DYNAMICS OF LIVESTOCK PRODUCTION SYSTEMS, DRIVERS OF CHANGE AND PROSPECTS FOR ANIMAL GENETIC RESOURCES

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Summary

This overview analyses the key drivers of change in the global livestock sector and assesses how they are influencing current trends and future prospects in the world's diverse livestock production systems and market chains; and what are their consequent impacts on the management of animal genetic resources for food and agriculture. The trends are occurring in both developing and industrialized countries, but the responses are different. In the developing world, the trends are affecting the ability of livestock to contribute to improving livelihoods and reducing poverty as well as the use of natural resources. In the industrialized world, the narrowing animal genetic resource base in industrial livestock production systems raises the need to maintain a broader range of animal genetic resources to be able to deal with future uncertainties, such as climate change and zoonotic diseases. This chapter discusses:

What are the global drivers of change for livestock systems? – Economic development and globalization; changing market demands and the "livestock revolution"; environmental impacts including climate change; and science and technology trends;

How are the livestock production systems responding to the global drivers of change? – Trends in the three main livestock production systems (industrial, crop-livestock and pastoral systems); the range and rate of changes occurring in different systems and how these affect animal genetic resources. The implications are that breeds cannot adapt in time to meet new circumstances. Hence new strategies and interventions are necessary to improve the management of animal genetic resources in situations where these genetic resources are most at risk.

What are the implications for animal genetic resources diversity and for future prospects of their use?
Industrial livestock production systems are expected to have a limited demand for biodiversity, while crop-livestock and pastoral systems will rely on biodiversity to produce genotypes of improved productivity under changing environmental and socio-economic conditions. All systems will rely on biodiversity, albeit to varying degrees, to cope with expected climate change.

What immediate steps are possible to improve animal genetic resources characterization, use and conservation?
Appropriate institutional and policy frameworks are required to improve animal genetic resources management and these issues are being addressed at national and intergovernmental levels, in a process led by FAO to promote greater international collaboration on animal genetic resources. Based on an analysis of the current situation, the continuing loss of indigenous breeds and new developments in science and technology, there are several complementary actions that can begin to improve the management of animal genetic resources and maintain future options in an uncertain world. These are summarized here as:

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(1) "Keep it on the hoof" – Encouraging the continuing sustainable use of traditional breeds and *in situ* conservation by providing market-driven incentives, public policy and other support to enable livestock keepers to maintain genetic diversity in their livestock populations.

(2) "Move it or lose it" – Enabling access to and the safe movement of animal genetic resources within and between countries, regions and continents is a key factor in use, development and conservation of animal genetic resources globally.

(3) *"Match breeds to environments"* – Understanding the match between livestock populations, breeds and genes with the physical, biological and economic landscape. This *"landscape livestock genomics"* approach offers the means to predict the genotypes most appropriate to a given environment and, in the longer term, to understand the genetic basis of adaptation of the genotype to the environment.

(4) "*Put some in the bank"* –- New technologies make *ex situ, in vitro* conservation of animal genetic resources feasible for critical situations and are a way to provide long-term insurance against future shocks.

The multiple values, functions and consequences of livestock production systems and their rapid rate of change lead to divergent interests within and between countries. Conversely, the uncertainty about the implications of rapid, multifaceted global change for each livestock production system and the resulting future changes in the required genetic make-up of animal genetic resources make collective action to tackle conservation of animal genetic resources a long-term, global public good. Conserving animal genetic resources will not by itself solve these problems, but it is an important first step towards maintaining future options.

Advances in science and the technology, in areas such as reproductive technology, genomics and spatial analysis, as well as progress in conceptualization of global public good production for the future management of animal genetic resources, should enable the international community to address both the short- and long-term challenges in innovative ways.

1. INTRODUCTION

This overview paper analyses the key drivers of change in the global livestock sector and assesses how they are influencing current trends and future prospects in the world's diverse livestock production systems and market chains; and what are their consequent impacts on the management of animal genetic resources for food and agriculture. The trends are occurring in both developing and industrialized countries, but the responses are different. In the developing world, the trends are affecting the ability of livestock to contribute to improving livelihoods and reducing poverty as well as the use of natural resources. In the industrialized world, the narrowing animal genetic resource base in industrial livestock production systems raises the need to maintain a broader range of animal genetic resources to be able to deal with future uncertainties, such as climate change and zoonotic diseases.

The range of livestock covered here are domesticated species, particularly the five major economic species (cattle, sheep, goats, chickens and pigs). There are no detailed figures yet to link specific breeds with specific production systems. We are tackling the problems from a production system angle. Throughout the paper, and based on the findings of *The State of the World's Animal Genetic Resources for Food and Agriculture*, we use the approximation that commercial breeds, as a subgroup of international transboundary breeds, are used in intensive, high-external input livestock production systems (termed "industrial systems"), and that local breeds are the basis in most extensive and low-external input systems. These are called here "pastoral systems" and "crop-livestock systems", respectively. This paper covers four main areas:

- What are the global drivers of change for livestock systems?
- How are the three main livestock production systems (industrial, crop-livestock and pastoral systems) responding to the global drivers of change, and what are the implications of the range and rate of changes for the management of animal genetic resources in these systems?
- What are the implications for animal genetic resources diversity and future prospects of their use?
- What immediate steps are possible to improve animal genetic resources characterization, use and conservation?

2. DRIVERS OF CHANGE IN GLOBAL LIVESTOCK SYSTEMS

2.1 Economic development and globalization

Livestock production is a complex and heterogeneous part of global agriculture. It ranges from highly automated, intensive large-scale production of pigs and poultry and, to a lesser degree, cattle, to small-scale, largely scavenging production of backyard pigs and chicken. Domestication of livestock started several millennia ago and humans have shaped the genetic make-up of domesticated animals to respond to human needs in different production environments.

This genetic make-up of livestock that resulted from this long-term process has been put under stress by fast-paced changes over the past few decades, across the entire range of biophysical, social and economic contexts in which humans keep animals. These changes can be subsumed under terms of economic development and globalization. These are themselves largely driven by technical progress, plus the global exchange of knowledge and products. These trends are also characterized by unequal access to natural resources, financing, markets, technology and personal mobility.

Since 1945, the world has seen an unprecedented economic growth, starting in the industrialized economies (countries of the Organisation for Economic Co-operation and Development [OECD]) and expanding into the rest of the world over the past two decades. The latter is epitomized by the economic growth path of China. A number of developing countries, mainly in Asia and Latin America, have undergone major transformations associated with significant growth in their economies and increases in per capita incomes.

