sometimes provide farmers with a better livelihood option than local breeds.

Provided by Kim-Anh Tempelman

For further information see FAO (2007b)

Although *in situ* conservation is the most frequently adopted conservation method in Europe, there are also several examples of *ex situ in vivo* conservation programmes, in farm parks and in a few cases in zoos. In the United Kingdom there are currently 17 Rare Breeds Survival Trust Approved Centres²⁰. One such farm, the Cotswold Farm Park²¹, attracts over 100 000 visitors annually. In Germany, Falge (1996) reported 124 institutions maintaining animals of 187 breeds and nine livestock species. Similar institutions exist in many other parts of Europe, for example, in Italy, France and Spain, and also in North America. A particularly valuable role of farm parks is that they contribute to public awareness of AnGR conservation. For some species, such as poultry, enthusiastic hobby-breeder organizations play a role in conserving local breeds. The first example of a protected area focused on rare domestic breeds was in Hungary, where native breeds are conserved on the Puszta (an area of grassy wetlands and plains in eastern part of the country). Such schemes are now found in other parts of Europe and elsewhere.

In the developing world, the most commonly observed *ex situ in vivo* conservation activities are in herds or flocks maintained by state-owned institutions. The evidence provided by the Country Reports

²⁰ http://www.rbst.org.uk/html/approved_centres.html

²¹ <http://www.cotswoldfarmpark.co.uk>

suggests that there is insufficient information to determine how sustainable such conservation programmes will be. It seems that virtually all *ex situ in vivo* conservation in the developing world is used to support ongoing use of the AnGR by farmers – raising the question of whether *ex situ in vivo* conservation is likely to be a viable approach to conservation of AnGR that are no longer in current use. There is very clearly a need to develop a far greater understanding of how to design and implement sustainable *in vivo* conservation, particularly in the developing world.

7 Current status and future prospects for cryoconservation

From the early development of AI in the mid-1940s to the most recent potential offered by DNA storage and transfer, reproductive biotechnologies have been instrumental in the transfer of genetic material *in vivo* and *in vitro*. The techniques that are currently accessible and economically feasible for *in vitro* conservation of AnGR are those for cryoconservation of reproductive cells, embryos and tissues. Materials conserved using these techniques may preserve their liveability and functional state for decades or even centuries. However, because of the relatively short period during which the technologies have been in existence, a precise evaluation of this putative longevity remains to be established. More recent biotechnologies, including cloning, transgenesis and transfer of somatic material, have great potential for future applications in AnGR conservation, but at present they are only accessible to a few laboratories. The low reliability and extremely high costs of these technologies are two factors likely to limit their use in AnGR conservation in the coming years. This chapter, therefore, focuses primarily on current state-of-the-art reproductive biotechnologies that are economically and technically accessible in most geographical areas. Previously published documents such as the “Guidelines for development of national farm animal genetic resources management plans” (FAO, 1998c) and “Guidelines for the constitution of national cryoconservation programmes for farm animals” (ERFP, 2003) provide more details about applications.

7.1 Gametes

Semen

Semen from all mammalian livestock species has been successfully frozen in past years, as has semen from some poultry species (chickens, geese). Freezing procedures for semen cryoconservation are species-specific, but the general procedures are as follows:

- following collection, semen is diluted in a suitable ionic (salt) or non-ionic (sugar) solution adjusted to near physiological osmolarity;
- suitable cryoprotectant is added – glycerol is most commonly used, but Dimethyl Sulfoxide (DMSO), Dimethylacetamide (DMA) or Dimethylformamide (DMF) are, depending on the species, of high practical interest;
- diluted semen is cooled, sampled and then frozen in liquid nitrogen (-196 °C);
- individual semen doses are generally frozen in straws rather than pellets to guarantee optimal sanitary conditions and permanent identification of each dose.

Following AI with frozen and thawed semen, global conception rates average 50–65 percent in more than 110 million yearly first-service inseminations in cattle; 70–80 percent in more than 40 million inseminations in pigs; 50–80 percent (intrauterine) or 55–65 percent (cervical) in more than 120 000 inseminations in goats; 50–80 percent (intrauterine) or 55–60 percent (cervical) in more than 50 000 inseminations in sheep; and 35–40 percent in more than 5 000 inseminations in horses (Ericksson *et al.*, 2002; Thibier, 2005; G. Decuadro, personal communication, 2005). Results in chickens reveal large between and within-breed variability in the range of 10–90 percent (Brillard and Blesbois, 2003).

The number of semen doses that need to be stored is a function of the number of doses required per parturition or hatching, the expected lifetime production of fertile refounder females, and the number of males and females desired in the reconstructed population. Where semen is used to reconstruct breeds by backcrossing, some percentage of the genes from the female population used in the

backcross will remain in the reconstructed breed. For example, five generations of backcrossing are needed to obtain animals carrying over 95 percent of the genotype of the breed restored from the frozen semen. Sufficient semen must be stored to produce the number of backcross generations required. In avian species in which females bear ZW heterochromosomes (males are ZZ), genes carried by the W chromosome cannot be transferred through standard semen cryoconservation. Moreover, in all species, some cytoplasmic effects of the donor breed may be lost or altered. Notwithstanding these limitations, this technique should be seen as playing a predominant role in the *ex situ in vitro* conservation of AnGR, because of the availability of advanced and reliable technology and the ease of application. However, if the number of doses available per male is low or if the number of females that can be obtained per dam is low, then the re-establishment of the breed via embryo transfer is, where possible, more desirable as a means of ensuring full recovery of the initial genes.

Oocytes

In the case of birds, despite interesting technical developments, hatched chicks have not yet been successfully obtained from eggs that have been frozen and thawed. This is, in part, because of the huge amount of lipid present in the vitellus. In contrast, embryos from some mammalian livestock species can be produced *in vitro* from matured oocytes collected at slaughter or from live females by ovum pick-up. Such oocytes can be frozen for prolonged periods prior to *in vitro* fertilization (IVF) to produce embryos. Two methods of freezing can be distinguished based on the rapidity of the freezing procedures. Slow-freezing procedures are currently feasible in cattle and potentially applicable in sheep and goats, but success rates in obtaining progeny remain extremely low (less than 10 percent). In part, this is a result of the limited success rate of embryo transfer, and high embryo mortality following fertilization. Moreover, such techniques, which require oocyte maturation prior to IVF, must be performed by highly qualified technicians. Ultra-rapid freezing procedures, also called vitrification, are currently developed experimentally to limit damage to the oocyte resulting from chilling injuries or the toxicity of cryoprotectants. Most protocols use high concentrations of cryoprotectants and sugars to remove water from the cells. This limits intracellular ice formation and, therefore prevents ice injuries to the oocyte. Promising results have been obtained in cattle. However, working procedures which would make the cryoconservation of oocytes useful for the preservation of AnGR remain to be validated on a large scale.

7.2 Embryos

In contrast to avian species, embryos of virtually all mammals can be successfully frozen, thawed and then transferred into recipient females to produce progeny. Currently, however, widespread use of embryo cryoconservation is limited to cattle, sheep and goats. Embryo collection in pigs requires the sacrifice of the female, and the procedure remains experimental in equine species. A number of factors including the method of embryo collection (biopsied, produced *in vitro*, or cloned), and stage of maturation, greatly affect the probability of obtaining live progeny. A variety of protocols to freeze and thaw embryos from livestock have been proposed, and as in the case of oocytes, they can be classified into two major categories based on the rapidity of freezing procedures.

In slow freezing approaches, equilibration of cryoprotectants and solutes between the medium surrounding the embryo and its intracellular compartments occurs slowly, thus limiting the risks of membrane rupture due to intracellular ice formation. Upon thawing, embryos are transferred into recipient females with or without removal of the cryoprotectant. Internationally, such techniques are at present the most commonly used in cattle, sheep and goats. Success rates at parturition vary depending on the species, genetic origin, source (*in vivo* or *in vitro*), and stage of development of the embryos. Embryos cryoconserved at an early stage of their development result in lower parturition rates than embryos cryoconserved at a more advanced stage (Massip, 2001).

Fast freezing (vitrification) techniques involve ultra-rapid cooling and freezing of embryos in a very small amount of suspending medium in which cryoprotectant and other solutes (sugars) are generally at high concentrations. Embryos from several mammalian species (cattle, sheep and goats) have been successfully vitrified and transferred. Survival rates of 59 and 64 percent have been observed in sheep

and goat embryos, respectively, using the so-called pulled-straw vitrification technique (Cognié *et al.*, 2003).

Embryo preservation techniques are of particular interest with respect to the cryoconservation of AnGR because they allow full recovery of the initial genome. Slow freezing rates require expensive programmable freezers, but offer more flexibility to untrained technicians because of the relatively long intervals between the two steps of the procedure. In contrast, vitrification requires only limited equipment, but highly trained technicians.

7.3 Cryoconservation of somatic cells and somatic cell cloning

Since the creation of Dolly the sheep, the first animal created by cloning of somatic cells, the technology has been shown to work for most mammals in which it has been tested. However, it has not been applied successfully in birds. The current state of the technology is costly, with extremely low success rates. If reconstitution of live animals from somatic cells is developed to the point where it becomes both reliable and cheap, preservation of somatic cells would become an attractive option for cryoconservation of AnGR. Its main advantage would be that it would be possible to choose exactly which animals to conserve, and later to reconstitute a population of clones of these animals. Unlike in the case of preserved embryos, the cytoplasmic DNA is not preserved in animals derived from somatic cells. Collection of somatic cells is, however, far simpler than collection of embryos, and it would be feasible to collect samples extensively from field populations. The current costs of developing somatic cell cultures, and uncertainty about future prospects for producing live animals from the preserved cells, mean that somatic-cell conservation is unlikely to be a priority in species where cryoconservation of gametes and embryos is well developed. However, cryoconservation of somatic cells would be a prudent back up where cryoconservation of gametes and embryos is not feasible or has low success rates.

Table 105 provides an overview of the feasibility of the above-discussed techniques in the major livestock species.

Table 105
Current status of cryoconservation techniques by species

| Species | Semen | Oocytes | Embryos | Somatic Cells |
|---------|-------|---------|---------|---------------|
| Cattle | + | + | + | + |
| Sheep | + | 0* | + | 0 |
| Goat | + | 0 | + | 0 |
| Horse | + | 0 | 0 | 0 |
| Pig | + | 0 | 0 | 0 |
| Rabbit | + | 0 | + | 0 |
| Chicken | + | - | - | - |

+ routine techniques available; 0 positive research results; - not feasible in the current state of art; * cryoconservation of the whole ovary

Box 104**Revival of the native Red and White Friesian cattle in the Netherlands**

In 1800, the cattle population in the province of Friesland consisted mainly of Red Pied cattle. Many red ancestors were imported from Denmark and Germany after widespread losses caused by rinderpest. Since 1879, the Friesian Cattle herd book had registered a Red and White phenotype, but pushed by export markets, black and white animals progressively became more popular than the original red and white. In 1970, only 50 farmers owning a total of 2 500 cattle joined the Association of Red and White Friesian Cattle Breeders. Within a short period, the sustained import of Holstein-Friesians from United States of America and Canada resulted in a further decline of the population, so that only 21 Red and White individuals (4 males and 17 females) were remaining in 1993. A group of owners started the Foundation for Native Red and White Friesian Cattle. In collaboration with the newly created Genebank for Animals, a breeding programme was developed. Semen from sires preserved in the genebank in the 1970s and 1980s was used to breed females under a contract system. Male progeny were raised by breeders, who were granted a subsidy from the genebank. Semen from these males was collected, frozen and later used under new contracts. The breed increased in number, reaching 256 registered living females and 12 living males in 2004. Currently, a total of 11 780 semen doses from 43 bulls are stored in the genebank and kept available for AI. The majority of cows are raised by hobbyists for milk production.

Provided by Kor Oldenbroek

Box 105**Revival of the Enderby cattle in New Zealand**

The case of the Enderby Island cattle illustrates that it is possible to resurrect breeds from extremely limited genetic material. However, it also shows that the process is complicated and requires a lot of time and resources.

Enderby is a small island situated 320 kilometres to the south of New Zealand. Cattle were first brought to the island in 1894, when one W.J. Moffett of Invercargill took up a pastoral lease and landed nine shorthorns. By the 1930s, farming on the island had been abandoned, but the cattle remained as a feral herd. After 100 years surviving Enderby's harsh climate and a diet of scrub and seaweed, the cattle were hardy, small, stocky and well adapted. In 1991, to help preserve the local wildlife, the Enderby cattle were shot. Sperm and oocytes from the dead animals were collected for cryoconservation, but attempts to fertilize the oocytes failed and it appeared that the Enderby breed had been wiped out forever.

