Animal genetic resources – time to worry?

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The genetic resource in domesticated animals has built up over thousands of years and many generations, in environments ranging from frozen tundra to hot semi-desert, through the breeding and selection efforts of farmers. Several thousand domestic animal breed populations have been developed in the 12,000 years since livestock were first domesticated, each adapted to specific environmental and farming conditions and each representing unique combinations of genes.

Within the animal species that are used, or may be used, for the production of food and agriculture, can be found wild and feral populations, landraces and primary populations, standardized breeds, selected lines, varieties, strains and conserved genetic material, all of which are currently categorized as breeds. Breed is is often accepted as a cultural rather than a biological or technical term. The differences, both visual and otherwise, between breeds account for much of the diversity associated with each domestic animal species. In the absence of direct measures of genetic diversity, breeds provide the best indication of total farm animal genetic diversity. Breeds are commonly classified as indigenous or exotic, where indigenous breeds are mainly kept in low-input – low-output production systems while exotic breeds are usually adapted to intensive, high-output systems and do not flourish in unimproved local production environments.

Genetic diversity measured at the molecular level does not always correspond to phenotypic breed diversity, because a long history of exchange, upgrading and crossbreeding has sometimes created similar genotypes in different phenotypes, or different genotypes within similar phenotypes. Brazilian sheep breeds (Paiva *et al.*, 2005) provide an example of similar genotypes in different phenotypes. The opposite has been observed in Djallonké sheep in West Africa where several sub-populations can be distinguished within the one breed using molecular methods (Wafula *et al*, 2005). About half of genetic variability may be found between breeds (Hammond and Leitch, 1996) but the share of within- and between-breed diversity varies among species and traits (Ollivier, 2004).

Why preserve animal genetic resources?

National governments must balance their priorities between demands that often conflict: shorter and longer term needs, the needs of small and large scale farmers, economic growth against equity, food security against agrobiodiversity, national priorities against international responsibilities. Developing country governments are under strong pressure to meet immediate needs for economic growth and equity. By comparison, conservation of genetic resources can seem a long term and less pressing goal. Why, then is it important to conserve the genetic resource of domestic animals?

There are different types of societal benefits, and beneficiaries. Genetic improvement is an important source of productivity in livestock. Moreover, animal genetic resource (AnGr) contributes to cultural heritage (Notter, 2004). There is also a moral commitment involved towards future generations. Future needs that have not been defined in the present day may require inputs from a diverse genetic pool and it would be undesirable to throw away what has not been evaluated.

Countries are the responsible legal entities for AnGR management and conservation under the Convention on Biological Diversity. There are no direct beneficiaries for the existence values of AnGR, but society globally is concerned. In the case of the conservation of specific genes of future importance (e.g. disease resistance), beneficiaries are likely to be found in many countries, and it can be argued that such programmes should be an international responsibility. In the case of locally defined cultural values or landscape or environmental benefits from AnGR conservation, the beneficiaries are mostly national, hence such programmes are a national concern.

The primary challenge for the conservation of AnGR is identifying sound reasons why society (national or international) should conserve breeds that farmers have already abandoned or that are in a critical state of endangeredness (Mendelsohn, 2003). The argument for public interest and conservation of AnGR is the same as with other types of biodiversity: to maintain use and non-use values, to preserve important components of cultural heritage or typical landscapes, or to preserve traits of future value.

Valuation of animal genetic resources

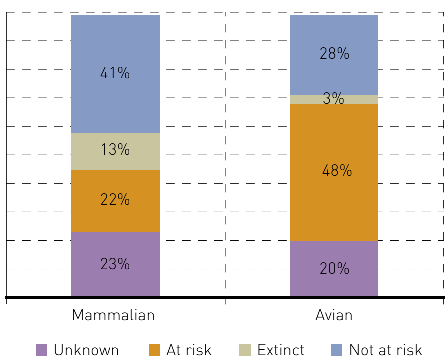
Goods that are rarely traded on markets tend to be undervalued, with prices, if recorded at all, not necessarily reflecting their economic scarcity. The value of the vast majority of AnGr is poorly understood by scientists and policy makers. Lack of valuation of local AnGR was noted in the majority of country reports submitted to FAO within the State-of-the World's Animal Genetic Resources reporting process.

Qualitative breed assessment has been done by a few groups in the recent past, mainly based on participatory assessment of priorities and preferences of livestock keepers and their communities, mostly in traditional or modified traditional livestock systems (e.g. Steglich and Peters, 2002; Lokhit Pashu-Palak Sansthan, 2005, Tempelman and Cardellino, 2005). Besides participatory methods, various economic tools such as conjoint analysis (Tano *et al.*, 2003) or hedonic price models assessing buyers' preferences for certain traits and breeds on livestock markets (Jabbar and Diedhiou, 2003) have proven useful for AnGR valuation. All these methods aim at assessing the use and non-use values of a breed. Use values indicate the direct value derived from food or fibre or other products or services, as well as the indirect value of contributing to landscapes or ecosystems. Another use value is the option value, which is the flexibility to cope with unexpected future events (e.g. climate or ecosystem change) or demands (e.g. disease resistance or product quality). Non-use value (existence value) is the satisfaction of individuals or societies stemming from the existence of the diversity.