The socio-economic indicators for selected countries are given in Table 1. The following inferences can be drawn from the data:

- The contribution of livestock to agricultural gross domestic product (GDP) (column 2) demonstrates the significance of the livestock sector in many economies (providing value addition); this occurs even in countries that are experiencing rapid economic growth (India and China) and/or have a growing share of industrial livestock systems (China, Brazil and Argentina).
- The key demand drivers of GDP growth and urbanization (columns 2 and 3) point towards growing demand for livestock products across all regions in the developing world. This “livestock revolution” is discussed further below.
- The trends in foreign direct investment (FDI) (column 4) show that increases in FDI are concentrated in a few countries (China and India). These countries are ones in which the industrialization of livestock production has been rising sharply. Some other countries in Africa (e.g. Kenya and Botswana) have also recorded significant increases in FDI over the past decade, although from a lower base.

Economic development has led to important changes in the spatial distribution of the world’s population, leading to a rapid process of urbanization in the developing world. At the same time, breakthroughs in medical research and their applications have led to dramatic increases of the human population in developing countries. In the industrialized world, population growth rates have declined in the last decades as social security, female employment in labour-scarce economies and cultural/social changes have led to declining birth rates and gradually aging populations. In terms of consumer demand, there is more demand for “fast food” and processed animal products. Food safety requirements are becoming increasingly stringent, due to disease problems such as bovine spongiform encephalopathy (BSE) associated with processed animal products. A similar trend is occurring in developing countries, although currently limited to the affluent urban class.

Another key driver of change that is leading towards larger-scale, cereal-based animal production systems around the world has been the rise in labour costs in the industrialized economies and in some parts of the developing world, as a result of economic growth and rising incomes.

Changing economic policy associated with rapid economic growth in parts of the developing world (e.g. Asian “tiger” economies) has changed the investment climate in emerging economies and led to massive inflows of FDI. Similarly, labour migration from developing to industrialized economies has generated capital flows back to developing countries, which are often larger than official development assistance. Capital investments from outside the farming community, for example in the feed industry and livestock production chains in Southeast Asia, are also influencing changes in livestock production systems.

The effects of globalization and growing incomes have by no means been evenly distributed within or between countries. In the context of rapid population growth, many countries and social and ethnic groups within countries have not participated in the growth process. Large numbers of poor people, particularly in rural areas, have been left behind or adversely affected by the changes. For example, such communities may actually suffer from loss of access to natural resources, bear the brunt of environmental impacts and be characterized by the breakdown of traditional social and economic ties and values, without a better (or at least viable) alternative. Also, local breeds of animals are often not competitive in this changing world.

These inequalities pose a major challenge for the global community, which has responded by setting the Millennium Development Goals (MDGs), a UN-driven process to address several core problems facing the world. The MDGs include a commitment to halve the numbers of people living in poverty by 2015, as well as setting several other key development targets, including protecting the environment and conserving biodiversity. The sustainable use and conservation of the world’s animal genetic resources for food and agriculture supports the Millennium Development Goals 1 and 7, and is also covered by the Convention on Biological Diversity (CBD).

Table 1: Socio-economic indicators for selected countries

	Contribution of livestock to agricultural GDP (%)		GDP growth (annual change) [a] (%)				Urban population[b]			FDI[c]		
							Total population (%)		Average annual growth (%)	Annual average in US$ million		
	1990–1995 average	2000–2005 average	1990	1995	2000	2005	1990	2004	1990–2004	1997–1999	2000–2002	2003–2005
Sub-Saharan Africa												
Botswana	85.0	82.1	6.8	4.5	8.3	6.2	42	52	3	77	161	363
Kenya	42.5	44.5	4.1	4.3	0.6	5.8	25	40	6.1	15	48	50
South Africa	46.1	44.0	–0.3	3.1	4.2	5.1	49	57	3	1 955	2 991	2 581
Latin America and Caribbean												
Argentina	45.9	36.5	–1.3	-2.8	-0.8	9.2	87	90	1.4	13 480	4 911	3 552
Brazil	41.8	44.4	–4.2	4.2	4.3	2.9	75	84	2.3	26 713	23 942	14 501
Peru	36.0	33.1	–5.1	8.6	3	6.4	69	74	2.2	1 908	1 370	1 890
East Asia and Pacific												
Cambodia	20.5	20.1	1.1	6.5	8.4	13.4	13	19	5.5	226	148	198
China	26.9	24.6	3.8	10.9	8.4	10.4	27	40	3.6	42 247	43 983	60 380
Viet Nam	16.7	18.0	5	9.5	6.8	8.4	20	26	3.4	1 768	1 333	1 671
South Asia												
India	26.51	30.75	6	7.6	5.3	9.2	26	29	2.5	2 794	4 894	5 552
Pakistan	49.1	53.5	4.5	5	4.3	8	31	34	3.3	585	505	

Sources:
a. IMF, 2007
b. World Bank, 2006
c. United Nations, 2007

2.2 Market demand for livestock products – the "livestock revolution"

Growing demand for animal products – as well as higher standards to improve the quality and safety of the products – and more processed animal products have substantial consequences for the evolution of livestock production systems. Overall, the processes of economic development, population growth, urbanization and changing patterns of consumption have led to a dramatic increase in the consumption of animal products in the developing world, a process that has been termed the "livestock revolution". FAO data suggest that this trend is expected to continue for several decades because of the strong direct correlation between rising income and increasing animal product consumption.

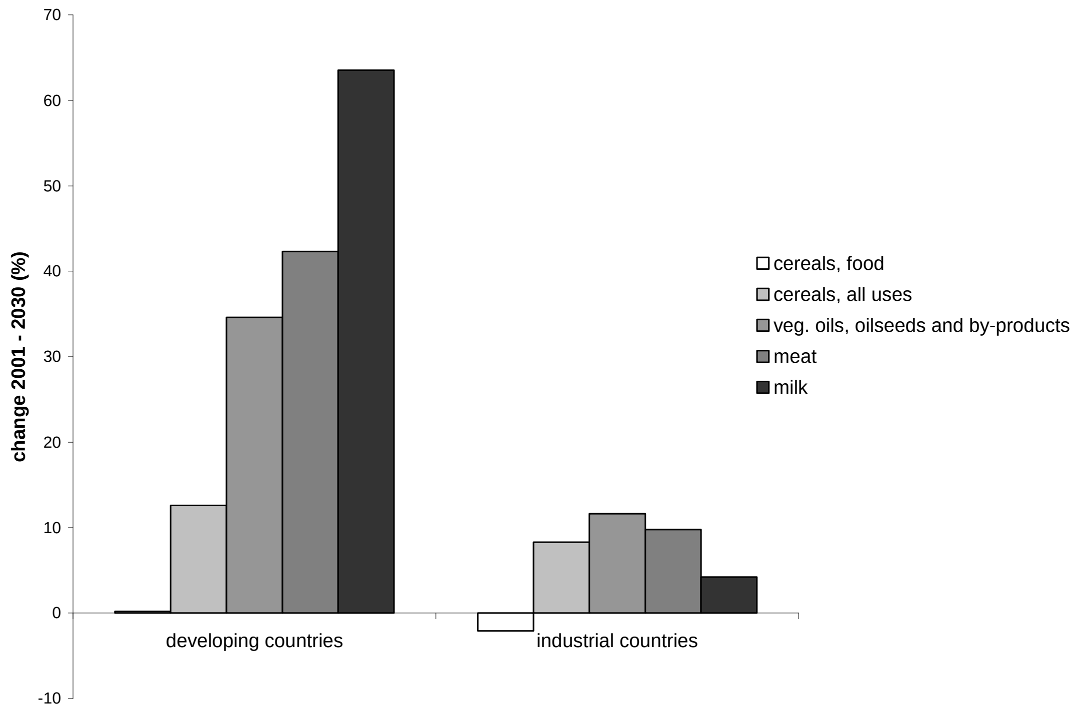
Figure 1 shows the expected percentage changes in per capita consumption of selected food commodities in developing and industrialized countries between 2001 and 2030, providing evidence of the "livestock revolution" occurring in the developing world. There are large differences between the projected per capita growth rates in consumption of livestock products (meat and milk) between developing and industrialized countries. There are also marked differences in the per capita growth rates of the different products in developing countries, with meat and milk being the highest, followed by oil seeds. Growth rates for cereal consumption as human food are stagnating everywhere, but increasing for other uses, especially for animal feed and biofuels.