The following year, members of the New Zealand Rare Breeds Conservation Society (NZRBCS), discovered a cow and a calf on the island. The animals were captured by helicopter and shipped to New Zealand. The subsequent death of the calf meant that "Lady", as the cow became known, was the last of the Enderby cattle. Attempts to produce a calf, through artificial insemination and MOET, using the cryoconserved semen taken from the bulls killed on the island, did not prove successful. Again it appeared that the breed faced extinction. However, in 1997 NZRBCS in collaboration with AgResearch successfully produced a calf, Elsie, cloned from a sample of Lady's somatic cells. Four more cloned heifers were born the following year. Meanwhile, efforts to produce an Enderby bull through *in vitro* fertilization using the cryoconserved semen and oocytes taken from Lady had also proved successful, with the birth of "Derby". Two of the clones later died, but in 2002 two more Enderby calves were born through natural mating of the cloned heifers and Derby.

For more details see Historical Timeline of the Auckland Islands; NZRBCS, (2002); Wells, (2004)

7.4 Choice of genetic material

Techniques to cryoconserve gametes and embryos are, extensively used for commercial purposes in most domesticated mammals; there are a few exceptions such as transfer of frozen embryos in equines and pigs (Thibier, 2004). In the case of cryoconservation programmes devoted to AnGR management, one major issue is to store sufficient biological material to allow the reconstruction of individual animals or populations bearing the desired traits. The choice of donor origin, number of donor individuals and type of material to be cryoconserved are, therefore, crucial if investments are to be of long-term benefit. Useful recommendations regarding these matters are available from the following sources: Blackburn (2004), ERF (2003) and Danchin-Burge *et al.* (2002).

7.5 Security in genebanks

Genebanks for AnGR germplasm must provide technically secure storage and meet strict zoosanitary requirements.

Technical security

Loss of liquid nitrogen for any period of time (literally minutes) can lead to complete loss of the cryoconserved material. Storage of cryoconserved materials in two separate containers, and preferably two separate locations, limits the risk of losses resulting from accidental failure to maintain liquid nitrogen.

Biosecurity

Materials of animal origin including fluids, gametes and embryos may carry pathogens capable of surviving cryoconservation. While additional research is needed to further assess risks of transmission through genebanking, biosecurity recommendations provided by the Terrestrial Animal Health Code of the World Organization for Animal Health (OIE) are universally applicable. Meeting the requirements of the code presents severe difficulties for many countries. It makes movement of germplasm from disease-affected to disease-free areas extremely difficult. It can also mean that samples that do not meet the code's requirements cannot be stored in the same facility as samples that do. Such issues could provide a substantial obstacle to the establishment of national, regional and international cryoconservation banks. Special structures and possibly some special exemptions to existing codes will be required.

8 Resource allocation strategies in conservation

8.1 Methods for setting priorities

A clear definition of objectives is crucial for all conservation activities. One criterion that will often be considered important is the preservation of genetic diversity. However, conserving as much diversity as possible will rarely be the sole objective. Other factors such as conservation of certain special traits (e.g. disease tolerance), and ecological or cultural values of breeds, also have to be taken into account. The objective is, therefore, to maximize the utility of a set of breeds, where utility is a weighted combination of measures of diversity and other traits/values. Definition of weights requires the valuation of diversity relative to the other criteria considered.

Another important consideration is the degree of endangerment of the breeds in question. This can be quantified in the form of an extinction probability. The parameter is mainly determined by the effective population size, and the demographic trend (i.e. whether the population size is increasing or decreasing), but should also take into account other factors such as geographic distribution, implementation of breeding programmes, specific ecological, cultural or religious functions, and risk from external threats (Reist-Marti *et al.*, 2003).

Various methods for combining different criteria have been proposed for prioritizing breeds to be targeted by conservation programmes. Ruane (2000), for example, proposed a method to be followed by a group of experts identifying breed priorities at the national level. The following seven criteria are included in the framework:

- species (i.e. breeds from which species are to be included in the priority setting exercise?);
- degree of endangerment;
- traits of current economic value;
- special landscape values;
- traits of current scientific value;
- cultural and historic value; and

genetic uniqueness.

It is suggested that breeds with high degrees of endangerment should be given priority. If it is necessary to prioritize among highly endangered breeds, it is then suggested that the extent to which the breeds meet the other listed criteria should be taken into account. It may be necessary to assign weights to the various criteria in order to allow further differentiation of priority ranks. The relative importance to be given to each criterion would be decided by the expert group.

Hall (2004) put forward a framework based on both genetic and functional diversity, using British and Irish breeds of sheep and cattle as an example. Each breed under consideration was compared to every other breed in terms of functional and genetic distinctiveness. The genetic component was assessed on the basis of the history of the breed and the likelihood of significant gene flow within the last 200 years. The functional component related to the economic, social and cultural functions of the breed. In cattle, functional distinctiveness was assessed subjectively, but this was more difficult to do in the case of sheep. As such, mean fibre fineness, almost the only parameter that had been measured in a comparable way across the breeds in the study, was used as an indicator of functional distinctiveness in sheep breeds. Breeds that scored highly both for functional and genetic distinctiveness were considered to be the most appropriate for inclusion in a list of priorities.

The Rare Breeds Survival Trust in the United Kingdom has also established a set of criteria for recognition of “rare breeds” which require special attention in terms of conservation measures (Mansbridge, 2004). The length of time for which a breed has existed, the number of female animals, and the breed’s geographical distribution are taken into account.

8.2 Optimization strategies for planning conservation programmes

Efficient conservation programmes should use available monetary or non-monetary resources in such a way that the conservation objective is maximized. The questions to be answered are:

- For which breeds within the species under consideration should conservation programmes be implemented?
- What share of the total conservation budget should be allocated to each of the chosen breeds?
- Which conservation programmes should be implemented for any chosen breed?

If it is assumed that the objective of the conservation measures being considered is to conserve as much genetic diversity between breeds as possible, then the following method may be used to identify priority breeds (Simianer, 2002).

The total diversity of an existing set of breeds can be calculated, as can the contribution of each breed to the total diversity. Extinction probabilities and the diversity of different subsets of breeds are used to calculate what is referred to as the “expected diversity” (Box 106). This is the diversity expected at the end of the planning horizon assuming that no conservation activities are undertaken. It may happen that at the end of the planning horizon some of the most endangered breeds will have become extinct. If, however, conservation efforts are undertaken, the extinction probability of breeds will be reduced and the expected diversity will increase. The amount of change in the expected diversity as a function of the change in the extinction probability of a particular breed is referred to as the breed’s “marginal diversity”. This marginal diversity reflects the breed’s phylogenetic position. It also indicates whether closely related breeds are safe from extinction, but is independent of the breed’s own extinction probability.

The conservation priority of a breed has been shown to be proportional to its “diversity conservation potential” (Box 106) – a measure which reflects the additional amount of diversity that would be conserved if a breed were made completely safe from extinction. A high conservation potential can either result from a high degree of endangerment, or from a high marginal diversity.

The parameters discussed here (marginal diversity, conservation potential etc.) are elements of the general diversity theory put forward by Weitzman (1992; 1993), which has attracted considerable interest as a framework for decision-making in livestock conservation. The approach does not require

that Weitzman's diversity metric, which is diversity between breeds, is the quantity maximized. The methodology can be applied to any objective function, including more comprehensive diversity metrics or utilities (in the sense of a weighted sum of a diversity component and other values).

Box 106

Glossary: objective decision aids

Diversity: numeric quantification of the amount of genetic variability in a set of breeds, ideally covering both the diversity within and between breeds.

Utility: numeric quantification of the total value of a set of breeds, e.g. a weighted sum of diversity and various economic value components.

Diversity contribution: the amount that the existence of a breed contributes to the diversity of the whole set of breeds.

Extinction probability: the probability that a breed becomes extinct within a defined planning horizon (often 50 to 100 years). The extinction probability can take values between 0 (breed is completely safe) and 1 (extinction is certain).

Expected diversity: the projection of the actual diversity to the end of a planning horizon, combining the actual diversity with extinction probabilities. The expected diversity reflects the amount of diversity to be expected if no conservation efforts are made.

Marginal diversity: reflects the change of expected diversity of the total set of breeds if the extinction probability of a breed is modified (e.g. through conservation measures).

Diversity conservation potential: a quantity proportional to the product of the marginal diversity and the extinction probability. This parameter approximately reflects how much the expected diversity can be increased if a breed is made completely safe. Weitzman (1993) suggested that this measure is the "single most useful [breed] alert indicator".

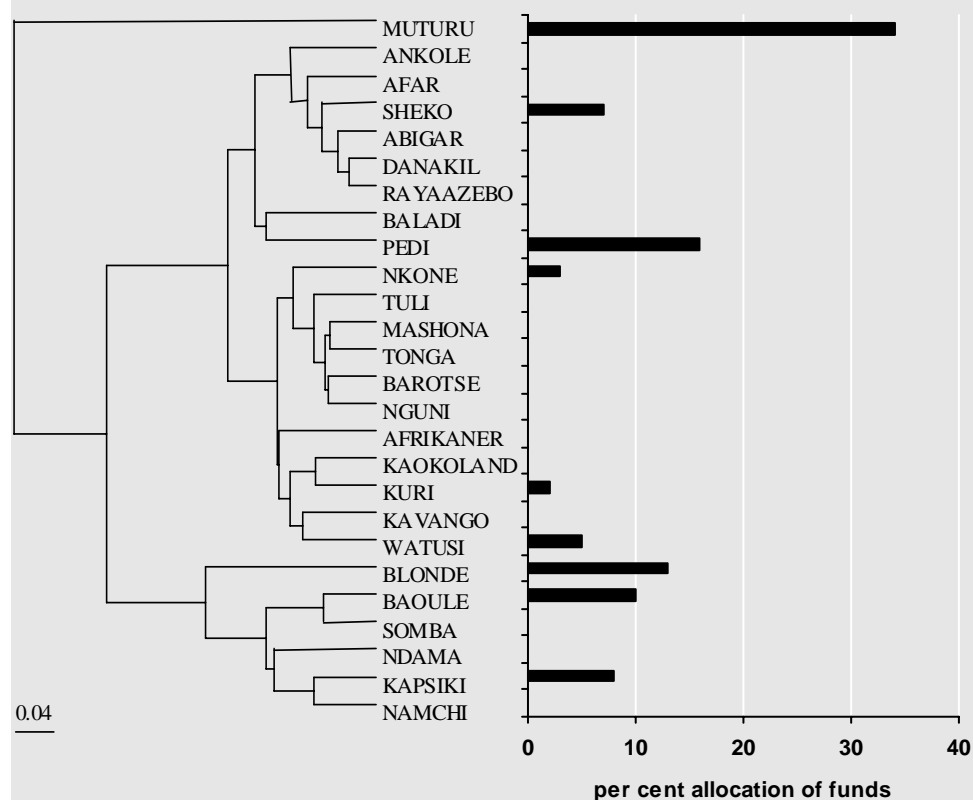
If utility rather than diversity is to be maximized, "utility contribution", "expected utility", "marginal utility" and "utility conservation potential" are the relevant terms, and the word "diversity" in the above definitions should be replaced by "utility."

Source: adapted from Simianer (2005)

Box 107 describes an example in which an optimum allocation of conservation funds could increase cost efficiency by almost 60 percent compared to that achieved using simplistic approaches.

Box 107**Optimum allocation of conservation funds – an example featuring African cattle breeds**

Simianer (2002) illustrated the application of an optimum allocation scheme to a set of 26 African taurine and Sanga cattle breeds for which estimates of genetic distances (based on 15 microsatellites) and extinction probabilities had been calculated. Using the extinction probabilities, the expected loss of diversity in the absence of conservation over the assumed planning horizon of 50 years was estimated to be 43.6 percent of the current diversity. It was assumed that a conservation budget was available which, if allocated equally across all breeds, would prevent 10 percent of the expected loss of diversity. If this same total budget is allocated to the conservation of only the three most endangered breeds, the diversity conserved decreases slightly to 9 percent of the expected loss, and so is 10 percent less efficient than allocating funds equally across breeds. With an optimum allocation scheme based on Weitzman's diversity concept, 10 of the 26 breeds receive funds, with 34 percent of the funds being used for Muturu and only 2 percent for Kuri (see figure).



With the optimum allocation strategy, the expected loss of diversity is reduced by 15.7 per cent. This is 57 percent more efficient than allocating funds equally across breeds. The same impact on diversity as the uniform allocation strategy could be achieved with an optimum allocation of only 52 percent of the available funds. The example illustrates that optimum allocation can substantially increase the efficiency of use of conservation funds.

Provided by Henner Simianer

Defining conservation priorities by ranking breeds according to their conservation potential assumes that conservation costs are roughly identical between breeds. More precisely, the assumption is that opportunity costs for the reduction of the extinction probability by one unit are uniform across breeds. This of course is not true: reducing the extinction probability from, say, 0.8 to 0.7 (i.e. by 12.5 percent) can be achieved by relatively simple means and is much cheaper than reducing the extinction probability from 0.2 to 0.1 (i.e. by 50 percent).

For a more detailed and realistic analysis it is necessary to define the cost of particular conservation activities (e.g. establishing cryoconservation, or giving subsidies to farmers to maintain an *in situ* population of a breed at risk), and also to assess the effect of such activities in terms of a reduction in the extinction probability of the respective breed. If allocation of resources is undertaken in an international context, different cost levels, technical standards, and currency exchange rates need to be taken into account: it may well be the case that cryoconservation is established as a routine application

in one country, while in another country, the required infrastructure would first have to be developed. Another consideration is that labour costs for *in vivo* conservation schemes may differ substantially between countries.