However, the transformation of complex relations into a single unit such as a market price encounters several problems. Production traits are of secondary importance in many smallholder production systems, therefore, conventional productivity evaluation criteria are inadequate to evaluate subsistence livestock production as they fail to capture the multiple benefits of the animals and the production process (Ayalew *et al.*, 2003; Bebe, 2003). AnGR values are made up of use and non-use values. Any economic valuation of goods and services from AnGR tends to render them commodity-like. Steinfeld (2002) noted a danger with the commodity consideration of AnGR, when in a theoretical market exchange hypothetical money is traded for hypothetical opportunities. The market is imperfect with regard to AnGR as it is for other natural resources. Besides the absence of prices, AnGR have characteristics of private and public goods, which complicates the issue further. They are private goods, as the use of a single breeding animal is exclusive and rival, and they are public goods, as the gene pool of the populations is not exclusive but can be used by other farmers and future generations. Since no single owner can obtain the value of the resource as long as other owners exist, individuals will be unwilling to pay for the continued existence of a breed. The assessment of the use and non-use values of a current breed entails the additional problem that the value contribution of a specific gene added into another breed is difficult to show.

In a fully functional agro-ecological system the value of any single component cannot be understood, or priced, separately from its contribution to the whole. This problem is not limited to AnGR, but is also valid for environmental impacts resulting from agricultural activities. In parallel to the discourse on values in economic and social science, there is an increasing focus on ecosystems services and functions in biological science. The discussion about ecosystem function is a difficult one, because for most ecosystem function attributes, such as productivity or nutrient flux and storage in rangelands, a small subset of abundant species dominate, suggesting that most ecosystem function can be maintained with a reduced number of species. However, many species may have an impact on valued ecosystem attributes beyond their obvious contributions through production. Hence, Schwartz *et al.* (2003) argue that biodiversity should be conserved on behalf of ecosystem attributes. This precautionary argument for species conservation may be far stronger than arguments based on functional relationships. In developing indicators for genetic diversity of agricultural livestock and crops, Eaton *et al.* (2004) therefore propose to concentrate on breeds and varieties that are characteristic for landscapes or production environments that are important for biodiversity.

RISK STATUS OF DOMESTIC BREEDS WORLDWIDE



Source: World Watch List for Domestic Animal Diversity

Many of the external costs and benefits of livestock systems are not accounted for. This means that the costs of negative impacts of livestock production are not borne by the originator but by society as a whole. These include resource degradation, pollution and public health costs from food-borne diseases. Equally, the originator of positive externalities is not rewarded by the market. This applies to landscape maintenance through livestock grazing, or to AnGR diversity maintenance by keeping of rare breeds.

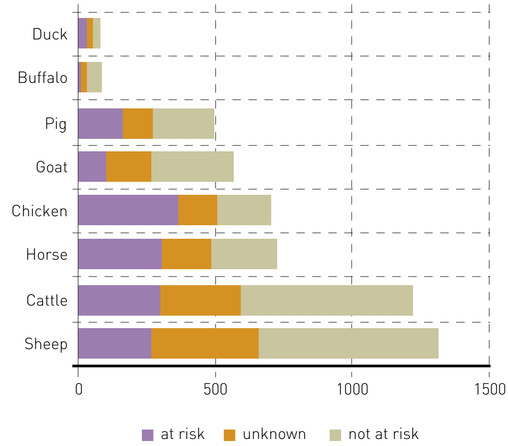
Loss of animal genetic resources and its causes

Genetic resources naturally ebb and flow within ecosystems and it can be expected that over long periods, certain livestock breeds or even species will emerge while others become extinct. However, the actions of human beings accelerate the speed with which the genetic resource changes. Human development has created the breeds found today, but current economic and social trends have the potential to erode them very rapidly. Environmental changes or shifts in agro-ecosystems including the effects of global warming (Anderson, 2004) can affect the genetic resource. So can wars, pest and disease outbreaks and other natural disasters.

In the year 2000, over 6300 breeds of domesticated livestock were identified. Of these, over 1300 are now extinct or considered to be in danger of extinction. Many others have not been formally identified and may disappear before they are recorded or widely known. Europe records the highest percentage of extinct breeds or breeds at risk (55% for mammalian and 69% for avian breeds). Asia and Africa record only 14% and 18% respectively, but the data for developing countries are much less fully documented in the World Watch List for Domestic Animal Diversity than those of developed countries. When breeds recorded in the Global Databank for Farm Animal Genetic Resources are considered, 1687 are classified at risk. When breeds without recorded population data are included, the number at risk may be as high as 2255. These figures represent a 10 percent increase since 1995, and a 13 percent increase since 1993. (Scherf, 2000).

