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THE USE AND EXCHANGE OF ANIMAL GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Submission by the Food and Agriculture Organization of the United Nations (FAO)

Note by the Executive Secretary

1. Further to the request of the Commission on Genetic Resources for Food and Agriculture, the Executive Secretary is pleased to circulate herewith, for the information of participants in the ninth meeting of the Ad Hoc Open-ended Working Group on Access and Benefit-sharing, a study entitled "The use and exchange of animal genetic resources for food and agriculture" prepared at the request of the Secretariat of the Commission on Genetic Resources for Food and Agriculture and considered at its twelfth regular session.

2. The paper is being circulated in the form and language in which it was received by the Secretariat.

July 2009

COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

THE USE AND EXCHANGE OF ANIMAL GENETIC RESOURCES FOR FOOD AND AGRICULTURE

This document has been prepared at the request of the Secretariat of the Commission on Genetic Resources for Food and Agriculture by the Agriculture and Consumer Protection Department of FAO (in particular by Dafydd Pilling of the Animal Production Service) as a contribution to the cross-sectoral theme, *Consideration of policies and arrangements for access and benefit-sharing for genetic resources for food and agriculture*, which the Commission will consider at its Twelfth Regular Session.

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ABOUT THIS PUBLICATION

The Commission on Genetic Resources for Food and Agriculture (the Commission), at its Tenth Regular Session, recommended that the Food and Agriculture Organization of the United Nations (FAO) and the Commission contribute to further work on access and benefit-sharing, in order to ensure that it moves in a direction supportive of the special needs of the agricultural sector, in regard to all components of biological diversity of interest to food and agriculture.

At its Eleventh Regular Session, the Commission agreed on the importance of considering access and benefit-sharing in relation to all components of biodiversity for food and agriculture, and decided that work in this field should be an early task within its Multi-Year Programme of Work (MYPOW). Accordingly, the Commission decided to consider arrangements and policies for access and benefit-sharing for genetic resources for food and agriculture at its Twelfth Regular Session (19-23 October 2009). To facilitate discussions and debate on access and benefit-sharing for genetic resources for food and agriculture at the Twelfth Regular Session, the Secretariat of the Commission has commissioned several background study papers on use and exchange patterns of genetic resources in the different sectors of food and agriculture. The studies provide an overview of past, current and possible future use and exchange patterns, as well as a description of terms and modalities for use and exchange of animal, aquatic, forest, micro-organism genetic resources; and of biological control agents. The current Background Study Paper deals with animal genetic resources for food and agriculture. Cross-sectoral studies have been commissioned to analyse use and exchange patterns in light of climate change and to review the extent to which policies and arrangements for access and benefit-sharing take into consideration the use and exchange of genetic resources for food and agriculture in particular.

The broad ranges of studies are intended to provide insight, necessary to maintain, establish and advance policies and arrangements for access and benefit-sharing for biodiversity for food and agriculture. The studies may also contribute to the negotiations of an International Regime on Access and Benefit-sharing in the Ad Hoc Open-ended Working Group on Access and Benefit-sharing under the Convention on Biological Diversity.

EXECUTIVE SUMMARY

Livestock are important to the livelihoods of many hundreds of millions of people around the world, many of them poor, making a living in harsh environments and reliant on their animals to provide diverse products and services. The genetic diversity created by natural selection and many centuries of human-controlled breeding and husbandry underpins livestock production and provides vital options for the future of a sector faced with many challenges.

The major livestock species have spread throughout world as a result of human migration, colonization and trade. In all regions, the livestock keepers and breeders utilize animal genetic resources for food and agriculture (AnGR) that originated in other regions. The current pattern of international exchange of genetic material in livestock species is, however, rather one-sided. The transfer of genetic material from the developed "North" to the developing "South" and between the regions of the North is far greater than that occurring from South to North. South-South exchanges are also significant – the cattle sector in Latin America, for example, predominantly utilizes breeds of South Asian ancestry. As well as inter-regional trade there are substantial, often unrecorded, exchanges between neighbouring countries within regions.

North–South transfers of AnGR have contributed to increasing the output of animal products in developing countries. However, there have been many cases in which exotic breeds have been introduced into production environments that could not support them adequately, sometimes leading to negative consequences to people's livelihoods, and to genetic diversity.

Although South–North transfers of genetic material are currently very limited in the main livestock species, various driving forces have the potential to increase the significance of AnGR from the South to the global livestock sector. The most prominent among these seem to be climate change, changes to the distribution of livestock diseases, and technological developments that make it easier to identify and utilize specific genes. The current pattern of exchange of AnGR is markedly different from that prevailing in the crop sector. It has been argued that one consequence of this is that the scope for a benefit-sharing mechanism based on tapping into current flows of benefits arising from the use of AnGR from the South is limited.

While a centralized and large-scale breeding industry has developed in the poultry industry and to a lesser extent in the pig industry, in most livestock species the management of breeding continues to lie largely in the hands of livestock keepers. Most exchange takes place on the basis of private contracts or informal arrangements between individuals or companies. Unless otherwise specified in the contract, the assumption is normally that the owners of the breeding animals (or other genetic material) acquired through such exchanges are permitted to use the genetic resources involved for further breeding as they wish. Few AnGR are held in the public domain. This, again, contrasts with the situation in the crop sector where large national and multinational firms, operate alongside publicly supported national institutions and the international centres of the Consultative Group on International Agricultural Research, and where national and international *ex situ* collections are important sources of breeding material.

Private ownership of AnGR stands alongside, and potentially in conflict with other notions of ownership. For example, within traditional livestock-keeping communities, breeding animals may be held within communal or collective ownership systems of various kinds. Intellectual property rights are increasingly being exerted in animal genetics and breeding; the impacts on access and exchange have so far been limited, but the eventual consequences of such developments are uncertain and giving rise to major concerns among some stakeholders. National sovereignty, as re-affirmed by the Convention on Biological Diversity, also has to be taken into account.

Livestock keepers remain the main custodians of AnGR diversity. The marginalization of traditional livestock production systems is one of the main factors contributing to the loss of genetic diversity in livestock species. The *Global Plan of Action for Animal Genetic Resources* and the *Interlaken*

Declaration on Animal Genetic Resources recognize the important role of livestock keepers in the use, development and conservation of AnGR. Effective implementation of the *Global Plan of Action* would no doubt help to counter threats to the roles of livestock keepers. Some stakeholders, however, call for further recognition and support for the roles of livestock keepers, preferably backed up by legally binding international agreement. Arguments for "livestock keepers rights" – a bundle of rights that includes rights to grazing, water, markets, training and capacity building, and participation in research design and policy-making, as well as rights to the genetic resources of their animals – have over recent years been put forward by livestock keepers' representatives and civil society organizations.

International exchange of AnGR is at present little affected by regulatory frameworks except in zoosanitary matters. Sector-specific national access legislation is rare and there is no legally binding international legal framework specifically for the AnGR sector. Many stakeholders appear to be satisfied with this state of affairs. However, some point to examples in which exchange of AnGR has not been accompanied by adequate provisions for benefit sharing. Concerns mostly relate to exchanges in which there are major differences in knowledge or market position between the suppliers and the recipients of genetic material. There are also concerns regarding the potentially harmful effects of importing AnGR that are unsuited to the receiving production systems. Some countries have sought to counter the latter problem by requiring impact assessments prior to the introduction of new exotic breeds. There is some debate as to whether such measures are a useful means to promote efficient matching of breeds to production environments, are unnecessary barriers to exchange or are impractical.

It is possible that if AnGR from the South becomes more important in the future to the global livestock sector, such concerns and demands for regulatory measures to address them will become more prominent. The International Treaty on Plant Genetic Resources for Food and Agriculture is clearly a reference point for those who wish to see a more active regulatory approach at the global level. However, it is widely accepted that as the structure of the animal breeding sector and patterns of exchange of genetic material differ greatly from those prevailing in the crop sector, the provisions for plant genetic resources cannot simply be transferred to the livestock sector. Many stakeholders, however, express concern at the prospect of AnGR being included within a general access and benefit-sharing regime that does not take the specific needs of the sector into account and might lead to the imposition of burdensome and unnecessary procedures for access. Proposals for sector-specific initiatives been generally been quite modest in their scope and have included the development of a model material transfer agreement for AnGR.

An immediate priority has to be the effective implementation of the *Global Plan of Action for Animal Genetic Resources*. By adopting the *Global Plan of Action* and the *Interlaken Declaration on Animal Genetic Resources*, the international community reaffirmed its common and individual responsibilities for the sustainable use, development and conservation of AnGR, recognizing the need for substantial and additional resources, the need to strengthen capacity in developing countries and countries with economies in transition, and the enormous contribution made by local and indigenous communities and the farmers, pastoralists and animal breeders of all regions of the world. It also committed itself to facilitating access to AnGR and the fair and equitable sharing of the benefits arising from their use. The modalities for meeting some of these commitments remain to be fleshed out, but they should not be neglected. Implementing the *Global Plan of Action* as a whole is a key to ensuring that the AnGR needed in the future remain available to be accessed, exchanged and benefited from.

CHAPTER I: Scope of the study

1. Genetic resources addressed in this paper

This paper covers use and exchange of animal genetic resources for food and agriculture (AnGR). According to the *Global Plan of Action for Animal Genetic Resources*, adopted in 2007 as the first internationally agreed framework for the management of AnGR "the term *Animal Genetic Resources* refers specifically to animal genetic resources used in or potentially useful for food and agriculture" (FAO, 2007a). The paper focuses on the species included in the Global Databank for Animal Genetic Resources,[1] which are all either avian or mammalian and are domesticated (apart from a few wild relatives of domesticated livestock, wild populations that are used for food and agriculture or populations undergoing domestication).

The five species that are most important to global agriculture are cattle, sheep, goats, pigs and chickens. Table 1 presents an overview of the characteristics of these five species. Differences in the reproductive biology and in the management systems in which the different species are kept give rise to differences in the extent to which control can be exerted over reproduction and the use of genetic material. These differences, in turn, have implications for the development and exchange of AnGR and for the legal and policy frameworks that may be required to manage them. Differences between the reproductive biology of plants and animals to some extent account for the different patterns of use and exchange of genetic resources in the crop and livestock sectors.

[1] Alpaca, ass, Bactrian camel, buffalo, cattle, chicken, Chilean tinamou, deer, dog, dromedary, dromedary x bactrian camel crosses, duck (domestic), domestic duck x Muscovy duck crosses, goat, goose (domestic), guinea fowl, guinea pig, horse, llama, Muscovy duck, ñandu, ostrich, partridge, peacock, pheasant, pig, pigeon, quail, rabbit, sheep, swallow, turkey, vicuña, yak (domestic).

Table 1. Characteristics of the "big five" livestock species

	Ruminants				Monogastrics	
Species	Cattle		Sheep	Goats	Pigs	Chickens
	Dairy	Beef				
Birth type	Single	Single	Single > twins, triplets	Single > twins, triplets	5 to 15	Many
Age at first delivery	22 months to 4 years	22 months to 4 years	1 to 2 years	1 to 2 years	10 to 18 months	5 to 18 months
Time between two deliveries (calving interval)	350 to 730 days	350 to 730 days	180 to 360 days	180 to 360 days	6 to 12 months	
Offspring per female per year	0.5 – 0.9	0.5 – 0.9	1 to 3	1 to 3	8 – 22	20 – 200
Generation interval for breeding	> 4 years	> 4 years	2 years	2 years	1 year	1 year
Use of artificial insemination and reproductive biotechnology	+++	+	+	+	+	+
Control of genetic progress	+++	++	+	+	+++	+++
Structured breeding programmes	Cooperatives, private companies		Breeders' organizations	Breeders' organizations	Private companies	Private companies
Natural diet	Herbivory		Herbivory	Herbivory	Omnivory	Omnivory
Feed types	Roughage > concentrates		Roughage > concentrates	Roughage > concentrates	Concentrates	Concentrates
Land dependence	++	+++	+++	+++	+	+
Products	Milk > meat	Meat	Meat, milk, wool	Meat, milk, fibre	Meat	Meat, eggs
Products perishable within a few days	Milk	Meat	Milk, meat	Milk, meat	Meat	Meat
Mechanization of slaughter and product processing	+++	++	+	+	++	+++

Note: The higher production figures are typical for commercial breeding programmes; the lower figures are typical for production systems in developing countries.

2. Variety of users and uses

The primary users of AnGR are those whose livelihoods are based on livestock production, i.e. on the use of domesticated animals to supply goods and services for domestic use or sale. The range of uses in the livelihood context is very wide: milk, meat and eggs; fibres, feathers, hides and skins; inputs for crop production (draught power and manure); fuel; transport; assistance with herding; insurance and savings; a basis for social networks; and various sporting, cultural and religious functions. This group of users is distributed across all regions of the world and across a great variety of production environments – deserts, high mountains, arctic zones, humid tropical areas, and so on. In some of these ecosystems no other form of agriculture is practical. Alongside the smaller-scale users who typically use their livestock for more than one purpose stands a commercial livestock industry focused largely on producing single products (mostly meat, milk and eggs) and which generally uses a high level of external inputs to control the production environment in which their animals are kept. Table 2 presents an overview of how livestock are used in these two contrasting parts of the livestock sector.

Other users of AnGR include the research sector (universities, research institutes, etc), the conservation sector (e.g. the use of grazing animals to manage vegetation in nature reserves or to maintain culturally significant landscapes), parks and zoos, state farms and various other public sector institutions (e.g. police forces, and educational and therapeutic establishments). Development organizations of various kinds utilize AnGR as part of their efforts to enhance rural (or in some cases peri-urban or urban) livelihoods and combat poverty. Individuals sometimes keep livestock as a hobby or as pets. Less direct users include the consumers of animal products, and the general public who may benefit from the ecological and landscape services provided by livestock, from the pleasure of seeing the animals or even from the knowledge that they continue to exist (Roosen *et al*., 2005).

As reaffirmed in the Convention on Biological Diversity, countries have sovereignty over their national genetic resources, including AnGR, as well as an obligation to promote the conservation and sustainable use of biodiversity and the fair and equitable sharing of benefits arising from the use of genetic resources. By adopting the *Global Plan of Action for Animal Genetic Resources* countries have committed themselves (in a non-legally binding sense) to the sustainable use, development and conservation of their AnGR.