A conservation scheme always has a number of costs which will vary markedly between species and countries. The fixed costs are those required to establish and run the scheme as such (e.g. establishing a cryoconservation centre), while variable costs depend on the number of animals included and the type of genetic material (semen, oocytes or embryos) conserved in the scheme. Different conservation schemes vary in terms of the level of the fixed cost and the variable cost per genetic unit conserved. If this cost structure can be modelled with sufficient accuracy, optimum allocation schemes will not only assign a share of the conservation budget to a certain breed, but will also indicate which of the available conservation techniques will be most cost effective for this breed.

Since optimum allocation procedures are based on mathematical optimization, it is relatively simple to include certain restrictions or side conditions. This could relate to geographic balance, i.e. require that conservation activities are implemented in all parts of the target region. It could also force the optimum solution to avoid the loss of certain special traits by putting a high penalty on solutions in which, for example, all trypanotolerant cattle breeds become extinct.

Other strategies to find the optimum pattern of resource allocation are restricted to more specific decision-making problems. Eding *et al.* (2002) suggested the selection of a so-called core set of breeds based on marker estimated kinships. A core set can be thought of as a live or cryoconserved mixed population, which is constituted of various proportions of different breeds. The breed contributions to the core set are derived in such a way, that the expected diversity of the total core set is maximized. The advantage of this approach is that it combines between and within-breed diversity. However, it does not take into account the degree of risk faced by particular breeds, which limits its usefulness to special cases of decision-making, such as finding the optimum design for a cryoconservation programme with limited storage capacity.

Resource allocation for the efficient conservation of AnGR diversity requires good information on the phylogenetic substructure of a species, on factors affecting the degree of threat faced by the breeds considered, and on any special values that the breeds may have. A substantial knowledge of potential conservation programmes, including their costs, is also required. The more complete and reliable this information, the more cost-effective the design of the optimum conservation programme will be. Further work is required to resolve the question of what are the most appropriate factors to be optimized in conservation efforts, because use of different factors may lead to different conservation decisions. Substantial further work is also required to develop tools that will assist the maximization of a diverse range of measures of diversity and utility.

Final decisions on investments in conservation will be driven by many economic, social and political factors. Thus, the decision-aids described above should be regarded as tools to allow decision-makers a better understanding of the consequences of alternative investment strategies for conservation.

9 Conclusions

Traditions and cultural values are important driving forces for conservation in Western societies, and are also becoming increasingly important in some developing countries. Another strong motivation that is shared by many stakeholders is safeguarding as much diversity as possible for an unpredictable future.

Conceptually, the most basic unit of diversity is the allele, and thus, from a scientific point of view, one definition of maintaining genetic diversity could be considered to be maintaining high allelic diversity. This would avoid the problems associated with scientifically defining a breed. At present, however, molecular measures of genetic diversity provide only indirect indications of genetic diversity in functional or potentially functional regions of the DNA. Thus, the best proxy for functional diversity remains the diversity of breeds or distinct populations that have developed in distinct environments, and possess different production and functional traits. Furthermore, cultural arguments for conservation are linked to breeds not to genes. Nevertheless, there is a need to develop objective

criteria to decide whether a certain breed is of unique scientific value, or whether, for example, it could be substituted by a neighbouring population. This requires the combination of all available information on breed characteristics, origin and geographical distribution. Wherever possible, additional information, including results from molecular characterization, should be also considered.

In vivo and *in vitro* conservation methods are clearly distinct in terms of what they can achieve. Preserving live animals allows further evolution of the breeds in interaction with the environment, while *in vitro* conservation preserves the current genetic status. *In vitro* methods provide an important back-up strategy when *in vivo* conservation cannot be established or cannot conserve the necessary population size. It may also be the only option in the case of emergencies such as disease outbreaks or wars. The past focus on cryoconservation as a supporting tool for breeding programmes has led to technically sound solutions for the main livestock species. However, there is an urgent need to develop standard procedures for all livestock species. Freezing tissue samples seems an appealing method, because of the ease with which the genetic material can be sampled. However, the difficulty of reproducing living animals from these samples suggests that it should be regarded as a method of last resort.

It is interesting to note that it has long been accepted that international genebanks financed by the international community should preserve plant genetic diversity. The Global Trust Fund Initiative aims to create the framework for long-term financial support for these genebanks to make them independent of the short-term financial priorities of the host institutions. Furthermore, the Norwegian government has offered to provide a last resort for PGR, which will be put in place in 2007 (Box 108).

Box 108**The Svalbard Global Seed Vault: an international seed depository in the Arctic**

The Government of Norway recently initiated planning for the construction of the Svalbard Global Seed Vault to serve as an ultimate “fail-safe” back-up facility for genebanks. The facility will be established near the town of Longyearbyen, on Svalbard, at 78 degrees North and will open in the spring of 2008.

The depository will be large enough to conserve a copy of all distinct accessions now held in genebanks around the world, with additional space available for new collections. It will be located in a “vault”, carved out of solid rock inside a mountain, and lined with reinforced concrete. There will be an air-lock door for moisture control, and a number of robust security devices. The remote location, the presence of Norwegian authorities, and the occasional wandering polar bear, will combine to make this facility the most secure and reliable in the world. Under normal conditions, collections will be housed at approximately -18 °C. However, as the vault will be located in permafrost, long-term electricity failures would only result in the temperature gradually rising to -3.5 °C.

The town of Longyearbyen, a dropping-off point for expeditions to the North Pole, is served by daily flights, and has excellent infrastructure and power supplies utilizing locally procured coal.

The seed depository will not be a “genebank” in the normal sense of the term. Instead, it will be intended to house distinct accessions that are already conserved and duplicated in two traditional genebanks that would serve as the source of seed for plant breeders and researchers. Materials from the depository, stored in “black-box” conditions, would be available only when all other copies had been lost, in keeping with the intention of providing a safe and secure facility that could provide protection for plant genetic resources for food and agriculture in the case of large-scale catastrophes such as nuclear war, or major acts of terrorism.

Participation in the scheme will be purely voluntary. Management will be “passive” the depository will not engage in characterization, evaluation, regeneration or other similar activities. The Nordic Gene Bank will be responsible for placing materials in the depository and retrieving them as necessary. It already has its back-up collection in another facility at Svalbard, and duplicate collections from SADC are also currently stored there. Due to the necessity of keeping management operations and costs at a minimum, and in keeping with the intention of constructing a facility that will function without day-to-day human involvement, the depository will only be in the position to accept properly packaged orthodox seed. As the facility will be designed for the international community, Norway will not claim any ownership over the seeds stored there.

The FAO Commission on Genetic Resources has warmly welcomed the Norwegian initiative, and many countries, as well as centres of the CGIAR, have already signalled their desire to make use of the depository.

Provided by Cary Fowler

In general, it takes much longer to create a livestock breed than to create a plant variety – for some breeds it has taken centuries. However, the global community seems to be much less prepared to invest the necessary time, energy and money in safeguarding this heritage. Nonetheless, it is a global responsibility to ensure that valuable resources are maintained – a responsibility that includes all genetic resources for food and agriculture.

The analysis of *in vivo* conservation methods indicates that the distinction between *in situ* and *ex situ* *in vivo* conservation methods is not clear cut. It may, therefore, be appropriate to consider *in vivo* conservation methods as a continuum: ranging from conserving animals in their original production environment, (*in situ* conservation as defined above), to the extreme *ex situ* situation of conserving livestock breeds in zoos. While there is clearly a preference for maintaining livestock breeds in the production environments, in which they were developed, it is important to carefully evaluate whether conservation objectives might also be achieved in an *ex situ* context. This will clearly depend on the species and on the specific *ex situ* conditions. In the developing world, most reported examples of *ex situ* conservation are linked to *in situ* populations, and it appears doubtful whether they are independently viable.

While methodologies to maintain maximum diversity in small populations have been developed, implementation strategies for maintaining at-risk breeds in traditional production systems are rare. Various successful examples have been reported from developed countries and from some developing countries. In developed countries, several possibilities, such as niche markets, conservation grazing or subsidies, have been employed to increase the economic viability of endangered breeds. Conversely, in developing countries the only successful examples reported are linked to consumer or market demands for specific or traditional products. However, these practical examples of what has been achieved have not yet led to (scientific) concepts or models for implementation strategies. Furthermore, no reliable estimates of the costs and benefits of conservation strategies are available. Attempts to optimize the allocation of conservation funds are based on crude assumptions on the cost

side, and use rather simplistic objective functions. The development of more complex objective functions is constrained by the difficulties of quantifying desirable functional traits to be included.

The scientific concepts which are available for certain aspects of conservation have been developed mainly in the context of breeding programmes. Genuine research in the field of conservation of livestock genetic diversity (probably with the exception of molecular methods) is still in its early stages.

10 References

- Blackburn, H.D.** 2004. Development of national genetic resource programs. *Reproduction, Fertility and Development*, 16(1): 27–32.
- Brillard, J.P. & Blesbois, E.** 2003. Biotechnologies of reproduction in poultry: hopes and limits. In *Proceedings of the 26th Turkey conference*, held Manchester, UK, 23–25 April, 2003.
- Clark, C.W.** 1995. Scale and feedback mechanism in market economics. In T.M. Swanson, ed. *The economics and ecology of biodiversity decline: the forces driving global change*, pp. 143–148. Cambridge, UK. Cambridge University Press.
- Cognié, Y., Baril, G., Poulin, N. & Mermillod, P.** 2003. Current status of embryo technologies in sheep and goat. *Theriogenology*, 59(1): 171–188.
- CR Croatia, 2003.** *Country report on the state of animal genetic resources*. (available in DAD-IS library at <http://www.fao.org/dad-is/>).
- Danchin-Burge, C., Bibe, B. & Planchenault, D.** 2002. The French National Cryobank: creation of a cryogenic collection for domestic animal species. In D. Planchenault, ed. *Workshop on Cryopreservation of Animal Genetic Resources in Europe*, Paris, 23rd February 2003, pp. 1–4. Salon International de l'Agriculture.
- Eding, H., Crooijmans, R.P.M.A., Groenen, M.A.M. & Meuwissen, T.H.E.** 2002. Assessing the contribution of breeds to genetic diversity in conservation schemes. *Genetics Selection Evolution*, 34(5): 613–633.
- English Nature.** 2004. *Traditional breeds incentive for sites of special scientific interest*. Taunton, United Kingdom, English Nature. (also available at <http://www.english-nature.org.uk/pubs/publication/PDF/TradbreedsIn04.pdf>).
- ERFP.** 2003. *Guidelines for the constitution of national cryopreservation programmes for farm animals*, by S.J. Hiemstra, ed. Publication No. 1 of the European Regional Focal Point on Animal Genetic Resources.
- Ericksson, B.M., Petersson, H. & Rodriguez-Martinez, H.** 2002. Field fertility with exported boar semen frozen in the new Flatpack container. *Theriogenology*, 58(6): 1065–1079.
- Falge, R.** 1996. Haltung und Erhaltung tiergenetischer Ressourcen in *Ex-situ*-Haltung in Zoos und Tierparks. (Maintenance and conservation of domestic animal resources, *ex situ*, in zoos and domestic animal parks.) In F. Begemann, F., Ehling, C. & R. Falge, eds. *Schriften zu genetischen Ressourcen*, 5 (Vergleichende Aspekte der Nutzung und Erhaltung pflanzen- und tiergenetischer Ressourcen), pp. 60–77. Bonn, Germany. ZADI.
- FAO.** 1992. *In situ conservation of livestock and poultry*, by E.L. Henson. Animal Production and Health Paper No. 99. Rome.
- FAO.** 1998a. *The state of the world's plant genetic resources for food and agriculture*. Rome.
- FAO.** 1998b. *Primary guidelines for development of national farm animal genetic resources management plans*. Rome.
- FAO.** 1998c. *Secondary guidelines for the development of national farm animal genetic resources management plans: management of small populations at risk*. Rome.
- FAO.** 2003. Effectiveness of biodiversity conservation, by M. Jenkins & D. Williamson. In, *Biodiversity and the ecosystem approach in agriculture, forestry and fisheries*, Proceedings of the Satellite Event on the occasion of the Ninth Regular Session of the Commission on Genetic Resources for Food and Agriculture, Rome, 12–13 October 2002, pp. 100–116. Rome.

