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.

Section A

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.

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 comparisons 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.

Section B

Capacity in animal genetic resources management

1 Capacity in characterization, sustainable use and conservation of animal genetic resources

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 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 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 this 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.

Section C

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.

Section D

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
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 Produción Animale (http://www.alpa.org.ve)
AMOVA	Analysis of Molecular Variance
AnGR	Animal Genetic Resources for Food and Agriculture
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
BP	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	Communaute Economique et Monetaire 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, the Islamic Republic of 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 Biodiversity 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 Statisitcal Databases (http://faostat.fao.org)
FARA	Forum for Agricultural Research in Africa (http://www.fara-africa.org)
FEC	Faecal 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 Histocompatability 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
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
N_e	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 Organisation for Animal Health) (http://www.oie.int)
ORPACA	Organización de Productores Agropecuarios de Calientes
OSS	Obervatoire 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 for Food and Agriculture
PIR	Protein Information Resource
PMGZ	Breeding Programme for Zebu Cattle
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 desarollo rural sostenible (http://www.cyted.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 for Food and Agriculture
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 Aspects of 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

Sustainable management of the world's livestock genetic diversity is of vital importance to agriculture, food production, rural development and the environment. *The State of the World's Animal Genetic Resources for Food and Agriculture* is the first global assessment of these resources. Drawing on 169 Country Reports, contributions from a number of international organizations and 12 specially commissioned thematic studies, it presents an analysis of the state of agricultural biodiversity in the livestock sector – origins and development, uses and values, distribution and exchange, risk status and threats – and of capacity to manage these resources – institutions, policies and legal frameworks, structured breeding activities and conservation programmes. Needs and challenges are assessed in the context of the forces driving change in livestock production systems. Tools and methods to enhance the use and development of animal genetic resources are explored in sections on the state of the art in characterization, genetic improvement, economic evaluation and conservation.

The main findings of the report are summarized in *The State of the World's Animal Genetic Resources for Food and Agriculture – in brief.* Arabic, Chinese, English, French, Russian and Spanish versions can be found on the attached CD-ROM and are also available separately in printed form.

As well providing a technical reference document, the country-based preparation of *The State of the World* has led to a process of policy development and a *Global Plan of Action for Animal Genetic Resources*, which once adopted, will provide an agenda for action by the international community.

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