

Global perspectives on animal genetic resources for sustainable agriculture and food production in the tropics

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This first module provides some insight into the need for better use of animal genetic resources (AnGR) in the context of projected demand for food in developing countries until 2020. Worldwide, 850 million people do not have enough to eat; a livestock revolution is currently underway to meet the nutritional needs for improvement of the livelihood of poor people. The module provides the background, facts and reasons for increased attention to improved utilisation and the maintenance of AnGR in developing countries. It also provides a list of some key literature. References and links are made to web resources [\[blue\]](#) and to other parts of this resource [\[burgundy\]](#). Some case studies on breed resources and other relevant components of this resource (CD and the web version) help illustrate the issues presented.

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1 Summary

Livestock play important roles in the production of food and for other purposes. The diversified use of livestock on average contributes to between 10% and 50% of the gross domestic product (GDP) of countries in the tropical developing world. About 70% of the world's rural poor depend on livestock for their livelihood (FAO 2005a). Livestock therefore are of great socio-economic and cultural value in various societies around the world. This situation and implications for the future use of AnGR can be summarised as follows:

- There is a great challenge to alleviate poverty in developing countries by producing more and safe food, especially of animal origin, against a shrinking animal genetic diversity and increased global trade. There must be a livestock revolution in the developing world to meet the projected demands of more than double the current meat and milk consumption in these countries over the next 20 years. This demand cannot only be met by an increased number of animals; increased productivity is also required.
- The potential of indigenous breeds in developing countries is often inadequately documented and utilised.
- The value of AnGR conservation is generally underestimated, as the current indirect values are often neglected; the future option values are yet to be accurately estimated and predicted, yet the most efficient way to sustain a breed is to continuously keep it commercially competitive or culturally viable.
- Global initiatives must be locally internalised and accompanied by local activities to implement conservation programmes that increase animal productivity while maintaining the necessary genetic diversity. Previous conservation/improvement programmes have often failed. Good and simple examples that demonstrate effective breeding strategies (which take into account environmental, socio-economic and infrastructure constraints) must be developed.
- Research and capacity building at all levels to improve the knowledge of indigenous and alternative AnGR in different regions of the developing world is required. The implementation of sustainable breeding strategies in the tropical developing world will be instrumental in increasing awareness of the roles of livestock and their genetic diversity.

2 Food security and livestock—keys to poverty alleviation

At the dawn of the 21st century more than 1.2 billion people live in extreme poverty, while 850 million are chronically hungry and the number is rising. Most of these people are found in sub-Saharan Africa, and South and East Asia. Of the 40,000 people that die each day of malnutrition, about half are infants and children (FAO 2005a). Throughout the developing world poverty is linked to hunger and every other person in sub-Saharan Africa is considered poor, i.e. lives on less than one US dollar a day. It is estimated that 5 million children die of causes directly related to malnutrition annually (FAO 2005a). See: [\[Poverty maps\]](#).

Availability of affordable food of livestock origin would go a long way to helping alleviate this catastrophe. However, the challenge of adequately feeding people in the future is exacerbated by the fact that the global population increases by some 90 million people annually. This means that the world's farmers will have to increase their production by 50% to feed about 2 billion more people by the year 2020 (World Bank 2002).

The overall objective of the Millennium Development Goals (MDG) of the United Nations (UN 2004) is to reduce the proportion of people who are extremely poor and hungry by 50%

by the year 2015. Two of the specific MDG targets are: i) child mortality rate to be reduced by two-thirds for children under 5 years of age; and ii) environmental sustainability should be ensured. However, according to the Progress Report of the Millennium Development Goals (UN 2004), the sub-Saharan Africa, South Asia and western Asia regions still lag behind in terms of the set targets in almost all the eight goals. The incidents of extreme poverty are still very high, universal education is behind and child mortality rates remain high with no significant changes taking place. In addition, HIV/AIDS is still ravaging many populations and environmental sustainability is declining. In each of the goals, development and sustainable use of livestock, especially if targeted to the poor, provides a pathway to achieving the goals (ILRI 2003).

The per capita availability of food of animal origin is much lower in the developing than in the developed world (Table 1). However, it has improved in developing countries as a whole, but large discrepancies exist between regions. For example, in sub-Saharan Africa the per capita food supply decreased slightly between 1990 and 2002.

Table 1. Per capita daily supply of animal products in calories and gram protein for 1990 and 2004

	1990		2002	
	Calories	Protein (g)	Calories	Protein (g)
Developed world	938	59.1	873	56.9
Developing world	253	14.8	358	21.0
Sub-Saharan Africa	145	11.1	140	10.3

Source: FAO (2002; 2005a).

The increasing disparity between population growth and food production for sub-Saharan Africa is also illustrated in Figure 1 (CGIAR 1999). Unless constraints to higher yields are overcome, one-third of the population in this region will not have sufficient food by 2010.

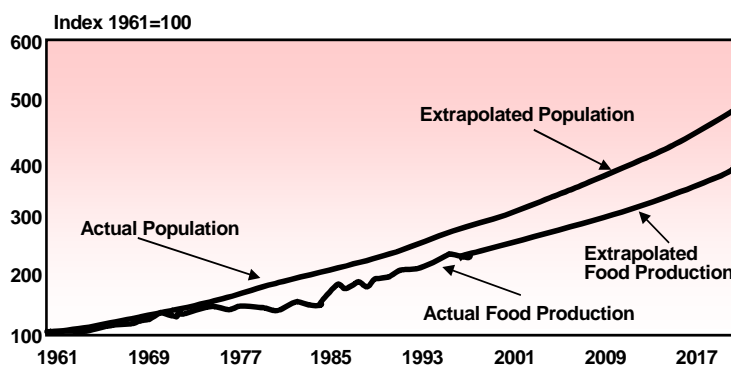


Figure 1. Trends in human population growth and food production in sub-Saharan Africa. Source: CGIAR (1999).

The human population numbers in 1990 and 2003 for the different regions of the world are shown in Figure 2. The meat and milk produced in the same period are shown in Figures 3 and 4 respectively. Africa and Asia have the largest population growth (Figure 2). The increase in meat (Figure 3) and milk (Figure 4) production, however, has occurred in the developing and not in the developed countries. For the two products, Asia had the highest increases (Figures 3 and 4).

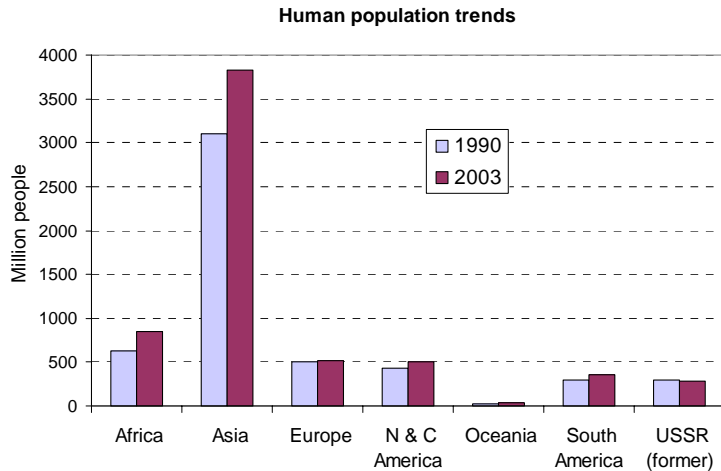


Figure 2. The world human population in 1990 and 2003. Source: FAO (2005a).

