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, about a billion people do not have enough to eat; a livestock revolution is currently underway to meet the nutritional needs and improve the livelihood of poor people. However, the recent international food and financial crises have again worsened the situation for many of the world's poor. The module provides the background, facts and reasons for increased attention to improved utilization and maintenance of AnGR for food and agriculture 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 web version) help illustrate the issues presented.

Contents

Citation

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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 animal genetic resources (AnGR) can be summarized 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 utilized.

- 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 internalized 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 to increasing awareness of the roles of livestock and their genetic diversity.

2 Food security and livestock - Keys to poverty alleviation

2.1 Food availability and human population growth

More than a billion people around the world live in extreme poverty, and the number is rising. There have been marked increases in hunger and as of 2009, the Food and Agriculture Organization of the United Nations (FAO) estimates that 1.02 billion people are undernourished (FAO, 2009). Most of these people are found in sub-Saharan Africa and South and East Asia. 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 30% or more of children under 5 years of age are malnourished in many parts of this region (see http://devdata.worldbank.org/atlas-MDGs/).

Availability of affordable food of livestock origin would contribute to alleviating 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 in the next 35 years (Watson, 2001).

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

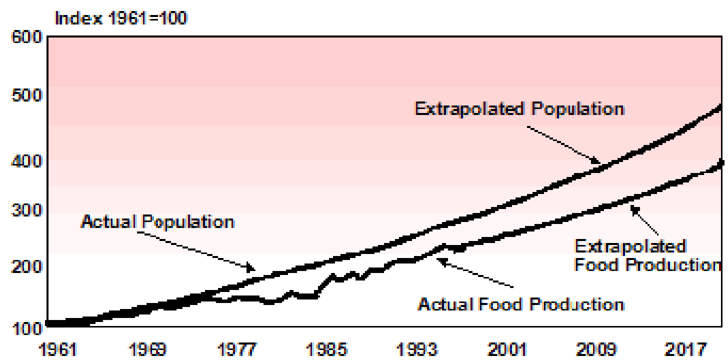

Figure 1. *Trends in human population growth and food production in sub-Saharan Africa.* Source: CGIAR (1999).

The overall objective of the Millennium Development Goals (MDGs) of the United Nations (UN, 2004) is to reduce the proportion of people who are extremely poor and hungry by 50% by 2015. Two of the specific MDGs 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 MDGs (UN, 2004), the sub-Saharan Africa, South Asia and western Asia regions still lag behind in terms of the set targets in most of 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 2003.

Table 1. *Per capita daily supply of animal products in calories and gram protein for 1990 and 2003.* Source: FAO (2002; 2009)

	1990		2003	
	Calories	Protein (g)	Calories	Protein (g)
Developed world	938	59	877	57
Developing world	253	15	369	21
Sub-Saharan Africa	145	11	140	10

The international food crisis in 2007–2008, caused by the competition between the use of agricultural products for food and fuel, underpinned by the international financial crisis, have further worsened the situation. A lowered intake of calories, and an even greater decrease in animal protein intake, has followed among poor people in sub-Saharan Africa. The demands for increased livestock productivity are further emphasized by the increase in human population size, urbanization and a general increase in demand for livestock sourced foods.

The human population numbers in 1990, 2000 and 2008 for the different regions of the world are shown in Figure 2.

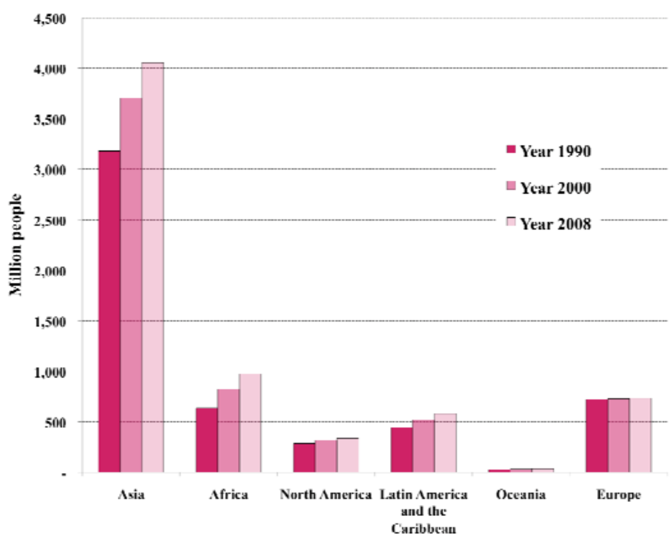

Figure 2. *The world human population in 1990, 2000 and 2008.*
Source: UN Population Division (2009).

The meat and milk produced during the same period are shown in Figures 3 and 4 respectively. Africa and Asia have the largest population growth (Figure 2). The increases in meat (Figure 3) and milk (Figure 4) production, however, have occurred in the developing and not in the developed countries. For the two products, Asia had the highest increases (Figures 3 and 4).