It is not easy to estimate the rate of loss of the AnGr. Besides knowledge gaps about the characteristics and the status of genetic resources, assessment is hindered because methodologies for breed survey tools (Ayalew and Rowlands, 2004; Lokhit Pashu-Palak Sansthan, 2005) and for assessing the risk status of populations (Scherf, 2000; Drucker, 2005) have not been standardized. All over the world, loss of breeds is occurring while it is still largely unknown which breeds contain significant genetic diversity or specific genes that should be targeted for conservation and/or incorporation into breeding programmes. Loss of genetic resource is related to changes in the organisation of production systems.

DOMESTIC ANIMAL BREEDS AT RISK AROUND THE WORLD



Source: Scherf (2000)

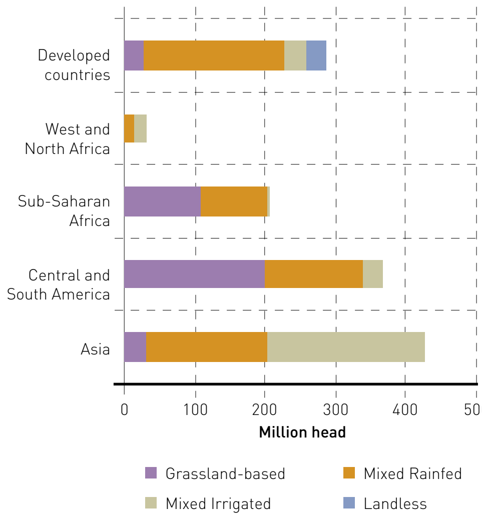
Intensification and changes in production systems

In most countries of the world, there is a shift from extensive, traditional systems towards more intensive systems. There are no widely available data that describe the distribution of breeds in production systems but approximations can be developed from agricultural survey data. Because intensive systems are based on high-output breeds fed on concentrate feeds, the average output in the national herd and the share of concentrate feed can serve as indicators for the level of industrialization in the sector. Also, the share of production from certain livestock production systems (Sere *et al.*, 1996) can be used as a proxy for the use of high-production breeds in these systems.

It is argued (IDL, 2002) that the risk of losing indigenous breeds is currently low as they are mainly kept by poor people in rural areas, who will not immediately change their production system or abandon their breeds. However, this situation may be changing as the poor either integrate with global market chains or move out of livestock production. During the 20th century, research and development in the commercial livestock sector has concentrated on a very small number of exotic breeds, in which rapid increases in meat, milk or egg production were achieved. Only 14 of the approximately 30 domesticated mammalian and bird species now provide 90 % of human food supply from animals. While production increases have been remarkable with a reduced number of breeds, erosion of local AnGr and intensive use of high production breeds occur at the same time.

The production systems with a high expected share of high-production breeds are the landless systems for monogastric species, and highland tropical environments for dairy cattle. Landless small ruminant production is based on local or improved local breeds (Groenewold, 2004). Today, landless pig production which is mainly found in OECD and Asian countries provides more than one third of global pig supply. In poultry, about 75% of meat and 66% of egg production occurs in landless systems (Groenewold, 2004). Assuming that high-output dairy cattle breeds or their crosses are found throughout all temperate zones and tropical highlands systems, about 40% of all

CATTLE IN DIFFERENT PRODUCTION SYSTEMS AND REGIONS



Source: Groenewold, J. (2004)

dairy cattle and 67% of global dairy milk production come from these systems.

Monogastric livestock, chiefly pigs and poultry, are more and more being raised in large-scale, intensive, production systems, where they show economies of scale and can be kept in biosecure conditions. Only a small number of breeds perform well economically in these conditions, mostly the exotics, while the indigenous breeds tend not to respond as well. The majority of small ruminants are raised in grassland-based systems using mainly local or improved breeds. Large ruminants are kept in grassland-based systems and mixed rainfed and irrigated systems as well as intensive feedlot or dairy operations. Independent of the production system, ruminants are mainly selected for characteristics such as meat and frame size or high milk volume. Nevertheless in less intensive systems, often their ability to survive in harsh conditions, suitability for traction or interesting appearance remain as secondary breeding goals.

Perhaps the largest single factor affecting the animal genetic resource is globalising livestock markets, driven by consumer demand in cities and developed coutries and increasingly cheap and rapid transport. The past three decades have seen considerable growth in the consumption of livestock products particularly in developing countries. Most of the increasing demand is being met by intensive production systems located in areas with access to ports and urban markets, with a few species and breeds providing the bulk of production. The increase in the size of the potential market strengthens incentives to invest in breeding research (Narrod and Fuglie, 2000). Better off urban consumers and large retail companies demand a narrow range of specifc products and product qualities and change their demands frequently. In order to respond, producers find that change of species or breed generally offers more flexibility and quicker adaptation than making use of within breed variation.