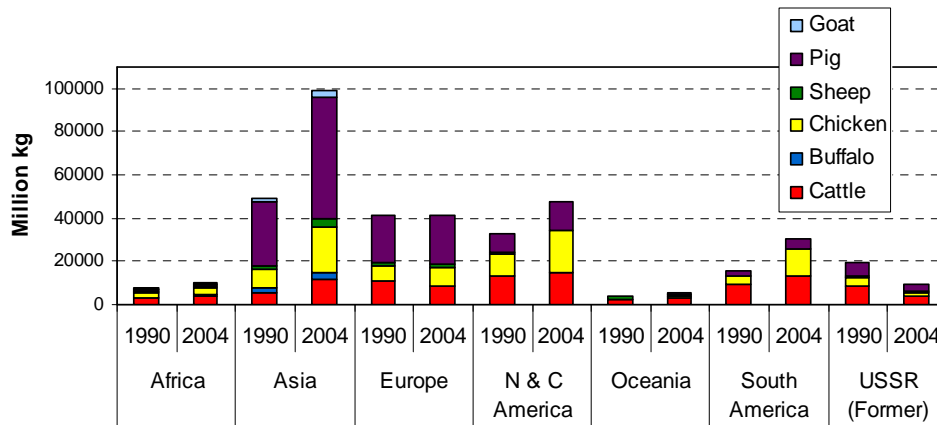


Figure 3. Total world meat production by region in 1990 and 2004. Source: FAO (2005a).

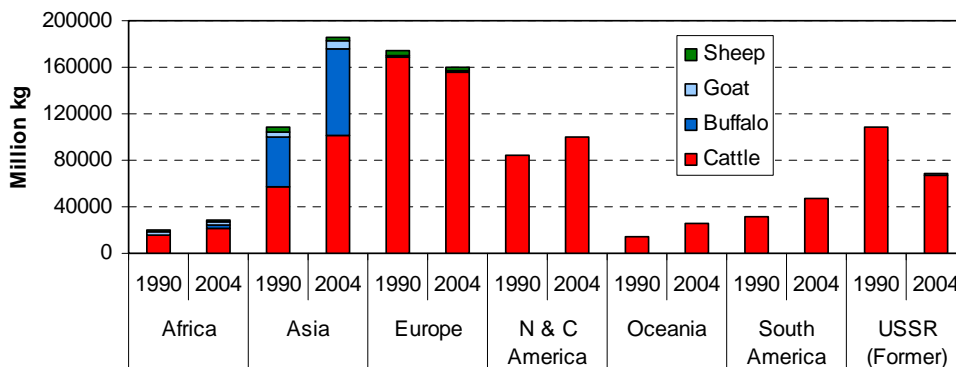


Figure 4. The total world milk production by region in 1990 and 2004. Source: FAO (2005a).

Enhanced food security is a key factor for poverty alleviation. The overwhelming challenge to improve the well-being of people in developing countries is thus highly dependent on the realisation of increased food production, and access to food of animal origin, in the coming decades. But if the global population increase could be curtailed at the same time then the level of increased food production required might decrease to something that may be more realistically attainable.

A study by ILRI's Livestock Policy Programme examined the food security and marketed surplus effects of intensified dairying in a peri-urban area of Addis Ababa, Ethiopia, where a market-oriented dairy production system using supplementary feed and management technologies for increased production had been introduced for smallholders. Results showed that women in households with access to crossbred cows earned nearly 7 times more dairy income than women in households with local breed cows for the same division of work, and had greater opportunities with the increased output and income (Mohammed et al. 2002). They consumed on average 22% more milk and 30% more calories per day and could afford 36% higher food expenditures, leading to the intake of a more nutritious diet (Mohammed et al. 2002).

In India, investment in research and extension in support of crossbreeding of cattle has yielded a return rate of 55% annually from the date of investment, with the primary beneficiaries being the livestock producers (Anjani-Kumar et al. 2003). For example, in Kerala State of India, 40 years of a dairy livestock-based development programme, in which a synthetic breed (Sunandini) was developed by crossing local cattle with different exotic dairy breeds (Brown Swiss, Friesian and Jersey), followed by stabilisation of the crosses through selection within the crossbred population, has resulted in great success. For example, daily milk consumption per person increased from 20 g per day to 280 g per day, through an improved daily milk yield per cow from just more than 1 litre to 6–8 litres (Kerala Livestock Dev. Board 2003) [CS1.40 by Chako]. The increased consumption of milk per person is reported to have had a significant positive effect on child nutrition and health and huge impacts on the livelihoods of the people.

A community-based dairy goat crossbreeding and animal health-care programme in the Meru area of the Eastern highlands of Kenya has demonstrated similar examples (Ahuya et al. 2004; Ahuya et al. 2005). In the Meru area improved goat genotypes accompanied by improved husbandry practices were adopted by hitherto very poor farmers whose livelihood was well below US\$ 1/head per day. Currently the same group, comprising of 3450 members, keeps improved goats each producing between 1.5 and 4 litres of milk per day. The group now produces about 3500 litres of milk daily, and is processing and packaging some of this for sale. Besides the primary producers, goat milk and meat traders and those employed along the production-to-consumption chains are also benefiting.

However, studies by Krishna et al. (2004) clearly indicated that loss of livestock assets through sales to pay for hospital bills for protracted sickness associated with HIV/AIDS and other diseases and costs associated with deaths may lead families to abject poverty. Ways out of poverty were consequently partly associated with the possession of livestock, starting with poultry and small ruminants, and at later stages with cattle. Similar results were obtained for rural communities in western Kenya (Kristjanson et al. 2004) and in different village types in Peru (Kristjanson et al. 2005).

3 World animal populations increase, but not everywhere

The distribution of livestock populations of different species by regions in 2004 is shown in Figure 5.

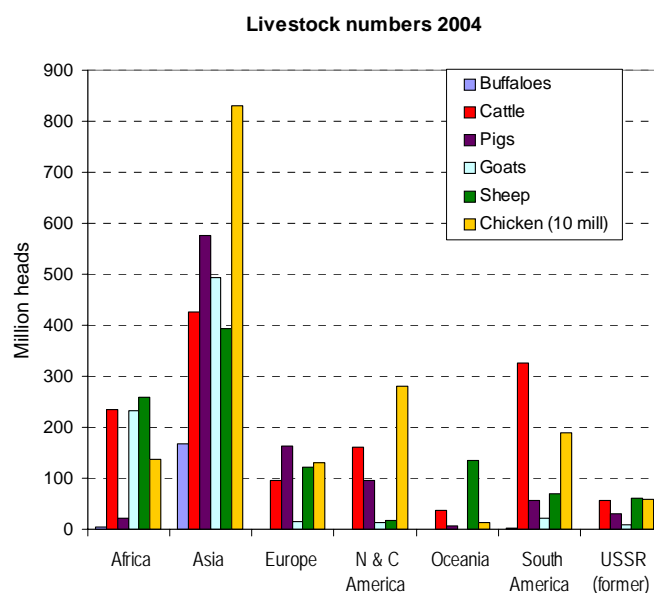


Figure 5. World livestock populations by regions in 2004. Source: FAO (2005a).

There are some striking differences, which are likely to be the result of different natural resources, climate, culture and socio-economic conditions (FAO 2005a). Whereas among the ruminants, cattle and sheep together dominate the animal populations in Asia, Africa and Oceania, the population of cattle, sheep and goats are quite similar in Europe and the former USSR. In North, Central and South America cattle dominate, while goats are primarily found in Asia (63%) and Africa, while 39% of sheep are found in Asia, mostly (40%) in East Asia. The swine populations are more or less confined to Asia and the western parts of the world. Asia keeps 97% of the world's buffaloes and 60% of the world's swine population, of which 50% are found in China. The world poultry population is estimated to be 16 billion and with the exception of Africa, Europe and the former USSR, they are fairly well distributed across regions, although Asia has the largest share (>50%), while Africa keeps the smallest number (Figure 5). Of the 19 million camels in the world today, most are found in Africa.

The most remarkable changes in the past 15 years as regards species are that poultry numbers have increased by more than 50% and goats by more than 30%, while sheep numbers have decreased by 13%. Regarding regions the most dramatic change has taken place in the former USSR, where the populations of all species have been about halved.

The different livestock population numbers have been converted into tropical livestock units (TLU) in Figure 6, considering the metabolic size of animals of different species. Europe shows slightly decreased animal numbers for all the livestock species, yet there is a surplus of livestock production in Europe today. Africa, Asia and South America show steady increases in TLU numbers.