Table 2. A comparison of large-scale intensive and smallholder livestock production systems

Defining Characteristics	Large-scale intensive	Small-scale, mixed crop-livestock or pastoral
External input	High	Low
Knowledge system	Scientific, global	Local, traditional
Species	Pigs, chickens, dairy and beef cattle, turkeys; sheep to lesser extent. Single-species operations.	Most livestock species. Multi-species operations and sometimes multi-breed within species.
Products and services	Milk, meat, eggs; fibre to a lesser extent.	**Production related services** Milk, meat, eggs, wool and fibre, hides and skins, drought power and transport, fuel, manure for soil fertility. **Socio-cultural services** Insurance and asset function, dowry, religious ceremonies, risk management, medicinal purposes, cultural heritage, sports and entertainment, hobby and affection, status of the owner. **Environmental services** Waste conversion and use of crop by-products, weed and shrub control, fire management, seed dispersal, maintenance of cultural landscapes.
Breeds	Transboundary*; structured and "high-tech" breeding programmes.	Local*; traditional breeding systems.
Exchange	Commercial sale, with or without associated knowledge and technology systems; with or without intellectual property restrictions on use of next generation.	Within extended family, village or local market, often reciprocal share-rearing contracts, within the same knowledge system.
Environments	Often protected (shelter, heating, cooling, filtered air).	Unprotected (open grazing, scavenging).
Selection	High yield of specific market products in controlled environments.	Low yield of different products and services, "multi-functionality" in uncontrolled production environments.
Feed type	Cereals, other concentrates or highly digestible sown fodder.	Crop residues or indigenous highly heterogeneous plant communities with variable nutritional value.
Feed supply	Constant, adapted to current physiological needs ("precision feeding").	High seasonal variability.
Disease control and biosecurity	Vaccination, prophylaxis and treatment; high biosecurity.	Little or none.

* Local breeds are reported by only one country. Many recorded national breed populations occur in more than one country; these populations have been linked, and are referred to as "transboundary" breeds. Regional transboundary breeds are reported by several countries of one region, international transboundary breeds are reported by countries of several regions.

CHAPTER II: Use and global exchange of AnGR and their benefits

1. Use of animal genetic resources

Extent of use addition of value

Livestock contributes significantly to food production and economic output in all regions of the world. Livestock production accounts for 40 percent of the value of world agricultural output (FAO 2006). In some developing countries its contribution is particularly important. In Mongolia, for example, it is reported that livestock production accounts for almost 90 percent of agricultural gross domestic product (GDP) and almost 30 percent of total GDP (Country Report Mongolia, 2004).

Global consumption of animal-derived food has been increasing rapidly since the early 1980s driven by rising human population, increased purchasing power, urbanization and changing consumer tastes and preferences – with developing countries accounting for a large share of this growth. It has been estimated that for the period between 1999-2001 and 2030 the overall growth rates of milk and meat production in developing countries will be 2.4 and 2.5 percent *per annum*, respectively, compared to equivalent figures of 1.7 percent and 1.4 percent for the world as a whole. The dramatic change that rising demand has induced and continues to do so in the livestock sector, particularly in rapidly growing developing countries, has been termed the "livestock revolution" (Delgado *et al*., 1999).

These developments potentially present an important economic opportunity for the livestock sector in many countries. However, meeting rising demand while also protecting the environment, enhancing livelihood opportunities for poorer livestock producers, controlling threats to animal and human health and maintaining the genetic resource base for future livestock production are major challenges.

Figures for economic output from the livestock sector do not indicate its full socio-economic significance. Livestock keeping is very prevalent among the world's poor. While precise global figures are difficult to come by, it is clear that many hundreds of millions of poor people are to a greater or lesser extent dependent on livestock keeping (Thornton *et al*., 2002). Another important consideration is that poor livestock keepers generally obtain multiple products and services from their animals. The value of less tangible outputs, and those that are not marketed, tend not to be included in economic statistics. The ubiquity of livestock keeping among the poor and the multiple livelihood functions that livestock fulfil means that the livestock sector is of great relevance to efforts to meet the Millennium Development Goals (particularly Millennium Development Goal One).

Typology of main users

There is no universally accepted typology of AnGR users. Various terms are employed to describe user groups, but tend not to have been precisely defined. The objective of this section is not to set out a definitive typology of users, but to discuss some aspects of AnGR-related terminology and to establish a framework for the discussion of user groups within the document.

Livestock keepers and specialized breeders

From the perspective of sustaining livestock biodiversity, and from the perspective of the potential of AnGR utilization to contribute to poverty alleviation and rural development, the most significant group of users are probably the individuals, households and communities whose livelihoods are based on livestock production. The terms "livestock keepers" and "breeders" – sometimes together as "livestock keepers and breeders" – are frequently used to describe these users. These terms will be employed in this paper. However, it is necessary to devote a few lines to clarifying this usage.

Those who raise livestock can be divided into three groups:

1. At one end of the spectrum lie those who specialize in the selective breeding of animals for sale to others, who in turn use them for production (i.e. to provide the goods and services listed in Chapter I) or in some cases for further breeding. This group includes private companies (some of which are very large and operate on an international scale), cooperative breeding enterprises, state-run breeding farms and individual operators. The relative importance of each of the various types of breeding enterprise varies around the world and among livestock species, with large-scale private breeding companies being particularly dominant in the poultry and pig sectors. This group of users can be described as "breeders" or "specialized breeders" (Hiemstra *et al*., 2006); larger operators tend to be referred to collectively as "the breeding industry".
2. At the opposite end of the spectrum lie those who specialize in production, but have no involvement in selective breeding. Examples include commercial producers in developed countries who obtain their animals from specialized breeders. Clearly, these operators are less directly involved in the management of AnGR. However, their demands affect breeding decisions via the market. They can be referred to as "end users" of genetic material (ibid.).
3. Between the two above-described groups lie those who combine production with breeding (producing breeding animals for sale or for their own future use). This group (the largest in terms of human population) will here be described as "livestock keepers" rather than "breeders". However, it is important to emphasize that this does not imply a lack of active management and development of the genetic resources that they keep.

The precise definition of the term "livestock keepers" remains unclear. Some members of each of the three above-described groups might reasonably be described as "livestock keepers" in a broader sense. In the AnGR-related literature, much of the discussion of "livestock keepers" as a group of users seems to be premised on their being actively involved both in caring for the livestock and in management decisions, particularly those related to breeding.

Production systems under which livestock keepers operate also vary greatly. Detailed descriptions of different types of livestock production are not presented in this paper. However, it should be emphasized that effectively matching the breed to the production system is one of the most important aspects of AnGR management. Livestock keepers in different production systems have different objectives and face different challenges. Their needs with respect to the use of AnGR and access to these resources vary. Various production system classifications have been developed. A distinction is often drawn between mixed (crop–livestock) systems, grassland-based systems and "landless" systems (e.g. FAO, 1996). This distinction is reflected in the terminology used to discuss livestock keeper groups. "Farmers" normally refers to those who grow crops as well as keeping livestock. "Herders" normally refers to those who keep grazing animals but are not crop farmers. "Pastoralists" normally refers to herders who keep their animals on communal grazing land and whose management system involves some degree of mobility (although such traditional systems are often breaking down). Those who keep animals in backyards or other restricted areas of land can be referred to as "landless". All these groups are "livestock keepers". The tendency is for pastoralists, who are highly dependent on livestock, to have greater specialized knowledge of animal breeding than mixed farmers have.

"Small-scale livestock keepers"

The scale of the production unit is another important consideration. The role of small-scale livestock keepers as custodians of much of the world's AnGR has received increasing attention in recent years.[2] However, no precise definition has been established for "small scale" in this context. A recent paper on the *Contributions of smallholder farmers and pastoralists to the development, use and conservation of animal genetic resources* (FAO, 2009a) notes that:

[2] See for example Paragraph 146, Report of the Conference of FAO Thirty-Fourth Session, Rome, 17–24 November 2007.

> *"a size-based definition of smallholders ... is of limited use, as it does not take into account many important factors that have substantial implications for farm productivity and efficiency, such as the nature of the production system, the types of crops or livestock used, regional and national differences, institutional and market arrangements available to farmers, access to key social services such as health and education, or labour arrangements."*

The paper further notes that "one way to define small-scale livestock keepers would be to describe them relative to the average livestock farm within a country, rather than by absolute herd size or land size". It also lists a number of characteristics that are typical of small-scale livestock keepers:

- They tend to have relatively limited resource endowments.
- They tend to have low levels of formal education and training.
- They often operate on communal rather than private land (or may be landless).
- They usually operate family enterprises that practise subsistence or a mix of subsistence and commercial production.
- The family is the major source of the workforce and livestock production is often the principal source of income.
- They usually have limited access to input and output markets, and to services and credit.
- Most of their market interaction is within informal local markets, for which they produce local or traditional products.
- They routinely face high transaction costs in securing quality inputs and getting market recognition for quality outputs.

Status, trends and threats to genetic diversity

On a global scale, the status of AnGR is at present assessed mainly in terms of the number of breeds classified as being at risk of extinction. The most comprehensive source information for this purpose is the Global Databank on Animal Genetic Resources,[3] which includes data reported to FAO by 181 countries. Breeds are assigned to risk-status categories largely on the basis of the reported number of breeding animals, with some adjustment possible according to trends in the size of the population.

Current figures indicate that there are significant grounds for concern over the state of the world's livestock biodiversity. Twenty-one percent of breeds are classified as at risk of extinction. Given that because of a lack of data, a further 36 percent of breeds are classified as being of unknown risk status, the true situation is likely to be worse. More than 60 breeds are reported to have become extinct during the first six years of this century. At present, it is the developed regions of the world such as Europe and North America that have the largest numbers (and proportions) of breeds classified as at risk. However, problems elsewhere may be masked by inadequate monitoring and reporting of breed demographic data; it is anticipated that the hotspots of breed loss and genetic erosion in the coming years will be in developing countries.

While assessments based on the number of breeds at risk probably provide the best available indication of the global status of AnGR, they do not take account of within-breed genetic diversity. In some of the world's most widely used breeds, such as Holstein-Friesian cattle, there are concerns about the loss of diversity associated with the use of a very limited number of male animals for breeding. Another problem is that it is difficult to account for the effects of cross-breeding: there may be breeds that appear quite abundant if estimates are based on the size of the population, while the reality is that there are few pure-bred animals left.

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[3] The backbone of the Domestic Animal Diversity Information System (DAD-IS http://www.fao.org/dad-is).

A number of reasons for the decline of AnGR diversity can be identified. The large number of rare breeds in Europe and in North America reflects a trend towards the domination of animal production in developed countries by a limited number of high-output breeds. These populations have been subject to intense genetic improvement that has enabled them to achieve high levels of production in environments that are highly controlled through the provision of veterinary health care, balanced feeds, housing and other external inputs to the production system. Modern food-processing and retail industries tend to demand uniform products that can only be provided by certain types of animal. A further driving force of change is that some traditional livestock functions, such as the provision of draught power in agriculture, have almost totally disappeared in these regions, while the importance of some other products, such as wool, has declined.

As describe above, production systems that are more intensive in their use of external inputs, more specialized and often larger in scale are now expanding rapidly in many developing countries. This has led to increased use of exotic (largely developed-country) genetics, often at the expense of local breeds. Mechanization in agriculture and transport is spreading. Other livestock functions are being displaced as artificial fibres, fertilizers and modern financial services become available. Cultures and lifestyles are changing. Where economic growth and job creation have been strong, many former small-scale livestock keepers who once kept local breeds have now found alternative employment. These trends are, however, far from universal. For many smallholders, pastoralists and landless people livestock remain vital assets – with the animals often meeting several functions as they have always done. These livestock keepers still largely rely on their traditional local breeds. While this might suggest that the breeds in question will remain in use for the foreseeable future, their status may in fact be less secure.

Several factors can threaten traditional livestock-keeping livelihoods: degradation of natural resources or restrictions on access to these resources (particularly pastureland and water) threaten grassland-based production systems; marketing animals may become more difficult because of increased competition or stricter demands for product quality; traditional institutions for managing natural resources may break down in the face of population pressure, social differentiation and inappropriate development interventions; labour power and livestock-keeping knowledge may be lost because of rural-urban migration or the effects of HIV/AIDS; armed conflicts and other disasters and emergencies disrupt livelihoods and drive livestock keepers from their homes. Acute events, such as disease epidemics, wars, floods or other “natural” disasters, which can rapidly wipe out large numbers of animals, also pose a threat – particularly to breeds that are geographically concentrated. In the case of epidemics it is often the culling measures introduced to control the diseases that pose the greatest threat; the foot-and-mouth disease epidemic that hit the United Kingdom in 2001 is an example.

Policies and development programmes often exacerbate the threats to AnGR diversity. Various kinds of direct and indirect subsidies tend to favour large-scale production at the expense of the small-scale livestock keeper. Land-use policies frequently promote other forms of use at the expense of grazing, with pastoralists and other small-scale livestock keepers often the worst affected. Badly planned interventions to promote “superior” genetic stock can also be a problem, particularly if cross-breeding takes place in an unmanaged way. Transfer and exchange of AnGR is not necessarily a threat to diversity. While the introduction of exotic breeds can lead to local breeds being replaced or being diluted out of existence by indiscriminate cross-breeding, there are a number of circumstances in which genetic transfers can increase diversity (FAO, 2007b):

- An imported breed may gradually become adapted to the local environment, becoming in the process distinct from the ancestral population.
- An imported breed may be deliberately crossed with local animals to develop a synthetic breed that has characteristics of both parent breeds. 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.

- Breeders may use sires from different breeds to provide an infusion of "fresh blood" to maintain the vitality of otherwise closed gene pools.
- Advanced breeding techniques may be used to transfer genes for specific characteristic into a target population.

In other cases, the introduction of exotic breeds and genes has had no sustained effect for better or worse on biodiversity in the receiving country or production environment. Many efforts to introduce breeds have failed. This has been most apparent in the case of European breeds imported into the humid tropics (ibid.).

2. Global exchange of animal genetic resources

Types, sources and providers of genetic material

AnGR are embodied either in live animals (*in vivo*) or in biological material – embryos, gametes (semen and oocytes) or somatic tissues – maintained outside the animal (*in vitro*). If genetic material is to be stored outside the animal for anything more than a very short period it has to be frozen and stored in liquid nitrogen. This requires a degree of technical expertise, equipment and infrastructure that is not present everywhere, and did not exist until recent decades. Technical constraints to the transfer of AnGR are described in more detail in Chapter III; however, it should be noted that the physical movement of animal genetic material is usually less straightforward than the movement of plant seeds.