When land pressure increases and livestock are kept more intensively, poor farmers tend to opt for crossbreds because their higher output offers higher returns to labour. Local AnGR are threatened through the indirect impact of market competition if the intensive commercial sub-sector gains a certain market share in the country. Subsidised meat imports may also play a role. In such cases, the livelihoods of farmers that supply the same markets with less productive breeds may be threatened, and if they remain in production, it may no longer be economical to keep a local breed (Tisdell, 2003).

Biotechnology has increased the variety of genetic material to include semen, embryos, oocystes, somatic cells or DNA. It has also improved the transportability and tradability of genetic material. Starting in the 1960s, the use of artificial insemination (AI) in developing countries increased, mainly in dairy cattle, and mainly based on imported semen from a few breeds. The ease of reproductive biotechnology use is highest in cattle (deep-freezing of semen and embryos), and lower in pigs (mainly fresh semen used in commercial breeding) and poultry (Hiemstra *et al.*, 2005).

Concentration in the animal industry is encouraged by reproductive rate, portability and transportation costs of breeding products, and the costs associated with breeding. Taking Europe as an example, about half of the pig breeding is in the hands of associations or cooperative companies, the other half owned by private companies, and international breeding companies of hybrid products are increasing their market share (Preisinger, 2004). In poultry breeding, because of the relatively low value of single animals, high reproductive rate and portability of eggs or day-old hatchlings, concentration is very high and all enterprises are privately owned. Fifty years ago there were hundreds of primary breeders in every Western country. Today, three groups of primary breeders dominate the international layer market while there are four major players in broiler breeding world-wide (Flock and Preisinger, 2002).

Economic growth tends to favour intensive systems and lead to reduced usage of indigenous animals. The trend in the European Union, for example, where several rare breeds are mainly kept by hobby farmers for biodiversity maintenance or very small niche markets, has shown that the food security role of local breeds declines with economic growth. However, the contribution of local breeds to household food security in developing countries, particularly in rural areas, cannot be overemphasized. For this reason it is unwise to allow loss of these breeds to occur too quickly. While the impact of food safety standards on the poor has recently been analysed (FAO, 2004a), no assessment has been made of ways to promote food safety within production systems of indigenous breeds. Some of the most valuable and interesting animal genetic resources (with regard to fitness and behavioural traits) are kept by traditional communities. Young people from these ethnic groups are no longer attracted to herding and prefer to migrate into the cities for employment, thus eroding their indigenous knowledge (Köhler-Rollefson, 2005). Although the removal of discriminatory government policies (such as land use policies that regulate common grazing grounds and displace pastoral societies) would "level the playing field", indigenous breeds would likely continue to be under economic pressure.

Assessment of needs

The analysis of country reports submitted to FAO as contributions to the State of the World's Animal Genetic Resources process revealed four major areas for action at national and international levels:

- National policies, institutional development and capacity building to ensure strong national programmes for animal genetic resources, and global and regional support to assist developing countries to build their capacity.
- Enhanced inventory and monitoring to increase understanding of the state of animal genetic resources and create a better understanding of the characteristics of animal diversity
- Identification of breeds of livestock that are at risk of extinction, and development of cost-effective monitoring and conservation measures to ensure genetic diversity is maintained.
- Enhancing the capacity to use and develop animal genetic resources by integrating traditional and modern approaches and technologies across the full range of available production systems.

Policies affecting genetic diversity

Analysis of country reports submitted to FAO shows that government policies favour intensive production systems and/or the use of narrow genetic base. Intensification and modernisation of the livestock sector are primary policy targets in food-deficit countries. Policies aim at intensification of either dairy cattle and poultry (in West and North African countries) or pigs and poultry (in Asian countries, particularly China). Associated with these production systems is the need to import exotic high-input high-output breeding stock and genetic material. In some particular cases entire production systems are imported as are all required inputs for layer operations to Saudi Arabia.

Increased economic competition, together with environmental restrictions will tend towards a migration of intensive production, in particular of monogastric species, to countries with less stringent regulations, and with available land, production technology and feed (Pomar *et al.*, 2004). Environmental concerns may also influence structural changes within countries. Poultry production in Malaysia is expected to relocate from the present farming areas to more remote areas because of rapid urbanization and the need for large-scale operations, environmental friendliness and the necessity to meet sanitary requirements. In several countries of eastern and Southern Africa, the occurrence of improved breeds has been linked to private land ownership (Bester *et al.*, 2003).

Lack of supporting infrastructure for domestic markets can pose a threat to indigenous AnGR. Larger scale and spatially better connected farmers, especially those in peri-urban areas, are able to capture a large share of the market, while it is difficult for poor farmers in remote villages, where the majority of indigenous AnGR are kept, to penetrate the market (IDL, 2002). Market and sanitary regulations may tend to impede market access for local breeds. The grading system for meat animals usually favours large-framed (exotic) animals. In South Africa, the change of the cattle grading system from size to age (price premium on animals before the change of first pair of incisors) increased the market opportunities for the late maturing local breeds (Ramsay, personal communication).