- FAO.** 2004. *Overview of the FAO global system for the conservation and sustainable utilization of plant genetic resources for food and agriculture and its potential contribution to the implementation of the international treaty on plant genetic resources for food and agriculture.* Item 3.1 of the draft provisional agenda, Commission on Genetic Resources for Food and Agriculture, Tenth Regular Session, Rome, 8–12 November, 2004. Rome.
- FAO.** 2007a. The Neuquén criollo goat and its production system in Patagonia, Argentina, by M.R. Lanari, M.J. Pérez Centeno & E. Domingo. In K-A. Tempelman & R.A. Cardellino eds. *People and animals. Traditional livestock keepers: guardians of domestic animal diversity*, pp. 7–15. FAO Interdepartmental Working Group on Biological Diversity for Food and Agriculture. Rome.
- FAO.** 2007b. Managing lowland buffaloes in the hills of Nepal, by K. Gurung & P. Tulachan. In K-A. Tempelman & R.A. Cardellino eds. *People and animals. Traditional livestock keepers: guardians of domestic animal diversity*, pp. 27–29. FAO Interdepartmental Working Group on Biological Diversity for Food and Agriculture. Rome.
- FAO/UNEP.** 2000. *World watch list for domestic animal diversity*, 3rd Edition, edited by B. Scherf. Rome.
- Gandini, G.C. & Villa, E.** 2003. Analysis of the cultural value of local livestock breeds: A methodology. *Journal of Animal Breeding and Genetics*, 120(1): 1–11.
- Hall, S.J.G.** 2004. Conserving animal genetic resources: making priority lists of British and Irish livestock breeds. In G. Simm, B. Villanueva, K.D. Sinclair & S. Townsend, eds. *Farm animal genetic resources*, pp. 311–320. Nottingham, UK. Nottingham University Press.
- Historical Timeline of the Auckland Islands** (available at <http://www.murihiku.com/TimeLine.htm>).
- Joost, S.** 2005. Econogene Consortium. In F. Toppen & M. Painho, eds. *Proceedings of the 8th 328 AGILE Conference on GIScience*, held May 26–28, 2005, Estoril Portugal, pp. 231–239. Association of Geographic Information Laboratories for Europe (AGILE).
- Köhler-Rollefson, I.** 2004. *Farm animal genetic resources. Safeguarding national assets for food security and trade.* Summary Publication about four workshops on animal genetic resources held in the SADC Region. FAO/GTZ/CTA.
- Mansbridge, R.J.** 2004. Conservation of farm animal genetic resources – a UK view. In G. Simm, B. Villanueva, K.D. Sinclair & S. Townsend, eds. *Farm animal genetic resources*, pp. 37–43. Nottingham, UK. Nottingham University Press.
- Marczin, O.** 2005. *Environmental integration in agriculture in south eastern Europe*, Background document to the SEE Senior Officials meeting on agriculture and environment policy integration, Durres, Albania, April 15–16, 2005. Szentendre, Hungary, The Regional Environmental Center for Central and Eastern Europe.
- Massip, A.** 2001. Cryopreservation of embryos of farm animals. *Reproduction in Domestic Animals*, 36(2): 49–55.
- Mendelsohn, R.** 2003. The challenge of conserving indigenous domesticated animals. *Ecological Economics*, 45(3): 501–510.
- Norton, B.G.** 2000. Biodiversity and environmental values in search of a universal ethic. *Biodiversity and Conservation*, 9(8): 1029–1044.
- NZRBCS.** 2002. *Enderby Island cattle: a New Zealand Rare Breed Society rescue project.* (available at <http://www.rarebreeds.co.nz/endcattlepro.html>).
- Oldenbroek, J.K.** 1999. *Genebanks and the conservation of farm animal genetic resources.* Lelystad, the Netherlands. DLO Institute for Animal Science and Health.
- Raoul, J., Danchin-Burge, C., de Rochambeau, H. & Verrier, E.** 2004. SAUVAGE, a software to manage a population with few pedigrees. In Y. van der Honing, ed. *Book of Abstracts of the 55th Annual Meeting of the European Association for Animal Production*, Bled, Slovenia, 5–9 September 2004. Wageningen, the Netherlands. Wageningen Academic Publishers.
- Reist-Marti, S.B., Simianer, H., Gibson, J., Hanotte, O. & Rege, J.E.O.** 2003. Analysis of the actual and expected future diversity of African cattle breeds using the Weitzman approach. *Conservation Biology*, 17(5): 1299–1311.

- Ruane, J.** 2000. A framework for prioritizing domestic animal breeds for conservation purposes at the national level: a Norwegian case study. *Conservation Biology*, 14(5): 1385–1393.
- Simianer, H.** 2002. *Noah's dilemma: which breeds to take aboard the ark?* Proc. 7th World Congress on Genetics Applied to Livestock Production (WCGALP). CD-Rom Communication No. 26–02.
- Simianer, H.** 2005. Decision making in livestock conservation. *Ecological Economics*, 53(4): 559–572.
- Small, R.** 2004. The role of rare and traditional breeds in conservation: the Grazing Animals Project. In G. Simm, B. Villanueva, K.D. Sinclair & S. Townsend, eds. *Farm animal genetic resources*, pp. 263–280. Nottingham, UK. British Society of Animal Science.
- Springbett, A.J., MacKenzie, K., Woolliams J.A. & Bishop, S.C.** 2003 The Contribution of Genetic Diversity to the Spread of Infectious Diseases in Livestock Populations. *Genetics*, 165(3): 1465–1474.
- Steane, D.E., Wagner, H. & Khumnirdpetch V.** 2002. Sustainable management of beef cattle and buffalo genetic resources in Asia, In J. Allen & A. Na-Chiangmai, eds. *Developing strategies for genetic evaluation for beef production in developing countries*. Proceedings of an International Workshop held in Khon Kaen Province, Thailand, July 23–28 200, pp. 139–147. Canberra. Australian Centre for International Agricultural Research.
- Thibier, M.** 2004. Stabilization of numbers of *in vivo* collected embryos in cattle but significant increases of *in vivo* bovine produced embryos produced in some parts of the world. *Embryo Transfer Newsletter*, 22: 12–19.
- Thibier, M.** 2005. The zootechnical applications of biotechnology in animal reproduction: current methods and perspectives. *Reproduction, Nutrition and Development*, 45(3): 235–242.
- Tisdell, C.** 2003. Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. *Ecological Economics, Valuing Animal Genetic Resources*, 45(3): 365–376.
- Vergotte de Lantsheere, W., Lejeune, A. & Van Snick, G.** 1974. L'élevage du porc en Belgique: amelioration et sélection. *Revue de l'Agriculture*, 5: 980–1007.
- Weitzman, M.L.** 1992. On diversity. *Quarterly Journal of Economics*, 107: 363–405.
- Weitzman, M.L.** 1993. What to preserve? An application of diversity theory to crane conservation. *Quarterly Journal of Economics*, 108: 157–183.
- Wells, D.N.** 2004 The integration of cloning by nuclear transfer in the conservation of animal genetic resources. In G. Simm, B. Villanueva, K.D. Sinclair & S. Townsend, eds. *Farm animal genetic resources*, pp. 223–241. Nottingham, UK. Nottingham University Press.
- Williams, J.L.** 2004. The value of genome mapping for genetic conservation of cattle. Conservation of farm animal genetic resources – a UK view. In G. Simm, B. Villanueva, K.D. Sinclair & S. Townsend, eds. *Farm Animal Genetic Resources*, pp. 133–149. Nottingham, UK. Nottingham University Press..

SECTION G: RESEARCH PRIORITIES

In this section, priorities for research and development are identified based on the expert analysis of the state of the art in AnGR management. The priorities have been identified in order to fill gaps in knowledge and provide the tools required to develop and implement management programmes more effectively, efficiently and sustainably. The rationale for the research and development priorities has been set out in the earlier sections, and only the briefest description is presented here.

1 Information for effective utilization and conservation

A major obstacle to decision-making in utilization and conservation of AnGR is the shortage of information on key traits and performance of local or indigenous AnGR, and the lack of reliable data on population size and structure. The following research tasks have to be completed so that researchers, policy-makers, decision-makers and advisors to farming communities have the information they require to make appropriate recommendations and take appropriate decisions for the conservation and utilization of AnGR.

- Improved methods and greater use of phenotypic characterization: is required in order to assign livestock populations to the appropriate breeds, and to overcome a lack of information regarding key adaptation traits of indigenous AnGR.
- Production environment descriptors: need to be refined and implemented in existing AnGR information systems to indicate the environment to which particular breeds are suited, and as a proxy for adaptation traits.
- Improved methods of risk definition and monitoring: methods for estimating probability of extinction are poorly developed and need substantial further research. Improved monitoring methods have to be linked to regular entry of data on population size and structure into information systems to ensure that they remain up to date and relevant.

2 Information systems

Existing information systems have relatively little functionality beyond simple searches by country or breed. The functionality needs to be extended to provide stakeholders with the information they require in a more aggregated and user friendly way.

- Regular updating and correction of existing data, and completion of missing data: should be facilitated by system routines.
- Information system functionality: needs to be improved and expanded to allow extraction and customized analysis of phenotype and molecular genetic data within and between data sources. To supply such functionality will require development of improved methods of analyzing and interpreting diverse forms of genetic diversity data (molecular and phenotype).
- Georeferencing of AnGR information systems: to allow access to multilayered geophysical information linked to attributes of AnGR (specific adaptation), and to provide precise information about current and past geographic location and distribution of AnGR.
- Interconnectivity and interoperability between information resources/databases: options and modalities need to be further developed.

3 Molecular methods

Opportunities for utilizing molecular techniques in the management of AnGR are going to increase in the near future. However, the costs and benefits of applying these technologies, and, hence, appropriate strategies for their utilization, will vary depending on local conditions.

- Improved understanding of genetic diversity in the main livestock species: comprehensive assessments of genetic diversity using molecular genetic markers are required. This needs to be achieved in ways that maximize the value of the large amount of data which exist at present but are in fragmented form. Improved sampling methods will be needed, along with the development and supply of international reference samples. Results need to be entered into publicly accessible information systems.
- Worldwide identification of variants in genes for key traits.
- Enhanced understanding of the genetic basis of adaptive traits: explore the potential of new and emerging technologies to reveal the genetic basis of disease resistance, adaptation to difficult environments and production efficiency. Such understanding may provide new routes for conventional and transformative genetic improvement.
- Development of methods for the integration of molecular information into conservation and breeding programmes: methods have to be adapted to different environmental, agricultural and socio-economic circumstances.

4 Characterization

The increasing importance given to animal welfare, distinctive product qualities, human health concerns, improving the efficiency of resource utilization, and reducing environmental impact will require a wider range of selection criteria in future breeding programmes. To date, little is known about the genetic aspects of adaptation.

- Develop and apply methods for molecular and phenotypic characterization and for the capturing of knowledge associated with the breed and its management. Additionally, methods to assess the extent of genetic dilution of a breed need to be well developed. Linking the outcome of such research to regular inventories will inform decision-making about risk status and measures to be taken to halt the decline of genetic diversity.
- Understanding robustness: the value of different breeds with respect to robustness, as measured by reduction in genotype–environment interactions, needs to be determined; genes that explain variation in robustness and factors contributing to homeostatic imbalance under a given husbandry system or management practice need to be defined.
- Improved understanding of disease resistance: infection mechanisms and host–pathogen interactions need to be studied.

5 Genetic improvement methods

There is little information on how to adapt breeding strategies to low external input environments with little or no organizational infrastructure. In this regard, selection for functional traits such as robustness, disease resistance, behavioural traits, and efficiency of feed utilization are particularly relevant. Guidance is also needed for the initial decision as to whether to implement genetic improvement programmes.

- Detailed guidelines for the design of genetic improvement programmes in low external input systems: need to be developed and validated. These should include the development of breeding and production objectives in relation to national goals and policies and the role of adaptive traits.
- Development of stable cross-breeding systems with a role for native breeds.
- Simulation tools to predict the consequences of introducing exotic breeds into local populations should be developed (part of genetic impact assessment).

- Selection for disease resistance, where determining genes have been identified: strategies of how to implement DNA-based selection without compromising production traits should be developed.
- Selection for welfare traits: a clear definition of welfare traits is needed for each species; methods for the measurement of stress and psychological status (aggression, discomfort and frustration) need to be improved; and selection methods for more appropriate temperament, reduction of foot and leg problems, and incidence of cardio-vascular problems (in poultry raised for meat) need to be developed.
- Selection for increased efficiency of feed utilization: better knowledge of nutrient (e.g. amino acid) requirements under different conditions and genetic variation in digestion of specific amino acids and phosphorus is needed.

6 Conservation methods

There is little experience in establishing conservation programmes that will be sustainable in less developed countries, or in how to operate conservation programmes that operate across a number of countries, or regionally rather than nationally. Research is required better to understand the socioeconomic, infrastructural, technical and policy constraints to the establishment and sustaining of conservation programmes.

- *In situ in vivo* conservation methods: research and development is required to understand how to implement *in situ in vivo* conservation in ways that are sustainable, maximize livestock keepers' livelihoods and support development objectives.
- *Ex situ in vivo* conservation methods: there is a need to identify approaches to *ex situ in vivo* conservation in the developing world that are closer to being self-sustaining, and thereby less vulnerable to collapse than are approaches that are heavily dependent on state support.
- Sampling and storage for genetic material for backup systems related to breeding programmes: methods are required to optimize ongoing sampling and storage in systems where the primary objective is to provide a backup to ongoing genetic improvement programmes.
- Cryoconservation and reproduction techniques: improved effectiveness and expanded access to cryopreservation and reproductive techniques for gametes and embryos are required for species for which the technologies already exist. The technologies also need to be extended to other species. Cheap and effective somatic cloning would substantially improve the safety and cost-effectiveness of *in vitro* conservation.
- Policy, legislative and zoosanitary frameworks for *in vitro* conservation: research and development is required to identify the policy, legislative and zoosanitary frameworks that will permit storage and promote access to AnGR held in national and multinational genebanks.