Tropical Livestock Units (TLU) by region in 1990 and 2004

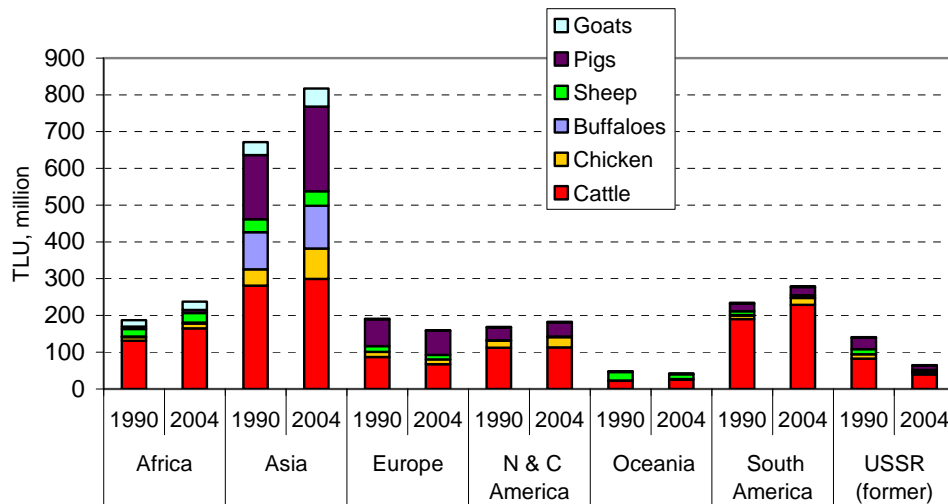


Figure 6. Trends in livestock numbers measured as total tropical livestock units (TLU) by region. Conversion factors: Buffalo and cattle 0.7; Pig 0.4; Sheep and Goat 0.1; Chicken 0.01. Source: FAO (2005a).

When contrasting the TLU numbers with the output of food products in Figures 3 and 4 it emerges that high livestock numbers (Figure 5) and TLU (Figure 6) do not necessarily equate to high productivity (Figures 3 and 4). Neither do they reflect the overall utility functions that the various livestock play in each region. For example, whereas a cattle TLU in Africa is the same as a cattle TLU in Europe, on average the European cattle are almost 2–3 times bigger, and thus the two are not comparable from a productivity point of view. Secondly, the African/Asian animals are used for many more tasks than food production (e.g. draft, energy, social security etc.) compared to animals in temperate climates in the developed world.

To meet increasing future milk and meat demands in the developing countries, improvement in productivity will be needed. Such improvements will be realised through a combination of improved husbandry and careful utilisation of the existing livestock genotypes.

4 Livestock revolution underway

Estimates of realised and projected consumption trends by the International Food Policy Research Institute (IFPRI), the Food and Agriculture Organization of the United Nations (FAO) and the International Livestock Research Institute (ILRI) shows that production of certain food commodities will have to increase more rapidly than others (Figure 7) in different parts of the world to meet expected demands (Delgado et al. 1999). Whereas only marginal increases in consumption of meat and milk are expected in the developed world, increases of 114% and 133% respectively are projected until the year 2020 for meat and milk consumption in the developing world. The projected production increases to meet these demands in developing countries amount to 108% for meat and 145% for milk. The greatest (85%) increase in world meat consumption will be developing countries, with highest increases occurring in Asia, specifically East Asia. Also, more than 90% of the world's predicted 60% increase in milk consumption will occur in Asia, mainly South Asia (FAO 2005a). However,

for the next 10 to 25 years, minimal growth will take place in the overall global consumption of these two livestock products.

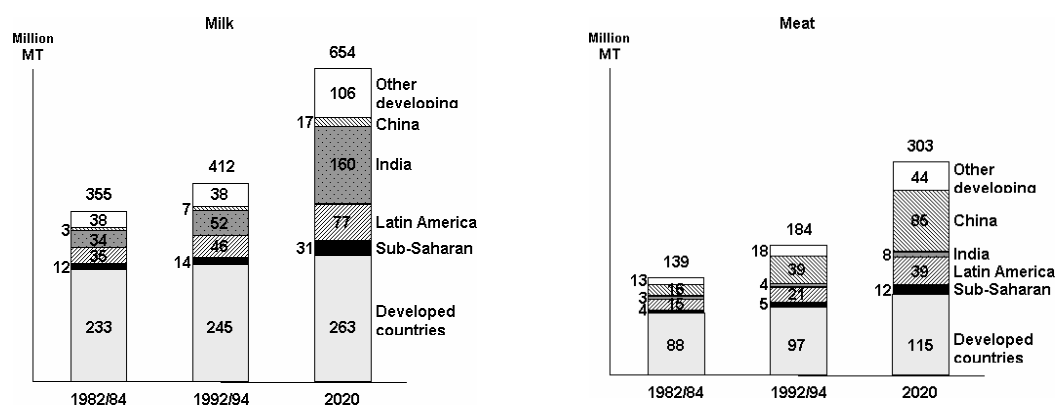


Figure 7. Total milk and meat consumption during 1983 and 1992 and projection for 2020.

Source: Delgado et al. (1999).

The demands for increased animal products are higher than for cereals because of changing consumption patterns following urbanisation, population growth and projected income growth (Figures 3, 4 and 7). Diets with more high-value protein and micronutrients will improve human health and the livelihood of many poor people. The implications of increased food production and changed diets of billions of people may be dramatic in the next few decades and could improve the well-being of many rural poor as both consumers and producers.

In contrast to the familiar Green Revolution that started in plant production 30 years ago, a livestock revolution is just underway to meet the increase in demand for food of animal origin. Such a revolution assumes a wise use of natural resources, including animal and plant genetic resources, in order to be realised. The challenge is how to take advantage of prevailing trends for the benefit of the rural and sub-urban poor livestock keepers in developing countries rather than the more industrialised production in other parts of the world. Already predictions are that unless major improvement in productivity occurs, East Asia and Africa will increasingly remain net importers of meat and milk products (FAO 2005a). For cereals, milk and dairy products, South Asia, Africa and East Asia will increasingly become net exporters of cereals (Figures 3 and 4). More than 70% of the predicted increase in the world's meat consumption will be in form of pork and poultry, most of which will be produced under intensive industrial production, partly explaining the predicted trends in inter-regional cereal trade.

The higher pace of industrialisation will continue, especially for pig and poultry production. This process is predicted to drive the small producers out of the ever-increasing competitive global market, for both economic and biological reasons. The benefits derived from economies of scale, leading to better resilience against disasters and calamities such as the ongoing bird flu outbreaks and favourable domestic trade support and policy environments may further favour industrialised livestock production systems in the future.

Although mixed crop–livestock production systems will persist in the foreseeable future, higher levels of intensification will be required, with increased use of livestock genotypes that are likely to respond better to the changes in production systems. Consequently, small-scale mixed crop–livestock production systems will eventually be confined to more remote areas,

with poverty persisting and livestock playing a more central survival role and a key first step out of poverty. Under such conditions livestock on their own are unlikely to create overwhelming riches to their keepers.

ILRI, in its strategy to 2010 (ILRI 2003), has identified activities in livestock research and development (R&D) for developing countries, which focus on poverty reduction, food and nutritional security and environment and human health. It includes a substantial programme on characterisation of indigenous AnGR and development of strategies for sustainable utilisation of the diversity in livestock species, which assumes increased productivity, to improve the livelihoods of people in developing countries. Equally important, innovative ways must be sought to secure market access for the livestock products of developing countries. If this is not achieved the globalisation in trade of agricultural products is going to wipe out less competitive production systems in favour of products from industrialised ones in other parts of the world. See [ILRI Strategy to 2010].

5 Diversified use of livestock

Domestic animals have, for more than 10 thousand years, contributed to human needs for food and agricultural products such as meat, dairy products, eggs, fibre and leather, draft power and transport, manure to fertilise crops and for fuel. Livestock also play an important economic role as capital and for social security.