Policies to increase production are sometimes supported by direct subsidies on feed (e.g. subsidized grain imports evidence), artificial insemination (AI) or other inputs which tend to favour exotic breeds, or by indirect subsidies on production inputs. For example, subsidies on fuel and fertiliser favour concentrate feed production which is better used by exotic breeds and available to farmers with access to infrastructure (ILRI, 2005a,b). Credit and insurance schemes, inflation, interest and exchange rates also promote certain production systems and thereby breeds (de Haan *et al.*, 1998; Delgado and Narrod, 2002). Support to the sector can be indirect, for example governments may be tempted to spatially concentrate their veterinary or other livestock services in areas of high livestock concentration, leading to a decline of services in more remote areas.

Governments restrict livestock movements within the country for trade or disease control, or control the trade of breeding material thus potentially favouring certain production systems and related breeds. Some governments require licensing of male breeding animals or enforce the castration of male animals of local breeds (Bester *et al.*, 2003). They also influence the availability of semen of certain breeds directly through importation and distribution, or indirectly by setting semen prices, setting up artificial insemination (AI) stations or linking sales of genetic material and breeding stocks with health programmes. In developing countries, semen of local breeds is often not available. In Kenya for example, public and private AI service supply only Friesian semen. Zoosanitary restrictions impede the export of live breeding animals or their products from developing countries, many of which are not free from OIE list A and B diseases.

In addition to erosion of breeds, there is a potential danger of loss of within-breed genetic diversity in commercial breeds. Exchange of genetic material and genetic relationships are not confined within country borders. Globalization of dairy cattle breeding has improved selection intensity, but has also led to increased relationships among animals and thus higher risk for inbreeding with its related problems (Mark *et al.*, 2002). Increased rates of inbreeding may thus be a worldwide problem which requires actions to be taken at the international level.

When policies are designed to conserve the genetic resource, there is a need to identify whether the primary objective is maintenance of breed diversity or maintenance of genetic variability, since these aims are not fully congruent. This decision will have implications on breeding and conservation methods and on the research and technologies for characterisation and valuation needed.

Monitoring and characterization

Understanding of the extent, distribution, basic characteristics, comparative performance and the current state of each country's AnGr is essential for achieving their efficient and sustainable use, development and conservation. A good understanding of breed characteristics and current performance levels is necessary to guide decision making in livestock development and breeding programmes, and selection in breed development to achieve optimum production levels. Complete national inventories of all breeds stating their main characteristics are a basic requirement for effective management of AnGR. Since genetic resources are not static, routine inventories and ongoing monitoring are needed, to prevent breeds becoming endangered before farmers and local people, government officials and the international community are aware of their significant decline. Few developing countries have sufficient current data to make an accurate analysis of the state of their AnGr.

Conservation

Since all governments aim for economic growth, but conservation of biodiversity is also desirable, in order to slow the loss of genetic resource it may be necessary to pursue parallel policies with quite different aims. Despite the valuable efforts of individuals, governments and non-governmental organizations, animal genetic resources continue to become extinct. Enhanced strategic investments in the conservation of animal genetic resources are now critical and international collaboration is essential.

Country reports submitted to FAO indicate that many breeds at greatest risk are in developing countries which have limited resources for designing and implementing conservation programmes. This is a serious situation, as breeds used in developing countries often possess unique genetic traits that enable their survival in environments with combinations of intense stresses, such as disease and drought. Present conservation efforts vary significantly between countries, as does the capacity to implement conservation measures. Many developing countries and several developed countries report that they do not have a comprehensive national conservation programme or policies for AnGr. However they believe that the conservation of AnGr should be considered within an overall national programme for AnGr, which would encourage them to study carefully the reasons for breeds becoming less popular with farmers and provide an opportunity to re-examine policies that promote exotic breeds and may contribute to the decline of indigenous breeds. Other countries report that they have established a comprehensive national programme for animal genetic resources although the capacity for conservation measures varies significantly. A number

MONITORING OF ANGR

*Surveys in remote areas in **China** have resulted in the discovery of 79 previously unregistered breeds or populations being used by farmers.*

*In **El Salvador** there is a lack of even basic livestock statistics. The last national inventory was carried out in 1971.*

*Surveys have been conducted in **Botswana**, but they do not provide adequate information to assess the status of breeds within each animal species.*

*In **Malaysia**, general surveys on all animal genetic resources important to food and agriculture are undertaken on an annual basis.*

Source: country reports submitted to FAO.

of developing countries indicated that even when there is significant awareness of the need to conserve animal genetic resources, the lack of financial and human capacity and facilities is preventing implementation of conservation measures.