7 Decision-support tools for conservation

Tools to analyse complex data and optimize resource use, and to design programmes that assist researchers, policy makers and advisors better to understand the consequences of decisions, as well as to optimize such decisions are required. Since conservation will often involve utilization and improvement of the genetic resources, such decision aids need to include aids to the design and operation of breeding programmes. The following are the key areas for research and development:

- Methods for resource optimization: research is required into how to combine information of varying degrees of uncertainty to optimize the choice of AnGR for conservation, and the allocation of resources for conservation.

- Optimization tools: user friendly tools for optimization of resource allocation in conservation need to be developed, and these tools need to be included within the next generation of information systems.
- Early warning and response mechanisms: with defined triggers and actions need to be developed for use at country level.

8 Economic analysis

In relation to individual conservation and utilization decisions, improved methods that can be used in a wide range of situations to accurately value individual AnGR and the various characteristics of AnGR which might be conserved or improved are required. It is important to continue to field-test promising valuation methods, and to systematically apply proven ones to different traits, breeds and species across diverse production systems. In addition, it will be necessary to facilitate application of the methodologies and results at regional and national levels, thereby providing opportunities for influencing policy decisions related to conservation and sustainable use. A detailed costing of conservation alternatives across a wide spectrum of situations is needed to assist countries and other agencies to make decisions on cost-effective conservation programmes. Analytical methods are required to define the global benefits of AnGR conservation. This will require:

- Identifying uses and farmers' trait preferences for local breeds under different production systems: this analysis should include a systems evolution perspective as well as the forces influencing such factors and the use of alternative breeds. This will necessarily include measuring breed performance parameters, in addition to characterizing actual and potential breeding systems.
- Carrying out market analysis for livestock breeds and their products, and cost-benefit analysis of breeding programmes: this will guide decision-making whether to embark on structured breeding programmes with local breeds.
- Carrying out *ex ante* analyses of the effects on livelihoods of using alternative breeds: this will support pro-poor targeting of interventions, together with constraints to adoption, and potential access/dissemination mechanisms.
- Estimation of the costs of alternative conservation strategies: choice of the appropriate balance of conservation strategies will depend on the costs of alternative approaches. The costs of a given conservation approach will vary markedly between countries and regions, depending not just on local costs for various inputs, but also on the levels of existing infrastructure and accessible expertise.
- Developing and applying decision-support tools for prioritization of breeds: these tools should identify best options for cost-efficient diversity-maximizing conservation programmes.

9 Access and benefit sharing

Access and benefit sharing in the field of the exchange and use of AnGR is a matter of increasing international debate, the outcomes of which will have a large impact on the willingness of various states, agencies, institutions and companies to invest in the conservation and further development of AnGR. It is necessary to ensure that the anticipated international debates on the subject are well informed, and that effective decisions can be taken. Detailed analyses are required to improve understanding of the relationship between access and trade in livestock germplasm, and research and development, along with an assessment of the costs and benefits arising from such research. The need for, and the potential impacts of, frameworks for access and benefit sharing of conserved AnGR need to be assessed. Better information on the costs and benefits of past movements of AnGR would provide a valuable background to such analysis. This requires:

- Assessment of how to improve public and community use of biodiversity (e.g. improved community-based management of AnGR), including through the enhancement of existing benefit sharing at local level.
- Improved understanding of the significance of national regulatory interventions (i.e. macroeconomic interventions, regulatory and pricing policy, investment policy, institutional policy and animal disease control protocols).
- Ensuring current and future benefits from global flows of livestock germplasm: design of mechanisms at national and international levels to protect and enhance existing forms of benefit sharing, and assessment of needs in relation to future scenarios which might affect or change flows and the share of benefits.
- Explore the legal and technical framework for the setting up of a genebank of AnGR, including wild relatives, to be used for research purposes.

Part 5

Needs and challenges in animal genetic resources management

Introduction

This final part of the Report draws together the evidence presented in the other four parts to provide an assessment of needs and challenges in the management of animal genetic resources for food and agriculture (AnGR). The analysis relates the current state of genetic erosion and threats to AnGR to current capacities in AnGR management and the state of knowledge regarding methodologies and their application.

1 Knowledge of animal genetic diversity: concepts, methods and technologies

Only few mammalian and avian species have been domesticated. Some additional species such as capybara and giant African snails are utilized for food and agriculture, but have not undergone the same long process of development as the 40 or so domesticated species. Most of the genetic diversity in AnGR is therefore inherent in the various populations developed over time by livestock keepers to fulfil diverse needs in diverse terrestrial ecosystems all around the world. These subpopulations (the breeds) were partially isolated, but periodic exchanges of animals yielded new genetic combinations. This situation was ideal to maintain the evolutionary potential of the species.

Information on current patterns of genetic resource exchange is sketchy. Nonetheless, the distributional pattern of breeds and information on trade in genetic material provide evidence for an intense exchange between developed countries, and a steady flow of AnGR from developed to developing countries. There is also an exchange of genetic material between developing countries, and a much smaller flow from developing to developed countries.

Genetic variation within livestock species is partly attributed to differences between breeds and partly to differences among individuals within breeds. Selection both between and within breeds has potential to contribute to development. Given that AnGR are human-made or influenced, a breed population is the usual unit for genetic improvement measures and the associated knowledge. This is true for both local and commercial breeds, and for traditional and scientific knowledge.

Originally, the concept of the breed was closely linked to the existence of breeders' organizations. Where the traditions of formalized breeding organizations do not exist, as is the case in many developing countries, it is more difficult to identify breeds. A broad definition of breed, such as that used by FAO, accounts for social, cultural and economic differences and is, therefore, globally applicable. It also implies that as long as breeds fulfil the diverse livelihood functions required by their keepers, the breeds and their inherent genetic diversity will be maintained. There are, however, cases in which the concept of the socioculturally defined breed and the breed as unit of genetic diversity dissociate, for example when indiscriminate cross-breeding leads to dilution of the genetic make-up of local breeds without this being reflected in national inventories. In other instances, local breeds become threatened when, for various reasons, the livelihood strategies of their keepers change, in which case both the genetic and the cultural aspects of the breeds are at risk.

Livestock owners in most production systems practise breeding interventions, but there is considerable variation in the extent of control over this process. In the last few decades, use of reproductive technologies and standardized production conditions have led to the worldwide spread of a few specialized breeds, especially for poultry, pig and dairy cattle production, rather than the development of a broad range of genetic material. While this exchange of genetic material from high-output breeds – the international transboundary breeds – has resulted in impressive production increases, and many countries regard it as a means of enriching their livestock population, it is also threatening the existence of some local breed populations.

If a breed or population becomes extinct, this means the loss of its unique adaptive attributes, which are often under the control of many interacting genes, and are the result of complex interactions between the genotype and the environment. It is increasingly being recognized that in addition to the many benefits animal breeds provide for their keepers, livestock genetic diversity is a public good.

The coverage of breed diversity in the Global Databank for Animal Genetic Resources was substantially improved during the State of the World's Animal Genetic Resources for Food and Agriculture (SoW-AnGR) preparation process. Twenty percent of breeds are classified as being "at risk", and a total of 690 breeds have been reported as extinct. However, breed-related information remains far from complete, particularly in developing countries. A fundamental problem is the lack of knowledge regarding the characteristics of AnGR; their distribution geographically and by production system; the role that their special characteristics play in meeting the livelihood needs of their keepers; and the ways in which their utilization is affected by changing management practices and broader trends in the livestock sector. Methods for breed characterization and valuation need to be further developed to include the various products and services that livestock supply.

The description of livestock diversity needs to be refined. To improve the understanding of a breed's contribution to diversity and to further explore exchange patterns, it is necessary to define objective (scientific) criteria for deciding whether breed populations that occur in different countries belong to a common gene pool and should be linked. Improved methods for characterization are needed to facilitate prioritization in AnGR development and conservation. Given that in some cases immediate decisions are required, there is a need for methods that make effective use of information that may be incomplete and consider material drawn from different sources such as molecular characterization, phenotypic descriptions, specific breed characteristics and uses, and breed origin. Furthermore, member countries have long requested FAO to develop early warning and response mechanisms. Such systems would need to be combined with breed prioritization and the georeferencing of breed distribution, but information necessary to achieve these steps is lacking.

For more than one-third of all reported breeds, risk status is not known because of missing population data. Besides the missing population data, a major weakness of the current monitoring of breed erosion is that it does not capture genetic dilution of local breeds by indiscriminate cross-breeding – a problem that is considered by many experts to be a major threat to AnGR diversity. At the same time, there are many nondescript local breeds for which it is unclear whether they form (relatively) homogenous groups that can be distinguished from neighbouring populations. Molecular characterization studies help to unravel the existing relationships, but need to be better coordinated and the results better combined.

The reasons for breed extinctions have not been well studied, and in many cases the endangerment of a breed cannot be related to a concrete cause. Case studies give indications of the mechanisms involved, but not a global picture. The majority of reported breed extinctions have occurred in Europe and the Caucasus, and in North America. In these regions it can be assumed that multipurpose breeds kept by small-scale farmers have been replaced by high-output breeds kept in large-scale farm enterprises, and that local breeds are now largely maintained in marginal areas or in low external input systems, such as organic farming. The decline of traditional livestock production systems and the replacement of local genetic resources by exotic high-performing breeds are also a reason for endangerment or extinction in developing countries. Unplanned cross-breeding and gradual replacement of local breeds is reported by many developing countries. Some native breeds may not appear to be at risk if their status is measured in terms of population size, but are gradually losing their specific traits. It is a major challenge to find a way of assessing and reacting to this type of risk.

The erosion of AnGR needs to be understood in the context of environmental, socio-economic and cultural drivers of change at global, national and local levels. Policies and legal measures, including those addressing access to natural resources, the environment, economic development, zoosanitary issues, infrastructure and services, markets, and research, affect the capacity of livestock keepers and other stakeholders to maintain and develop AnGR. Developments at global, regional, national and local scales interact more strongly today than ever before. A better understanding of the various factors that drive the erosion of AnGR is required in order to develop strategic and effective measures for conservation and sustainable utilization.

The creation of the "transboundary breeds" category (linking of national breed populations with a common gene pool) in distinction from "local breeds" has proved useful for identifying patterns of AnGR exchange, and has improved breed risk assessment. However, these categories need to be

further refined. The classification may be useful for identifying cases in which regional collaboration in breed management is needed. Breeds with a truly international distribution and exchange pattern are not under threat in terms of population size. However, in the case of some international transboundary breeds, a decline in the within-breed diversity that underlies efficient selection programmes may become a problem.

Although there is widespread agreement that sustainable use of breeds is the preferred approach for maintaining animal genetic diversity, a conceptual outline of the principles and elements that constitute sustainable use of AnGR are only slowly emerging. Some progress towards defining the concept of sustainable use was achieved through the development of the Addis Ababa Principles and Guidelines for the Sustainable Use of Biodiversity. These guidelines focus on biodiversity in general and on general principles and policies. Thus, the principles need to be interpreted and specified for use in the context of agricultural biodiversity, and concrete management strategies based on the principles need to be developed for AnGR. The interpretation of the relationship between sustainable use and conservation differs between the field of AnGR management and that of general biodiversity management. In the latter field, conservation tends to be interpreted as ensuring the long-term maintenance of biodiversity. Sustainable use is seen as an option that can be used to achieve conservation. However, in AnGR management, the term conservation is used in a narrower sense – to describe activities that need to be implemented when ongoing utilization of particular breeds is threatened. Understood in this sense, sustainable use of AnGR renders conservation measures superfluous.

Genetic improvement is an important element in sustainable use of AnGR as it allows livestock keepers to adapt their animals to changing conditions. Scientific principles and methods for genetic improvement are well developed, but have not been adapted to the requirements of lower external input environments: for example, defining breeding goals for multiple purpose breeds or implementing programmes under unfavourable infrastructural and institutional conditions. Viable organizational structures for breeding and also for *in situ* conservation programmes under such conditions still have to be elaborated. It would be useful to develop economic methods for *ex ante* assessment of the livelihood implications of genetic improvement programmes in comparison to the effects of other livestock development interventions.

The analysis of risk status reveals gaps in information, but also shows that a high proportion of breeds with a known population size are threatened to various degrees. Only for some of the breeds at risk is it known whether they are being effectively “maintained” by national conservation programmes, because even where programmes are reported, the data that would allow a judgement to be made as to the programmes’ quality are not available. The analysis of countries’ capacities in conservation suggests that only very few threatened indigenous breeds are covered – with the exception of those from western Europe and North America. In view of the ongoing loss of genetic diversity, both between and within breeds, and given that this diversity can be considered to be a public good, stronger action to safeguard these resources needs to be taken. The question then becomes: how can this most effectively be done?