The vast majority of AnGR are under human management. In the context of AnGR management the term "*in situ"* is used to describe the production systems in which the AnGR are normally kept. Depending on the breed, the production systems in question might be farms, ranches, pastoral rangelands or "industrial" livestock production units. *Ex situ* AnGR collections for conservation purposes exist both *in vivo* (zoos, farm parks, etc) and *in vitro*, but such collections are less well developed than their equivalents in the crop sector and are less significant as sources of genetic material for use and exchange. Breeding companies and operators of artificial insemination or embryo transfer services store genetic materials *in vitro* and supply them to their clients. The range of AnGR stored in this context is usually quite narrow, being restricted mainly to breeds in which there is ongoing commercial interest. The sourcing of genetic material from wild populations is negligible.

Domestication, development of animal genetic resources by humans[4]

With the very minor exceptions noted in Chapter I, it is the fact of having gone through a process of domestication that distinguishes the species covered in this paper from other avian and mammalian species.[5] The domestication process involved action to modify animal species to make them more useful to humans, who afterwards controlled the animals' reproduction and provided them with care (shelter, protection against predators) and food (Diamond, 2002; Mignon-Grasteau, 2005). Domestication was a complex and gradual process, which altered the behavioural and morphological characteristics of the species involved. It is thought to have included the following steps: initial association with free breeding; confinement; confinement with breeding in captivity; and selective breeding and breed improvement (modified from Zeuner, 1963).

Several of the major domesticated livestock species are the only surviving depositories of the now vanished diversity of their wild ancestors; in a number of others the wild relatives are very rare. This lack of wild relatives is a major difference between livestock and crop species. In many of the latter the wild ancestral species are commonly found in the centres of origin and represent an important source of variation and adaptive traits for breeding programmes.

[4] This description of domestication is based largely on the respective section in *The State of the World's Animal Genetic Resources for Food and Agriculture*.
[5] Domesticated species not used for food and agriculture are also not covered.

The small number of animal species successfully domesticated is largely explained by the characteristics required for domestication, which are rarely found together in a single species (Diamond, 2002). 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 (e.g. the grasscutter: *Thryonomys swinderianus*) for human consumption, which may become more important at least locally or regionally (BOSTID, 1991; Hanotte and Mensah, 2002).

Livestock domestication is thought to have occurred in at least 12 areas of the world. Several species were domesticated in more than one region. While uncertainty still surrounds the location of some domestication events, the following geographic areas are recognized as important primary centres of origin, and therefore often of 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). The southern part of the Arabian Peninsula is thought to be the region of origin of the dromedary; the Bactrian camel may originate from the area that is now the Islamic Republic of Iran; and the horse from the Eurasian steppes (FAO, 2007b). It should be noted that in most livestock species the centres of origin do not, today, play a particularly prominent role as suppliers of internationally traded germplasm.

Patterns of exchange (past and present)[6]

Movement and exchange of livestock breeds and germplasm have been taking place since prehistoric times. From their centres of domestication livestock species spread gradually from neighbour to neighbour and or were moved as their keepers migrated to new areas. Colonization was an important vehicle of genetic transfer. The Romans, for example, invested in livestock breeding, and there is archaeological evidence that their improved, larger-sized breeds were disseminated to the lands that they occupied. Later, when Europeans colonized large areas of the world they brought their livestock with them. Christopher Columbus brought pigs from the Canary Islands to the Caribbean in 1493. Cattle, sheep and goats also arrived on the shores of the American continent in European ships. Australia had no domesticated livestock before the arrival of Europeans.

The late eighteenth century saw the beginning of a new phase in the exchange and transfer of genetic material. The introduction of the Arab horse into Britain had stimulated livestock breeders to copy the Arab breeding practices of careful selection and maintaining pure lines. Beginning with the pioneering work of Robert Bakewell (1725–1795) British breeders began to apply the same principles to their cattle and sheep. This led to the establishment of breeding societies and herd books in the early nineteenth century. From the 1850s onwards, transfers of genetic material in the form of registered pedigree animals became more commercial (Valle Zárate et al., 2006). International exchange was facilitated by the invention of steamships, and by the end of the nineteenth century European countries had developed legislation to support and regulate animal breeding. Much of the transfer of genetic material at this time was between European countries and their respective colonies, but there was also exchange within Europe. Moreover, because European cattle breeds failed to thrive in many tropical production environments, South Asian breeds were brought to Brazil and East Africa.

Since the middle of the twentieth century, a series of technological advances have facilitated the movement of genetic material. Commercial use of artificial insemination started in the 1960s, of embryo transfer in the 1980s and of embryo sexing in the mid-1990s (ibid.). Developments in animal

[6] This descriptions of international gene flows presented in this section draw on the respective section in *The State of the World's Animal Genetic Resources for Food and Agriculture*. The data on breed distribution presented are based on the breeds' reported presence in different countries in 2006 as recorded in the Global Databank for Animal Genetic Resources.

breeding have increased production differentials between the elite animals produced by specialized commercial breeders and those found in the traditional production systems of developing countries.

Advances in animal health, housing and feeding have made it possible to recreate highly controlled production environments in distant parts of the world. Combined with increasing demands for animal products among consumers in many developing countries, these developments have fuelled transfers from North to South.[7] Transfers from South to North have been limited during this period. Where such transfers have occurred they have tended to involve grazing animals brought into the hotter parts of developed countries such as Australia and the United States of America. In addition, some breeding companies and universities from the North have imported breeds from the South for research purposes; there have been some transfers of breeding stock in less mainstream species such as ostriches and South American camelids.

In recent decades, advances in statistics and biotechnology have made it possible to target specific genes for introgression into a target population. As yet, however, such techniques have had little impact in terms of increasing the utilization of genetics from the South in breeding programmes in the North. Reasons for this probably include large production differentials, the fact that biological and commercial success in a new production environment is usually dependent on a number of traits, and the fact that genetic correlations between desirable and undesirable traits often mean that lengthy breeding programmes are necessary to take advantage of the positive attributes of the imported breed (Blackburn and Gollin, 2008).

While the historical overview presented above has focused on the movement and exchange of AnGR around the world, for most livestock keepers the management of AnGR was always a local affair. Animals drawn from local herds and flocks were used to produce the next generation, and breeding decisions were taken by the livestock keepers themselves. It is only in recent decades that large-scale specialized breeders who supply animals to producers beyond a fairly local scale have emerged. It should be noted that centralization in the production of breeding stock has been much more limited in the livestock sector than it has in the crop sector. Overall, livestock keepers remain more involved in breeding than their crop-producing counterparts.

A highly centralized breeding sector has been established only in industrial poultry production, where the relatively high prolificacy of the female birds has allowed genetic improvement to be consolidated in the hands of large-scale operators. Breeding stocks are multiplied in flocks that are owned by, or contracted to, the parent firm; chicks are delivered from hatcheries to the producers (FAO, 2004a). Similar structures are emerging in pig breeding, but are less developed than those for poultry. In ruminants, lower fecundity and generally more extensive production retard the establishment of a centralized breeding sector. A substantial multiplier layer can only be avoided through extensive use of artificial insemination with frozen semen; however, this approach has, to date, proven feasible only in industrial dairy cattle production, where there are very high total revenues per animal unit (ibid.). In meat cattle the use of artificial insemination is far more limited, and commercial use of frozen semen in sheep and meat goats is rare. Breeding in these sectors relies less on biotechnology, is less centralized and remains largely in the hands of the livestock keepers themselves.

Where centralized breeding systems do exist they are largely run by the private sector and increasingly concentrated in the hands of a few large companies that operate on a global scale. In the case of cattle, producer-owned breeding cooperatives play an important role in some countries. Public ownership of AnGR is declining and attempts to establish elite herds in public institutions have often failed due to inadequate resources, failure to establish multiplier herds and the small size of livestock production units (ibid.).

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[7] The terms "North" and "South" are frequently used in the context of genetic transfers to describe developed and developing countries respectively. The usage does not correspond exactly to geographical reality; Australia, for example, is a developed country located in the southern hemisphere.

The situation in the AnGR sector thus contrasts with that in the plant sector where large national and multinational firms, operate alongside publicly supported national institutions and the international centres of the Consultative Group on International Agricultural Research, and where national and international *ex situ* collections are important sources of breeding material. It should also be noted that in addition to the inter-regional movements emphasized above, considerable exchange of AnGR takes place between neighbouring countries. Such exchanges are often unrecorded and are difficult to quantify. They may involve the movement of transhumant livestock keepers across national borders – many regional transboundary breeds in Africa, Asia, Latin America and the Near East were developed in, and are adapted to, dryland production environments (Scherf *et al*., 2006). The following sections describe how AnGR from the main livestock species have been distributed, used and developed across the various regions of the world.

Cattle

Breeds of European descent account for eight of the world's top ten most widely distributed cattle breeds. By far the most widespread breed is the Holstein-Friesian, which is reported in at least 128 countries, and in all regions.[8] Next is the Jersey (also a dairy breed, utilized in 82 countries), the Simmental (dual-purpose, utilized in 70 countries), the Brown Swiss (dual-purpose, utilized in 68 countries) and the Charolais (beef, utilized in 64 countries). Almost all the most successful European cattle breeds originate from Northwestern Europe: principally the United Kingdom, France, Switzerland and the Netherlands. Many are based on traditional breeds that emerged in the Middle Ages or earlier. 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 in continental Europe, 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, Piedmont and Highland) – areas which offered isolation from other breeds and (in the case of mountains) the environmental stress needed to select for the hardiness prized in these breeds.

European breeds have been further developed in other regions, particularly in North America, Australia and New Zealand, where production of meat and milk often outstrips the levels achieved by the breeds in their areas of origin. North America has become an important source of genetic material for European livestock producers. New breeds have also been developed based on European stock. Examples include, Polled Hereford, Red Angus and Milking Devon, all developed in the United States of America. European breeds have been successful in temperate areas of South America and in South Africa, as well as in parts of 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 animals are poorly adapted to the heat and low-quality forage, and often suffer badly from the local 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; these breeds may also be present but not reported in additional countries. In Latin America and the Caribbean, European cattle introduced by colonists developed into various new breeds, the most prominent of which is the Creole. European breeds have also been crossed with various tropical breeds to create new composite breeds that are more suited to the tropics (see below).

South Asian cattle breeds have also spread over many parts of the world. These breeds are all of the humped Bos indicus type, rather than the humpless Bos Taurus type. South Asian breeds have been most successful in tropical Latin America and Africa. Prominent examples include the Sahiwal – a dairy breed originating from Pakistan and India that has been introduced to 12 African countries – and the Nelore. The latter breed originates from Indian Ongole cattle imported into Brazil in the early twentieth century. The breed thrived in South America and was subject to selective breeding programmes. It was exported to the United States of America, where it became one of the progenitors

[8] The regions referred to in this report are the seven regions used in *The State of the World's Animal Genetic Resources for Food and Agriculture* (FAO, 2007b): Africa, Asia, Europe and the Caucasus, Latin America and the Caribbean, the Near and Middle East, North America, and the Southwest Pacific.

of the Brahman, which in turn is found in 18 countries in Latin America and 15 in Africa. In 1995, the Nelore made up more than 60 percent of Brazil's 160 million cattle; in 2005, some 85 percent of Brazil's 190 million cattle had Nelore blood.

South Asian cattle genetics have also made a major contribution to composite breeds. 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 or Australia. Many of these breeds have been re-exported to other countries, especially in the tropics, where they generally perform better than European pure-breeds. However, despite superior performance, uptake of breeds with South Asian ancestry is often limited; this may in part be accounted for by the well-developed distribution and marketing networks that exist for European and North American breeds.

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. 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, South Africa's most popular native breed, 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), Senepol (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). Very few cattle breeds from other parts of the world – the Near East, and Central, East and Southeast Asia – have spread beyond their regions of origin. Some, however, are distributed across several countries within their home region, and may be known by a number of different names.

Sheep

Sheep are one of the most widely distributed domesticated 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. Artificial insemination is less successful in sheep than in cattle. It is important only where the use of fresh semen is practical and economically viable, for example in breeding programmes for dairy sheep in France, Italy and Spain (Schäfer and Valle Zárate, 2006). 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 most widely distributed breeds. The top three breeds are all European in origin, the Suffolk (a meat/wool breed from eastern England, found in 40 countries), the Texel (a meat breed from the Netherlands, 29 countries) and the Merino (a wool breed from Spain). The Merino would probably rank first, if all its many derivative breeds were counted together – it has been widely cross-bred and selected to produce a multitude of new breeds. Many of the most widely distributed breeds of European origin are from southern and eastern England; others originated in France, Finland, Germany, the Netherlands, the Russian Federation and Spain. As in the case of cattle, many of these breeds are traditional landraces that were formalized into breeds in the nineteenth century. Outside their region of origin, European sheep breeds 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. New breeds of European or mixed European and non-European ancestry have been developed in these regions. Three are very widely distributed – the Corriedale, which is the fourth most widespread breed; the Katahdin (based on a cross between African Hair Sheep and the Wiltshire Horn from England) and the Poll Dorset.

European breeds have been exported to relatively few countries in the South. The most widely distributed are the Merino and the Suffolk. Latin America and the Caribbean have received more European breeds than other developing regions. The Criollo, descended from early European imports, is present in nearly every country in Latin America and the Caribbean. The Barbados Black Belly – a hair breed of mixed European and African ancestry which emerged in the seventeenth century – is also very widely distributed in Latin America and has also been exported to Asia and Europe. Another widely distributed breed of mixed African and European ancestry is the Dorper – developed in South Africa from the Dorset Horn (from England) and the Black Headed Persian (from Somalia). The Black Headed Persian itself has spread widely in Africa and has also been exported to the Caribbean, as has the West African Dwarf sheep. The Damara of Southern Africa has been exported to Australia where it is both kept as a pure breed and crossed with the Merino (Country Report Australia, 2004).

Very few breeds from Asia or from the Near and Middle East have spread outside their home ranges – despite the fact that Asia is home to around 36 percent of the world's sheep population and about 25 percent of sheep breeds. Important 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 Australia, Brazil, India, many European countries and the United States of America. The Awassi, a widespread breed in the Near East, was improved in Israel during the 1960s and has since spread to 15 countries in southern and eastern Europe, Central Asia and Australia. In some countries such as Spain and Portugal the Awassi is now being replaced by the Assaf, also originating from Israel (De la Fuente et al., 2006). In Israel itself, a new breed known as the Afec Awassi has been developed by introducing the so-called Booroola gene encoding litter size into the improved Awassi. The gene in question can be traced to a flock of Indian Bengal sheep imported into Australia at the end of the eighteenth century.