In-situ conservation (sustainable on-farm operations) is the only practical conservation measure that some countries are able to employ. When linked to utilization, conservation of AnGr has a much stronger appeal to policy-makers and producers. Some breeds would see their numbers increased to safe levels if they could be associated with a product for which there was market demand. In developing countries, there is some evidence that people prefer buffalo or zebu milk to milk from crossbreds or exotic taurine cattle. Up to double the price is paid by consumers for local poultry in Asia (Dolberg, 2005). For all animal species in Africa, higher prices are paid for animals purchased for specific cultural purposes. Marketing of non-food products, such as high-quality skins of parasite-resistant local breeds, may contribute considerably to the economic sustainability of local breeds (Ramsay, 2002).

A number of developed countries have seen the establishment of niche markets for products of specific breeds and this supports conservation, as consumers are willing to pay premium prices for speciality products. Not only the genetic characteristics of traditional breeds but also the vegetation consumed in extensive production systems, or special processing of meat or cheese contribute to its special taste (Kuit and van der Meulen, 1999). There are small but growing domestic markets for locally produced or organic animal products in countries such as Argentina, Brazil, South Africa and India and regional markets in the Middle East, Latin America and Asia. However, the registration of goods of geographical origin or trademarks is beyond the capacity of most keepers of local livestock in developing countries.

National initiatives on cryopreservation of semen, oocystes and somatic cells are ongoing (Blackburn 2003; Hiemstra *et al.*, 2005). Guidelines for national cryopreservation programmes have been developed by the European Regional Focal Point for the Management of AnGR (Hiemstra, 2004).

Several methods are available to assess genetic diversity at molecular level, using measures of gene diversity or of pair-wise genetic distances between breeds in order to derive individual breed contributions to diversity (Ollivier, 2004). A variety of markers is available to assess different types of diversity (Bruford *et al.*, 2003; Hoffmann *et al.*, 2004; Lenstra *et al.*, 2005; Hiendleder *et al.*, 1998). Molecular methods of structural genome analysis have allowed for the identification of causal genes for defects and monogenic traits, and contributed to the understanding of genetic mechanisms on trait expression and variation. Today a wide range of quantitative trait loci (QTL, loci with significant influence on production performance) have been identified and analysis tests developed (Schwerin, 2004). Use of QTLs is most beneficial for traits that have low heritability and are difficult, expensive or impossible to record in a breeding programme. Use of QTLs could therefore be particularly beneficial in the low to medium input systems of the developing world, where disease resistance and adaptation traits are particularly important. If marker-delimited genome regions that control such traits are identified, the corresponding markers could be used in marker-assisted selection. Although very promising, practical application of marker-assisted selection programmes has as yet been limited (Kuehn *et al.*, 2004, Arias *et al.*, 2004).

There is an increasing discussion in the literature about decision-making for conservation of AnGR, be it in gene banks or in-situ conservation (Weitzman, 1993; Simianer *et al.*, 2003; Bruford *et al.*, 2005). Based on Weitzman (1993), a diversity matrix which is derived from a genetic distance matrix is usually taken as the basis. When the diversity information is combined with extinction probabilities and conservation potential, it is assumed that the expected diversity will be maximized. Between-breed diversity is considered as one major criterion to be taken into account when setting priorities for conservation of domestic animal breeds, but choosing priority breeds with the largest within-breed diversity has also been proposed. Hanotte and Jianlin (2005) propose "livestock diversity hotspots" as priority areas for conservation. Reist-Marti *et al*. (2005) developed first approaches for the optimal allocation of a hypothetical conservation budget under several conservation schemes with known costs.

Genetic improvement

Breeding is the most important component of the management, use and development of animal genetic resources. Livestock breeding starts with planned reproduction, which is difficult to manage in some free-ranging production environments. Breeding has always been influenced by current biological, genetic, technological and statistical knowledge. Systematic breeding requires controlled mating, individual animal identification, progeny and performance testing and recording to identify superior parents (particularly on the male side), and sophisticated data processing. The high-output breeds of today have been selected for at least 20 generations in pure-breeding systems.

Direct or indirect government support to breeding programmes has always taken place, for example through research in genetics. The establishment of breeding organisations in developed countries was state supported in the past in many cases. Today, breeding programmes with established breeds are found in the more favourable parts of the tropics where exotic breeds are well established, whereas indigenous breeds without systematic breeding programmes dominate in regions such as West Africa and large marginal parts of Asia and Latin America.

Private breeding enterprises are fully commercial and invest in those species (dairy cattle, pigs, chicken, turkey) with high technology responsiveness and high returns on investment. Private incentives for animal breeding research are strongest where markets for improved technology are large, advances in husbandry can be implemented relatively easily and quickly, and where knowledge can be protected (Rothschild *et al*., 2004). Private research tends to concentrate on technologies that are likely to result in market applications in the near future. The driving factors are high reproduction rate (at least of the male side), low unit cost, economies of scale in research, the appropriation and control of produce, and uniformity of product to comply with regulations on standards. With emerging possibilities of breeding for disease resistance or specific quality traits, industry may increasingly include genetic material from local breeds in their breeding programmes. Although zoosanitary restrictions are an impediment for the transfer of genetic material from developing countries, new biotechnologies may change this in future.