While conceptually the most basic unit of diversity, and thus of conservation, is the allele, it is recognized that alleles do not act in isolation, and that animal performance is affected by the interaction of alleles present across the genome. The process of breed development has involved the creation of allelic combinations that are associated with specific levels of animal performance and adaptation. The orientation of conservation towards conserving individual alleles would ensure the maintenance of the individual building blocks of diversity, but as the combinations needed to reproduce specific traits are not well known, this seems to be a risky approach.

At present, adoption of the breed as the unit of conservation is expected to maximize the maintenance of evolutionary potential within livestock species, and likewise to maximize access to a broad array of allelic combinations, which represent the outcome of a diverse set of adaptive processes. The broad definition of breed used by FAO encompasses the social significance of breeds, but complicates the use of the breed as a unit for assessing allelic diversity. This is because the contribution of breeds to genetic diversity may vary greatly. Existing livestock breeds are less genetically uniform than most

varieties of crop plants. Measuring diversity on the basis of the number of breeds tends to overestimate genetic diversity in regions where a long tradition of breeders' associations has led to the distinction of breeds that are, in some cases, closely related. Conversely, breeds in regions where structured breeding is less developed (e.g. the Awassi) have a wide distribution, high within-breed diversity, and may well include distinct subtypes that need to be identified.

Given the drawbacks in the breed concept, a picture of diversity based on the number of breeds is necessarily incomplete. Nonetheless, when combined with other available information such as the history of domestication, it indicates hotspots of diversity for the various livestock species, and helps to direct further research. To date, it is mainly between regions that comparison of genetic diversity can be made, but it would be very useful to link diversity to production systems. Furthermore, contribution to allelic diversity should not be assessed only by genetic distances measured on neutral gene loci, but also needs to be combined with information on functional traits.

The analysis of risk status, along with evidence from case studies shows that it is neither possible nor appropriate to wait for perfect information before starting conservation measures, as unique resources may be lost in the interim. In these circumstances it is necessary to combine all sources of information to inform decisions on the allocation of scarce resources to conservation programmes. This would be greatly facilitated if AnGR were geographically mapped so that information related to breeds and to potential threats could be linked in spatial terms. AnGR could then be more easily linked to production systems or particular agro-ecological conditions (e.g. drylands), and emergency interventions (e.g. precautionary cryoconservation of genetic material or compartmentalization in disease outbreaks) would be facilitated. Understanding the diversity and status of AnGR provides the basis for raising awareness, and for management actions. However, raising awareness without ensuring capacities to realize actions will not lead very far.

The surprisingly large gaps in knowledge in the field of AnGR management, and the resulting need for basic and adaptive research are indicative of the much smaller pool of human resources working in this field (and in animal science in general) as compared to plant genetic resources (PGR) and crop science. This is exacerbated by the greater complexity of the issues involved in AnGR than in PGR management. It is, therefore, important to reverse the decline in public funding for agricultural research, and the low level of funding for AnGR research in particular should be addressed. Privately funded research inevitably focuses on the needs of the industrial livestock sector. Restoring public funding for research and participatory extension services is essential to give small producers access to the technology and knowledge they need. This includes the adaptation of new technologies for small-scale use in order to make their adoption more likely.

2 Capacity in animal genetic resources management

2.1 Capacity in characterization, sustainable use and conservation of AnGR

Big knowledge gaps exist in many countries as a result of a lack of capacity in AnGR characterization, inventory and monitoring. This means that changes in the status of animal populations at the country level cannot be adequately identified. Moreover, as characterization and inventory of AnGR is the basis for planning livestock development programmes, very few national breeding and conservation programmes for local breeds have been implemented.

Although livestock owners in most production systems practise breeding interventions, the review of the Country Reports reveals considerable variation in the extent of control over the selection process and the degree to which genetic change takes place in a planned direction. There are large differences between regions and species with respect to formalized breeding activities and their support with public funding. The opportunities which exist in the developed world to implement formal breeding programmes through farmer organizations are the consequence of structures that had a long process of development during which they received public and research support. Many developing countries where such structures do not exist face problems in implementing formal breeding programmes. This is particularly true for the low and medium external input production systems where many locally

adapted breeds are kept and where the producers are scattered and lack the knowledge, capital, extension services and market access needed to establish breed development schemes. In this context, the question is whether there are technical solutions and business models that can enable the engagement of these marginal groups.

The reproductive capacity of pigs and poultry allows the implementation of planned breeding programmes by a small number of breeders within a short period of time. Thus, the breeding of chickens, and to a lesser extent of pigs, is increasingly in the hands of commercial breeding companies. However, the characteristics of cattle and small ruminants make this more difficult to achieve. Given the limited potential for increased production, it is unlikely that the private sector will invest significantly in new national ruminant breeding programmes in developing countries. Costs would, therefore, have to be borne by national institutions.

The cost of breeding activities, market competition, and the international availability of suitable breeding material are important considerations in decisions regarding public funding for national breeding programmes. At present, many governments choose to rely on international genetic material for the improvement of their national herds and flocks – especially in the case of poultry and pigs. Collaboration in breeding activities between countries with similar production conditions (as already occurs in Europe) is an opportunity to share costs and make breeding programmes more sustainable.

When changing economic, ecological and political conditions threaten the viability of production systems (e.g. pastoral systems) and the associated breeds, opportunities for *in vivo* conservation, including *in situ* and *ex situ in vivo* conservation, need to be explored. Examples of *in situ* conservation strategies are mainly reported from developed countries. However, these examples have rarely been examined from a theoretical or conceptual standpoint to assess reasons for their success or failure. Even less is known about which models could work in developing countries.

Conservation measures should aim to ensure the survival of the targeted breeds, but also, where possible, seek to facilitate a transition to new forms of sustainable utilization. There is a need to explore the full range of potential means to promote these objectives. Financial incentives will often be needed, at least to maintain breeds through the transition period. However, public sector support is dependent on the availability of resources and on political willingness to support AnGR conservation. Even where incentive measures to promote the keeping of rare breeds have been put in place (e.g. in the European Union), there is evidence that they have not always been sufficiently well targeted. Nature management, organic farming, participatory breeding, production for niche markets and hobby farming all have potential to enhance conservation efforts and promote sustainable utilization. Environmental services provide roles mainly for ruminants, while for pigs and chickens, niche markets offer the main opportunity for continued use. Judging from the available evidence, success seems to depend to a large extent on the presence of customers with sufficient purchasing power to pay higher prices for speciality products, or on society's willingness to pay for environmental services.

In vitro conservation can be an important supplement to *in vivo* conservation, or in some cases, may be the only option for conserving a breed. Up to the present, cryoconservation has been used mainly by breeding organizations and the breeding industry to maintain genetic diversity within breeds and as a back up for their breeding material. In most countries, cryoconservation facilities are lacking and cannot be established without international support. However, to safeguard genetic diversity against unpredictable threats, it is necessary that countries have their own or shared genebanks containing material from their locally developed breeds and lines. Coordination between countries is required to organize conservation of transboundary breeds.

The available cryoconservation methods do not at present cover the full range of domesticated species. In addition to the technical problems associated with freezing avian oocytes, the development of methods for cryoconservation has focused on species that have been included in planned breeding programmes. With regard to genebanks, biosecurity issues can present problems for the inclusion of genetic material from local breeds. Minimum requirements and safe options for the parallel storage of material meeting different biosecurity standards need to be identified. To allow informed decision-making, cost estimates and optimization methods for different conservation strategies need to be developed.

2.2 Capacity in institutions and policy-making

In most parts of the world, public policies are needed to improve institutional and organizational structures for the sustainable use and conservation of AnGR at all levels. The limited recognition of the relevance of AnGR is reflected in the low level of awareness of the subject at governmental level in many countries, and by its limited presence on international agendas and in the work of international organizations. As a result, legal structures, policies and development programmes with a focus on AnGR are often lacking at country level, as are institutions for characterization, inventory and monitoring, and structures for national, regional and international cooperation. Even where networks for cooperation exist, further efforts to strengthen them or to establish new structures are often required. In many countries there seem to be few national non-governmental organizations interested and active in AnGR management. The National Agricultural Research Systems, key players in research and knowledge at the country level, have often not prioritized AnGR management in their activities. The same has been true for the international research and donor community. However, during the last 15 years, more activities have been undertaken and capacities for AnGR management are being developed in Europe and the Caucasus, North America, South America, the Caribbean and East Asia. The Consultative Group on International Agricultural Research (CGIAR) has identified conservation of indigenous livestock as one of 20 priorities for its research from 2005 to 2015. Some Country Reports indicate that the SoW-AnGR preparation process has further induced changes in the field of AnGR management. Opportunities for training in utilization or conservation of AnGR need to be established and enhanced. The increasing prominence of the topic in the curricula of universities and research centres is a step towards achieving these objectives, but progress has only been very gradual. The national and regional structures established as a part of the reporting process should receive continued support. Awareness, the key to policy and institutional change, is growing in most countries, and new networks are being developed. Further efforts are needed, both at the country level and by the international community, to strengthen the involvement of all stakeholders in AnGR management.

Formulating and implementing effective livestock development policies is complicated by the fact that the sector is affected by policy developments in many fields (e.g. environment, economic development, access to natural resources, and gender and social development) both at national and international levels. There is a need to review the influence of these broader policies on the management of AnGR. Moreover, aspects of livestock sector development may be the responsibilities of many different government ministries, including those responsible for agriculture, economic development, international trade, the environment, public health, land-use planning and research. It is clear that trade-offs between different policy goals have to be taken into account. The effectiveness of public policies is often determined as much by the process through which they are formulated and implemented as by the characteristics of the instruments themselves. The formulation process requires the involvement not only of many different government agencies, but also of representatives of all stakeholders and their organizations along the production chain. Policies are far more likely to address local conditions, be accepted and win broad compliance if all major stakeholders have an opportunity to participate in shaping them. Mechanisms to ensure stakeholder participation in formulation of AnGR policies need to be improved.

The Country Reports clearly document deficiencies in management capacities and the need for capacity building in many fields of policy-making, but many also indicate the pressing need to meet shorter-term objectives such as increased food production in general, increased supply of food of animal origin in particular, and poverty alleviation. Livestock sector development takes place in an unplanned way in many countries, as coherent development plans are lacking or have only been drawn up for the major livestock species. The replacement or crossing of local genetic resources with exotic breeds is often seen as an easy and rapid approach to achieve the desired increase in livestock production.

Another reason for the deficiency in capacities may be that the relevance of AnGR diversity to food security is not yet fully recognized – which indicates that the case has not been convincingly made. It is comparatively easy to show a direct link between keeping livestock and food security at the household level, or to demonstrate the role of livestock in enabling their keepers to step out of poverty.

It is more difficult to convince policy-makers that a broad range of AnGR diversity will be needed in the future. A clearer description of the portfolio of future options provided by current breed diversity, and of the range of situations for which livestock are required at all spatial scales, is needed if a better case is to be made. Policies should ensure that genetic resources remain available to allow the re-orientation of breed development in response to changes in resource availability over the long term. They should provide an enabling environment for farmers' organizations and NGOs to enhance breed development in low external input environments. Based on such organizational structures, advances in terms of resource-use efficiency may be achieved through the development of species and breeds that are well adapted to marginal areas. However, tools to support rational decision-making and balancing of policy objectives still need to be developed.

The rapid growth and transformation of the livestock sector can offer substantial economic benefits. In the case of breeds adapted to industrial systems, public policies to support development (including research) are not required. For these systems, regulatory frameworks are needed to address public health, ethical, equity and long-term environmental sustainability implications. Policy and market mechanisms that facilitate the supply of cheap animal products to urban populations may disadvantage small-scale rural producers and contribute to the decline of the associated AnGR. The effect of livestock sector policies on smallholders who keep local breeds requires further attention. For example, there is a need to clarify the effects of food safety regulations on market access for smallholders. In turn, the implications of these policies for the use of locally adapted AnGR need to be elaborated. Legislative and policy measures that, for whatever motivation, seek to support smallholder production are potentially of importance to the maintenance of AnGR diversity. There needs to be further development and assessment of policies that promote the availability of credit, livestock services and improved genetic material to keepers of local breeds to enable them to take advantage of rising demand. In the more specific field of AnGR management, policies that favour indiscriminate cross-breeding are a particular threat to some local breeds.

The analysis of the legal framework provided in the Report is largely limited to an inventory of legal instruments that have been established at national, regional and international level. This analysis provides limited information on the effectiveness of existing regulations aimed at promoting AnGR improvement or conservation. The implications of the many other aspects of legislation that potentially affect AnGR management are only identified in broad terms. It is clear that zoosanitary regulations have to be examined closely at country and international levels, as they have a strong effect on the movement and trade of live animals and genetic material, and can act as a barrier to exchange. It is also clear that specific legal regulations have to be designed to address questions of ownership, access, information and documentation in genebanks. Some examples of such regulations exist, and could form a template for the regulation of new genebanks. The issue of intellectual property rights may become more significant in the livestock sector, and recent patent applications have highlighted potential effects on AnGR management.