The value of livestock has also been clearly demonstrated for soil nutrient management, especially in soils in rapidly intensifying crop–livestock systems (Tarawali et al. 2004) and in those already intensified (Olson 1998; Olsen et al. 2004). Integration of livestock into crop systems enhances smallholder farm productivity and profitability (Peden et al. 2005).

The multiple uses of livestock also include their cultural roles in many societies. Hence, the use of animal resources varies considerably between various parts of the world as the social, environmental and other conditions for animal production differ enormously.

Currently, an estimated 30 – 40% of the world’s total agricultural output is produced by its variety of livestock (FAO 2005a). In some parts of the world, including some parts of Africa, where intensive mixed livestock–crop systems are practised, as much as 70–80% of the farm income is from livestock. In such systems, much of the crops produced are fed to livestock and converted to high quality food for human consumption.

5.1 Adaptation to environment a necessity

In most parts of the developing world difficult environmental conditions and a lack of availability of capital, technology, infrastructure and human resources have not allowed intensification of agriculture, including development of genetic resources. Instead, harsh climate, less feed of low nutritional value, irregular feed availability, diseases, and lack of education and infrastructure, have kept the agricultural output per animal at a low and rather unchanged level for a long time. However, livestock breeds in the tropical parts of the world have during thousands of years become adapted to cope with harsh environments, including disease challenges (ICAR 2000), and produce under conditions in which breeds developed in more favourable environments will not even survive [CS 1.1 by Mpofu & Rege]; [CS 1.37 by Kharel et al.]. Such differences among animal populations have a genetic background and are the result of the interaction between genetic constitution and environment that has evolved over time from natural and human selection of animals for performance in different environments (see section 1.1 in Module 2). That is why we have such a variety of indigenous breeds. However, when appropriately utilised in pure or crossbreeding programmes,

indigenous breeds can contribute to increased productivity in smallholder production systems [CS 1.34 by Panandam and Raymond]; [CS1.40 by Chako].

5.2 Increased productivity to avoid degradation of natural resources

The challenge now is to find ways of exploiting the potential for improved and sustainable livestock production that the variability among and within the indigenous breeds may offer different environments and production systems in various parts of the tropics and sub-tropics. Otherwise, we will not be able to produce what is needed for the people of the developing world to survive. To date, demand for increased livestock production has largely been met by increasing the number of indigenous animals without improving yield or efficiency per animal or area used. Such trends will not hold in future as industrialisation is predicted to continue at a higher pace, especially for pigs and poultry production, using mainly genetically improved breeds and composites. Non-structured crossbreeding of indigenous breeds with imported high yielding breeds has been practised too often in the tropics, sometimes with disastrous results (Okeyo 1997; Payne and Hodges 1997; Ahuya et al. 2005; Kosgey et al. 2006). This development cannot continue.

Land degradation and the increasing amount of resources required to just maintain the animal populations must be replaced by more efficient systems demanding higher outputs per animal or area of land used to meet the future demands of livestock products (Taneja 2005). For sustainability, these systems must emphasise effective resource input/output ratios and more integration of livestock and crop production rather than industrialised monocultural production systems that seriously challenge the wise use and care of our natural resources.

Consumer concern and the consumer perceptions in light of the increasing global push for product standardisation and wider impacts of production systems on environments is of increasing concern. Whereas such trends provide potential scope for environmentally friendly produced livestock products, the effects of over-exploitation (deforestation and overgrazing) of common and open-access resources, especially by the rural poor, may undermine the potential gains. Besides, to fully benefit from better prices offered by niche markets for more naturally produced products, better levels of producer organisation, in terms of product quality assurance and standardisation and general marketing will be required of producers to enable such potentials to be exploited.

It is rightly argued that animal production systems, especially with ruminants, contribute to undesired methane emissions. However, it is also well established that these greenhouse emissions can be substantially reduced by increasing productivity and lowering the number of animals kept for a given total amount of produce (Kirchgeßner et al. 1995; McCrabb et al. 2003). Thus, increased productivity per animal concentrating production on fewer but more valuable animals is a way forward in reducing the negative environmental impacts of livestock production. However, this intensification must also be designed to effectively manage all other risks to environmental degradation of land and water, e.g. efficient ways of using manure and wastes from other farm products. For example, in large commercial tree plantation systems like those practised in Malaysia, increased resource utilisation and profitability may arise from integration of livestock in rubber and palm oil plantations. Such integration also has the potential for reducing the country's annual demands for imported beef and milk to meet the domestic deficits.

More productive breeds of a number of livestock species have been genetically developed to fit different markets and environments for both developed and developing countries [CS 1.4 by Mpofu]; [CS1.40 by Chako]. Such genetic changes, in combination with better and continuously available feeds and management, have in a few decades led to the doubling of

food production in a number of breeds and species. Such increases in agricultural produce require high technology and large inputs of feed, labour, energy and capital, as well as good disease control and management practices. However, in high input and resourceful industrialised systems limited considerations regarding total efficiency in nutrient cycling and pollution have been made. Without such considerations these production systems will not be sustainable. Conversely, in low and medium input pasture production systems small ruminants, camels and beef cattle provide the most efficient way of utilising such environments to produce valuable livestock products (milk, meat and leather). To date the potentials of many of the indigenous livestock populations and breeds remain largely unexploited. Through well organised conventional selection programmes much more could be achieved [See breed information on [Kenya Boran](#), [Tuli](#), [Butana](#) and [Kenana](#) cattle breeds in Africa; [Khari](#) and [Boer](#) goats in Africa and Asia as well as the [Murray](#) and [Nari Ravi](#) buffaloes from India and Pakistan]. Exploitation of local and foreign niche markets that favour the smaller and more adapted indigenous breeds exist in the Middle East and many Asian countries. Strategic use of such breeds as dam-lines/breeds in terminal crossbreeding programmes present great potential and prospects.

Most local breeds are kept under smallholder systems, though pastoralists may also keep large herds. The role of the smallholder farmers may also be important in the future, but most likely the production will need to be intensified. Smallholder animal production may need to be combined with crop production, and be relocated to peri-urban and urban areas. This will then require increasing focus on environmental and product quality issues and on market access and competitiveness. The interaction between genotypes and environments would continue to be a key element in choice and development of future breeding stocks while some environmental changes, such as improved feeding (including concentrates) and management practices, will also have to take place [[CS 1.39 by Okeyo and Baker](#)].

6 Diversity in animal genetic resources invaluable for future developments

The consistent contribution over thousands of years of animal production to human needs under different environmental conditions as diverse as, arctic and tropical, maritime and mountain, humid and arid semi-desert ecozones, stems from the development of some 4000–5000 breeds of different species. Of these, about 70% are found in the tropical developing world [[DAD-IS](#); [DAGRIS](#)]. They have been domesticated from about 40 wild animal species according to different needs and uses under the variable environments that have covered the world over time. The adaptation of different species and breeds to a broad range of environments provides the necessary variability that offers opportunities to meet the increased future demands for food and provide flexibility to respond to changed markets and needs [[Breed information](#)]. The role of AnGR and the need to conserve their diversity are articulated elsewhere by Anderson (2003), Rege and Gibson (2003) and Wollny (2003).

6.1 Considerable genetic variation among breeds

The diversity among breeds is known to contribute about half of the genetic variation found among animals within species, while the other half is attributed to genetic variation within breeds. The variation within breeds is less vulnerable to loss but breeds are easily irretrievably lost when they are considered to be commercially non-competitive. That is why the maintenance of local breeds is of great importance for the maintenance of genetic diversity [[CS 1.17 by Drucker](#)]; [[CS 1.37 by Kharel et al.](#)]. However, it may not be possible to maintain all breeds forever, especially if they are not competitive enough, all values considered. The definition of a breed is somewhat arbitrary and has, throughout history, allowed for some

dynamics (see Module 2, section 1.1). Some breeds are disappearing or have disappeared, while others have been formed [Breed information]. Such changes have been possible and necessary as part of the evolution and the dynamics that the variability of the genetic resources allows for interaction with environmental changes.