The consumption of milk and meat per capita are shown in Figures 2 and 3 respectively. These data illustrate substantial differences in current consumption of meat and milk between industrialized and developing countries; the rates of growth in consumption are higher in the developing world. This trend is part of the "livestock revolution" and is the result of increased demand and increased incomes, economic growth and urbanization in developing countries. Consumption per capita of milk and meat is currently between two and four times higher in industrialized countries than in the developing world but, in absolute terms, demand is higher in the developing world.

The growing demand for animal products in the developing world is associated with the changes in production location, facilitated by the increasing ease of transporting feed and animal products around the world. Animal products were previously produced close to where the consumers live. Increasingly, livestock production now takes place close to the locations with good access to feed, either in feed production areas or ports. The animal products are then transported to markets. This trend is changing the competitiveness of diverse livestock production systems worldwide, with more animal products being produced in lower cost economies (mainly in industrial and crop-livestock systems) and traded in domestic, regional and international markets.

At the same time, large numbers of poor people depend on livestock production for their livelihoods and, for some of them, livestock offer a pathway out of poverty. These smallholders and pastoralists frequently compete for markets with the commercial sector, which is producing animal products in industrial systems worldwide. Smallholders and pastoralists together with their traditional breeds are increasingly being pushed out by the industrial systems coming into the developing world. Hence there is pressure for smallholders and pastoralists to replace their traditional breeds with more productive but less resilient breeds in order to be able to compete in the expanding livestock markets in the developing world.

Figure 1. Expected percentage changes in per capita consumption of selected food commodities in developing and industrialized countries, 2001–2030

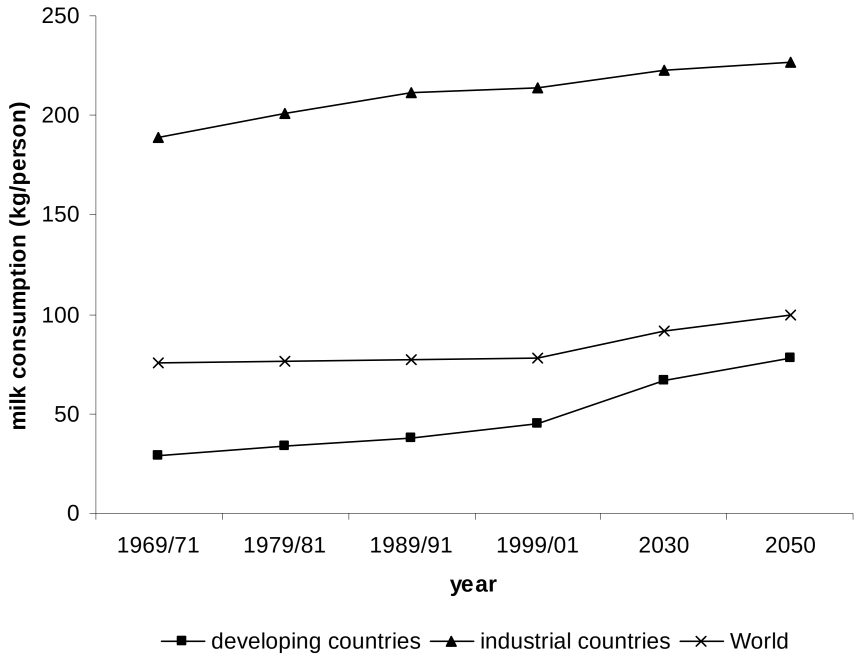


Source: adapted from IAASTD, 2007.

Technological developments associated with international transport, partially related to the increased access to capital and the opening of many economies, have dramatically increased the role of international trade in animal products. The expansion of international trade in animal products has brought to the fore the need to establish more stringent animal health and food safety standards, in order to manage the risks to the domestic sector of individual countries and to protect consumers. These health and food safety requirements have been driven by the growing problems of animal diseases, including zoonoses. These disease risks are linked to a number of factors including increasing stock numbers, the intimate cohabitation of poor families with their animals and the increased global movement of animals and animal products.

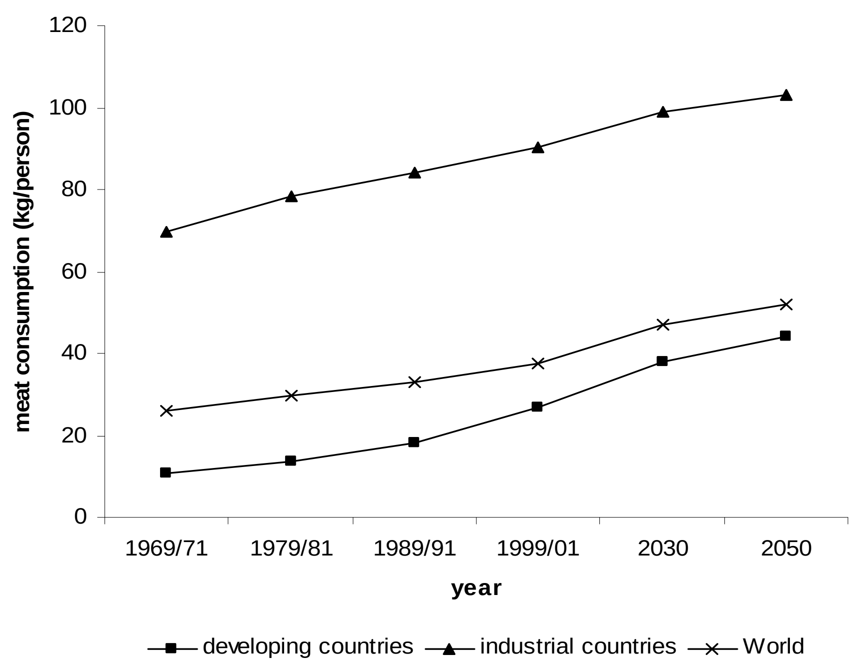
Domestic markets, including the informal livestock product markets, handle the largest share of the livestock products consumed in developing countries. However, in urban areas, the modern food retail sector is also growing rapidly, and imposing specific requirements in terms of quality assurance and homogeneity of the products (of national and international origin). The term “supermarket revolution” has been coined for these processes. These two marketing systems require markedly different food safety and biosecurity standards, affecting livestock production systems supplying these markets.