The international debate on access and benefit sharing needs to be informed by analysis of potential regulatory instruments in this field. This analysis must consider the differences and similarities between the exchange of AnGR and the exchange of plant genetic resources for food and agriculture. Understanding of the relationship between access and trade in livestock germplasm, and research and development needs to be improved. The need for, and the potential impacts of, frameworks for access and benefit sharing of AnGR, particularly from genebanks, need to be assessed. An analysis of the costs and benefits of past movements of AnGR would provide a valuable background to such analysis. The outcome of the debate over these issues will have a large effect on the willingness of various states, agencies, institutions and companies to invest in the conservation and further development of AnGR.

Relatively little is known about the regulatory frameworks needed to ensure that genetic diversity is maintained and that exchange of AnGR is not hindered; this field will require more extensive research and further analysis. For many keepers of local breeds, for example, establishing secure land tenure rights and regulating access to communal grazing lands is essential.

3 Major challenges for livestock development and animal genetic resources management

The past decades have seen a rapid change in the structure of the livestock sector and in the demands placed on the world's AnGR. The roles of livestock in the fulfilment of human needs are constantly evolving. The industrialization of livestock production has been driven particularly by increasing purchasing power and urbanization. Changes to consumer preferences, trade flows, the organization of market chains, and the development of new production technologies also promote the spread of industrial systems. The evolution of food chains led by the private sector has provided benefits in terms of food safety and price reductions. It is clear that the drivers of change and the resulting threats to AnGR diversity differ between production systems. However, a lack of data makes it impossible to conclusively establish causal linkages between drivers, threats and the risk status of specific breeds. Analysis of threats is, therefore, to a large extent based on assessment of changes at the production system level, and of the linkages between production systems and breed categories (e.g. international transboundary breeds in intensive systems).

Industrial production systems and the associated private breeding companies have effectively developed highly specialized breeds, which serve the purpose of maximizing productivity in the context of current consumer requirements and resource costs. These developments have been particularly marked in poultry and pig production, but are also seen in dairy cattle. The process has encompassed international transboundary breeds kept in favourable environments close to markets. However, in the medium or long term, breed selection criteria in industrial systems may have to be revised, and more research is needed on the inclusion of functional traits.

In parallel to the development of industrial systems, low to medium external input production systems persist, particularly in marginal areas where there is no strong economic growth, or where the resources and support services required for industrialization are lacking. Such production systems have specific requirements for AnGR. They rely on local breeds selected for a wider set of characteristics, or in some cases, on cross-breeds or composite breeds that contain genetic material from local breeds. Scarcity of natural resources is a growing concern which should be increasingly factored into selection processes for local breeds.

The biggest challenge for the livestock sector is to balance different policy objectives such as maintaining animal genetic diversity and environmental integrity, meeting the increasing demand for livestock products, responding to changing consumer requirements, ensuring food safety, and contributing to rural development and the alleviation of hunger and poverty. This will require choices to be made and careful consideration of unintended side-effects. The complex data needed for such decision-making are missing in many countries.

A range of policy options are available to reduce the adverse environmental effects of livestock production. Price policies including taxation can be used to ensure that the bill for intensive livestock production comes with the price of water usage, services and responsible waste management included. Taxes and levies, or codes of conduct for livestock operations, backed by price and market-access incentives and technical support services, can be used to support land-use planning and zoning regulations to make it more expensive for producers to situate their operations in unsuitable locations. Land-use planning and geospatial information would in turn facilitate the emergency management of valuable genetic stock, for example in the event of disease outbreaks. New tools that include data relevant to AnGR management would need to be developed.

Where control measures are inadequate, the concentration of intensive livestock production in and around urban areas heightens risks to public health from contaminated food, pollution and diseases. Zoonoses such as brucellosis, tuberculosis and various parasitic diseases are also a threat to human health in traditional production systems. Steps need to be taken to establish and enforce food safety standards and veterinary public health regulations that neither exclude small producers nor compromise consumer safety or disease control. Measures need to be put in place for keepers of local breeds to prevent a decline in the quality and accessibility of veterinary health services as they become increasingly privatized. Disease control strategies should be based on analysis that takes account not

only of clinical effectiveness, but also of biodiversity, and economic and social impact. Surveillance for infectious diseases and response management in the event of outbreaks remain public sector responsibility, and require improved coordination among institutions at the local, national and international levels.

Negative environmental effects of livestock production need to be minimized. The desire to reduce the emission of methane per animal and to efficiently convert feed into meat, milk and eggs promotes the use of a limited number of high-output breeds. However, the efficient conversion achieved by chickens and pigs is based on protein-rich, energy-dense diets that compete, at least partly, with direct human consumption. Changes in price ratios, or the environmental impacts of poorly controlled industrial livestock production units may lead to policy responses that reduce incentives to adopt high external input production methods. The result may be a requirement for more diverse livestock genetic resources. Payments for ecosystem services can be used to encourage livestock producers to adopt more environmentally friendly forms of production, and could favour local breeds.

Another challenge ahead is climate change. Scenarios predicting the effects of climate change vary, but changes in temperature and precipitation, rising sea levels and increased frequency of extreme weather events are expected. Some dry areas are predicted to experience lower and more erratic rainfall. Recent increases in regional temperatures have already had significant effects on biodiversity and ecosystems in dryland environments such as the African Sahel.

The environmental impacts of climate change that are likely to affect livestock development include changes in disease challenge, changes in fodder and water availability, and land degradation. The specific direction of change – whether demand for AnGR suited to extensive or to intensive systems will increase – is difficult to predict. Livestock products from intensively managed livestock systems will tend to become costlier if agricultural disruption leads to higher grain prices. However, intensively managed livestock systems will probably adapt more easily to climate change than crop systems. This will not be the case for pastoral and crop–livestock systems, where livestock depend on the productivity and quality of the local feed resources. Extensive systems are also more susceptible to changes in the severity and distribution of livestock diseases and parasites. Negative effects of climate change on extensive systems in the drylands are, therefore, expected to be substantial. Climate change is likely to have its greatest adverse impacts in areas where resource endowments are poorest and the ability of farmers to respond and adapt is most limited.

The predicted effects of climatic change will require farming systems to adapt relatively rapidly. The fact that the speed of climate change will be faster than the speed of evolutionary adaptation of livestock and forage means that in some areas a complete reassessment of farming systems may be necessary. The effectiveness of adaptation to the effects of climate change will depend critically on the availability of both plant and animal genetic resources suited to the new conditions.

Well-adapted, in particular disease-tolerant or resistant, breeds may become more important in the future if pathogen resistance to drugs increases further. Animal welfare also requires that non-adapted animals are not introduced into difficult production environments. Exposure to heat stress, for example, is a problem that cannot easily be alleviated through better management. Again, characterization of breeds needs to be improved as a prerequisite for decision-making regarding the most appropriate breeds for specific production environments.

Sustainable livestock development in the face of these challenges will involve mixing species, breeds and individual animals with the qualities needed to meet the specific demands of particular production conditions. Consequently, defining livestock development objectives and the characteristics of the AnGR required to achieve them is essential. Sustainable development also has important socio-cultural aspects. It is important to determine how best to involve farmers in activities such as breeding programmes and ensure their continuity. New technologies – powerful tools for statistical analyses and emerging biotechnological methods – will increase the ease and speed with which AnGR can be further developed. The extent to which new biotechnologies such as cloning and in particular transgenesis will affect the development of AnGR is difficult to foresee. Major genes have been found, and more will be discovered. However, it is likely that the genetic control of heat resistance or tolerance to internal parasites is the result of complex interaction among the genes controlling the

animal's metabolism. It is also likely that there are trade-offs with productivity. It will probably not be easy to recombine genes for both high performance and robustness.

Another challenge is the field of animal health, which is the most regulated aspect of livestock management on a global scale. While effective disease control is essential for the utilization and development of AnGR, restrictions on movement and trade potentially present challenges for AnGR management. Culling policies implemented in the event of epidemics can pose a threat to rare breed populations. It is a matter of concern that throughout most of the world, very little attention has been paid to this threat in the development of legal frameworks and policies for disease control.

4 Accepting global responsibility

Livestock development and the management of AnGR need to account for the dynamic nature of production systems and to respond to changing circumstances. Further losses of local breeds are probably inevitable. However, some indigenous breeds have unique traits and are specifically adapted to particular combinations of environmental factors. They are not easy to replace. Breed extinction should, therefore, not occur without awareness of what is being lost – and the loss of unique resources or important components of our future food security and cultural heritage should certainly be avoided.

If maintaining livestock diversity is accepted as an important policy objective, and the complexity of production systems is well understood, more differentiated livestock sector policies will be the consequence. Their ultimate aim should be to use the world's wealth of AnGR in the best possible way to meet the current and future needs of the human population. The industrialization process which has allowed the livestock sector to respond efficiently to a surge in demand will continue. However, it should also be recognized that marginal and niche production systems will endure, and that policies to address their needs must be put in place. Most policies which sustain small-scale low external input production systems will, in general, favour maintaining a greater diversity of AnGR.

National sovereignty over genetic resources is understood by the Convention on Biological Diversity (CBD) to include both rights and duties. These can only be met if adequate human and technical capacities are in place. There may be a need to reinforce the capacity of developing countries and countries with economies in transition to characterize their AnGR and to implement measures for their sustainable use and conservation. There is increasing awareness within the international community that genetic resources for food and agriculture are a common concern of all countries, as all depend to a great extent on resources that originated elsewhere. There is a need for further analysis and debate as to the best means of ensuring equitable international exchange of AnGR.

Assessing the global state of AnGR – the main objective of this Report – enabled a gap analysis in a broad sense. However, this is only one part of the reporting process. A second important element has been the development of Strategic Priorities for Action – a global synthesis in which countries identified strategic priorities in the field of AnGR management as a basis for concrete actions. The Strategic Priorities for Action will be reviewed in an intergovernmental process to ensure that they reflect a global consensus on future actions. Attention has to be given to addressing global responsibilities and formulating a global programme, and to providing the institutional capacities and resources needed for its implementation at national and regional levels.

Abbreviations and Acronyms

| | |
|---------|--|
| A | Adenine |
| ABCZ | Associação Brasileira dos Criadores de Zebu (Brazilian Association of Zebu Breeders) (http://www.abcz.org.br) |
| ABS | Access and Benefit Sharing |
| ACP | Asia-Caribbean-Pacific |
| ACSAD | Arab Center for Studies of Arid Zones and Dry Lands (http://www.acsad.org) |
| AD | Anno Domini |
| ADB | Asian Development Bank (http://www.adb.org) |
| AFLP | Amplified Frequency Length Polymorphism |
| AGAL | Livestock Information, Sector Analysis and Policy Branch |
| AGB | Animal Germplasm Bank |
| AI | Artificial Insemination |
| AIA | Advanced Informed Agreement |
| AIDS | Acquired Immune Deficiency Syndrome |
| AIPL | Animal Improvement Programs Laboratory (http://www.aipl.arsusda.gov) |
| ALPA | Asociación Latinoamericana de Producción Animale (http://www.alpa.org.ve) |
| AMOVA | Analysis of Molecular Variance |
| AnGR | Animal Genetic Resources |
| ANTHRA | a trust of women veterinary scientists (http://www.anthra.org) |
| AOAD | Arab Organization for Agricultural Development (http://www.aoad.org) |
| APEC | Asia Pacific Economic Cooperation (http://www.apec.org) |
| ARCBC | Association of South East Asian Nations Regional Center for Biodiversity Conservation (http://www.arcbc.org) |
| ARR | Alanine-Arginine-Argenine amino acids - one of five variant alleles affecting susceptibility to scrapie |
| ASAR | Asociación de Servicios Rurales y Artesanales |
| ASARECA | Association for Strengthening Agricultural Research in Eastern and Central Africa (http://www.asareca.org) |
| ASEAN | Association of South East Asian Nations (http://www.aseansec.org) |
| ASF | African Swine Fever |
| ATCWG | Agricultural Technical Cooperation Working Group |
| BC | Before Christ |
| BCBS | Boran Cattle Breeders' Society (http://www.borankenya.org) |
| BLAD | Bovine Leukocyte Adhesion Deficiency |
| BLUP | Best Linear Unbiased Prediction |
| BLUP-AM | Best Linear Unbiased Prediction – Animal Model |
| BLV | Bovine Leukosis Virus |
| bp | base pair |
| B.P. | Before Present |
| BSE | Bovine Spongiform Encephalopathy |
| BV | Bequest Values |
| C | Cytosine |