In the absence of appropriate breed characterisation, breed attributes and genes that are potentially beneficial in the future may not be saved. Instead, some breeds are condemned to extinction and in the process, some of the good genes that they may have possessed disappear with them, never to be recovered. However, well planned crossbreeding systems could help save the desirable genes, even when the livestock breeds that once possess such genes are lost (Rege and Gibson 2003). The successive development of a synthetic breed is a typical example on how valuable genes can be saved for the future (see Module 3, section 4.3).

6.2 Within-breed variation for sustainable use and improvement

The sustainable use and improvement of indigenous breeds has been justified on the grounds that they are already adapted to local conditions [CS 1.8 by Mpofu]; [CS 1.35 by Neopane and Pokharell]. It is also a fact that genetic variation exists in productivity within these breeds for most traits of importance and that this potential for genetic improvement has so far only been exploited to a very limited degree [CS 1.2 by Mpofu]; [CS 1.36 by Sartika and Noor]. To wisely select breeding stock, adequate definitions of broad long-term breeding objectives must be established in relation to the prevailing and expected changes of environmental conditions and production systems [CS 1.3 by Mpofu]. Crossbreeding for rapid improvement of traits, such as milk production, requires even more consideration in the choice of breeds and the design of both the crossbreeding programme [CS 1.5 by Kahi] and the breeding programmes of the pure breeds. This is necessary to ensure the future availability of genetic materials needed to develop appropriate genotypes as the environment and human needs change.

6.3 A decreasing diversity

Developments in world trade, agricultural policies, consumption patterns, demands for cheaper food and increased productivity, and the availability, but sometimes inappropriate use, of new reproduction technologies and selection tools, have favoured the use of high yielding breeds. These breeds require high input and intensive care and management in environments which normally cannot support them adequately. The short-term economic benefits of such replacements of low yielding but well adapted breeds could be seriously challenged if these high yielding animals cannot withstand the climatic stress and lack the disease resistance needed for the new environments into which they are placed [CS 1.4 by Mpofu]; [CS 1.8 by Mpofu]. This type of breed replacement, often caused by importing exotic breeds or practising crossbreeding with exotic breeds without any long-term breeding plans, has contributed to severe genetic erosion, including extinction of a number of locally adapted breeds in the last few decades.

Although previous World Watch List of global animal genetic resources suggested that approximately 30% of all current livestock breeds are at risk of extinction (FAO 2001, 2003), on critical analysis these are mostly overestimates. However, erosion of animal genetic resources continues to take place, while at the same time some new breed combinations create additional diversity. In general, erosion of diversity is anticipated to continue according to current trends in population statistics (Gibson and Pullin 2005). Such a development may threaten the future opportunities to cope with the increased or new human needs and the environmental challenges and market changes for future food and animal production. It also may present new opportunities for better utilisation of the preferred breeds and populations.

6.4 Why worry about loss in genetic diversity?

Genetic improvement of animal populations is dependent on the existence of genetic variation. Such variation exists between species, between breeds within species and among animals within breeds. As species and breeds are adapted to certain environments, through centuries or thousands of years of natural and artificial selection, it may be difficult to restore such genetic variation that may still be desired, but that has been lost by breed replacements in certain regions or environments. The continuous loss of breeds and genetic diversity is usually fuelled by short-sighted and restricted genetic and socio-economic considerations [CS 1.17 by Drucker] (also see Tisdell 2003). The real long-term values, including ecological effects, may not have been taken into account. Also not usually considered are future changes that may have an impact on the needs for variable genetic resources. The irreversible losses of genetic diversity therefore, reduce our opportunities for future developments. That is why it is imperative to critically consider both the present and future breeding programmes of all species and breeds in relation to environmental and economic developments and needs.

The distribution of species by world regions (Figure 5) may lead to the conclusion that ruminants, which today have the largest world coverage [see livestock distribution maps] and are represented by a large number of breeds that are adapted to different environments, would have the best opportunities to adapt to future environmental changes. Similarly, populations confined to a few regions or specialised production systems are more vulnerable to changes in production or economic systems in those regions. Such effects may dramatically reduce the genetic diversity and our future opportunities for development of efficient animal food production under variable conditions. The importance of the Asian region, and especially China, for conservation of a variety of indigenous pig breeds is extremely high, as these breeds are not found elsewhere [Chinese pig breeds-breed info].

6.5 Animal genetic diversity undervalued

To put the right emphasis on long-term genetic improvements or the need to conserve genetic variation for present and future use, it seems important to find ways of economic valuation of the genetic resources (Gianni et al. 2003; Scarpa et al. 2003a) [CS 1.17 by Drucker] and their developments. There are well developed procedures for economic evaluations of the improvements of individual traits and for multi-trait breeding objective programmes within a breed [see Weller J. in ICAR Tech. Series No. 3]. Such procedures may consider different time horizons and the probability of the different traits to be expressed in monetary terms. However, these models do not automatically capture the non-monetary values, e.g. social or cultural values, which may also be quite important [CS 1.18 by Drucker]. Lessons learnt from conservation of plant genetic resources call for urgency in the comprehensive valuing of animal genetic resources before further losses occur (Gollin and Evenson 2003); an approach to optimal allocation of available funds that minimises genetic diversity losses is discussed by Simianer et al. (2003). Economic valuation methodologies are presented elsewhere by Anjani-Kumar et al. (2003) Scarpa et al. (2003b) and Gianni et al. (2003).

Furthermore, beyond economic evaluation of alternative breeding schemes within a breed or crossbreeding programmes, it seems even more important to value different genetic resources, especially when the choice has to be when all are not currently commercially viable. Unfortunately, there is no single method to readily apply for such economic valuations, but a few important principles need to be understood (Gianni et al. 2003; Scarpa et al. 2003a; Scarpa et al. 2003b).

Normal economic market forces have driven much of the extinction of the world's biodiversity, whereby lower yielding animals or breeds have been replaced by higher yielding stock. Without considering the total economic merits of the different characteristics such as

production, fertility and disease resistance, the total economic effects in the long run have been small and even negative in many cases. The total economic value (TEV) of a genetic resource compared to another must therefore include all functional aspects of the animals and also all indirect use values (IUV), such as long-term ecological or social effects, along with the direct use values (DUV), which also must consider the long time horizon [CS 1.18 by Drucker]. Furthermore, TEV should include option values (OV) which account for the unforeseen future needs, just as an insurance.

All valuations assume correct weighting of traits in the breeding objectives defined, meaning that proper consideration must be given to production as well as adaptive traits and health under prevailing and expected future environmental conditions. For these reasons, the value of conservation of AnGR has generally been underestimated. However, OV may have underestimated the effects of dramatic changes taking place in livestock product trades and markets following globalisation of communication and trade. Thus, the future needs to exploit the genetic resources using both conventional and non-conventional ways must be openly sought.

6.6 Global initiatives to secure animal genetic resources variability

The increased awareness of the importance of genetic variability among livestock species, breeds and individuals within breeds as a potential for increased food and agricultural production, as demonstrated in many countries and breeds around the world, has led to several global initiatives to ensure the future availability of these resources.

In 1972 the UN conference on environment in Stockholm recognised the need to consider biodiversity as an essential resource for humankind's future well-being. Since then, the Food and Agriculture Organization of the United Nations (FAO) has had AnGR and their development on its agenda. However, it was not until 1980 that a strong AnGR programme, funded by the United Nations Environment Programme (UNEP), was launched by FAO. The many initiatives and studies on AnGR around the world, and publications by FAO (i.e. the Animal Genetic Resources Information (AGRI)) made within the framework of that programme, formed the foundation of the next official and crucial step of AnGR development at the global level (FAO 1993). The State of the World report on AnGR and the subsequent report on strategic priorities for action by FAO (2005b) are important achievements at global level. At the UN Conference on Environment (UNCED) in Rio de Janeiro in 1992 the awareness and seriousness of the loss of biodiversity was expressed to such an extent by representatives of many nations that it led to the development of the Convention on Biological Diversity (UNEP 1992) which was ratified in 1993. The CBD is a legally binding framework for the conservation and sustainable use of all biological diversity and it is intended to establish a process for the equitable sharing of benefits from the use of biodiversity. This development was underpinned by many national and regional activities as well, e.g. by ILCA (International Livestock Centre for Africa) collecting and publishing all kinds of 'grey' literature on local AnGR. The foundation of RBI (Rare Breeds International) in 1989 was another milestone that has proven its value in raising important issues of AnGR in collaboration with many NGOs.