Figure 2. Milk consumption per capita to 2050 (kg/person)



Source: adapted from IAASTD, 2007.

Figure 3. Meat consumption per capita to 2050 (kg/person)



Source: adapted from IAASTD, 2007.

Table 2 shows that the share of supermarkets in food retailing has been increasing over the past two decades in much of the developing world. If current trends in expanding urban populations continue, the share of supermarkets in the urban food retail sector in the developing world will increase to levels that they are now in the industrialized economies (i.e. about 80 percent of the total food retail sector). The changing set of actors implied by the supermarket revolution and the growing importance of agribusiness in food retailing will have important implications for poor farmers.

The coexistence of three markets for animal products in the developing world (the traditional, frequently informal markets, the growing formal (super)markets for the urban middle classes and the regional/international export markets) poses particularly daunting challenges for policy-makers in pursuing mutually compatible policies of: (1) protecting livelihoods among the smallholder livestock keepers and pastoralists; (2) supporting efficient markets for the urban population; and (3) encouraging active engagement of livestock producers and their traditional breeds in the regional and global livestock markets.

Table 2: Trends in share of supermarkets in total food retail for selected countries

Waves of diffusion and average market share	Country	Year	Supermarket share in food retail (%)
Industrialized countries e.g.	USA	2005	80
First wave of developing countries (10–20% market share around 1990)	Argentina	2002	60
	Brazil	2002	75
	Taiwan Province of China	2003	55
	Czech Republic	2003	55
	Costa Rica	2001	50
	Chile	2001	50
	Republic of Korea	2003	50
	Philippines	2003	50
	Thailand	2003	50
	South Africa	2001	55
Second wave of developing countries (5–10% market share around 1990)	Mexico	2003	56
	Ecuador	2003	40
	Columbia	2003	47
	Guatemala	2002	36
	Indonesia	2001	30
Third wave of developing countries (Virtually zero market share around 1990)	Bulgaria	2003	25
	Kenya*	2004	20
	Nicaragua	2006	20
	China*	2004	30
	India	2007	9

*share of urban food retail
Source: Reardon, Henson and Berdegué, 2007.

The livestock product markets in industrialized countries are evolving along quite different paths. Besides consuming relatively inexpensive livestock products from large-scale industrial systems, there is increasing demand for niche products, frequently linked with certification of origin, often produced in traditional ways or with specific breeds, by “organic agriculture”, and/or with particular concern for animal welfare.

Animal welfare is an increasing area of concern, especially in markets in industrialized countries. These concerns include caring for animals in all types of production systems. There is particular criticism of intensive housing systems for animals (e.g. chickens, pigs, dairy cows). This is leading to more animal friendly housing systems such as group housing of sows; and free range hens as alternatives for the caging for laying hens. Some consumers in industrialized countries are prepared to pay a premium for animal products coming from such production systems that take account of animal welfare concerns. Animal welfare concerns are highly culture-specific and, while important in some societies, others consider them to be non-tariff trade barriers. Some of these trends will dictate breeds and breeding practices – for example, performance under range conditions and "broodiness" of hens will be important attributes for the niche markets.

In the industrialized countries, hobby farming has become a popular activity, using relatively small land areas for limited numbers of livestock such as sheep, goats, horses and cattle. For *in situ* conservation of species and breeds within species, these part-time farmers are important contributors.

2.3 Environmental effects of livestock production

The rapid population growth and the growing consumption of goods and services by people whose incomes are growing puts pressure on natural resources and the environment. Livestock production, under certain conditions, is driving degradation processes and is at the same time affected by them. Increasing land use for food crops and crops for biofuels is increasing the pressure on rangelands and other open access or community managed resources. This affects the viability of the low-input production systems, the sustainable use of traditional breeds and thus the livelihoods of pastoralists and smallholders.

At the same time, the rapid growth of large-scale, intensive animal production units puts a serious constraint on the capacity of the environment to deal with carbon dioxide and methane output, nutrient loading in certain areas, effluent into rivers and seas, loss of biodiversity because of land clearing to grow feeds (for example, soybeans in Latin America) and other environmental impacts.

The recent FAO (2006) report *Livestock's long shadow: environmental issues and options* focused on the effects of livestock on the environment. The "long shadow" refers to the negative effects of the livestock food chain on almost all aspects of the environment; livestock production is associated with carbon dioxide, methane and nitrous oxide emissions, water depletion, soil erosion, soil fertility, damage to plants, loss of biodiversity and competition with wildlife.

As population and living standards grow, natural resources become a limiting factor. Particularly in marginal zones for rangeland-based animal production (pastoral systems), alternative land uses such as provision of opportunities for carbon sequestration through trees or wildlife conservation may become increasingly competitive with livestock production. On the other hand, livestock production in pastoral systems can be complementary to other services – for example, livestock production provides a means to maintain shrub/rangeland systems, with grazing reducing the risk of fire in extensive rangelands and providing other ecological services.

Climate change effects

The relationship between livestock production and climate change works in both directions. On the one hand, livestock contributes significantly to climate change via carbon dioxide, methane and nitrous oxide production (calculated in FAO (2006) at 18 percent of the total global greenhouse gas emissions from human sources). On the other hand, climate change will have important effects on farming systems and on the role of livestock, both directly and indirectly.

For example, large parts of Africa and Central Asia are likely to experience reductions in the length of growing period as a result of increased temperatures and lower rainfall. This is likely to lead to lower crop yields and reduced rangeland productivity, thus affecting the provision of feeds for animals. Climate change is also likely to change the distribution of animal diseases and their vectors. Large parts of South and Southeast Asia are likely to experience increases in rainfall and in the number of extreme climatic events (e.g. cyclones). This could lead to increased exposure of livestock to diseases, such as those caused by helminthes. Crop losses due to extremes in climate could result in less animal feed being available, especially in crop-livestock and pastoral systems.

2.4 Science and technology drivers of change: general aspects and in relation to animal breeding and genetics

Science and technology have had a major influence on the transformation of animal production in industrialized economies and increasingly in developing countries. With increasing labour scarcity, larger, high-output and more productive animals were bred. From multipurpose breeds, highly specialized breeds were developed. Generally, disease resistance was sacrificed for higher output, taking into account that through capital investments it became possible to adapt the environment to the existing animals in ways that had not been possible in the past. Research into housing and mechanization allowed significant labour productivity increases. These advances occurred in many species but particularly in short-cycled monogastric species such as poultry and pigs.