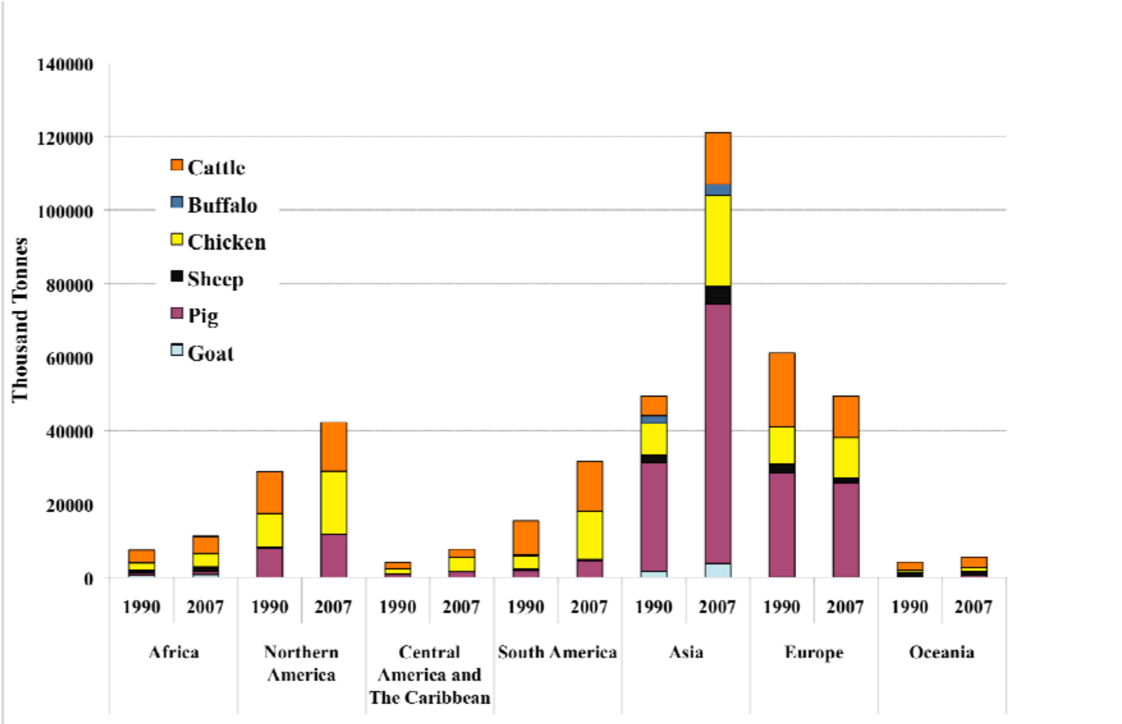

Figure 3. *Total world meat production by region in 1990 and 2007.*
Source: FAO (2009).