| | |
|----------|--|
| CAP | Common Agricultural Policy of the EU |
| CARDI | Caribbean Agricultural Research and Development Institute (http://www.cardi.org) |
| CARICOM | Caribbean Community and Common Market (http://www.caricom.org) |
| CBD | Convention on Biological Diversity |
| CBPP | Contagious Bovine Pleuropneumonia |
| CDN | Canadian Dairy Network (http://www.cdn.ca) |
| cDNA | Complementary Deoxyribonucleic Acid |
| CE | Choice Experiment |
| CEIP | Special Certificate of Identification and Production |
| CEMAC | Communauté Economique et Monétaire de l'Afrique Centrale (http://www.cemac.cf) |
| CENARGEN | National Research Centre for Genetic Resources and Biotechnology (http://www.cenargen.embrapa.br) |
| CGIAR | Consultative Group on International Agricultural Research (http://www.cgiar.org) |
| CGRFA | Commission on Genetic Resources for Food and Agriculture |
| CIAT | International Center for Tropical Agriculture (http://www.ciat.cgiar.org) |
| CIC | International Council for Game and Wildlife Conservation (http://www.cic-wildlife.org) |
| CIHEAM | Centre International de Hautes Etudes Agronomiques Méditerranéennes (http://www.ciheam.org) |
| CIRAD | Centre de Coopération Internationale en Recherche Agronomique pour le Développement (http://www.cirad.fr/fr/index.php) |
| CIRDES | Centre International de Recherche-Développement sur l'Élevage en Zone Subhumide (http://www.cidres.org) |
| COP | Conference of the Parties |
| CORAF | Conseil Ouest et Centre Africain pour la Recherche et le Développement Agricole (http://www.coraf.org) |
| CR | Country Report |
| CRED | Centre for Research on the Epidemiology of Disasters (http://www.cred.be) |
| CSF | Classical Swine Fever |
| CTSB | cathepsin B |
| CVM | Complex Vertebral Malformation |
| CYTED | Ciencia y Tecnología para el Desarrollo (http://www.cyted.org) |
| D8 | Developing Eight - Consists of Bangladesh, Egypt, Indonesia, Iran, Malaysia, Nigeria, Pakistan and Turkey |
| DA | Cavalli-Sforza distance |
| DAD-IS | Domestic Animal Diversity Information System (http://www.fao.org/dad-is) |
| DAHP | Department of Animal Health and Production |
| DAGENE | Danubian Alliance for Gene Conservation in Animal Species |
| DAGRIS | Domestic Animal Genetic Resources Information System (http://dagris.ilri.cgiar.org) |
| DARD | Department of Agriculture and Rural Development |
| DD | Daughter Design |
| DD | Differential Display |
| DDBJ | DNA Data Bank of Japan (http://www.cib.nig.ac.jp) |
| DHPLC | Denaturing High-performance Liquid Chromatography |
| DMA | Dimethylacetamide |
| DMF | Dimethylformamide |

| | |
|-----------|---|
| DMSO | Dimethyl Sulfoxide |
| DNA | Deoxyribonucleic acid |
| DS | Nei's Standard Genetic Distance |
| DUMPS | Deficiency of Uridine Monophosphate Synthase |
| DUV | Direct Use Values |
| EAAP | European Association for Animal Production (http://www.eaap.org) |
| EAAP-AGDB | European Association for Animal Production – Animal Genetic Data Bank (now EFABIS) |
| EAFRD | European Agricultural Fund for Rural Development |
| EAGGF | European Agricultural Guidance and Guarantee Fund |
| EBV | Estimated Breeding Value |
| ECOWAS | Economic Community of West African States (http://www.ecowas.int) |
| EFABIS | European Farm Animal Breed Information System (http://efabis.tzv.fal.de) |
| EFSA | European Food Safety Authority (http://www.efsa.europa.eu) |
| EMBL | European Molecular Biology Lab (http://www.embl.org) |
| EMBRAPA | Brazilian Agricultural Research Corporation (http://www.embrapa.br) |
| EM-DAT | Emergency Disasters Data Base (http://www.em-dat.net) |
| EPC | European Patent Convention |
| EPD | Expected Progeny Difference |
| eQTL | Expression Quantitative Trait Locus |
| EST | Expressed Sequence Tag |
| ET | Embryo Transfer |
| EU | European Union (http://europa.eu) |
| EU-15 | 15 countries that were then members of the European Union |
| FAO | Food and Agriculture Organization of the United Nations (http://www.fao.org) |
| FAOSTAT | Food and Agriculture Organization of the United Nations Statistical Databases (http://faostat.fao.org) |
| FARA | Forum for Agricultural Research in Africa (http://www.fara-africa.org) |
| FEC | Faecal egg count/Egg Count |
| FIRC | Federacion Iberoamericana de Razas Criollas (http://www.feagas.es/firc/firc.htm) |
| FMD | Foot-and-Mouth Disease |
| G | Guanine |
| GATS | General Agreement on Trade in Services |
| GATT | General Agreement on Tariffs and Trade |
| GDD | Grand Daughter Design |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility (http://www.gefweb.org) |
| GIS | Geographic Information System |
| GM | Genetically Modified |
| GMO | Genetically Modified Organism |
| GVIS | Geographic Visualization |
| He | Expected Homozygosity |
| HEIA | High External Input Agriculture |
| HIV | Human Immunodeficiency Virus |
| Ho | Observed Homozygosity |

| | |
|-----------|--|
| HPAI | Highly Pathogenic Avian Influenza |
| IAEA | International Atomic Energy Agency (http://www.iaea.org) |
| IAMZ | Mediterranean Agronomic Institute of Zaragoza (http://www.iamz.ciheam.org) |
| ICAR | International Committee for Animal Recording (http://www.icar.org) |
| ICARDA | International Center for Agricultural Research in the Dry Areas (http://www.icarda.org) |
| IE | Institut de l'Élevage (http://www.inst-elevage.asso.fr) |
| IES | Institute for Environment and Sustainability (http://ies.jrc.cec.eu.int) |
| IFAD | International Fund for Agricultural Development (http://www.ifad.org) |
| IGAD | Intergovernmental Authority on Development (http://www.igad.org) |
| IGADD | Intergovernmental Authority on Drought and Development |
| IGC | Intergovernmental Committee |
| IICA | Inter-American Institute for Cooperation on Agriculture (http://www.iica.int) |
| ILRI | International Livestock Research Institute (http://www.ilri.org) |
| INTA | Instituto Nacional de Tecnología Agropecuaria (http://www.inta.gov.ar) |
| INTERBULL | International Bull Evaluation Service (http://www-interbull.slu.se) |
| IPGRI | International Plant Genetic Resources Institute (http://www.ipgri.cgiar.org) |
| IPM | Integrated Parasite Management |
| IPR | Intellectual Property Rights |
| IRD | Institute de Recherche pour le Développement (http://www.ird.fr) |
| ISAG | International Society of Animal Genetics (http://www.isag.org.uk) |
| IT-PGRFA | International Treaty on Plant Genetic Resources for Food and Agriculture |
| ITWG-AnGR | Intergovernmental Technical Working Group on Animal Genetic Resources |
| IUV | Indirect Use Values |
| IVF | In Vitro Fertilization |
| LAC | Latin America and the Caribbean |
| LD | Linkage Disequilibrium |
| LEIA | Low External Input Agriculture |
| LMO | Living Modified Organism |
| LPP | League for Pastoral Peoples (http://www.pastoralpeoples.org) |
| LPPS | Lokhit Pashu Palak Sansthan (http://www.lpps.org) |
| LRC | Livestock Recording Centre |
| LU | Livestock Units |
| MARD | Ministry of Agriculture and Rural Development |
| MEG3 | Callypige |
| MERCOSUR | Mercado Común del Sur |
| MFN | Most Favoured Nation |
| MGBA | Meru Goat Breeders' Association |
| MHC | Major Histocompatibility Complex |
| MNA | Mean Number of Alleles |
| MOA | Ministry of Agriculture |
| MoDAD | Measurement of Domestic Animal Diversity |
| MODE | Market Oriented Dairy Enterprise |
| MOET | Multiple Ovulation and Embryo Transfer |
| mRNA | Messenger Ribonucleic Acid |

| | |
|---------|--|
| Mt | Metric Tonne |
| mtDNA | Mitochondrial Deoxyribonucleic Acid |
| MYH1 | Myosin 1 |
| NACI | National Agricultural Classification Institute |
| NAGP | National Animal Germplasm Program |
| NARS | National Agricultural Research Systems |
| NC | National Coordinator for the Management of Animal Genetic Resources |
| NCC | National Consultative Committee for the Management of Animal Genetic Resources |
| NDA | National Dairy Authority |
| Ne | Effective Population Size |
| NIAH | National Institute of Animal Husbandry |
| NGO | Non-Governmental Organization |
| N-J | Neighbour-Joining |
| NRF | Norsk Rødt Fe (Norwegian Red) |
| NZRBCS | New Zealand Rare Breeds Conservation Society (http://www.rarebreeds.co.nz) |
| OECD | Organisation for Economic Co-operation and Development (http://www.oecd.org) |
| OIE | Office International des Epizooties (World Organization for Animal Health) (http://www.oie.int) |
| ORPACA | Organización de Productores Agropecuarios de Calientes |
| OSS | Observatoire du Sahara et du Sahel (http://www.unesco.org/oss) |
| OSTROM | Office de la Recherche Scientifique et Technique Outre-Mer (now IRD) |
| OV | Option Values |
| p.a. | per annum |
| PBR | Plant Breeders' Rights |
| PBV | Predicted Breeding Value |
| PCR | Polymerase Chain Reaction |
| PCV | Packed Cell Volume |
| PDB | Protein Data Bank |
| PDO | Protected Designation of Origin |
| PED | Production Environment Descriptor |
| PGC | Primordial Germ Cell |
| PGI | Protected Geographical Indication |
| PGR | Plant Genetic Resources |
| PIR | Protein Information Resource |
| PMGZ | Breeding Programme for Zebu Cattle |
| PPLPI | Pro-Poor Livestock Policy Initiative (http://www.fao.org/ag/againfo/projects/en/pplpi/home.html) |
| PPP | Purchasing Power Parity |
| PROMEBO | Breeding Programme for Meat Cattle |
| PSE | Pale Soft Exudative |
| QTG | Quantitative Trait Gene |
| QTL | Quantitative Trait Locus |
| QTN | Quantitative Trait Nucleotide |
| RBI | Rare Breeds International (http://www.rbi.it) |

| | |
|-----------|--|
| Red XII-H | Red Iberoamericana sobre la consevación de la biodiversidad de animales domésticos locales para le desarrollo rural sostenible (http://www.cytod.org) |
| REML | Restricted Maximum Likelihood |
| RFI | Residual Feed Intake |
| RFLP | Restriction Fragment Length Polymorphism |
| RFP | Regional Focal Point |
| RNA | Ribonucleic Acid |
| rRNA | Ribosomal Ribonucleic Acid |
| SAARC | South Asian Association for Regional Cooperation (http://www.saarc-sec.org) |
| SACCAR | Southern African Center for Cooperation in Agricultural Research and Training (http://www.info.bw/~saccar/sacca.htm) |
| SADC | Southern African Development Community (http://www.sadc.int) |
| SAGE | Serial Analysis of Gene Expression |
| SAM | Spatial Analysis Method |
| SAVE | Safeguard for Agricultural Varieties in Europe (http://www.save-foundation.net) |
| SEVA | Sustainable-Agriculture and Environmental Voluntary Action |
| SGRP | System-wide Genetic Resources Programme (http://www.sgrp.cgiar.org) |
| SINGER | System-wide Information Network for Genetic Resources (http://www.singer.cgiar.org) |
| SMS | Safe Minimum Standard |
| SNP | Single Nucleotide Polymorphism |
| SODEPA | Société de Développement et d'Exploitation des Productions Animales |
| SoW-AnGR | State of the World's Animal Genetic Resources |
| SPC | Secretariat of the Pacific Community (http://www.spc.int) |
| SPLT | Substantive Patent Law Treaty |
| SPS | Sanitary and Phytosanitary |
| SRS | Sire Referencing Scheme |
| SSCP | Sequencing Single-stranded Conformational Polymorphism |
| SSR | Simple Sequence Repeats |
| STR | Simple Tandem Repeats |
| STS | Sequence Tagged Site |
| T | Thymine |
| Taq | Thermus aquaticus |
| TEV | Total Economic Value |
| TLU | Tropical Livestock Units |
| TRIPS | Trade-Related Intellectual Property Rights |
| tRNA | Transfer Ribonucleic Acid |
| TSE | Transmissible Spongiform Encephalopathies |
| U | Uracil |
| UHT | Ultra High Temperature |
| UNDP | United Nations Development Programme (http://www.undp.org) |
| UNESCO | United Nations Educational, Scientific and Cultural Organization (www.unesco.org) |
| UPOV | International Union for the Protection of New Varieties of Plants (http://www.upov.int) |
| USDA | United States Department of Agriculture (http://www.usda.gov) |

| | |
|-----------|---|
| VND | Viet Nam Dong |
| VNTR | Variable Number of Tandem Repeats |
| VRQ | Valine-Arginine-Glutamine amino acids - one of five variant alleles affecting susceptibility to scrapie |
| WAAP | World Association for Animal Production (http://www.waap.it) |
| WECARD | West and Central African Council for Agricultural Research and Development (http://www.coraf.org) |
| WHFF | World Holstein-Friesian Federation (http://www.whff.info) |
| WHO | World Health Organization (http://www.who.int) |
| WIEWS | World Information and Early Warning System on Plant Genetic Resources (http://apps3.fao.org/wiews/wiews.jsp) |
| WIPO | World Intellectual Property Organization (http://www.wipo.int) |
| WTA | Willingness to Accept |
| WTO | World Trade Organization (http://www.wto.org) |
| WTP | Willingness to Pay |
| WWL–DAD:3 | World Watch List for Domestic Animal Diversity, 3rd edition |
| XV | Existence Values |