Animal nutrition research, linked with breeding, has made major contributions to improving feed efficiency and shortening production cycles and thereby reducing maintenance feed requirements and allowing a more efficient use of the capital investments and natural resources.

In the developing world, the impact of modern livestock science and technology has been uneven. Industrial livestock production systems (mainly for chickens) with limited links to the local resource base have been developed in some locations close to urban demand and/or to ports, given their frequent dependence on imported feed. Smallholder crop-livestock systems are much more reliant on locally available feed and traditional breeds. These crop-livestock systems are highly complex, delivering multiple products and services. Progress in improving the sustainable productivity of these systems has been much more limited and is a significant research challenge. System-based research is required to help these systems change in line with the changing social, economic and environmental context in which they operate. Currently, the speed of change of animal production systems and market chains is very high in some locations/regions, and is accompanied by loss of animal genetic resources. (This is discussed further below.)

Science and the management of animal genetic resources

The science related to the management of animal genetic resources has made significant progress, based mainly on advances in molecular biology and genetics as well as new developments in information and communications technology (ICT). The main advances are summarized in this paper and are discussed in more detail in the following papers. The advances include:

- Technologies are increasingly available for **characterizing** animal genetic resources

Molecular characterization is providing a better understanding of the genetic diversity in global livestock populations. Functional genomics is also making it possible for genomes to be characterized, specific genomic regions and genes identified and gene functions elucidated. These technologies are based on a combination of genetic analysis and bioinformatics.

- New technologies are becoming increasingly available for **utilizing** animal genetic resources better, to meet changing needs, threats and opportunities

New genetic technologies enable the better characterization of breeds and populations. Other technologies, such as geographic information systems (GIS), enable the better characterization of the environment. Linking this knowledge will enable making a better fit between a genotype and an environment and, in the longer term, understanding the genetic basis of genotype x environment interaction. In this way, we can begin to identify appropriate genotypes for fast-changing environments. For example, there are increasing threats from drier climates that increase the need for hardier animals, tolerant to drought and disease. Animal reproduction technologies such as sexed semen and *in vitro* fertilization of embryos will enable the rapid development of new populations and faster distribution of superior animal genetics. These technologies are not yet widely used in developing countries, but offer future options in areas where a genetic solution is possible.

- Technologies are increasingly available for **conserving** animal genetic resources

New technologies are available for improved cryopreservation of embryos and semen that are applicable in more species. These technologies lead to new options for *ex situ, in vitro* conservation of animal genetic resources. For example, use of testes and ovaries obtained from livestock as sources of frozen semen and *in vitro* fertilization (IVF) embryos for long-term cryopreservation of animal genetic resources in gene banks.

- ICTs enable more precise linkage of genotypes and locations/production environments

New developments in ICTs also have implications for animal genetic resources characterization and conservation. These developments are linked to improvement of infrastructure and communication systems, such as the widespread use of mobile phones. ICTs also allow georeferencing to link particular genotypes with specific geographic locations. This knowledge provides the scientific underpinning of *in situ* conservation practices.

In order to take full advantage of the opportunities presented by advances in ICT, it is necessary to develop common standards for characterizing animal genetic resources, in terms of their genetics, phenotype and production system, so that knowledge can be shared among different communities and countries. Given such systematic and standardized descriptions of livestock, the intersection between new ICTs and modern genetics, through genomics and bioinformatics, presents opportunities to examine genome function by integration of these rich data sets.

3. CURRENT STATUS AND TRENDS IN LIVESTOCK PRODUCTION SYSTEMS

In the light of the above drivers of change, this section discusses:

- the relative importance of the three main livestock systems worldwide (industrial, crop-livestock and pastoral) and the breeds they harbour;
- the implications of global drivers of change for the different livestock production systems;
- the implications for livelihoods
- the implications of the scope and rate of changes in the main livestock production systems for current and future animal genetic resources management

3.1 Livestock species by region

The geographic distribution of the major livestock species worldwide is given in Table 3. This table shows that for all species the majority of animals are in the developing world. It also shows the importance of different species by region. For example, ruminants are most important in sub-Saharan Africa (SSA) and Latin America (LAC), both continents with vast areas of savannah and relatively low population densities. Poultry is most important in East Asia and the Pacific and LAC, regions of either high economic growth or with middle-income countries with high degrees of urbanization and adequate market infrastructure.

3.2 Livestock production systems by region

Three major types of livestock production systems can be identified worldwide – industrial livestock systems (IS); crop/livestock systems, mainly in high potential areas (CLS); and pastoral systems, mainly in marginal areas (PS).

Table 3: Geographic distribution of livestock (millions of heads)

	Cattle	**Sheep and goats**	**Pigs**	**Poultry**
Sub-Saharan Africa[a]	219	365	22	865
Near East and North Africa[a]	23	205	0	868
Latin America and Caribbean[a]	370	112	70	2 343
North America[a]	110	10	74	2 107
East Europe and Central Asia[a]	84	121	72	1 ,160
West Europe[a]	83	119	125	1 072
East Asia and Pacific[a]	184	514	543	7 168
South Asia[a]	244	303	15	777
Industrial world[b]	318	390	284	4 663
Developing world[b]	1 ,046	1,460	659	12 735

Source*:* FAOSTAT, 2007.
Notes*:* a. average 2000–2005 number; b. reported number for 2004

The share of livestock in each of these systems in different geographic regions is shown in Table 4. These data show that most livestock are located in crop-livestock systems. The proportion of livestock in industrial systems by region is mainly a function of economic status and rate of growth (e.g. higher proportions of industrial systems in the industrialized world and Asia).

Table 4: Share of livestock (total livestock units [TLU]: cattle, goats, sheep, pigs and poultry) per livestock production system for selected regions and countries

	TLU shares (%)		
	Livestock production system		
	PS	CLS	IS
Sub-Saharan Africa			
Botswana	80	19	0.14
Kenya	34	50	14
Mali	47	51	0.9
South Africa	55	36	8
Latin America and Caribbean			
Argentina	42	40	16
Brazil	18	63	17
Peru	44	21	33
East Asia and Pacific			
Cambodia	6	73	20
China	9	70	19
Viet Nam	0.75	82	16
South Asia			
India	2	82	15
Pakistan	25	63	10
Developed World			
European Union	9	67	22
Russian Federation	16	50	32

Source: FAO, 2004.

3.3 Implications of global drivers of change for livestock production systems

Current status of livestock production systems

Each of the three main livestock production systems responds differently to the effects of the global drivers of change, and therefore has different development and investment needs. The overarching trends are increasing intensification in both industrial systems and in crop-livestock systems in order to meet increasing demand for animal products and consumer preferences for higher-quality products that meet stringent food safety standards.