Goats

Goats are of major economic significance for smallholders in the South, particularly in ecologically marginal areas such as drylands and mountains. In developed countries their importance relative to cattle declined drastically during the twentieth century. In general, goat breeds are much less widely distributed than either cattle or sheep breeds, with fewer having spread outside their regions of origin. Purely European breeds are less dominant in this species than they are in sheep and cattle, accounting for only 6 of the 25 reported transboundary breeds. Several of these breeds originated in the Alps or were bred from stock originating from this area. The Saanen dairy goat is the world's most widely distributed breed – found in 81 countries and in all regions of the world. Also widely distributed is the Angora, a mohair breed which originated in 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). European breeds have contributed to several important breeds of mixed ancestry such as the Anglo-Nubian (developed in the United Kingdom by crossing British, African and Indian goats), Boer (bred in South Africa from indigenous, European and Indian animals), and Criollo (developed in the Caribbean from European and African breeds). Pure African breeds (as distinct from the mixed-ancestry Boer) have remained largely confined to Africa, but several including the West African Dwarf, Sahelian, Small East African and Tuareg are found in many countries within the region. Some of these breeds have been exported in small numbers to other regions to be kept as experimental flocks or by hobby breeders. Breeds from Asia and the Near East are also largely confined to their regions of origin. 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).

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 and Swedish Landrace from the United Kingdom to Australia, New Zealand, South Africa, Kenya and Zimbabwe (Musavaya et al., 2006). In the late 1970s, commercial operations started producing fattening pigs through hybrid breeding programmes using crosses between specialized sire and dam lines that had 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.

The worldwide distribution of pigs is dominated by breeds from Europe or the United States of America. The most important are the Large White (117 countries), Duroc (93 countries), Landrace (91 countries), Hampshire (54 countries) and Piétrain (35 countries). Among the list of 21 pig breeds reported in five or more countries, 15 are European breeds (all from northwest and central Europe) four are from the United States of America, and one is a commercial strain supplied by a large British pig breeder. Only one, the Pelon (seven countries) a miniature pig from Central America, is from another region of the world. Despite the huge numbers of pigs in East Asia (more than half the world's total population), none of the world's most widespread breeds come from this region. As noted above, however, Asian breeds contributed to the development of some of the world's dominant pig breeds. In more recent years, Northern commercial pig-breeding companies have not incorporated breeds lines/genes from Asia or other developing regions in their breeding stock. The only serious attempt, the introgression of genes from the Meishan breed into commercial lines was not successful, because of the big production differentials between the Meishan and the lines being used by the breeding companies (Hiemstra *et al*., 2006).

Chickens

Commercial strains dominate the worldwide distribution of chickens, accounting for 19 of the 67 breeds reported in five or more countries. These strains are controlled by a small number of transnational companies based in northwestern Europe and the United States of America. Because the companies involved do not make their breeding information publicly available, there is limited 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) and are thus largely of European and North American ancestry.

Chickens have been domesticated for many thousands of years, but the most important breeds developed only in the second half of the nineteenth century. Chickens were introduced to North America by the Spanish and then by other Europeans in the sixteenth century. These populations gradually developed into distinct breeds. The top three are Rhode Island Red, Plymouth Rock and New Hampshire, all of which are distributed worldwide. The White Leghorn breed is based on Italian country chickens were brought to the United States of America in the 1820s, where they were selected for egg yield. They were re-imported into Europe after the First World War. Widely distributed European breeds include the Sussex, from the United Kingdom, which is reported from 17 countries. Another British breed, the Black Orpington, gave rise to the Australorp breed of Australia which holds the world record for egg-laying – a hen once laid 364 eggs in 365 days.

The most widely distributed breed from Asia is the Aseel, which hails from India, and is reported in 11 countries. 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). Several other Asian breeds are found in other parts of the world where they are considered "ornamental". Examples include the Sumatra (from Indonesia), Malay Game and Onagadori (a long-tailed breed from Japan). The Langshan chicken of China is reported to have been introduced into the United Kingdom in the

1870s where its genes contributed to the development of the above-mentioned Black Orpington (Country Report China, 2003).

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 introduced 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 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 external inputs. Their meat can be marketed and they attract tourists. From the United States of America yaks 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 reindeer were introduced from Norway into Greenland (Benecke, 1994). South American camelids have in recent decades been exported in substantial numbers to countries including Australia and the United States of America. In Europe they are also becoming popular largely among hobbyists. Ostrich farming has also spread from Southern Africa to Europe, North America and elsewhere.

Attempts to quantify current patterns of exchange

While the information presented above indicates that livestock keepers and breeders in all regions of the world utilize genetic resources that originated elsewhere, it reveals little about current patterns of genetic transfer or about the quantity or value of the material involved. Quantitative assessments of international exchange of AnGR are constrained by a number of factors: data on international movements of live animals often do not distinguish between breeding animals and those used for production; transnational breeding companies do not provide data on within-company exchanges; import and export data frequently do not indicate the source or destination of the material involved; and in some parts of the world, unrecorded movements take place (e.g. in transhumant livestock systems that extend across national borders) (Hiemstra *et al*., 2006).

The United Nations COMTRADE database contains data on trade in live bovine animals for breeding, bovine semen, live pigs for breeding and live equines for breeding. These figures are subject to limitations of the type described above and to a lack of reporting by individual countries in particular years. However, this is the most comprehensive source of global data. Gollin *et al.* (2008) analysed COMTRADE data for bovines (both live animals and semen) and pigs in order to assess global trade flows of genetic resources. The outcomes of the study indicate that exports of genetic material are dominated by North America and Europe. The only exceptions to this pattern revealed by the analysis are described as follows:

> *"Australia holds a moderate share in the export market for breeding cattle, and the countries of Latin America and the Caribbean plus Asia together account for a modest share of the swine genetics market – although this may reflect the fact that in North America, shipments of semen have largely replaced movements of animals as a means of exchanging genetic material" (ibid.).*

The findings show that for all three commodities, flows from non-OECD countries to OECD countries (roughly equating to the rich "North") are very limited. Conversely, there are substantial flows from OECD to non-OECD countries, amounting to about one-third of the value of international trade in the above-mentioned commodities in 2005 – a figure that had risen from about 20 percent in 1995. The study found that North–North trade was still dominant overall, but its share had declined since the 1990s largely reflecting the collapse of cross-border trade in live animals in North America.

Other studies that have sought to quantify global trade flows in AnGR in the recent past have reached broadly similar conclusions regarding the dominance of North America and Europe as exporters (Valle Zárate et al., 2006; Mathias and Mundy, 2005; Alandia Robles *et al*., 2006; FAO, 2007b). Hiemstra *et al*. (2006) conclude that:

> *"movements of livestock germplasm from South to North have been rare in the past century, and in most cases the economic benefits to both North and South have been relatively small."*

While the general pattern of global exchange is clear, it should be borne in mind that trade figures do not necessarily reflect the full economic significance of these exchanges. As Gollin *et al*. (2008) note, the COMTRADE data represent "*private* value; i.e. the value placed on the genetic resources by private buyers and sellers, which may differ from the true economic value. In general, the private vales reflect anticipated contributions to productivity gains that will result in appropriable benefits. The buyers and sellers may be incorrect in their anticipation of the benefits derivable from the exchanged AnGR. The imported breeds might prove to be unsuited to the conditions in the receiving production systems or they might prove to have characteristics that provide unforeseen economic benefits to the recipient (the former eventuality seems to be more common than the latter). To these considerations, can be added the possibility of negative impacts on public goods (e.g. loss of biodiversity), and the possibility of differences in market power and knowledge between providers and recipients.

Future trends

The global livestock sector is experiencing an unprecedented rate of change. It cannot be taken for granted that current patterns of exchange will necessarily continue far into the future. Hiemstra *et al*. (2006) identify four scenarios that may affect the future management of AnGR – globalization, developments in biotechnology, climate change, and emerging diseases and disasters.

Globalization

The so-called livestock revolution (see above) is leading to a major increase in developing countries' share of total livestock production and consumption. Livestock production is shifting from being a multipurpose activity with mostly non-tradable outputs, to one focused on food production in the context of globally integrated markets. Retailers and supermarkets are leading actors in the globalization process. Vertical integration is expected to become the primary business model on a global scale. The competitiveness of small-scale livestock keepers may be adversely affected.[9]

Biotechnology

A series of developments in biotechnology is expected to accelerate ongoing changes in the livestock sector:

- Continued progress in reproductive and cryoconservation technologies for all livestock species;
- Development of a new generation of quantitative genetic tools, linking genomics and quantitative genetics;
- Improved efficiency and safety of transgenic and cloning technologies; and
- Better control of animal diseases and increased availability of vaccines.

[9] The references cited by Hiemstra *et al*. (2006) in their discussion of globalization include Delgado *et al*. (1999), Delgado *et al*. (2001), FAO (1997), Dirven (2001), Hobbs and Kerr (1998), Tisdell (2003), and Popkin and Duy (2003).

Such a scenario is likely to mean that genotypes can be distributed and used across the globe more easily than they can today. Developments in biotechnology are providing new opportunities to explore and possibly exploit genetic resources.[10]

Climate change

There are five main climate change-related drivers of change in livestock production systems:

- Changes to temperature;
- Changes to precipitation;
- Rising sea levels;
- Changing incidence of extreme weather events; and
- Increasing atmospheric carbon dioxide and other greenhouse gas content.

Climate change can be expected to affect livestock productivity directly by influencing the balance between heat dissipation and heat production, and indirectly through its effect on the availability of feed, fodder and water, as well as via changes in disease challenge. Climate change may significantly shift the location of livestock production away from current marginal rangelands, and may thus contribute to the shift in favour of intensive production systems.[11]

Diseases and disasters

Increased international trade and travel, along with the effects of climate change, are expected to promote the spread of livestock diseases into new geographical areas in the coming years. The number of animals dying as a result of epidemics or disease control measures (culling) may increase. Changes in disease distribution may also mean that the livestock populations face disease challenges that they have not previously experienced and to which they are therefore unlikely to be well adapted. Other natural and human-caused disasters can seriously affect livestock populations in the affected areas.[12] The potential contribution that breeds with high levels of genetic resistance or tolerance can make to disease-control strategies is discussed in more detail in Section 3 of this chapter.

Potential consequences of future trends for the use and exchange of AnGR

Based on stakeholder consultations and an e-conference, Hiemstra *et al*. (2006) conclude that all four of the above-outlined scenarios are likely to affect the future use and exchange of AnGR to some extent at least. Globalization is expected to continue – creating conditions in which animals of high genetic merit belonging to high-output breeds will be increasingly sought after. For the foreseeable future, such genetic material will largely be obtained from specialized breeders based in developed countries. The globalization scenario is, thus, not expected to alter the direction of global gene flows and is likely to increase their quantity. Consequences for AnGR diversity are likely to be negative unless major efforts are made to promote sustainable use and conservation of local breeds that would otherwise be displaced. The emergence of niche or regional markets for animal products that can only, or best, be provided by local breeds may be a countervailing factor to the homogenizing effects of globalization.

[10] The references cited by Hiemstra *et al*. (2006) in their discussion of developments in biotechnology include AEBC, (2002), EC (2003); Gibson and Pullin (2005), Hiemstra *et al*. (2005), Meuwissen (2005), Rothschild *et al*. (2003), Hoffman and Scherf (2005) and Andersson and Georges (2004).
[11] The references cited by Hiemstra *et al* (2006) in there discussion of climate change include IPCC (2001), CCAA (2002), MAFF (2000), FAO (2004e), FAO (2004b) and Kenny (2001).
[12] The references cited by Hiemstra *et al*. (2006) in their discussion of climate change include Kouba (2003), FAO (2004c), FAO. (2004d), FAO/OIE/WHO (2005), Kadomura (1994) and Charron (2002).

It is unclear to what extent biotechnologies that are currently available or in the pipeline will find practical application in the foreseeable future, and hence the consequences for AnGR utilization are also unclear. Some stakeholders fear that increased use of biotechnologies will further promote the domination of the sector by large-scale operators at the expense of poorer livestock keepers, traditional production systems and the associated AnGR diversity. It is, however, possible that it will pave the way for AnGR from developing countries to be utilized more widely in commercial breeding – for example, if genes contributing to disease resistance are identified. This might increase the significance of gene flow from South to North. Another consequence might be increased use of patenting in animal breeding and genetics.

Climate change can be expected to present a number of challenges to the utilization of AnGR. Breeds may be threatened if the production systems in which they are kept are disrupted or transformed as the climate changes. They might also be threatened by an increase in the frequency of natural disasters such as droughts and floods. Depending on the speed of climate change and the speed with which breeders are able to adapt livestock populations, there may be an increasing need to bring in suitably adapted AnGR from other parts of the world. This may promote greater interest in AnGR from hotter and drier regions.

Increased frequency of diseases and disasters would pose a threat to geographically concentrated breed populations. The spread of diseases into new areas may promote interest in resistant or tolerant breeds, which if they exist are likely to be found in the areas where the diseases in question have previously been prevalent.

3. Benefits of use and exchange of animal genetic resources

Adaptation potential of animal genetic resources

The value of AnGR diversity comprises both its value for current use and its potential as a resource for the future. The range of the products and services currently obtained from livestock and the range of conditions in which livestock keeping is practised were briefly described in Chapter I. Diverse production objectives in diverse production environments cannot be met without diverse animals. AnGR diversity remains essential to the world's livestock sector. In fact it is probably underutilized. High-output breeds have, in places, spread beyond the high external input/single-output systems to which they are suited. Few of the local breeds found in the low external input systems of developing countries have been thoroughly studied to assess whether they have unique characteristics that might be useful more widely or that give them particular advantages in their home production environments. Comparative studies of breed performance that take place under field conditions in such environments and that account for all the products and services obtained by local livestock keepers are very few and far between. As to the future, despite advances in animal health, nutrition, housing and husbandry, and the development of alternatives to many livestock functions, it would be unwise to conclude that the livestock sector will be able to meet all the demands placed on it simply by utilizing a handful of breeds. Controlling the production environment can only be taken so far. It is, for example, difficult to insulate animals kept in the tropics from the prevailing high temperatures. There are also constraints to the sustainability of disease control strategies based on high levels of external inputs. Problems include the evolution of resistance in the disease-causing organisms or their vectors (FAO, 2007b). Animals utilized to provide ecological and landscaping services are, by definition, not isolated from the environment. The same is true for animals that provide draught power in agriculture or are used for transport. There are also economic, social and political factors that come into play. Poor livestock keepers, in particular, are often unable to afford (or to access) animal health services, high-quality feeds or other inputs needed to raise high-output breeds successfully. Rising input prices may threaten the economic sustainability even of larger-scale operations (medium-scale producers may find themselves particularly badly affected). Hobby farmers seeking an escape from urban life tend to prefer to keep animals under conditions that are – or at least seem to be – more "natural" than those of conventional livestock management. Industrial-type production systems are beset by criticisms of their impacts on the environment and animal welfare – pressure on producers to adapt to meet these concerns may be felt via consumer choices in the market place or via government regulations.