The recognition of the importance of both conserving and efficiently using AnGR and other biological diversity for global food security, as expressed in the CBD, led FAO to initiate the development of a global strategy for the management of AnGR (FAO 1993; FAO 1999). Since 1996, FAO has implemented its Global Strategy for the Management of Farm Animal Genetic Resources as a framework for its member nations to give proper consideration to the development of AnGR at national, regional and global levels (Figure 8).

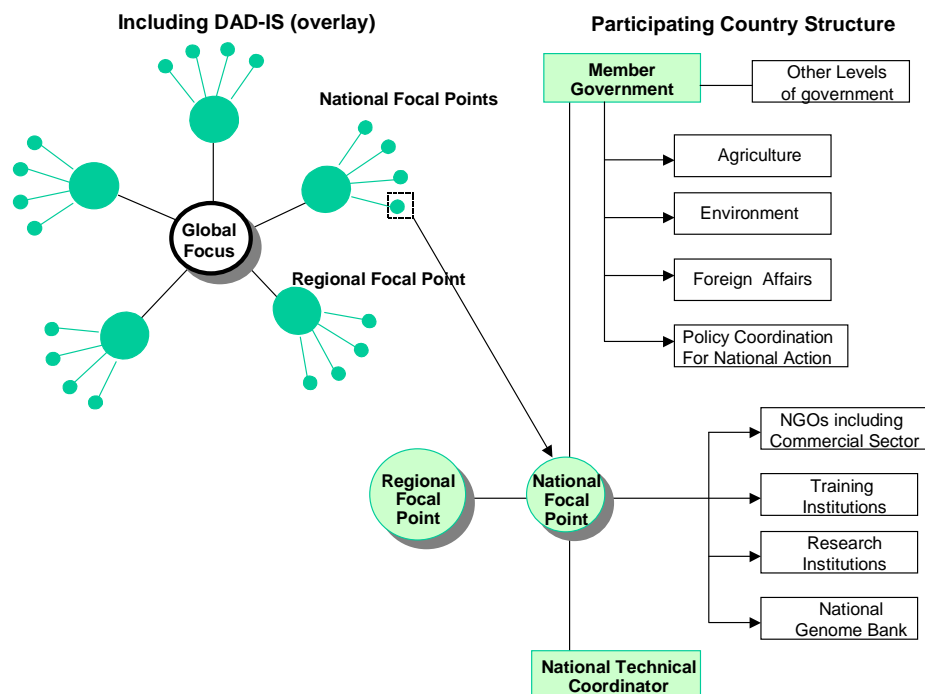


Figure 8. Structure of the FAO management of Global Farm Animal Genetic Resources.
Source: FAO (1999).

This framework assumes the participation of government organisations to provide information on the AnGR of each country and to establish operational action plans for conservation and utilisation of their AnGR. One important outcome of the implemented global strategy is that an information system called **DAD-IS** (Domestic Animal Diversity Information System) has been established to facilitate the monitoring of AnGR at all levels. An overview of the structure and its integration with national organisations is given in Figure 8. As a basis for development of appropriate conservation programmes, FAO member countries are involved in producing a report on the State of the World's Animal Genetic Resources. The information from the 141 country reports clearly indicates that countries face organisational problems that if not effectively addressed would prevent effective implementation and management of the respective AnGR. However, the experiences gained from such reports and the pool of expertise and institutions that form the regional focal points would be able to develop the necessary capacities and influence and formulate the policies needed to sustainably manage the AnGR in their respective countries and regions.

Preliminary analyses of the State of the World reports from 141 countries and the other parallel efforts have provided a detailed assessment of roles and values of AnGR and the state of these resources. The analyses also reveal the relatively high importance of the livestock sector within agriculture, which is in contrast to its minor role in national development programmes and policies compared to the plant sector. The State of the World country reports also identified national and regional needs and priorities aimed at enhancing capacity to better use and develop AnGR in all production systems. Countries also indicated specific strategic priorities for action for sustainable use, development and conservation of the AnGR available to the country and the world livestock farming community now and also to enable them to respond in future to inevitable changes in conditions (FAO 2005b).

Examples of the listed priorities for action include: the need for implementation of effective breeding strategies, institutional and individual capacity building and further research in the area of AnGR. Approaches aimed at addressing each of these at both country and regional levels are currently under discussion under the facilitation and stewardship of FAO. Besides FAO, other international institutions such as the International Livestock Research Institute (ILRI) will increasingly be needed to facilitate and/or contribute to the regional initiatives.

ILRI is the leading international research organisation with a comprehensive programme on AnGR research and development for developing countries. The ILRI programme aims to characterise indigenous breeds in developing countries; to quantify the extent of genetic and production systems diversity and rate of diversity loss; and discover the special genes responsible for population and breed uniqueness so as to better inform and contribute to their sustainable conservation and improvement. Such improvements include planned crossbreeding with the other livestock breeds and genotypes, in appropriately designed breeding programmes. To date, ILRI has undertaken a comprehensive characterisation of African and Asian cattle, sheep, goat, camel, yak and chicken populations at the molecular and phenotypic levels [CS 1.10 by Okomo-Adhiambo]; [CS 1.11 by Gwakisa]; [CS 1.37 by Kharel *et al*]. Similar work in other regions, especially in Asia is underway. At the same time ILRI is working with national agricultural research systems (NARS) on on-farm phenotypic characterisation of indigenous livestock (Mwacharo and Drucker 2005; Wurzinger et al. 2005).

ILRI has also since 1999 been developing a web based electronic source of information on indigenous farm animal genetic resources [DAGRIS] Domestic Animal Genetic Resources Information System DAGRIS is backed up by bibliographic information and will support research, training, public awareness and genetic improvement and conservation programmes. In Asia, India and China have also allocated tremendous resources to breed characterisation, with significant positive achievements so far. In this regard, ILRI in collaboration with the Chinese National Academy of Science and the Indian Council for Agricultural Research (ICAR) is expanding such activities within the Asia region. On their part, the Federal Government of India is working with the state governments to phenotypically and genetically characterise all the Indian indigenous livestock breeds. This information is kept and continuously updated in the Indian National Animal Resource Information Systems (INARIS) database, to which a link to DAGRIS is being negotiated. Similar efforts are ongoing in all the developing countries, albeit at varying levels of detail. What is urgently needed is a strategy on how to use this information in formulating and effectively managing breeding programmes.

6.7 How could we ensure future diversity of AnGR?

Realising that a substantial number of breeds are currently at risk of extinction and that conservation programmes are lacking for more than 75% of these breeds [Breed information], ensuring genetic diversity to meet the future needs is of great concern. Three circumstances are quite obvious.

Firstly, there is no method to conserve a breed for future generations that is more efficient than continuing to improve the breed in such a way that it keeps its commercial value for food and agricultural production or for other economic or cultural reasons, while also considering the ecological aspects of its use [CS 1.2 by Mpofo]; [CS 1.7 by Khombe]. This sustainable use of AnGR imposes a tremendous challenge on the livestock policies and breeding programmes of indigenous breeds in developing countries, where the needs to increase food production are greatest, to wisely use the genetic diversity for improved animal production efficiency.