- Intensification and scaling up trends in industrial and crop-livestock production systems

The demand for livestock products has been met by intensification of livestock production systems in both developing and industrialized countries. Among other factors, this intensification has been based on using cereal grains as livestock feed. For example, in OECD countries, livestock feeding in intensive systems accounts for two-thirds of the average per capita grain consumption. In contrast, crop-livestock systems in sub-Saharan Africa and India use less than 10 percent of grains as feeds as they rely mostly on crop-residues (40–70 percent of feed), grazing and planted fodders.

- Market characteristics and demand

The trend towards intensification of industrial systems and crop-livestock systems is largely driven by consumer demands for livestock products, both fresh and processed. The market characteristics are increasing demand for animal products in developing countries, plus quality preferences and food safety requirements in all markets. Public–private partnerships that provide services and market opportunities also play a key role in intensifying industrial and crop-livestock systems.

Future trends in livestock production systems

Intensive systems. Intensive systems are facing increasing restrictions, owing to their associated negative environmental effects, such as problems of waste disposal and water contamination. Demand for cereals is also increasing for other purposes (e.g. biofuels) and this is driving up the price of cereals, and subsequently the price of livestock products coming from intensive systems.

Crop-livestock systems. Crop-livestock systems in developing countries are constrained by farm size and lack of access to inputs and services. These constraints affect soil fertility, crop yields, income generation and ultimately livestock production through the limited provision of high-quality feeds. There is also increasing competition for land and associated opportunity costs.

Pastoral systems. The remoteness and the limited agricultural potential of pastoral systems in marginal areas of the developing world create difficulties for these systems to integrate into the expanding markets for livestock products. This poses a set of different needs related to adaptation of systems to reduce the vulnerability of livestock keepers and their animals and expanding access to markets.

A major driver of change in pastoral systems over the past decades has been the widespread policy to settle pastoralists and allocate them individual land rights. This approach and the increasing encroachment of crop production have seriously affected the viability of these systems by reducing the mobility of livestock and access to feed resources. Although the negative aspects of these policies are increasingly acknowledged, they will continue to shape political processes in many developing countries.

Future implications of structural changes in livestock production systems

In the industrial and mixed crop-livestock systems, rising demand for livestock products will continue to drive structural changes in these livestock production systems and markets. Market transformation, particularly in urban markets, will lead to the increasing importance of supermarkets, large livestock processors and transformation of wholesale livestock markets. Much of this transformation has taken place in the industrialized countries. This pattern is expected to increase in the developing world with a growing share of industrial livestock systems.

Farmers in intensifying crop-livestock systems will diversify their production into dairy and other livestock products even more in response to market opportunities arising from rising demand for high-value foods. Similarly, income growth and urbanization will increase diversification of consumer diets and the share of livestock products in diets.

The major changes in livestock markets are going to take place in domestic markets. The relative importance of domestic markets versus trade in the future will reflect past trends in which domestic market dynamics were far more important than trade. For example, in 1980 and 2001, meat exports and imports were approximately four percent of output and consumption in the developing world. In contrast, the share of domestic urban markets in total livestock consumption has been increasing over the past 25 years.

The growing importance of domestic urban markets as opposed to international trade implies changes of actors in domestic livestock industries, particularly in agribusiness in wholesale markets, livestock processing and the retail industry, with more fresh and processed animal products being sold through supermarkets.

These structural changes in markets, transformation in urban markets, and in retail and distribution sectors in the livestock industry will have profound impacts for the future of smallholders and poor livestock keepers in competing with intensifying industrial and crop-livestock systems in high potential areas. Empirical evidence from Asia shows that smallholder farmers provide up to half of the share of production in dairy and meat markets. Undercapitalized small producers are likely to be squeezed out of dynamic domestic livestock markets. Policy action that supports small producers who can be helped to become competitive will have substantial equity pay-offs. In the absence of such pro-poor policies in the livestock sector, market changes and the entry of new actors in livestock processing, distribution chains and the retail sector can marginalize poor people who depend on livestock for their livelihoods.

High transaction costs and limited access to markets will lead to a dramatic decline of share of livestock production from pastoral systems in marginal areas. Without significant public investments in infrastructure and services, poor producers in these areas will become increasingly marginalized and many will have to leave livestock production as a source of income. Livestock will continue to be important in traditional pastoral systems as sources of food and fulfill multiple other uses, providing traction, transport, skins and hides for shelter.

Implications for livelihoods

In terms of livelihood impacts, the above changes will lead to changes in the role of animal genetic resources for livelihoods in two divergent ways: in intensive systems livelihoods will have a weak link to genetic resources, which will play very specialized production roles. The major livelihood impacts will be through employment. Frequently this will be limited direct employment in large-scale operations but some increased employment will be expected along the value chain. Consumer livelihoods will be affected in terms of impact of prices and of changed attributes of the animal products coming from these intensive systems. Society-wide, there may be negative impacts on livelihoods of traditional smallholders displaced from markets by industrially produced animal products. The net effects will depend significantly on the policy environment and the extent of substitution between animal products produced by industrial systems and smallholder systems.

In crop-livestock systems, livelihoods will be affected by the pressures to intensify and specialize production. Systems may change from grazing to zero-grazed systems, increasing milk production while reducing animal traction. This will imply changes in the labour patterns and possibly gender distribution of work and benefits from animal production. More intensively kept animals will require higher levels of management and external inputs. Increasing livelihood opportunities can be expected to develop in these forward and backward linkages associated with these commodity chains.

Pastoral systems in developing countries tend to have very strong linkages to diverse species and breeds of animals, which allow them to adapt to the exploitation of natural resources with very unique attributes and generally very limited alternative uses. Livelihoods are intimately linked to the animal genetic resources under these conditions. Risk is a major issue and the management of multiple species and multiple outputs is a key way of coping. Increasing competition for the resources, as well as policy orientations towards settling pastoralists, significantly affect these peoples' livelihoods.

In the industrialized world, highly specialized pastoral production systems rely heavily on their animal genetic resources – normally a narrow genetic base comprising one or two commercial breeds of one or two species or a defined crossbred animal population. In relation to pastoral and smallholder systems in developing countries, these systems do not involve much labour. Therefore, the livelihoods of fewer people are generally involved in these production systems.

3.4 Implications of the scope and rate of changes in livestock production systems for animal genetic resources management

The drivers of change and the evolution of the farming systems that they induce will have important effects on livestock biodiversity and its use. This in turn implies that needs and opportunities for human intervention will vary.

In industrial systems, where it is largely possible to adapt the environment to the needs of the animals, highly productive commercial breeds and hybrids are going to be the main genetic pillar. Genetic resources are handled by the specialized private sector firms and traded internationally. Their interest in hardiness or disease-resistance traits will be limited unless diseases emerge for which no alternative control strategies are available or policies require important changes in the management systems, e.g. free-ranging instead of caged laying hens.