The other important factor to consider is the unpredictability of the future. The scenarios described in the preceding section indicate some of the many challenges facing the livestock sector; they also indicate that the outcomes are uncertain. AnGR diversity offers s form of insurance in the face of this uncertainty. It is impossible to fully describe, let alone place a precise value on, the adaptive potential of current livestock populations. However, it is possible to identify breeds or populations that have characteristics that make them well adapted to specific environmental stressors or to fulfilling particular functions. If such conditions or demands become more widespread in the future, then the breeds in question or their genes may become much more widely sought after (assuming the relevant knowledge is available to the potential users). The following paragraphs, therefore, present a cross-section (intended to be illustrative rather than comprehensive) of the published evidence for the presence of valuable adaptive characteristics in specific livestock.

Role of genetic diversity in disease-control strategies[13]

Livestock diseases adversely affect animal production throughout the world and, as noted above, many conventional disease control strategies face sustainability problems. As such, managing genetic resources to create animal populations with enhanced levels of resistance or tolerance[14] to disease offers an additional and valuable tool for controlling diseases. A number of advantages of incorporating genetic elements in disease management strategies have been recognized (FAO, 2002) 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; and
- Adding to the diversity of disease management strategies.

Options for utilizing genetic diversity for disease management 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.

In the case of many economically important diseases there is evidence for differential disease resistance or tolerance among livestock breeds (see table in Annex 1). Tsetse transmitted trypanosomiasis – one of the most important animal health problems in Africa – is an example. Drug resistance in the disease-causing organisms (trypanosomes) and sustainability problems in the implementation of tsetse fly control programmes, have increased interest in the use of disease tolerant breeds (FAO, 2005a). The most trypanotolerant breeds include N'Dama and West African Shorthorn cattle, and 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). Ticks are another major problem for livestock producers, particularly in the tropics. Ticks

[13] This description draws on the respective section of *The State of the World's Animal Genetic Resources for Food and Agriculture*.
[14] "Resistance" refers to the ability of the host to resist infection. "Tolerance" refers to a situation where the host is infected by the pathogen, but suffers little adverse effect.

themselves weaken animals by withdrawing blood, cause tick paralysis through the injection of toxins secreted in their saliva, damage hides and provide sites for secondary infections. Moreover, they spread a number of very serious diseases, the most notable being anaplasmosis, babesiosis, theileriosis and cowdriosis (heartwater). 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 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 that found pure-bred Bos indicus cattle to be less susceptible to babesiosis than 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). Worm infections are one of the most serious animal health problems affecting the livestock kept by poor people in all developing regions (Perry et al., 2002). Resistance or tolerance to Haemonchus contortus, a ubiquitous and harmful nematode worm that infests the stomachs of ruminant animals, has been subject to many studies. The Red Maasai sheep breed of East Africa, for example, is noted for its resistance. A study conducted under field conditions in subhumid coastal areas of Kenya found that Red Maasai lambs showed lower faecal egg counts for Haemonchus contortus and lower mortality than Dorper lambs (another breed widely kept in Kenya but which originated in South Africa). The Red Maasai were estimated to be two to three times as productive as the Dorpers under these conditions where the parasites flourish (Baker, 1998). Similarly, Small East African goats were found to be more resistant and productive than Galla goats (which originated in semi-arid areas of East Africa) under the same conditions (ibid.). In the case of cattle, it has been observed that humped Bos indicus animals are more resistant to gastro-intestinal nematode parasites than the non-humped Bos taurus (Turner and Short, 1972; Frisch and Vercoe, 1984).

Breed differences in susceptibility have also been found for some of the most serious poultry diseases. A study comparing the effects of infection with Newcastle disease and infectious bursal disease virus (both diseases that frequently devastate village chicken flocks in developing countries and remain a potential threat to industrial-scale commercial operations) on four Egyptian chicken breeds found that Mandarah 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). In the case of Marek's disease, Lakshmanan et al. (1996) report that a study of Fayoumi and White Leghorn chickens revealed the former to show greater resistance to the development of tumours.

Adapation to climatic and nutritional stress

High temperatures and poor quality feeds can also be major constraints to livestock production if the animals are not well adapted genetically. The greater adaptability of tropical breeds to the effects of heat has long been recognized in the scientific literature (Bonsma, 1949; Turner 1982; Turner, 1984; Lemerle and Goddard, 1986; Singh and Bhattacharyya, 1990). The superior heat tolerance of these breeds has been attributed to their coat type and colour, skin thickness and pigmentation, high sweating capacity (which is a consequence of the higher density of sweat glands in the skin), low body heat production because of their lower production levels, body conformation and some physiological characteristics (Simianer, 2000). It has also been shown that Zebu cattle (B. indicus) are better able to utilize lower-quality feeds than are temperate breeds (Ashton, 1962; Moore et al., 1975; Dunkel, 1981; Hunter and Siebert, 1985). King et al. (2006) provide an example of what this can mean in practice.

Their study revealed that high-output Holstein Friesian dairy cattle, promoted among small-scale dairy farmers in Kenya, were subjected to constant physiological stress by the high ambient temperatures and the additional heat generated by having to digest tropical grasses. The animals' productive lives were shortened and their fertility was affected; their milk yields although high in early lactation declined rapidly. Their lifetime productivity is reported to be worse than that achievable with local dairy breeds or cross-breeds in similar production environments (ibid.).

High ambient temperature is regarded as the most important inhibiting factor for poultry production in hot climates (Horst, 1990). Under hot conditions chickens cannot dissipate the heat that their bodies produce following meals rapidly enough this leads to reduced feed intake and lower weight gain or egg production (Cahaner and Leenstra, 1992). Systematic comparisons of naked-neck[15] frizzle feathered[16] and normally feathered chickens at various ambient temperatures have been undertaken, with the normally feathered birds proving inferior to the other types for a number of important production parameters under tropical conditions (Horst, 1988; Mathur and Horst, 1990; Cahaner *et al.*, 1993; Ibe, 1993). Several breeds exhibiting the naked-neck trait have been described, including the Cou Nu du Forez from France, the Malay Game from Malaysia, the Shingangadi from the Democratic Republic of the Congo, the Transylvanian Naked Neck from Hungary and Romania, and the Peel-Neck from Belize and Guatemala (Mérat, 1986; Mallia, 1999).

Commercial benefits of use and exchange

The commercial benefits obtained from the use of AnGR are substantial – as noted above, livestock production accounts for 40 percent of the value of the world's agricultural gross domestic product. The overall value of trade in AnGR is difficult to estimate because of a lack of data on many types of genetic material. According to Gollin *et al*. (2008) the value of international trade in bovine animals for breeding has varied between US$300 million and US$500 million annually in recent years (the variations being caused largely by zoosanitary factors); trade in bovine semen was worth US$180 million in 2005; the figure for breeding pigs was about US$80 million in 2005. Data for other species (and for boar semen) are either unavailable or very limited.

Contributions to food security and poverty alleviation

As noted in chapters I and II, livestock production makes a substantial contribution the livelihoods of large numbers of poor people around the world. Many poor livestock keepers continue to use the breeds traditionally kept in their local production systems. These breeds tend to be well suited to providing the multiple outputs often utilized by poor households. They also tend to be well adapted to the local environment, sparing their keepers from the need to obtain expensive inputs and reducing the risk that flocks or herds will be devastated by disease or feed shortages. In such circumstances the exchange of genetic material is largely local.

In some places, poor households have benefited from the introduction of breeds or germplasm from elsewhere, including from other countries and regions of the world. Clearly, this requires that there are no legal, technical or financial barriers to accessing the relevant germplasm. Successful adoption of exotic higher-output breeds or their crosses normally requires greater use of external inputs such as veterinary medicines and higher-quality feed. Consistent access to these inputs at affordable prices is essential, as is access to markets for the products of the higher-output animals. Unfortunately, these prerequisites are not always met and as Hiemstra *et al*. (2006) note, there are many examples of unsustainable livestock development projects that were based on the import of exotic genetic material. It has been argued that transfers of AnGR to developing countries are sometimes motivated more by the interests of the suppliers than those of the recipients, with adverse consequences for both AnGR diversity and livelihoods (Gibson and Pullin, 2005).

An alternative development strategy for poor livestock-keeping communities may be to add value to the products of their existing genetic resources. A few innovative development projects have taken this approach (Cardinaletti *et al*., 2008; Gopikrishna, 2008: Köhler-Rollefson *et al*., 2008), but it is unclear how widespread the potential for this kind of development is. Structured breeding programmes for local breeds have potential to raise production levels. However, organizing genetic improvement strategies in low- and medium-input production systems is challenging (FAO, 2009b). Utilizing local AnGR would appear to raise few access issues. However, ongoing access to AnGR depends on the sustainability of the production systems that reproduce them, which in turn relies on access to the necessary resources (pastures, water, knowledge, etc.). It could also be affected by legal constraints –

[15] These birds have no feathers on their necks.
[16] These birds have feathers that curve outwards rather than lying flat on the body.

such as intellectual property rights (IPRs) – if they were to interfere with livestock keepers' freedom to use and breed their animals as they choose.

Changing environmental conditions, for example the effects of climate change or the introduction of a new livestock disease, may mean that the breeds traditionally kept by poor livestock keepers in a given area no longer meet the needs of the local livestock keepers, as well as they did in the past. In such circumstances, access to AnGR from outside the locality and access to the knowledge needed to raise them are likely to be important. In some cases, the AnGR best suited to the new conditions might only be available from outside the country. Effective arrangements for international exchange of AnGR and associated knowledge are vital in such circumstances.

4. Conclusions

Livestock production in all regions of the world utilizes AnGR that originated or were developed elsewhere. Many of today's widely used breeds are of mixed ancestry and would never have come into existence without the contribution of livestock keepers and breeders on more than one continent or if the movement and exchange of the ancestral animals had been more restricted. International exchange of AnGR gives rise to substantial benefits. The current pattern of exchange is, however, rather one-sided – the major flows of germplasm are from North to South (as well as among the countries of the North). Many of the world's breeds are not heavily exchanged internationally; indeed the majority are "local" (meaning that they are present in only one country) rather than "transboundary" breeds. Many countries are little involved as suppliers of internationally traded germplasm. However, it is possible, given the effects of climate change, changing patterns of disease challenge, biotechnological developments and the generally dynamic and unpredictable nature of the livestock sector that demand for AnGR from the South may increase in the future.

Many breeds have characteristics that make them particularly well adapted to specific environmental conditions or to meeting particular functions. If such breeds become extinct, options for adapting the production systems of the future are lost. The potential loss of the option value provided by a wide portfolio of genetic diversity is one of the main reasons for the growing recognition of the need for action to promote the sustainable management to the world's AnGR. The fact that many breeds are falling out of use – and hence into danger of extinction – is a major cause of concern. One of the fundamental problems to be addressed is that the costs of more sustainable management arise in the present and are certain, while many of the benefits are potential and will arise in the future.[17] Moreover, future benefits if they do arise may accrue not to the individuals, communities or countries that bear the costs of conserving the genetic resources, but to others. The issues appear even more acute if it is recognized that much of the world's AnGR diversity is held by small-scale, often poor, livestock keepers (FAO, 2009a). The future of many breeds is largely dependent on livestock keepers being both able and motivated to continue raising them and if necessary to become involved in *in situ* conservation programmes. It also depends on the capacity and willingness of national authorities and of the international community to provide an enabling policy environment for sustainable use and to support conservation programmes where they are needed.

Benefit-sharing mechanisms are sometimes conceived, in addition to being matters of equity, as means by which the holders of genetic resources can be motivated to conserve and to use them sustainably. The other side of the equation is that if it can be assured that the conserved resources will be widely accessible at whatever future time they are needed, a wider range of stakeholders are likely to be motivated to support conservation programmes or policies favourable to sustainable use. Ongoing access to the relevant genetic resources on the part of those who raise them is, self-evidently, another prerequisite for sustainable use and conservation. Translating this theory into practical steps to support for conservation and sustainable use is far from straightforward in the livestock sector. The global pattern of exchange means that attempting to provide support to countries and livestock keepers in

[17] The possibility that there might be additional current benefits to be derived from better matching breeds to production systems should not be overlooked.

developing countries by tapping into current flows of benefits arising from the use of AnGR from these countries is likely to have limited impact. The mixed origins of many breeds have the potential to complicate the implementation of any benefit sharing measures that are based on an attempt to share the benefits derived from an individual breed with individual countries or livestock-keeping communities. Yet, if individual countries and communities are not confident that they will receive equitable shares of any benefits that arise from the use of their AnGR now or in the future, they are likely to be less motivated to conserve them and may seek to restrict access. Reduced access could in turn reduce the motivation of some stakeholders from supporting measures to promote conservation and sustainable use.

CHAPTER III: Current practices of exchange of animal genetic resources

1. Current terms and modalities for exchange of animal genetic resources

Property rights to AnGR

AnGR can be subject to various, sometimes potentially conflicting, types of property rights. The following paragraphs present an overview.

Private ownership

The majority of the world's AnGR are in private ownership. When a breeding animal is sold, the assumption is normally that its value as a genetic resource is accounted for in the price paid by the buyer. Unless there are specific contractual arrangements to the contrary, the new owner is then able to use or sell the animal and its descendants (or any genetic material derived from them) for breeding or for production as he or she sees fit. The same provisions operate if the genetic material is bought and sold as semen, embryos or other *in vitro* form. Commercial livestock breeders normally operate within this system of classical ownership, protecting their investments by staying ahead of the competition and physically controlling access to their most valuable breeding animals, or by biological methods such as only selling one sex of a breed or line or only selling hybrids. Information related to the breeding process may be treated as a trade secret and protected under relevant legislation.

The seller of genetic material may, through a contract or through an informal arrangement, retain some rights to the next generation of animals (or semen, embryos, etc) or to dictate how they are used. Contracts disallowing the buyer from selling breeding material from the purchased animals, or requiring the payment of a royalty when breeding stock are sold, are commonly used by pig and poultry breeding companies (Hiemstra *et al*., 2006). Pig breeders operate a "gentleman's agreement" that stipulates that genetic material from competitors' pigs will not be used for further breeding (ibid.).