Subsistence farmers only rarely buy animals but supply their breeding animals from their own herds or through social networks (Blench, 1999). Breeding animals of local breeds are rarely sold. In many pastoral and mixed farming systems, traditional animal exchange systems exist, which are often related to extended human family linkages. Local breeds are 'multi-functional', and breeding goals for such breeds are targetted towards the provision of an array of products and services, and towards adaptation to harsh environments and disease resistance (Tano *et al*., 2003; Wurzinger *et al*., 2005).

Better management and breeding may lead to profitability of improved genetics at farm level. Such economic improvement at individual farms may add up to welfare gains and improved food security at the national level. However, public goods benefits from breeding such as maintenance of AnGR for future generations are not usually paid for. An analysis of dairy cattle crossbreeding schemes in Kenya revealed that research and development costs, veterinary costs, foregone non-market benefits from indigenous livestock and overall loss of AnGR biodiversity were not taken into account (Karugia *et al*., 2000).

FAO (1998a,b,c, 1999, 2000, 2001a) has developed guidelines for the development of national animal genetic resources plans, including the management of small populations at risk and for recording in medium input systems. A comprehensive methodology to define the private and public costs and benefits of sustaining breeding programmes (pure- and cross-breeding) is still lacking, but would be essential to make sensible investments in animal breeding.

While crossbreeding and breed replacement can be effective means for increasing production, their potential in the tropics is limited to benign environments. Unfortunately, introduction of exotic genetic material continues to be seen as a solution to low output of local breeds even in areas where the exotic genotypes are ill adapted (ILRI, 2005a,b). In quantitative terms, most genetic material flows from developed to developing countries. The extension of markets and economic globalization including the global marketing of exotic breeds have contributed significantly to the loss of local breeds through indiscriminate crossbreeding (Tisdell, 2003; Country Reports).

After government breeding stations have not proved successful in most developing countries for a variety of reasons, and breeding programmes have been difficult to implement (Galal *et al*., 2000), today Open Nucleus Breeding Systems (ONBS) are being developed as one way of community-based AnGR management (Mhlanga, 2002; FAO, 2003; Tempelman and Cardellino, 2005). There is a movement of increasing interest in local breeds and community-based management of AnGR (Köhler-Rollefson, 2003; Mhlanga, 2002, Gondwe and Wollny, 2002; Almekinders, 2002; FAO, 2003; Tempelman and Cardellino, 2005). A few examples show achievements of sustainable genetic gain by selecting within local breeds (FAO, 2001b). With improved management and the inclusion of non-market benefits such as disease and parasite resistance in the productivity assessment local breeds can outperform crossbreds (Setshwaelo, 1989; Ayalew *et al*., 2003). Some commercial farmers in Zimbabwe and Namibia favour local breeds due to their higher overall productivity.

Matching specific genetics to specific environments

Information about the performance of indigenous or improved breeds and their suitability for specific production systems and environments is very important for farmers to make choices. If exotics and their crossbreds are disseminated to less favourable production environments, the production risk increases and economic loss may occur. The opposite case, that farmers continue to utilize local breeds for too long, seems hardly ever to hardly occur.

After all the progress made in molecular genetics, identifying gene variants that encode breed specific phenotypes remains a challenge (Lenstra *et al*., 2005). Breed formation and selection are reflected in differences in allele frequencies rather than in breed-specific alleles. Breed is more a cultural than a technical term; therefore the line of argument of breed conservation differs from the one for genetic diversity conservation. Local animal breeds are increasingly recognized as part of culture and landscape, and as attractive for tourism, thus their conservation as a part of habitat conservation is pursued by governments and NGOs equally. Breeds are also conserved because of their historical significance or because of their cultural importance for traditional communities. New developments in "landscape genetics" combining geo-statistics and molecular genetic diversity (Joost and ECONOGENE, 2005, Bruford *et al*., 2005) will allow for the analysis of gene and environment interaction and its spatial distribution.

There is still a lack of information about existing or potential levels of productivity, production characteristics of local breeds managed in their production system and the genetic make-up of the indigenous breeds. The little research that has been undertaken found that there are highly productive indigenous breeds (e.g. Setshwaelo, 1989; Hossary and Galal 1995; Ramsay 2002; Ayalew *et al.*, 2003; Bester *et al.*, 2003). Several adaptation traits have been documented, such as trypanotolerance, or resistance against parasites, the ability to cope with difficult feed resources or adaptation to extreme climatic conditions. However, hard data are scarce and more research is needed, in particular about the genetic and functional mechanisms of adaptation traits.