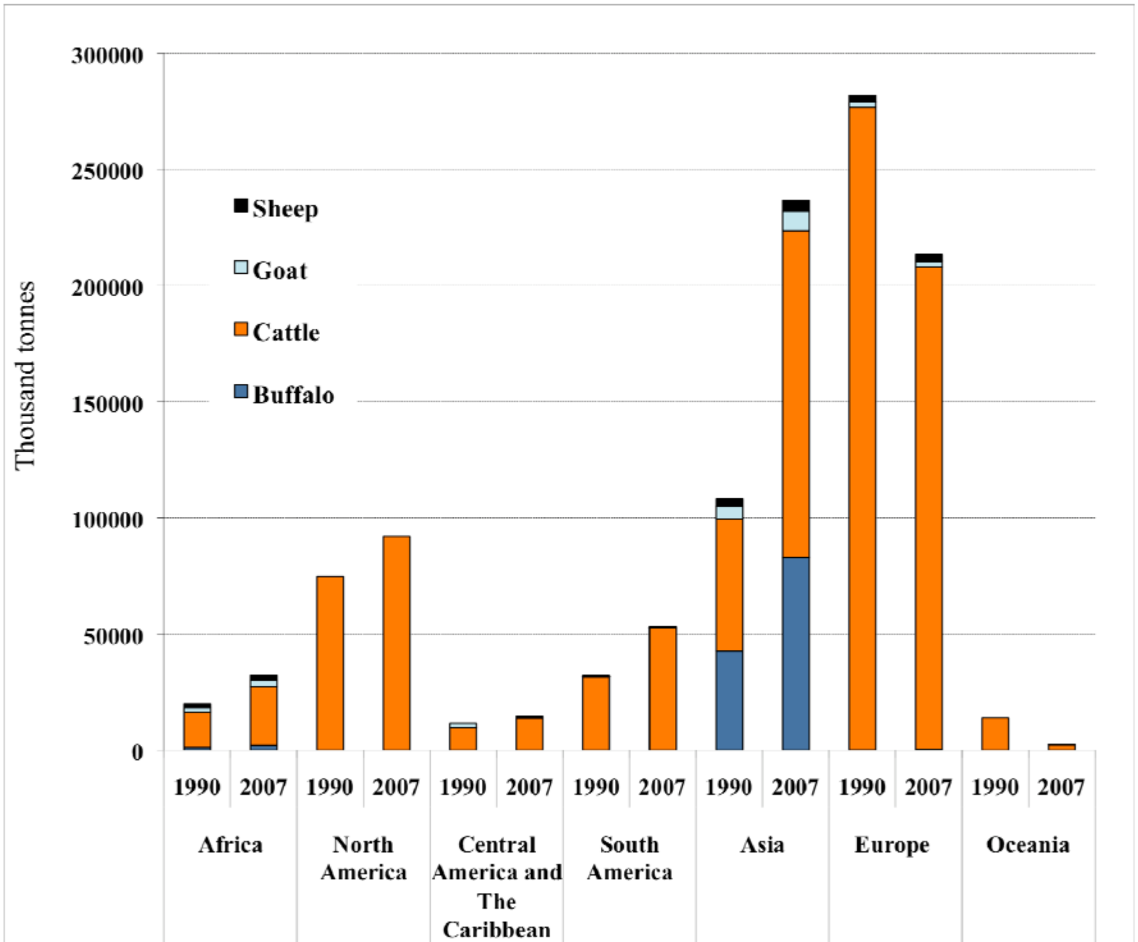

Figure 4. *Total world milk production by region in 1990 and 2007.*
Source: FAO (2009).

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

2.2 Climate change affects food availability

We are facing climate change and the demands for food have to be taken into concern. Expected changes would prompt food prices to increase due to a slowing expansion of global food supply relative to growth in global food demand (IPCC, 2001). It is feared that climate change would lower incomes of already vulnerable populations and increase the absolute number of people at risk of hunger. It is further anticipated that climate change, mainly through increased extremes and temporal/spatial shifts, will worsen food security, especially in Africa where the relative increase in food demand is greatest. Such considerations pose considerable challenges for development, food security and poverty alleviation and raise many questions (Nardone et al., 2008).

The impacts of climate change on AnGR will have both indirect and direct consequences. The direct impacts on livestock will most probably be an increase in catastrophic events and weather changes such as increase in drought, floods and cyclones, epidemic diseases, productivity losses and physiological stress. Droughts and floods may cause epidemic diseases to appear more frequently, which might lead to the loss of local and rare breeds. The indirect impacts from the climate change will most probably cause a change in fodder quality and quantity, and in the interactions between the host animal and the pathogen. With an increase in temperature parasites and vectors might change. These types of disease pressure to the animals will favour genotypes that are resistant or tolerant.

For countries in the tropics climate change may also mean that it will not be possible to produce enough of the grain and pasture necessary for the livestock. To solve this, livestock need to be adapted to be productive even under more harsh conditions. Less grain and pasture will lead to less human food and livestock feed. The challenges for livestock production are great. Livestock need to meet climate change and be genetically competitive even with the increased temperature and changes in flora. They also still need to meet the increased demand for food. Losses of large populations or breeds due to e.g. severe droughts emphasize the issues related to restocking of livestock, including choice of species and breeds, for future production.

2.3 Animal genetic resources for improved food security

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 show that women in households with access to crossbred cows earn nearly seven times more dairy income than women in households with local breed cows for the same division of work (Mohammed et al., 2002). The women with access to crossbred cows also have greater opportunities with the increased output and income. They consume on, average, 22% more milk and 30% more calories per day and can afford 36% higher food expenditures, leading to the intake of a more nutritious diet.

In India, investment in research and extension in support of cross-breeding 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, 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 stabilization 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

Development 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 to have had huge impacts on the livelihoods of the people.

A community based dairy goat cross-breeding and animal health care programme in the Meru area of the Eastern highlands of Kenya demonstrated similar results (Ahuya et al., 2004, 2005) [CS by Ojango et al.]. Improved goat genotypes accompanied by improved husbandry practices were adopted by hitherto very poor farmers whose livelihood was well below one US dollar per 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 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. Studies by Krishna et al. (2004), however, clearly indicate 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., 2007).