Most international exchange of AnGR takes place on a commercial basis, with any stipulations regarding the use of the genetic material transferred being agreed privately between the individuals or companies involved. Some transfers from North to South are implemented or promoted by governmental or non-governmental development organizations, which may retain a degree of supervision over the subsequent use of the animals in the short term. There is no multilateral system regulating international exchange of AnGR, such as exists for many crop species under the International Treaty on Plant Genetic Resources for Food and Agriculture. One proposal that has been put forward as a means to promote responsible international exchange of AnGR is the development of a model material transfer agreement (or more than one). The availability of such a model might reduce the time and costs involved in negotiating agreements. Hiemstra *et al*., (2006) suggest that such a model agreement might include aspects related to:

i) The characteristics of the AnGR;

ii) Transfer prices and conditions;

iii) Use restrictions; and

iv) Supplementary benefit sharing.

Community ownership

Not all livestock keepers hold their AnGR within a system of straightforward private ownership. In many traditional livestock-keeping communities, particularly pastoralists, decisions regarding the management of AnGR do not lie entirely in the hands of individual owners. Some animals may be the common property of the community – for example a village bull – while others are the property of individuals. There may also be rules that restrict the ways in which individual owners can use and dispose of their animals. Among Raika pastoralists in India, for example, the sale of female animals outside the caste is forbidden (Anderson and Centonze, 2007). More broadly, traditional livestock-based livelihoods are often underpinned by networks of mutual obligation in which animals are loaned or exchanged and in which ownership may not be clear cut. Animals may be kept under various kinds of share-rearing arrangements in which original supplier retain some rights over the offspring of animals being kept by somebody else. Such arrangements frequently operate under customary rules, rather than written contracts or formal legal frameworks.

Traditional regimes for the management of AnGR tend to go hand in hand with traditional regimes for managing access to the resources needed for raising livestock (most notably grazing land and water). Compared to straightforward private ownership, such systems often enable better management of risks and imbalances in the availability of resources, and allow for a longer-scale perspective in resource management. If such systems are disrupted there is a risk that the sustainability of AnGR management will decline. Customary rules, if respected, may affect the access of both community members and those from outside the community to AnGR. The latter may not be accustomed to (or accept) operating on any basis other than individual ownership or they may be unaware of the existence of alternative systems of ownership. Conversely, livestock keeping communities may find it difficult to accept that collectively developed resources, laden with social significance, should be treated merely as commodities to be exchanged on the basis of financial transactions between individuals. The interface between local or communal systems of ownership and those operating at national or global levels can therefore present a challenge from the perspective of ensuring efficient and equitable exchange and utilization of AnGR.

Public-sector ownership

Few AnGR are held by the public sector. Where national gene banks do exist they operate largely as back-up collections for conservation purposes and are not involved in large-scale exchanges of genetic material. Only about 40 percent of countries that submitted country reports during the preparation of *The State of the World's Animal Genetic Resources for Food and Agriculture* reported that they operate cryoconservation programmes of any sort (FAO, 2007b), and well-established gene banks are few and far between. The way in which cryoconservation work is organized varies between countries. In many cases the deposition and maintenance of *ex situ* banks relies on the expertise and facilities of artificial insemination cooperatives (Mäki-Tanila *et al*., 2008).

Little or no progress has been made towards establishing international gene banks for AnGR. While it is recognized in the *Global Plan of Action for Animal Genetic Resources* that international cooperation in implementing *ex situ* conservation programmes is a potential means to increase efficiency and to reduce costs, it is also recognized that effective collaboration is dependent on fair and equitable arrangements for storage, access and use of the material held.[18] Both zoosanitary concerns and the question of national sovereignty over the stored resources need to be addressed. Public-sector animal breeding programmes are also not widespread. Where they exist, they may be a source of improved genetic material for livestock keepers. However, international cooperation and exchange of genetic material among public sector breeding programmes is limited. Some public sector research organizations hold AnGR, normally in limited quantities, for research purposes.

National sovereignty

Private or communal ownership of AnGR, is potentially at least, challenged by national sovereignty over genetic resources. Individual owners may find that their rights to sell breeding animals or other genetic material, particularly across national boundaries, are restricted (Hiemstra *et al*., 2006). Those seeking to buy specific AnGR may find that they are unable to do so, or that they can only do so on terms that are acceptable not only to the owner of the resources but also in compliance with national legislation.

[18] Strategic Priority 10.

Attempts by national authorities to control access to AnGR have a long history. Examples from the past include bans on the export of Merino sheep from Spain, Angora goats from Turkey and Ostriches from South Africa (FAO, 2007b). Such attempts to retain complete control over national genetic resources have usually proven difficult to maintain indefinitely.

Even if they do not wish to maintain a total ban on exports, countries may be concerned about the genetic quality of their national herds or flocks. Peru, for example, has been faced with the problem that overseas demand for high-quality pedigree alpacas has led to the loss of many of the countries' best breeding animals. Despite a ban on the export of registered pedigree alpacas, smuggling has continued and the authorities have had to introduce micro-chipping of the animals in an attempt to control the problem.[19] Another motivation for exerting national sovereignty over AnGR, is concern that benefits derived from the use of exported AnGR will not be equitably shared with the providers. In such cases, if exports are to go ahead, the standard practice is to draw up a material transfer agreement by which the importing and the exporting countries agree on the terms for the use of the AnGR, and any provisions for the sharing of benefits.

Intellectual property rights

Another challenge to the rights of livestock owners (whether private individuals or companies, livestock-keeping communities or institutions within the public sector) to use the genetic resources that are embodied in their animals may come from the assertion of IPRs, particularly patents. The legal situation with regard to IPRs in the AnGR sector varies from country to country, but a number of international instruments and processes affect provisions at the national level. The World Trade Organization's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) allows countries to exempt plants and animals from patentability. In the case of plant varieties there is a requirement for an alternative "*sui generis*" system of IPR protection, but this is not stipulated for animals. Notwithstanding the exemptions allowed for under TRIPS, free trade agreements established among groups of countries commonly include requirements that go beyond the minimum requirements of TRIPS. The same is often true of bilateral trade agreements. There are a number of examples of regional cooperation and harmonization of patent law by regional search and granting authorities for patents (Hiemstra *et al*., 2006). Finally, there are ongoing moves to further harmonize national IPR rules through the Substantive Patent Law Treaty negotiated under the auspices of the World Intellectual Property Organization.

The AnGR sector has no parallel to the plant breeders' rights provided for under the International Union for the Protection of New Varieties of Plants (UPOV) Convention. This is probably, at least in part, a reflection of the differences between plant and animal breeding, particularly the fact that the concept of the plant variety has no clear parallel in animals. A plant breeder can claim rights over a variety if it can be shown to be new, distinct, uniform and stable. These criteria cannot be easily applied to animal breeds. Livestock breeds are heterogeneous rather than uniform. Development of highly inbred, genetically uniform lines of livestock is difficult because of lower fecundity and greater sensitivity to the negative effects of inbreeding (FAO, 2004a). Even within highly selected and superficially uniform breeds of poultry, pigs and dairy cattle, within-breed genetic diversity far exceeds that present in most crop varieties (ibid.). Breeders, thus tend to be concerned about maintaining control over their elite breeding animals, rather than over a whole breed or population.

Genetic diversity within breeds is utilized over time to produce animals that perform better, often in terms of higher output. There is less focus on targeting individual traits such as disease resistance than there is in plant breeding. This is partly a consequence of the greater practical difficulty of exploiting unique genetic combinations or new mutations in animals, particularly those with long generation intervals, than in many plant species. Thus, animal breeding commonly involves continuous processes of improvement rather than distinct processes that produce "new" types of animal. Moreover, the very concept of the breed is ill-defined; there is no generally accepted method for objectively establishing

19 http://news.bbc.co.uk/1/hi/world/americas/4314237.stm.

whether an animal population is sufficiently distinct from other populations to be considered a breed. The diverse nature of livestock production and breeding systems around the world make it difficult to conceive a definition that is applicable everywhere.[20]

As there is no equivalent of plant breeders' rights in the AnGR sector, there are also no provisions equivalent to the "breeders' exemption" and "farmers' privilege" that accompany this form of IPR in the plant sector. These provisions allow farmers to use the protected varieties for propagation purposes on their own holdings and allow breeders to use them to breed new varieties. Notwithstanding the differences between plant varieties and animal breeds as currently conceived, it is possible that there will be increasing demands from animal breeders who develop distinct breeding populations based on one or more unique and heritable traits for systems to protect their intellectual property (Hiemstra *et al*. 2006). These pressures would be likely to increase if the use of technologies such as genetic modification or cloning becomes more widespread.

To date, the use of patents in the animal-breeding sector has been limited and seems to have had little practical impact on most livestock keepers and breeders. Nonetheless, an increasing number of patents, both for genetic sequences and for breeding methods, are being granted. Recent prominent patent applications in the sector have given rise to concerns about the far-reaching scope of this kind of protection and its possible impact on the exchange and use of AnGR by breeders, livestock keepers and researchers. The full implications of these developments remain unclear at present, particularly due to the fact that patent legislation has usually been developed without distinction between sectors. Hiemstra *et al.* (2006) note several key points that need to be resolved:

> "Prior art – *where current practices or best techniques are not published in a sufficiently formal manner, there is a risk that common knowledge (e.g. traditional knowledge or common breeding methods) could become patent protected.*
>
> Novelty and inventiveness – *closely linked to the prior art criterion, it should be noted that the novelty and inventiveness of an invention are considered by comparing the prior art with the invention described in the patent claims. If extensive publication is not the norm in the livestock (breeding) sector, the livestock sector might be exposed to patent protection of relatively common principles and methodologies.*
>
> Scope of the granted right – *the extended scope of patent claims on live organisms is a major source of criticism of the patent system applied to biological material. In particular, there is concern that the scope and coverage of products by process patents could be applied to animal breeding.*
>
> Exemptions to the patent protection – *the TRIPS agreement specifies that countries have discretion to implement exemptions in the right conferred by the patent at a general level in the patent act (Article 30). Exemptions that apply to AnGR may be useful to render the patent system more appropriate to the specific requirements of the livestock sector. However, such exemptions have not yet not widely explored."*

Other IPR instruments that operate in the AnGR sector include trademarks, geographical indications and the above-mentioned trade secrets. Neither trademarks nor geographical indications directly restrict the use of genetic resources. They do, however, affect utilization by allowing the holders certain advantages when marketing their products. Hiemstra *et al*. (2006) note the possibility that both types of protection might play a role within a *sui generis* system for AnGR as well as promoting the conservation and sustainable use of local breeds. Some (although not all) geographical indications involve a link between a specific breed and a specific geographical area and set of production practices. This may help livestock keepers to continue operating profitably with their traditional breeds

[20] The difficulty is reflected in the following definition used 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" (FAO, 1999).

rather than adopting more mainstream breeds or dropping out of production altogether. From another perspective, it makes it slightly more difficult for outside operators to force their way into niche markets at the expense of the local communities who developed the production systems and the AnGR on which these markets are based. Trademarks might play a role in connection with the recognition of breed associations and herdbook registration (ibid.).

Existing regulations and provisions for exchange

As noted elsewhere in this paper, much exchange of AnGR takes place between private individuals or organizations based on private contracts and with little interference from regulatory authorities. In some countries, particularly developed countries, breeders' organizations play an important role in the management of AnGR at national level and exert some influence over international exchanges. These organizations may be registered with the national authorities. However, their legal authority to dictate how genetic material is used and exchanged is usually limited. The area of regulation that currently has the greatest influence on international exchange of AnGR is animal health (FAO, 2005b; FAO, 2008). The potentially devastating economic consequences of livestock diseases mean that countries maintain strict controls over imports of live animals, semen and embryos. (see Box 1 for an example). Some countries also have stipulations aimed at ensuring the quality of the imported genetic material, for example that it should come from registered sources.

Box 1. ***Veterinary and sanitary requirements No. 13-8-01/1-8 regarding import to the Russian Federation of boar sperm***[21]

For boar semen to be admitted to the territory of the Russian Federation, it must have been collected at artificial insemination 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 artificial insemination 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.

The international legal framework covering animal health-related restrictions on trade is the World Trade Organization's Agreement on Sanitary and Phytosanitary Measures, under which standards are set by the World Organisation for Animal Health (OIE). Developing countries seeking to export genetic material, particularly in the form of live animals, to developed countries will often face health-related restrictions. Exports from developed countries are also affected – Gollin *et al*. (2008) note the impact on trade in AnGR of outbreaks of foot-and-mouth disease or bovine spongiform encephalopathy in major exporting countries. On the receiving side, tropical countries with superior animal health statuses often face particular problems obtaining suitably adapted genetic resources because imports from most countries with similar climates – and hence with suitably adapted AnGR – are restricted (Country Report Brazil, 2003; Country Report Papua New Guinea, 2004; Country Report Trinidad and Tobago, 2005). The import of cattle genetic material from India into Brazil, where the majority of the national herd is made up of breeds of South Asian origin, has proved

[21] http://faolex.fao.org/cgi-bin/faolex.exe?database=faolex&search_type=query&table=result&query=LEX-FAOC027039&format_name=@ERALL&lang=eng.

particularly problematic for several decades. The arrival of a consignment of Zebu embryos in Brazil in late 2008 was the culmination of a lengthy process of negotiation between the two countries.[22]

Some regional initiatives have been taken to address zoosanitary issues. For example, in West Africa, where transhumant movements of animals across national borders are common, the Economic Community of West African States has instituted a system of International Transhumance Certificates as a means to manage such cross-border movements and to promote disease control. There have, however, been some difficulties implementing the scheme on the ground (SWAC-OECD/ECOWAS, 2008). Zoosanitary issues are potentially an obstacle to the development of regional or international gene banks for conservation purposes. The problem is recognized in the *Global Plan of Action for Animal Genetic Resources* which calls for "Review [of] the impact of zoosanitary standards on the conservation of animal genetic resources, and in particular, their accessibility." Zoosanitary regulations can even pose problems with respect to accessing cryoconserved genetic material within an individual country if the material was frozen before the latest standards were introduced (FAO, 2007b).

Many countries have enacted national legislation prescribing the requirements that have to be met before genetic resources can be accessed, particularly by parties from foreign countries. These laws often make no distinction between wild biodiversity, plant genetic resources, AnGR and micro-organisms, or between industrial and agricultural uses of the genetic resources (Hiemstra *et al*., 2006).

National access legislation specific to the AnGR sector is rare. An example is presented in Box 2. Where it exists, such legislation tends to be motivated by a desire to ensure that AnGR, particularly their indigenous breeds, are not adversely affected by excessive transfers out to the country and to ensure that benefits derived from their national AnGR are equitably shared. Countries with advanced breeding industries are usually happy to allow the products of these industries to be exported with as little restriction as possible. Given the current pattern of international exchange of AnGR the effectiveness of access legislation where it exists is difficult to assess (some – see Box 2 – is also very recently introduced). It is hard to find reports of cases in which access legislation has created significant problems for breeders who wish to obtain AnGR from outside their home countries.