In crop-livestock systems, pressure to intensify will be a major force shaping the production system and the genetic resources underpinning it. Significant increases in productivity will be required to meet demand and these will be achieved by simultaneously improving the conditions (feed, health, etc) and adapting the genetic resources. Given the heterogeneous environments, many different breeds will be required. In higher potential areas with good market access this specialization will increasingly involve crossbreeding with exotic breeds. Given the relatively small numbers of animals of each breed required in these niches, these genetic materials will not be produced by private multinational companies but will require active engagement of farmers, public sector and non-governmental organizations (NGOs). These systems will continue to be an important source of genetic diversity and will also demand a range of solutions to fit their specific conditions. As science improves its capacity to understand the role of specific genes and their interaction with environmental factors triggering their expression, the value of local breeds in targeted breeding programmes for these systems will increase. These systems will naturally use a diverse genetic base and will be amenable to engage with *in situ* conservation. Supportive institutional arrangements will be key to driving such efforts.

In pastoral systems in developing countries, high levels of diversity can be encountered and traits of disease-resistance and tolerance of harsh environments are widely present. These systems are frequently declining in livestock numbers and in particular small endemic populations are at risk. In these settings, conservation will require public action because of the limited resources of the generally poor pastoralists. This will be an area where NGOs can be expected to play a key role in assisting in *in situ* conservation.

Given the fragility of institutional arrangements in many developing country contexts and their exposure to natural and human-induced crises, there is merit in designing *ex situ*, *in vitro* conservation strategies as a back up and long-term insurance against loss of diversity in the field. These conservation strategies will need to be coordinated at national and regional/international levels to be efficient and cost-effective.

Climate change considerations add an important dimension to the discussion of livestock biodiversity. Different systems will be affected in different and highly uncertain ways, but access to genetic resources could be a critical ingredient for most adaptation responses in the medium to long term.

Table 5 summarizes major trends in livestock system evolution and their implications for the management of animal genetic resources.

Table 5. Trends in livestock system evolution and their implications for the management of animal genetic resources

Livestock production system: description and trends	**AnGR* – current status in system**	**AnGR management: future strategy for each livestock production system**
Industrial systems (IS)		
Industrial systems changing quickly, expanding globally Controlled system, almost "landless" environment, able to adapt environment to genetics Systems changing to reduce negative environmental impacts, meet market demands and consumer preferences, and address new issues (e.g. animal health and welfare) Changing systems require broader genetic base to address new issues and future shocks	Breeding by private sector, with narrow genetic base in pigs, poultry, cattle High-value genetic stock protected by know-how and traded internationally Limited interest or incentive for private firms in conserving species/breed biodiversity	Commercial systems will continue to *adapt environment to suit genetics* (IS prefer to use most productive breeds and manage other production issues by non-genetic means) IS need to be able to respond to future shocks (e.g. identify tolerance to zoonotic diseases such as avian influenza and also identify more disease-resistant breeds able cope with diseases of intensification without antibiotics) Conserving AnGR of main industrial species (pigs, poultry, cattle) to maintain biodiversity is a long term, public (and private) good to enable IS to deal with future options and new shocks
Crop-livestock systems (CLS)		
Diverse systems with broader genetic base, in industrialized and developing countries; CLS dependent on natural resource (NR) base CLS less in control of environment than IS Future of CLS affected by market demands, NR availability, climate change, land-use options CLS changing and intensifying production, especially in developing countries; but rate of change less than for IS Intensification options – better feed, land, water use, genetic improvement	Developing and conserving AnGR by use in CLS *(in situ)* Genetic base more diverse than IS, as animals need to be in balance with system and coevolve with natural resource base Sustainable delivery of genetic material occurring in some CLS	Need to adapt animal genetics to changing environment CLS need to be able to respond to changing environment, climate change effects, other drivers of change; conserving diverse AnGR in CLS is a public good; Sustainable use of AnGR will help CLS maintain diversity and ability to respond to future drivers of change Smallholders may require incentives to continue to conserve AnGR *in situ* with changing, more productive CLS (e.g. foster niche markets to encourage farmers to keep traditional breeds, for short- and long-term value) Mobility of AnGR critical to maintain future options as CLS change in response to global drivers (mobility favours sustainable use of AnGR) Example of moving adapted AnGR to new areas when climate change affects

		system, such as moving hardier animals to areas more prone to drought. Institutional development to support sustainable AnGR management in CLS (e.g. farmers associations, environmental, food safety and animal health regulations)
Pastoral systems (PS) in marginal areas		
PS comprise rangelands in industrial and developing countries Systems determined by NR base, usually in marginal environments Multiple value and uses of animals in traditional PS in developing countries PS changing more slowly than IS or CLS as least likely to be influenced by global drivers of change Some PS changing more quickly (e.g in parts of India where there is competition for pastoral land for alternative uses) PS closely related to traditional (cultural) practices and institutions for the management of natural resources and traditional knowledge	PS in industrial countries have narrow genetic base PS in developing countries have diverse AnGR, conserved through sustainable use Traditional AnGR conservation *in situ* by livestock keepers, linked with indigenous knowledge of animals and land	Need to adapt animal genetics to marginal environment Maintaining diverse AnGR is desirable to reduce vulnerability of livestock keepers Future need to improve productivity of PS, maintain livelihoods, with less people likely to be living in marginal lands (e.g. animal health interventions) Genetic solutions through hardier animals, able to adapt to harsher environments, with few interventions Incentives to maintain *in situ* conservation practices and promote sustainable use (e.g. improve market access through better infrastructure; foster niche markets for traditional animal products) Risk mitigation (e.g. better forecasting and strategies for handling risks in PS, such as droughts) Payments for environmental services may mean alternative land-use options that complement or compete with livestock production; requires adaptation of PS and related AnGR, depending on the nature of the environmental service Institutional development to support policies and practices for grazing, water and land-use rights

4. CONCLUSIONS AND NEXT STEPS

What immediate steps are possible to improve animal genetic resources characterization, use and conservation?

Appropriate institutional and policy frameworks are required to improve animal genetic resources management and these issues are being addressed at national and intergovernmental levels, in a process led by FAO to promote greater international collaboration. Based on an analysis of the current situation, the continuing loss of indigenous breeds of farm animals, new developments in science and technology, and the strategies suggested for the future management of animal genetic resources (as summarized in Table 5), there are several complementary actions that can begin to improve the management of animal genetic resources and maintain future options in an uncertain world. The scientific basis that underpins these proposed actions is discussed in more detail in subsequent papers. Four areas for action to improve the sustainable use and *in situ* conservation, characterization and long-term *ex situ* conservation of animal genetic resources are summarized here, and are addressed in further detail in the companion papers:

Sustainable use and *in situ* conservation of animal genetic resources

"Keep it on the hoof" *– Encouraging the continuing sustainable use of traditional breeds and in situ conservation of* animal genetic resources*, by providing market-driven incentives, public policy and other support to enable livestock keepers to maintain genetic diversity in their livestock populations.*

In this context, ***sustainable use*** refers to the continuing use of traditional breeds by livestock keepers, as a result of market-driven incentives. ***In situ* conservation** refers to animal genetic resources conservation measures supported by public policy and, on occasion, public investments to support *in situ* conservation of traditional breeds by livestock keepers.