Protection of intellectual property

Increased industrialization has led to heightened interest in protection of intellectual property (Rothschild *et al.*, 2004). The boundaries of the intellectual property system are widened as industries extend their orbit of operation by developing and applying innovative technologies. This expansive process is likely to succeed, except in cases where other interest groups voice their opposition. To date, technological resources and contractual practices, rather than formal intellectual property rights strategies, have been the norm in the livestock industry. In pure-breeding programmes usually the buyer of a breeding animal acquires the right to breed from the animal and its offspring without limitations.

Related to the increasing appreciation of indigenous breeds are efforts for their protection in legal terms. Initiatives of non-governmental or civil society organisations range from the registration and description of local breeds and the traditional knowledge associated with their breeding to the call for unrestricted access, use and exchange of AnGR and the refusal of patenting of indigenous breeds or parts thereof (e.g. in the Karen-Commitment on Pastoralists/Indigenous Livestock Keepers' Rights; LPP and ITDG, 2003). Issues of traditional knowledge, folklore and genetic material, and the rights of the communities where these originate are discussed in the Convention on Biological Diversity (CBD), the TRIPS Council and in the World Intellectual Property Organization (WIPO). Since the continued use of AnGR, in particular in pastoral systems, depends on access to other natural resources, such issues are also discussed in fora such as the International Labour Organisation or the UN Economic and Social Council (ECOSOC).

Conclusion

The Global Databank for Farm Animal Genetic Resources covers more than 30 species used for food and agriculture, with data provided from more than 190 countries. Analysis of the databank suggests that about 30 percent of livestock breeds are close to extinction, with a 13 percent increase in the number of breeds recorded at risk since 1993. Erosion in animal genetic resources is alarming.

Even though data have been collected for more than 10 years, there is still a big gap in information on population sizes and structures. Consistent nation-wide surveys and inventories have not been conducted by most developing countries. The same applies to regular monitoring of threatened breeds. Methods are being developed to assist countries in this task but sufficient capacities and funding are lacking. The lack of information also hinders proper decision-making about what to conserve and how to allocate limited funds available for conservation. Most local breeds, particularly those that have been created in harsh environments of developing countries, have not been sufficiently characterized. If they become extinct, their lost value to humankind will never be known.

The globalization of market chains for livestock and their products is creating a changing market environment in almost all countries that encourages farmers to intensify their production systems or move out of livestock production. Privately funded research and development in support of intensive systems has focused on a very small number of breeds and species and a small number of production traits that offer positive returns to investment. Breeding for low-input production systems will continue to remain a task for the public sector and can be supported by producer cooperatives or community-based breeding programmes. However, given the choices, dynamism and the adaptation inherently embedded in indigenous knowledge on the one side, and the limited availability of resources for conservation in the public sector on the other side, a certain loss of local breeds will be inevitable. The question is: do we know the value of what is getting lost?

Some of the policies directly or indirectly affecting breed choice are well intended and conscious of their impact. Others pursue more general social or economic objectives but distort the playing field on which different genetics compete. While the impacts of such policies are readily discernable in broad terms, little is known about their impact on animal genetic diversity. They may have helped to supply affordable and safe animal products, but they have disadvantaged less intensive production systems and compromised household food security. Where livestock policy changes affect animal genetic resources directly, the net costs and benefits of such policies have usually not been documented, and policy environments or strategies that promote conservation and appropriate utilization have not been defined. The challenge at national, regional and global level is the formulation of policies that consider animal genetic resources and favour their sustainable management.

Market and policy have been identified as the strongest drivers for changes in the livestock sector that may negatively affect animal genetic resources. A reversal of such trends would require putting in place and enforcing national and regional regulatory frameworks that account for externalities of livestock production, e.g. raising taxes or levies on waste disposal, pricing water, imposing sanctions to polluters, charging producers for disease surveillance in the case of intensive production; providing incentives for landscape and agricultural biodiversity management and conservation in the case of extensive production.

Enabling institutions need to be developed. Most countries do not provide a legal framework for the registration of animals of indigenous breeds or the establishment of breeding associations or cooperatives. Particularly in communities without history of systematic breeding, the establishment of breeding programmes requires significant capacity building and training. A conceptual framework taking these factors into consideration has been developed by Dossa and Wollny (2004). Like other community-based natural resources management, community based breeding programmes are not easy to implement because human group development is as important as breed development. Considerable investment is needed for participatory development of the breeding and management protocols, including livestock management protocols, and community participation rules and responsibilities (Wollny *et al.*, 2005). The marginalisation of poor farmers or communities may impede community-based AnGR management. If government subsidies are part of the programme, their withdrawal may threaten the sustainability of the programme (Yapi-Gnaoré *et al.*, 2003). Decision-makers are also challenged by the choice of technologies required for the management of animal genetic resources in specific socio-economic contexts. Some systems might be currently stable and need to be protected from application of new technologies.

It is certainly high time to worry about our breeds of livestock, our common heritage and basis for food security and increased production of the wide range of products of animal origin. Appropriate measures to halt erosion in our animal genetic resources and most effectively use our heritage for future generations and human wellbeing have to be taken at all levels ranging from farmers and herdsmen to the international level.

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