The main international legal framework in this field is the Convention on Biological Diversity (CBD), the objectives of which are the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising from its utilization. It stipulates that access should take place on "mutually agreed terms" and "be subject to prior informed consent". In its decision V/5, the Conference of the Parties to the CBD recognized "the special nature of agricultural biodiversity, its distinctive features, and problems needing distinctive solutions". However, this recognition has not yet been translated into specific rules related to AnGR. As well as provisions for the genetic resources themselves, the CBD calls for equitable sharing of benefits arising from the utilization of knowledge, innovations and practices of indigenous and local communities (Article 8j). A relevant example from the AnGR sector might be a case in which a livestock-keeping community knows that a particular breed is resistant to a particular disease and this knowledge provides the basis for developments that benefit the wider livestock sector.

[22] http://www.portalms.com.br/noticias/MAPA-autoriza-importacao-de-embrioes-bovinos-da-India/Brasil/Agropecuaria/29922.html

Box 2. China's *Measures of examination and approval of the entry and exit of animal genetic resources and the research in cooperation with foreign entities in their utilization*[23],

China's regulations, introduced in 2008 in accordance with the country's Stock-Breeding Law (2005), requires that AnGR imported from abroad shall meet the following conditions:

- have a clear objective and rational purpose of use; conform to the plan for the protection and utilization of livestock and poultry genetic resources;
- be imported from non-epidemic areas and comply with the relevant provisions on quarantine and agricultural genetically modified organisms;
- and constitute no threat to the safety of the domestic livestock and poultry genetic resources or the ecological environment.

The prospective importer must supply the authorities with "Production business certificate of sire and breeding poultry;

(2) Pedigree of sire or generation-order certificate of breeding poultry issued by statutory agencies of livestock or poultry genetic resource exporting countries or regions; and

(3) Documents concerning place of origin, distribution, breeding process, bionomics features, reproductive performance and main genetic defect and special diseases in the group of livestock or poultry genetic resource."

Decisions are taken by the relevant Provincial Animal Husbandry Departments.

Conditions for export of AnGR included in the China's "Protection List" are similar to the import conditions in that they must have a rational purpose, conform to the China's AnGR utilization and protection plan and pose no threats to domestic production. A rational scheme for sharing benefits among the countries concerned must also be developed. The benefit-sharing plan has to be submitted to the authorities as part of the application process for permission to export.

The export of "newly discovered and unverified" AnGR in cooperation with "any foreign institution of individual" is prohibited. Research and utilization of AnGR that involves foreign collaborators also requires permission from the authorities. A benefit-sharing plan must again be included in the documentation submitted as part of the application.

Some countries are concerned about the effects that imported genetic material may have both in terms of socio-economic impact on livestock keepers' livelihoods and on AnGR diversity. This has led in some cases to the introduction of requirements for "genetic impact assessments" to be conducted prior to the import of any new breed into the country (Box 3). Other countries have import regulations that are less detailed in their prescriptions but are nonetheless intended to ensure that AnGR brought into the country are appropriate (China's legislation described in Box 2 is an example).

Box 3. Biological impact studies required for import of animal genetic resources to South Africa

In South Africa, any party wishing to import new exotic breeds has to arrange for an impact study which has to be completed and evaluated before the breed will be considered for recognition and importation under the terms of the Animal Improvement Act 1998 (Act No. 62 of 1977). This study must be prepared by reputable South African animal scientists and submitted to the relevant authorities. The framework for these studies requires description of the breed itself (morphology, performance, grazing behaviour, etc), its normal production environment (where it is kept), production system (what it is used for) and level of management under which it is normally kept, along with details of any known genetic defects. Assessments of potential impacts on local production systems and local genetic resources are also required, along with case studies of previous introductions of the breed into other countries.

Source: Department of Agriculture (2003). See also Pilling (2007).

[23] http://faolex.fao.org/docs/texts/chn61879.doc.

Research projects that involve international exchange of AnGR are increasingly tending to involve material transfer agreements setting out rules for the use of the material and for sharing any benefits that arise. Box 4 presents an example of such an agreement used during a collaborative research project on pig biodiversity funded by the European Union.

Box 4. Example of a material transfer agreement for AnGR used in a research project

An agreement for the long-term conservation and use of genetic resources was developed and signed initially by 13 contracting parties, including FAO. The objective of the initial agreement was to protect the ownership and property rights of the blood and DNA samples transferred among participants to the project. Written permission from both the individual provider and the country of origin was an obligatory requirement for using the material, which remains the property of the individual providers.

A second long-term agreement, to be applied in a manner consistent with the provisions of the CBD, is aimed at facilitating the conservation of the genetic material collected under the project, to be used for international research and development; clarifying property rights in all genetic material sampled in the project; and establishing a structure for the management and use of the stored DNA and project data. According to the agreement, a management group, representing the interests of all parties, is responsible for the governance of the agreement and for taking decisions on control of access to the stored DNA and project data, taking into account the provisions of the CBD and of FAO's Global Strategy for the Management of Farm Animal Genetic Resources.[24]

Under this agreement, stored DNA will be maintained for each breed and animal, using internationally accepted methods. The original material providers own the intellectual property rights related to the genetic material. Control and access to the material providers' DNA for further research and any other use resides with the original material provider. The project DNA remaining with the typing laboratories can be retained by the laboratory or returned to the material providers, as specified by the material provider. The agreement is for a period of ten years, renewable for another five unless otherwise specified. Any dispute between the contracting parties, arising out of the interpretation or execution of the Agreement, shall be settled by mutual accord.

Source: FAO (2005b).

2. Technological constraints to the exchange of AnGR

The technical feasibility of moving genetic resources over long distances and utilizing them in recipient countries has been greatly increased in recent decades by the development of techniques for storing semen and embryos in liquid nitrogen and for reproducing animals via artificial insemination and embryo transfer. However, it should be recalled that capacity to use these technologies is very uneven on a global scale. Few developing countries use embryo transfer at anything beyond an experimental level, if at all. Artificial insemination is more widespread, but a number of countries report no operational services either in the public or private sectors (FAO, 2007b.). Moreover, coverage tends to be limited to more accessible areas and to more commercially oriented production systems. Human expertise and technical capacity is also necessary on the supply side, particularly to collect embryos. Widespread use of embryo cryoconservation and hence, obviously, of embryo transfer as a means of exchanging genetic material is limited to cattle, sheep and goats. Embryo collection in pigs requires the sacrifice of the mother and the procedure remains experimental in equines (ibid.). Live birds have not been produced successfully from frozen embryos.

3. Conclusions

The legal framework for international exchange of AnGR is relatively undeveloped except in zoosanitary matters. On the one hand this allows trade to proceed unencumbered by restrictions, on the

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[24] Now superseeded by the Global Plan of Action for Animal Genetic Resources.

other hand it creates uncertainty regarding, for example, the competing claims of the different sets of property rights that co-exist, or potentially co-exist, within the AnGR sector. Another source of uncertainty is the lack of a specific AnGR focus in most legal provisions for the exchange of genetic resources, particularly given the fact that these provisions are the subject of ongoing international negotiations.

CHAPTER IV: Stakeholders' views

1. Perceptions of users and providers regarding access and benefit sharing

Before attempting to present an overview of stakeholders' views it should be acknowledged that different stakeholders have degrees of opportunity to make their voices heard. One group of stakeholders who have been systematically canvassed for their opinion are national governments – via the reporting process for *The State of the World's Animal Genetic Resources for Food and Agriculture*.[25] Another useful source, more specifically focused on the issue of use, access and exchange, is the study conducted by Hiemstra *et al*. (2006) which sought the opinions of a range of stakeholders (government officials, scientists in the public and private sectors, representatives of breeding organizations, and livestock keepers or representatives of their organizations).[26]

The authors of the latter study conclude that almost all stakeholders across countries and regions agree that exchange is, and has been, of vital importance for animal breeding and livestock sector development. This view is reflected in the words of the *Interlaken Declaration on Animal Genetic Resources:* "we recognize the interdependence of countries, regions and peoples regarding these resources"[27] and the *Global Plan of Action for Animal Genetic Resources*: "Most countries are highly interdependent, with respect to animal genetic resources. Animal genes, genotypes and populations have spread all over the planet since ancient times …"[28] further "it is likely that international interdependence with regard to animal genetic resources will increase."[29]

It was generally accepted by the participants in the Hiemstra *et al*. (2006) study that the major flows of genetic material currently take place among the countries of the North and from North to South. However, there appears to be perception among at least some stakeholders in Southern countries that while genetic transfers from South to North are currently limited, there are valuable AnGR in the South which are likely to be important in the future to breeders in the North. Many stakeholders in both South and North recognize the possibility that future developments in biotechnology and the effects of climate change may increase demand for indigenous breeds from developing countries.

Participants generally felt comfortable with current exchange practices and conditions (ibid.). Nonetheless, several contributors argued that there is a need for better regulation of exchange between countries. Concerns were raised, for example, regarding harmful effects of imports or exports on local AnGR; the promotion of introduced breeding stock by means of unsustainable subsidies or dump prices; imbalances in the distribution of benefits arising from collaborative breeding efforts between countries; a lack of benefit sharing following the use of imported germplasm for breeding; commercialization of breeds under a new names; and breeders prohibiting buyers from using offspring for further breeding.

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[25] While the *State of the World* process did not focus specifically on access issues, the guidelines for the preparation of country reports on AnGR included questions such as "Are there policy related constraints to the improved use and to the increased genetic development of AnGR that are not directly related to capacity building needs, for example, problems associated with access, or laws preventing importation of export of animal genetic resources…?", "Are there AnGR that your country would significantly benefit from, but currently does not have access to these genetic resources? What are the main breeds that your country is pursuing and why are they needed?" and "How will trends in international policy (e.g trade, sanitary, environmental, food quality, property rights, benefit sharing and access etc.) potentially affect the genetic development for each species and production system in your country?" (FAO, 2001).

[26] The geographical coverage of the study was limited, but an attempt was made to involve a representative cross-section of countries as case studies (Brazil, Ethiopia, India and the Netherlands) supplemented by selected interviews in other OECD countries, as well as in Africa, Asia and Latin America. The study also involved an e-conference which targeted: i) professionals in the livestock and development sector; ii) experts from other sectors with experience regarding similar issues; and iii) policy- and decision-makers from different stakeholder groups. Participation in the e-conference was dependent on stakeholder internet access and competence in the English language, which meant much more limited participation from breeders, livestock keepers and NGOs.

[27] Paragraph 3.

[28] Paragraph 10.

29 Rationale to Strategic Priority 10.

The country reports on AnGR generally give little prominence to problems associated with international access and exchange of AnGR other than those associated with zoosanitary regulations (see Chapter III).[30] One of the few examples from a developed country is Country Report from Japan (2005), which when discussing exchange of AnGR between Japan and other Asian countries notes that:

> *"even though some breeds have attractive qualities for both countries, they cannot be taken out of their native countries in consideration of the national interest. This hurdle may become higher in the future."*

From the perspective of a developing country that exports some of its AnGR both to other developing countries and to a lesser extent to developed countries, Country Report South Africa (2005) notes that:

> *"Animal breeding and genetics have changed markedly and resembles those that have already taken place in the plant sector. These changes will become greater with the inclusion of technologies such as sequenced genomes, transgenic livestock and cloned animals. Animal scientists have now started to protect their intellectual property and these protective measures have alarmed both scientists and the public. The challenge for developing countries is to guard against bio-piracy of their indigenous animal genetic resources and to safeguard technologies that they have been using. A second concern is the export of genetic material to countries that did not ratify the Convention on Biodiversity."*

The reports from several countries note that they currently have no national legal framework for regulating access to AnGR; some list the development of such frameworks among their priority actions for the future. There is widespread recognition that where national legal frameworks exist, the specific needs of the AnGR sector – as they differ from those of other genetic resource sectors such as crops and wildlife – are not on the whole well accounted for. However, there are few concrete suggestions in the country reports as to what measures might be introduced to address the problem.

Similarly, there is a degree of concern that existing international legal frameworks that directly or indirectly affect the use of AnGR, and those frameworks that may emerge in the future, do not or will not adequately reflect the specific needs of the AnGR sector. The *Global Plan of Action for Animal Genetic Resources*, for example, calls for:

> *"Review [of] existing international agreements that impact upon the use, development and conservation of animal genetic resources, with a view to ensuring that international policies and regulatory frameworks take into account the special importance of animal genetic resources for food and agriculture for food security, the distinctive features of these resources needing distinctive solutions, the importance of science and innovation, and the need to balance the goals and objectives of the various agreements, as well as the interests of regions, countries and stakeholders, including livestock keepers"*[31]

The Interlaken Declaration on Animal Genetic Resources recognizes the importance of an equitable framework for access and benefit sharing:

> *"We also commit ourselves to facilitating access to these resources and the fair and equitable sharing of the benefits arising from their use, consistent with relevant international obligations and national laws"*[32]

[30] This pattern was reflected in the responses to a request for information sent to National Coordinators for the Management of AnGR and subscribers to FAO's AnGR-related e-mail discussion group, DAD-Net, in May 2009, asking for information on their countries' modalities for the exchange and use of AnGR and any problems that had been experienced in gaining access to AnGR from other countries. Fewer than ten responses were received and only one alluded to access problems that did not relate to zoosanitary factors.

[31] Strategic Priority 21.

[32] Paragraph 4.

Similarly, one of the aims of the *Global Plan of Action for Animal Genetic Resources* is:

> *"to meet the needs of pastoralists and farmers, individually and collectively, within the framework of national law, to have non-discriminatory access to genetic material, information, technologies, financial resources, research results, marketing systems, and natural resources, so that they may continue to manage and improve animal genetic resources, and benefit from economic development"*[33]

There is less agreement as to what would be the ideal means to meet the objectives. Some countries have called for an international legal regime to be developed specifically for AnGR. The above-quoted passage from Country Report South Africa (2006) is followed by the observation that "the development of an international framework for the protection of animal genetic resources is therefore becoming a matter of urgency ..."; in support of this view the report points to the international character of AnGR utilization, the need for cooperation to ensure sustainable use and conservation, and the need to address the question of access and benefit sharing as required by the CBD. The International Treaty on Plant Genetic Resources for Food and Agriculture is frequently a reference point for such arguments. However, it is widely accepted that because the structure of the animal breeding sector and patterns of exchange of genetic resources differ greatly from those prevailing in the crop sector, the provisions for plant genetic resources cannot simply be transferred to the livestock sector.