In regard to encouraging the sustainable use of animal genetic resources, market-driven incentives applicable in developing countries include facilitating access to markets for livestock products coming from traditional breeds. This may include identifying niche markets for traditional products and providing infrastructure (such as transport) to help livestock keepers to get their products to market.

Increasing the productivity of traditional breeds through breeding is also an incentive for livestock keepers to retain these breeds. (The companion paper discusses the role of breeding in more detail.) These breed improvement strategies could also make more use of the widespread crossing that has occurred in traditional populations over time, as livestock keepers seek to improve their breeds.

In regard to encouraging *in situ* conservation of particular breeds, especially in the diversity-rich crop-livestock and pastoral systems in developing countries, the incentives include having public policies that support the conservation of traditional breeds and providing public services (e.g. human and livestock health services, schools, roads) to support communities in livestock producing areas. Such services may encourage people to stay with their animals in rural areas rather than migrate to urban areas where more services are available.

In situ conservation makes use of local and indigenous knowledge, which can also be validated scientifically. For example, some farmers have realized that by crossbreeding part of their herd to an exotic breed, they can make more profit during the good times but avoid the risk of losing all their animals when conditions are bad. Exotic animals tend to be poorly adapted to harsh conditions and tend to die during droughts, for example. Thus genetic variability reduces vulnerability to sudden changes and shocks in the system.

The concept of *in situ* conservation also extends to conserving livestock as part of the landscape, within an overall biodiversity conservation strategy, as a long-term global public good.

"Move it or lose it" *– Enabling access and safe movement of animal genetic resources within and between countries, regions and continents.*

Maintaining mobility of animal breeds, populations and genes within and between countries, regions and continents is one of the key actions for facilitating the sustainable use and thereby the conservation of animal genetic resources. Safe movement of animal genetic resources enables their access, use and conservation for mutual benefit by livestock keepers worldwide. ***Mobility*** here refers to facilitating informed access to genetic diversity, based on systematic breed evaluations and analysing the potential usefulness of various breeds in different environments.

There are benefits and risks in increasing the mobility of animal genetic resources. The benefit is that, in a fast-changing, unpredictable world, mobility of animal genetic resources enables flexibility in response to changing climate, disasters, civil strife, etc. For example, when civil strife has occurred in some part of Africa, animals are moved across borders to avoid their unintended death in conflicts. One risk of increased mobility is that animals moving to different environments may not be adapted to their new environment, livestock system or social system. There are also animal health risks, in terms of the possible spread of disease, or by animals not being tolerant to the diseases prevalent in a new environment. For transboundary movements, these risks as well as the benefit should be identified and shared with stakeholders prior to importation, and risk mitigation steps taken before importing semen, embryos or live animals into a country.

Characterizing animal genetic resources

"Match breeds to environments" *– Understanding the match between livestock breeds, populations and genes and the physical, biological and economic landscape. This* ***"landscape livestock genomics"*** *approach offers the means to predict the genotypes most appropriate to a given environment and, in the longer term, to understand the genetic basis of adaptation of the genotype to the environment.*

In regard to the long-term prospects for this research, the advances in our ability to describe the genome of an animal in unprecedented detail, coupled with our ability (through spatial analysis) to describe the landscape in which it resides – a landscape description that includes biotic, abiotic, human and market influences – are beginning to provide an opportunity to probe genome function in a unique way. This is an approach already used to study the distribution of particular alleles in livestock and to probe the human genome for disease-causing genes. Its potential for understanding the fit between livestock genotype and landscape is significant, and it depends on sophisticated data-management tools. It also offers the opportunity not only to understand the function of the genome, but also to predict the genotype most appropriate to a given environment.

This is a long-term research objective that can be linked with existing data-gathering exercises to add to their value. For example, building in systematic sampling of DNA of livestock breeds in combination with a careful description of the systems under which each population presently functions, and georeferencing the data, will add greatly to our ability to understand and utilize animal genetic resources. For example, we can begin to ask "what combination of genotypes is appropriate for a milking cow under a given management regime, under a given range of disease pressures and under a given set of physical stresses?" Knowing this will enhance the value of genotypes "in the bank" or "on the hoof" and will provide the tools we need to identify intelligently appropriate genotypes for specific agro-ecological niches. (Approaches to characterizing AnGR are discussed further in the companion paper.)

***Ex situ* conservation of animal genetic resources in gene banks**

"Put some in the bank" *– New technologies make* **ex situ, in vitro** *conservation of* animal genetic resources *feasible for critical situations and a way to provide long-term insurance against future shocks in all livestock production systems;*

Improving technology (e.g. cryopreservation) is making long-term, *ex situ, in vitro* conservation of semen and embryos more feasible, affordable and applicable to a wider range of species. The challenge is to decide which animal genetic resources to conserve; how to collect them; where to store them; when and how to characterize them; and who can access, use and benefit from them in the future. It is particularly important to collect the rich diversity of traditional livestock breeds in crop-livestock and pastoral systems in developing countries before it is lost forever.

A risk is that *ex situ, in vitro* gene banks can become "stamp collections", put away in the deep freeze and never characterized. Another potential risk is that this approach may be a disincentive to *in situ* conservation through sustainable use, where the genetic resources are more accessible in the short to medium term and where not only the genetic resources but also the traditional knowledge associated with them are conserved. In fact, *in situ* and *ex situ* conservation approaches are complementary rather than competing approaches, serving short- and long-term needs. *Ex situ, in vitro* animal genetic resources conservation is a long-term insurance policy and an important first step in conserving animal genetic resources for future generations. (Further details on conservation approaches are given in the companion paper.)

Closing remarks

Several important drivers of change are leading to rapid changes in the livestock production sector that have implications for the future management of animal genetic resources. The multiple values, functions and consequences of livestock production systems and their rapid rate of change lead to divergent interests within and between countries. Conversely, the uncertainty about the implications of rapid, multifaceted global change for each livestock production system and the resulting future changes in the required genetic make-up of the animals makes collective action to tackle conservation of animal genetic resources a long-term, global public good. Developing and conserving animal genetic resources will not by themselves solve all these problems, but are important first steps towards maintaining future options.

Advances in science and technology, in areas such as reproductive technology, genomics and spatial analysis, as well as progress in conceptualization of global public good production for the future management of animal genetic resources, should enable the international community to address both the short- and long-term challenges in innovative ways.

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