Secondly, the awareness of shrinking diversity and the challenge to increase future food production must be translated into efficient long-term strategies and operational breeding schemes. This requires good knowledge of both the actual production and market systems, including socio-economic and cultural values, and the characteristics of the breeds in order to formulate adequate breeding objectives (Module 3, Section 4); [Hammond and Galal in ICAR Tech. Series No. 3]; [Groen in ICAR Tech. Series No. 3]. In this respect ‘indigenous’ knowledge is invaluable to capture. Facilitating the infrastructure needed using adequate selection tools assumes a high degree of both theoretical knowledge and practical experience of animal recording and genetic evaluation [Groen in ICAR Tech. Series No. 3]. Thus, *capacity building* at all levels is necessary, as are research for characterisation of actual breeds as a basis for choice and use of breeds, including the important genes that they possess and use of this information to design and implement sustainable breeding programmes.

Thirdly, because restricted short-term economic benefits may override the long-term benefits, including indirect and option values, in the decision process for choice of alternative genetic resources to be used, there should be policies that support conservation and use of potentially important breeds, which usually carry some unique valuable traits. That is the type of framework that FAO has established through its global strategy. However, ensuring that the right support is given, priorities are set and, appropriate action plans are put in place to allow AnGR to be sustainably used remains the responsibility of each country. In this context, ILRI’s research and capacity building programme [ILRI-SLU Progress Report, 2004] plays a significant role, in augmenting the efforts of FAO and regional research organisation in revealing the new knowledge needed and for strengthening the national capacities in synthesising and transforming such knowledge into sustainable programmes for conservation and utilisation of indigenous AnGR.

7 New approaches needed for sustainable livestock improvement

The awareness of the demands for increased productivity has not been lacking. In fact, many attempts have been made to genetically improve livestock in the tropics. Although it should be recognised that improved livestock have been produced or successfully introduced in favourable areas of the tropics, e.g. in some highland areas, in maritime climates and in relatively intense peri-urban production systems, many attempts have failed [CS 1.3 by Mpfungu]; [CS 1.6 by Mpfungu & Rege]. At least three primary reasons could be seen for these failures:

- Due to lack of domestic resources and enough trained staff with an animal breeding background, people from developed countries have usually been responsible for conducting improvement programmes. As a consequence of this lack of ‘indigenous’ knowledge, sophisticated methods, e.g. use of artificial insemination and progeny testing, have often been inappropriately applied, neglecting the necessary infrastructure [CS 1.3 by Mpfungu].
- The introduction of crossbreeding with temperate high yielding breeds without a long-term plan on how to maintain either a suitable level of ‘upgrading’, or how to maintain the pure breeds for future use in crossbreeding has been another reason. Upgrading to a level that is too high has generally led to animals without resistance to withstand environmental stress (Gibson and Pullin 2005). However, there are examples of successful breed replacements in parts of India (Anjani-Kumar et al. 2003) and Africa (Ahuya et al. 2005), [CS1.40 by Chako] including the highlands of Kenya. Furthermore, use of intermediate (F₁) crossbred cattle based on introduced breeds has been successfully demonstrated in

Brazil and is one way of combining diverse genetic attributes of the different breeds, so long as an organised crossbreeding programme is followed (Madalena 2005).

- The lack of analysis of the different roles of livestock in each specific area, usually leads to falsely defined breeding objectives and underrating the potentials of various indigenous breeds of livestock. Examples of these problems are illustrated in the case studies by Philipsson (2000) and in the comprehensive publications and reviews found in FAO (1993) and in Payne and Hodges (1997).

New approaches must better consider the potential of indigenous livestock breeds sometimes in crossbreeding with suitable exotic breeds, and realistic ways of improving them in the context of environmental and socio-economic demands and within the resources available. For this purpose there is a great need to characterise the indigenous livestock breeds and their crosses to determine which are the most suitable ones for further improvement and to implement simplified, but yet effective, breeding programmes [CS 1.7 by Khombe]; [CS 1.14 by Olivier]. Such programmes could be based on nucleus herds of pure and crossbred animals from which specified genotypes or semen can be widely disseminated to livestock herds (see Module 3, Section 4.3 & 4.4); [van der Werf in ICAR Tech. Series No. 3]; [Nitter in ICAR Tech. Series No. 3].

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9 References

- Ahuya, C.O., Okeyo, A.M., Mosi, R.O. and Murithi, F.M. 2004. Growth, survival and milk production performance of Toggenburgs and their crosses to East African and Galla goat breeds in the eastern slopes of Mount Kenya. In: Smith, T., Godfrey, S.H., Buttery, P.J. and Owen, E. (eds), *The contribution of small ruminants in alleviating poverty: communicating messages from research*. Proceedings of the third DFID Livestock Production Programme Link Project (R7798) workshop for small livestock keepers. Izaak Walton Inn, Embu, Kenya, 4–7 February 2003. Natural Resources International Ltd, Aylesford, Kent, UK. pp. 40–47.
- Ahuya, C.O., Okeyo, A.M., Mwangi-Njuru and Peacock, C. 2005. Developmental challenges and opportunities in the goat industry: The Kenyan experience. *Small Ruminant Research* 60:197–206.
- Anderson, S. 2003. Animal genetic resources and sustainable livelihoods. *Ecological Economics* 45:331–339.
- Anjani-Kumar, BIRTHAL, P.S. and Joshi, P.K. 2003. Research on crossbreeding in cattle: an analysis of its economic and social impact in India. *Agricultural Economics Research Review* 16(2):91–102.
- CGIAR (Consultative Group on International Agricultural Research). 1999. *Food in the 21st century: From science to sustainable agriculture*. CGIAR, Washington, DC, USA. 72 pp.

- Delgado C., Rosegrant M., Steinfeld H., Ehui S. and Courbois C. 1999. *Livestock to 2020—The next food revolution*. Food, Agriculture, and the Environment Discussion Paper 28. IFPRI (International Food Policy Research Institute), Washington, DC, USA. 72 pp.
- FAO (Food and Agriculture Organization of the United Nations). 1993. *The strategies for sustainable animal agriculture in developing countries*. Animal Production and Health Paper 107. FAO, Rome, Italy. 271 pp.
- FAO (Food and Agriculture Organization of the United Nations). 1999. *The global strategy for the management of farm animal genetic resources: Executive Brief*. FAO–iDAD, Rome, Italy. 443 pp.
- FAO (Food and Agriculture Organization of the United Nations). 2002. FAOSTAT database, FAO, Rome, Italy. <http://apps.fao.org/>. Accessed on 20 June 2002.
- FAO 2005a. FAO (Food and Agriculture Organization of the United Nations). *FAOSTAT database*. FAO, Rome, Italy.
- FAO 2005b. FAO (Food and Agriculture Organization of the United Nations). Draft report on strategic priorities for action for the sustainable use, development and conservation of animal genetic resources for food and agriculture. FAO, Rome, Italy.
- Gianni, C., Dércole, E. and Marino, D. 2003. Costs and benefits of preserving farm animal genetic resources from extinction: CMV and bio-economic model for valuing a conservation program for Italian Pentro horse. *Ecological Economics* 45:345–359.
- Gibson J. and Pullin R. 2005. Report presented at the Meeting of the Standing Panel on Priorities and Strategies (SPPS), CGIAR, Science Council, April 2005.
- Gollin D. and Evenson R. 2003. Valuing animal genetic resources: lessons from plant genetic resources. *Ecological Economics* 45:353–363.
- ICAR (International Committee for Animal Recording). 2000. *Developing breeding strategies for lower input animal production environments*. Proceedings of a workshop held at Bella, Italy, 22–25 September 1999. ICAR Technical Series 3. ICAR, Rome, Italy. 570 pp.
- ILRI (International Livestock Research Institute). 2003. *ILRI strategy to 2010: Making the livestock revolution work for the poor*. ILRI, Nairobi, Kenya. 112 pp.
- Kerala Livestock Development Board, 2003. Annual Report
- Kirchgeßner, M. Windisch, W. and Miller, H.L. 1995. Nutritional factors for the quantification of methane production. In: Engelhardt, W. v, Leonard-Marek, S., Breves, G. and Giesecke, D. (eds), *Ruminant physiology: Digestion, metabolism, growth and reproduction*. Ferdinand Enke Verlag, Stuttgart, Germany. pp. 333–348.
- Kosgey, I.S., Baker, R.L., Udo, H.M.J. and van Arendonk, J.A.M. 2006. Successes and failures of small ruminant breeding programmes in the tropics: a review. *Small Ruminant Research* 61:13–28.
- Krishna, A., Kristjanson, P., Radeny, M. and Nindo, W. 2004. Escaping poverty and becoming poor in 20 Kenyan villages. *Journal of Human Development* 5 (2):111–226.
- Kristjanson, P., Krishna, A., Radeny, M. and Nindo, W. 2004. Pathways out of poverty in Western Kenya and the role of livestock. Pro-Poor Livestock Policy Initiative (PPLPI) Working Paper 14. ILRI, (International Livestock Research Institute), Nairobi, Kenya.
- Kristjanson, P., Krishna, A., Radeny, M., Kuan, J., Quilia, G., Sanchez-Urrelo, A. and Leon-Velarde, C. 2005. Poverty dynamics and the role of livestock in the Peruvian Andes. *Agri Systems* (in press).
- McCraab, G.B., Fernandez-Rivera, S., Hunter, R.A., Kurihara, H., Terada, F. and Wirth, T. 2003. Managing greenhouse emissions from livestock systems. In: *Proceedings of the 3rd International Methane and Nitrous Oxide Mitigation Conference, Beijing, China, Nov 17–21, 2003*.