Serious doubts, for example, have been expressed as to whether given current patterns of exchange (see for example Gollin *et al*., 2008) an international benefit-sharing regime would provide a mechanism that could supply sufficient resources to address the urgent need to provide support to the conservation and sustainable use and development of the world's AnGR. Hiemstra *et al*. (2006) report this point being made by stakeholders from both developed and developing countries. Moreover, the view is often expressed that as most AnGR are in private hands, and much international exchange takes place on a commercial basis, apparently to the satisfaction of both the parties involved, regulation should be kept to a minimum. For example, Hiemstra *et al*., (2006) describing the results of their stakeholder consultations report that "in the Netherlands, government respondents confirmed commitment to the CBD, but are not in favour of developing further (binding) instruments on ABS, be they national or international."

Others, however, doubt whether an approach based simply on allowing the market to regulate international exchanges can provide a fully equitable framework. Large differentials in technical capacity, market position and negotiating strength between the parties involved in exchanges raise concerns that the providers of AnGR may not receive a share of the benefits arising from the further use of the resources that is equitable and commensurate with their contribution in terms of having developed and maintained the original stocks. Arguments focus both at the national and at the community level. On the one hand it is argued that there is a need for mechanisms to ensure fair exchange between countries that differ in terms of their capacity to utilize the AnGR that they hold. On the other, there are calls for a framework that ensures livestock keepers and livestock-keeping communities, particularly smallholders and pastoralists, are equitably treated when they exchange AnGR with other parties. Concern over access and benefit sharing with respect to the AnGR themselves may go hand in hand with concerns that associated knowledge (e.g. that a particular breed is resistant to a particular disease) held by the livestock-keeping community providing the resources may be inequitably exploited by the recipients. The above-mentioned trend towards greater exertion of IPRs in animal breeding and genetics has contributed to a growing sense of unease among many stakeholders, including many livestock keepers and their representatives, regarding the future of access and benefit sharing in the AnGR sector.

The call for an access and benefit sharing regime that accounts for the needs of livestock keepers is frequently an element in a more general argument regarding the need to ensure that the livelihoods of

[33] Paragraph 15.

smallholders and pastoralists are not undermined and that their capacity to continue their role as custodians of AnGR is maintained. It is in this context that calls have been made for the recognition of "livestock keepers' rights". Some have argued that such rights should become part of a legally binding international framework for the management of AnGR (see for example Köhler-Rollefson, 2005). The term – an allusion to the "farmers' rights" enshrined in the International Treaty on Plant Genetic Resources for Food and Agriculture – was first articulated and promoted by certain civil society organizations at the time of the World Food Summit in 2002. The concept has since been fleshed out at number international meetings and workshops (Box 5) and has come to include a bundle of rights that includes rights to grazing, water, markets, training and capacity building, and participation in research design and policy-making, as well as rights to the genetic resources of their animals.

Box 5. Declaration of Livestock Keepers' Rights

In December 2008 representatives of several livestock keepers' organizations met with a number of lawyers at a workshop in Kalk Bay South Africa. The outcome was a Declaration of Livestock Keepers' rights that are considered to be easily transferable into law:

"Principles

1. Livestock Keepers are creators of breeds and custodians of animal genetic resources for food and agriculture.

2. Livestock Keepers and the sustainable use of traditional breeds are dependent on the conservation of their respective ecosystems.

3. Traditional breeds represent collective property, products of indigenous knowledge and cultural expression of Livestock Keepers.

Livestock Keepers have the right to:

1. make breeding decisions and breed the breeds they maintain.

2. participate in policy formulation and implementation processes on animal genetic resources for food and agriculture.

3. appropriate training and capacity building and equal access to relevant services enabling and supporting them to raise livestock and to better process and market their products.

4. participate in the identification of research needs and research design with respect to their genetic resources, as is mandated by the principle of Prior Informed Consent.

5. effectively access information on issues related to their local breeds and livestock diversity".

Source: New Agriculturalist (2009).

Some countries have expressed support for the concept of livestock keepers' rights, but it remains controversial. *The Global Plan of Action for Animal Genetic Resources* recognizes that "In some countries, livestock keepers have specific rights, in accordance with their national legislation, or traditional rights, to these resources", and that "Policy development should take into account ... the rights of indigenous and local communities, particularly pastoralists, and the role of their knowledge systems." However, no prescriptions are offered as to what any such rights might include at the international level, and there are no calls for the establishment of such provisions.

The role of small-scale livestock keepers, particularly in developing countries, as custodians of most of the world's animal genetic resources for food and agriculture, was also recognized by the Thirty-fourth Session of FAO Conference, in 2007. The Conference requested the Commission on Genetic Resources for Food and Agriculture to address this issue in its report to the 2009 Session of the Conference.[34] There is widespread recognition, including in many Country Reports on AnGR, that the importation of exotic genetic resources, if not managed carefully, can have an adverse effect on local AnGR diversity. Few Country Reports, however, mention a need for this to be addressed by placing

[34] Paragraph 146 Report of the Conference of FAO Thirty-Fourth Session, Rome, 17–24 November 2007.

restrictions on which breeds can be imported. Among the wider stakeholder community, opinions on the possibility of demanding impact assessments prior to import (see example from South Africa described in Box 1) are mixed. The issue gave rise to a lively debate on FAO's AnGR-related e-mail discussion group, DAD-Net, in 2007 – see Pilling (2007) for a summary. Some argue that such measures are a useful way of preventing damaging impacts on biodiversity and on livelihoods; others argue that they would place unnecessary restrictions on access and exchange or that they would be unworkable. There have been few calls for such requirements to be imposed as part of an international legal framework.

2. Conclusions

While it seems that few stakeholders would dissent from the view that much current international exchange of genetic material takes place to the satisfaction of both providers and receivers with little intervention from any regulatory authority outside the zoosanitary field, there are some clear calls for a more rigorous regulatory framework to be established at the international level. Prominent among the concerns are the risk of inequity in exchanges between developing and developed countries and the need to ensure that the rights of livestock keepers are respected. Given current patterns of exchange, the former is more a concern about the future than about the current situation; however, some stakeholders draw attention to examples of current practices that they consider inequitable. The access-related elements of calls for livestock keepers' rights are also to some degree motivated by concerns about future or emerging trends such as patenting. The overall objective is to secure the resources and participation needed to sustain livestock keeping livelihoods.

Few specific proposals as to how the concept of benefit-sharing should be applied in the AnGR sector have emerged. Proponents of livestock keepers' rights put forward various proposals as to how recognition of the contributions of livestock keepers to maintaining AnGR diversity could be translated into practical measures to support livestock-keeping livelihoods.

Many stakeholders are of the opinion that there is no need for any additional legally binding measures to be brought into regulate exchange of AnGR. According to this view, additional measures might be burdensome to commercial exchange and would not be an efficient means to promote sustainable use and conservation of AnGR.

CHAPTER IV: Conclusions

Livestock are important to the livelihoods of many hundreds of millions of people, many of them poor, making a living in harsh production environments and reliant on their animals to provide diverse products and services. The genetic diversity created by natural selection and many centuries of husbandry and controlled breeding underpins livestock production and provides vital options for the future of a livestock sector faced with many challenges. This diversity is, however, under threat from a variety of causes, perhaps most significantly the rapid changes that are affecting the livestock sector in many developing countries and are often leading to the marginalization of traditional production systems and the spread of more uniform systems that utilize a narrow range of breeds.

The current livestock populations in all regions of the world are the result of inter-regional movement and exchange at some time in the past. At present, however, and for the last century or more, relatively little movement of livestock germplasm has occurred from the developing "South" to the industrialized "North". This contrasts with large-scale movements from North to South and among the countries of the North. There have also been important transfers between the regions of the South, perhaps most notably the transfer of South Asian cattle to Latin America. There is also substantial trade, between neighbouring countries within the regions of the North and (often unrecorded) the South. The main exceptions to the overall pattern have been in species of relatively minor global economic significance such as the ostrich and South American camelids, and to some extent in breeds of grazing animals that have proved well adapted to the conditions in the hotter parts of some developed countries.

The main suppliers of internationally traded germplasm are the advanced breeding industries of the North. These suppliers are for the most part happy with the current regulatory framework in which they are generally free to trade with little interference from the regulatory authorities either at home or in the receiving countries (except sometimes in zoosanitary matters). There are evidently many recipients who are also happy with the current state of affairs. Concerns are, however, sometimes raised regarding the possible negative effects on livelihoods and on AnGR diversity of supplying genetic material that is unsuitable for the receiving production environments. Some countries have sought to address the problem by requiring impact assessments before new breeds are allowed in. Doubts have, however, been raised regarding the practicality of such measures and their possibility that they will deny legitimate access to livestock keepers who would benefit from the imports. If regulatory solutions are to be avoided, there may be a need for a more responsible attitude on the part of the breeding industry, perhaps on the basis of a code of conduct. The other obvious requirement is to ensure the availability of better information on the relative merits of different breeds in the low and medium external input production environments of developing countries. This objective is clearly encompassed within Strategic Priority Area 1 of the *Global Plan of Action for Animal Genetic Resources*; efforts to ensure its implementation should be stepped up.

While transfers of genetic material from South to North are at present relatively insignificant, there are some trends that suggest that this might change in the future, perhaps most notably climate change, changing patterns of disease distribution and technological advances in breeding. If the AnGR of the South are to become more important in terms of international trade, this will bring to the forefront the question of access to these resources and as a corollary the question of equitable sharing of the benefits arising from the use of these AnGR. Some concerns are already being expressed regarding inequity in such transfers. Moves towards greater assertion of IPRs in the field of animal genetics and breeding are likely to fuel such concerns. There is a need to find a means by which the various, sometimes potentially conflicting, systems of property rights – private, community, national, IPRs, etc – can be resolved or managed in such a way that access and an equitable share of benefits are not denied to those who need them. A basic prerequisite for any wider utilization of AnGR from the South in the future is, of course, that they have not become extinct by the time they are needed.

Some stakeholders are likely to consider that the prospect of a future scenario in which greater use is made of AnGR from the South strengthens the case for an international legally binding framework to manage access and exchange. However, given the structure of the livestock breeding sector (and for the time being the predominant direction of gene flows) a solution that closely mirrors the International Treaty on Plant Genetic Resources for Food and Agriculture is widely regarded as impractical. No clear alternative frameworks for the AnGR sector have emerged. However, there have been some proposals aimed at promoting responsible exchange practices, such as the development of a model material transfer agreement for AnGR.

The general impression obtained from the consultations reviewed for this study is that for many stakeholders the state of access-related regulations is not a particularly high priority. The prospect of AnGR being included within a general access and benefit-sharing regime that does not take the specific needs of the sector into account is, however, giving rise to some concerns regarding the possible imposition of burdensome and unnecessary procedures for access. Articulate demands for the recognition of livestock keepers' rights have emerged over recent years and would be likely to accompany any movement towards the development of an international framework for access and exchange of AnGR.

An immediate priority has to be the effective implementation of the *Global Plan of Action for Animal Genetic Resources*. By adopting the *Global Plan of Action* and the *Interlaken Declaration on Animal Genetic Resources*, the international community reaffirmed its common and individual responsibilities for the sustainable use, development and conservation of AnGR, recognizing the need for substantial and additional resources, the need to strengthen capacity in developing countries and countries with economies in transition, and the enormous contribution made by local and indigenous communities and the farmers, pastoralists and animal breeders of all regions of the world. It also committed itself to facilitating access to these resources and the fair and equitable sharing of the benefits arising from their use. The modalities for meeting some of these commitments remain to be fleshed out, but they should not be neglected. Implementing the *Global Plan of Action* as a whole is a key to ensuring that the AnGR needed in the future remain available to be accessed, exchanged and benefited from.

In the case of regional transboundary breeds, regional cooperation in conservation, genetic improvement and other aspects of management may be an important means to promote efficiency and cost savings. There may be a need to need to ensure that arrangements are in place for equitable access to and use of any AnGR managed under such collaborative programmes, as well as to manage zoosanitary risks. The *Global Plan of Action* calls for harmonized approaches to facilitate such cooperation. Regional organizations might consider playing a more active role. Moves to establish regional or global gene banks for AnGR would similarly require modalities for access, use and benefit-sharing to be established.

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Annex 1. 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
Trypanosoma congolense	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 *et al.* (1999)
Ticks (*Amblyomma variegatum; Hyalomma spp.*)	N'Dama cattle	N'Dama × Zebu	Field conditions in the Gambia	Fewer ticks	Mattioli *et al.* (1993)
Ticks (various species)	N'Dama cattle	Zebu	Village herds in the Gambia	Fewer ticks	Claxton and Leperre (1991)
Theileria annulata	Sahiwal cattle	Holstein-Friesian	Artificial infection	Less severe clinical symptoms	Glass *et al,* (2005)
Anaplasma marginale; ticks (various species)	N'Dama cattle	Gobra Zebu	Field conditions in the Gambia	Lower serological prevalence of *A. marginale*; fewer ticks.	Mattioli *et al.* (1995)
Haemonchus contortus	N'Dama cattle	Zebu	Village herds in the Gambia	Fewer abomasal worms, lower FEC*.	Claxton and Leperre (1991)
Haemonchus contortus	Red Masaai sheep	Dorper	Lambs kept under field conditions in subhumid coastal Kenya	Lambs showed lower faecal egg count for *H. contortus*, higher PCV**, lower mortality then Dorper lambs. Estimated to be 2 to 3 times as productive as Dorper flocks under these conditions.	Baker (1998)
Haemonchus contortus	Small East African goats	Galla		Kids showed lower FEC for *H. contortus*, higher PCV, lower mortality then Galla kids. Estimated to be 2 to 3 times as productive as Galla flocks under these conditions.	Baker (1998)
Haemonchus contortus	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 *et al.* (2004)

Disease/ Parasite	Breed(s) showing greater resistance	Compared to which breed(s)	Experimental conditions	Results	Reference
Fasciola gigantica	Indonesian Thin Tailed sheep	Merino	Artificial Infection	Lower number of flukes recovered from liver; differences in immune response	Hansen *et al.* (1999)
Fasciola gigantica	Indonesian Thin Tailed sheep	St Croix	Artificial infection	Fewer parasites recovered from liver	Roberts *et al.* (1997)
Sarcocystis miescheriana	Meishan pigs	Piétrain	Artificial Infection	Less severely affected in terms of clinical, serological, haematological and parasitological indicators.	Reiner *et al.* (2002)
Ascaridia galli	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 *et al.* (1984)
Newcastle Disease virus, Infectious Bursal Disease	Mandarah chickens	Gimmazah, Sinah, Dandrawi (native Egyptian breeds)	Artificial Infection	Lower mortality rate than the other breeds	Hassan *et al.* (2004)

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