- Madalena, F.E. 2005. Considerations on the management of animal genetic resources in Latin America. Paper presented at the EAAP/SLU/FAO/ICAR Workshop on Sustainable Management of Animal Genetic Resources: Linking perspectives globally, Uppsala, Sweden, 2 June 2005.
- Mohamed, M.A., Bezabih, E., Jabbar, M. and Ehui, S. 2002. *Analysis of economic and nutritional impacts of market-oriented dairy production in the Ethiopian highlands*. Socio-economics and Policy Research Working Paper. ILRI (International Livestock Research Institute), Addis Ababa, Ethiopia. (Forthcoming).
- Mwacharo J.M. and A.G. Drucker 2005. Production objectives and management strategies of livestock-keepers in Southeast Kenya: implications for a breeding programme. *Tropical Animal Health and Production* 37: 635–652.
- Okeyo, A.M. 1997. Challenges in goat improvement in developing rural economies of Eastern Africa, with special reference to Kenya. In: Ahuya, C.O. and van Houton, H. (eds), *Goat development in East Africa*. Proceedings of a workshop held at Izaak Walton Inn, Embu, Kenya, 8–11 December 1997. FARM-Africa, Nairobi, Kenya. pp. 55–66.
- Olson, J.M. 1998. A Conceptual Framework of Land Use Change in the East African Highlands. Joint Global Change and Terrestrial Ecosystems and Land Use and Land Cover Change Open Science Conference on Global Change, Barcelona, Spain.
- Olson, J.M., Misana, S., Campbell, D.J., Mbonile, M. and Mugisha, S. 2004. The spatial patterns and root causes of land use change in East Africa. LUCID Working Paper 47. ILRI (International Livestock Research Institute), Nairobi, Kenya.
- Payne, W.J.A. and Hodges, J. 1997. *Tropical cattle: Origins, breeds and breeding policies*. Blackwell Science, Oxford, UK. 328 pp.
- Peden, D., Freeman, A., Abiye Astatke and Notenbaert, A. 2005. *Investment options for integrated water-livestock-crop production in sub-Saharan Africa*. ILRI (International Livestock Research Institute), Addis Ababa, Ethiopia.
- Philipsson, J. 2000. Sustainable dairy cattle breeding systems utilising artificial insemination in less developed countries—Examples of problems and prospects. In: ICAR (International Committee for Animal Recording). 2000. *Developing breeding strategies for lower input animal production environments*. Proceedings of a workshop held at Bella, Italy, 22–25 September 1999. ICAR Technical Series 3. ICAR, Rome, Italy. pp. 551–562.
- Rege, J.E.O. and Gibson J.P. 2003. Animal genetic resources and economic development: issues in relation to economic valuation. *Ecological Economics* 45:319–330.
- Scarpa, R., Drucker, A.G., Anderson, S., Ferraes, E., Gomes, V., Risopatronn, C.R. and Rubio-Leonel, O. 2003a. Valuing genetic resources in peasant economies: the case of hairless Creole pigs in Yukatan. *Ecological Economics* 45:427–443.
- Scarpa, R., Ruto, S.K., Kristjanson, P., Radeny, M. and Rege, J.E.O. 2003b. Valuing indigenous cattle breeds in Kenya: an empirical comparison of stated and revealed preference value estimates. *Ecological Economics* 45:409–426.
- Simianer, G., Marti, S.B., Gibson, J., Hanotte, O. and Rege, J.E.O. 2003. An approach to the optimal allocation of conservation funds to minimize loss of genetic diversity between livestock breeds. *Ecological Economics* 45:377–392.
- Taneja, V.K. 2005. Present status of animal genetic resources and programs for utilization-South and South East Asia. Paper presented at the EAAP/SLU/FAO/ICAR Workshop on “Sustainable Management of Animal Genetic Resources: Linking perspectives globally”, Uppsala Sweden, June 2nd, 2005.
- Tarawali, S.A., Keating, J.D.H., Powell, J. M., Hiernaux, P., Lyasse, O. and Sanginga, N. 2004. Integrated natural resource management in West African crop–livestock systems. In: Williams, T.O., Tarawali, S.A., Hiernaux, P. and Fernandez-Rivera, S. (eds), *Sustainable crop–livestock*

- production for improved livelihoods and natural resource management in West Africa*. IITA (International Institute of Tropical Agriculture), Ibadan, Nigeria. pp. 349–370.
- Tisdell, C. 2003. Socio-economic causes of loss of animal genetic diversity: analysis and assessment. *Ecological Economics* 45:365–376.
- Wollny, C.B.A. 2003. The need to conserve farm genetic resources in Africa: should policy makers be concerned? *Ecological Economics* 45:341–351.
- Wurzinger, M., Ndumu, D., Baumung, R., Drucker, A., Okeyo, A.M., Semambo, D.K. and Sölkner, J. 2005. Indigenous selection criteria in Ankole cattle and different production systems in Uganda. 55th Annual Meeting of the European Association for Animal Production (EAAP), Uppsala, Sweden, 5– 8 June 2005
- UN (United Nations). 2004. Millennium Development Goals: Progress report. <http://www.un.org/millenniumgoals>. Accessed March 2005.
- UNEP (United Nations Environment Programme). 1992. *Handbook on the Convention on Biological Diversity*. UNEP, Nairobi, Kenya.
- World Bank. 2002. World Bank development indicators—Millennium development goals. <http://www.worldbank.org>. Accessed October 2004.

10 Related literature

- ICAR (International Committee for Animal Recording). 2000. *Developing breeding strategies for lower input animal production environments*. Proceedings of a workshop held at Bella, Italy, 22–25 September 1999. ICAR Technical Series 3. ICAR, Rome, Italy. 570 pp.
- Kamuanga, K., Faminow, M.D. and Swallow, B. 2003. Using conjoint analysis to estimate farmers' preferences for cattle traits in West Africa. *Ecological Economics* 45:393–407.
- Livestock in Development. 1999. Livestock in poverty-focused development. Livestock in Development, Crewkerne, UK.
- Scherf, B.D. (ed). 2000. *World watch list for domestic animal diversity*. 3rd edition. FAO (Food and Agriculture Organization of the United Nations), Rome, Italy. 725 pp.
- Tangka, F.K., Emerson, R.D. and Jabbar, M.A. 2002. *Food security effects of intensified dairying: Evidence from the Ethiopian highlands*. Socio-economics and Policy Research Working Paper 44. ILRI (International Livestock research Institute), Nairobi, Kenya.
- World Bank. 2000. *Higher education in developing countries: Peril and promise*. <http://www.tfhe.net>. 172 pp. Accessed March 2004.
- World Bank. 2001. *World development report 2000/2001: Attacking poverty*. Oxford University Press, New York, USA. 335 pp.