3 World animal populations increase, but not everywhere

The distribution of livestock populations of different species by regions in 2007 is shown in Figure 5. There are some striking differences which are likely to be the result of different natural resources, climate, culture and socio-economic conditions (FAO, 2009). Whereas among the ruminants, cattle and sheep together dominate the animal populations in Asia, Africa and Oceania, the populations of cattle, sheep and goats are quite similar in Europe. In North, Central and South America cattle dominate, while goats are primarily found in Asia (59%) and Africa (34%), and 41% of sheep are found in Asia. The swine populations are more or less confined to Asia (58%) and the western parts of the world, as are buffaloes. Asia keeps 97% of the world's buffaloes. The world poultry population is estimated to be 18 billion. Of the 24 million camels in the world today, most are found in Africa (84%).

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%. Concerning 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 decreased animal numbers for all the livestock species, yet there is a surplus of livestock production in Europe today. The large lowered production in Europe is partly explained by the changed Russian Federation (FAO, 2009). Africa, Asia and South America show steady increases in TLU numbers.

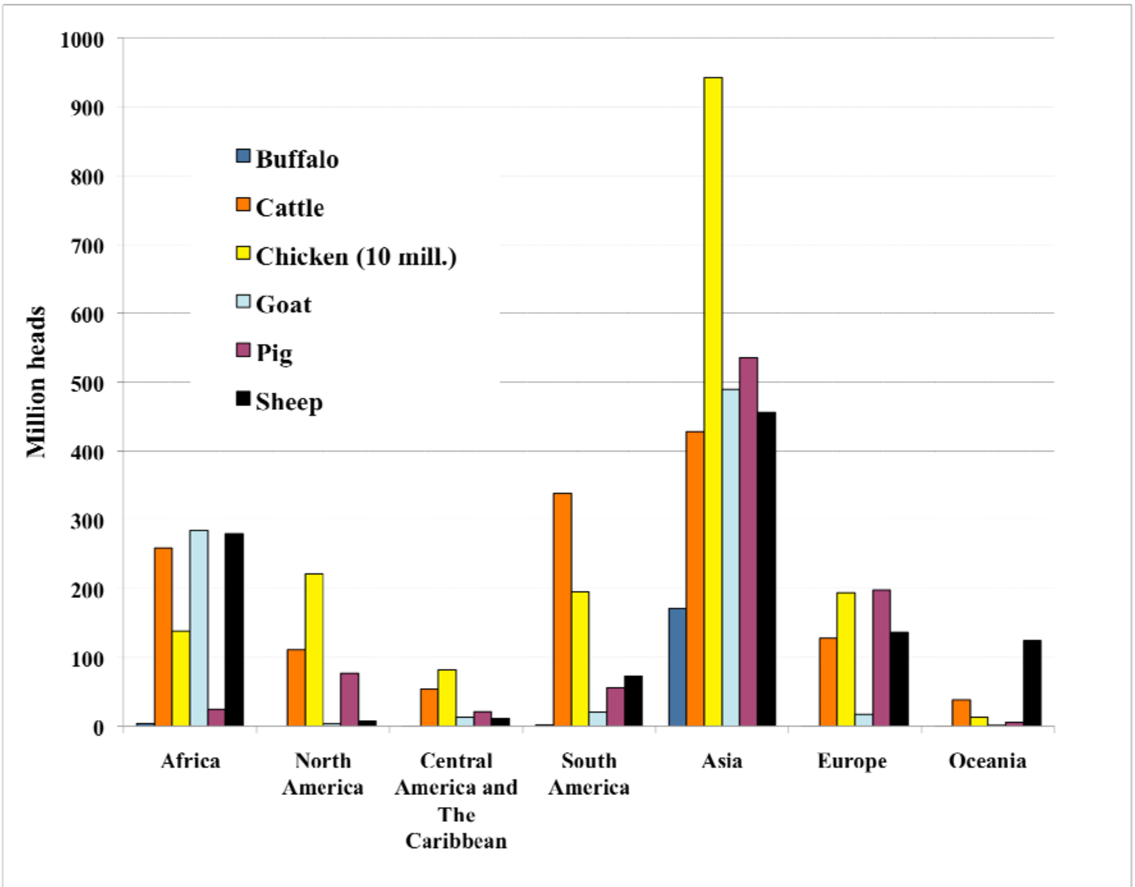

Figure 5. *World livestock populations by regions in 2007.*
Source: FAO (2009).

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 cattle TLU in Africa is the same as cattle TLU in Europe, on average, the European cattle are 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. However, the increased productivity in Asia is obvious.

The environmental and climatic aspects of livestock numbers are a focus of attention and critique, not least by FAO in the report “Livestock’s Long Shadow - Environmental Issues and Options”, due to overgrazing and greenhouse gas emissions (Steinfeld et al., 2006). However, the large numbers of livestock in developing countries could be reduced by increasing the productivity per animal. By doing that, the negative impacts of livestock on environment and climate can be reduced, while still increasing the output of animal products and meeting the growing demands for these. Increased productivity will be realized through a combination of improved husbandry and careful utilization and development of existing and new combinations of livestock genotypes of different species.

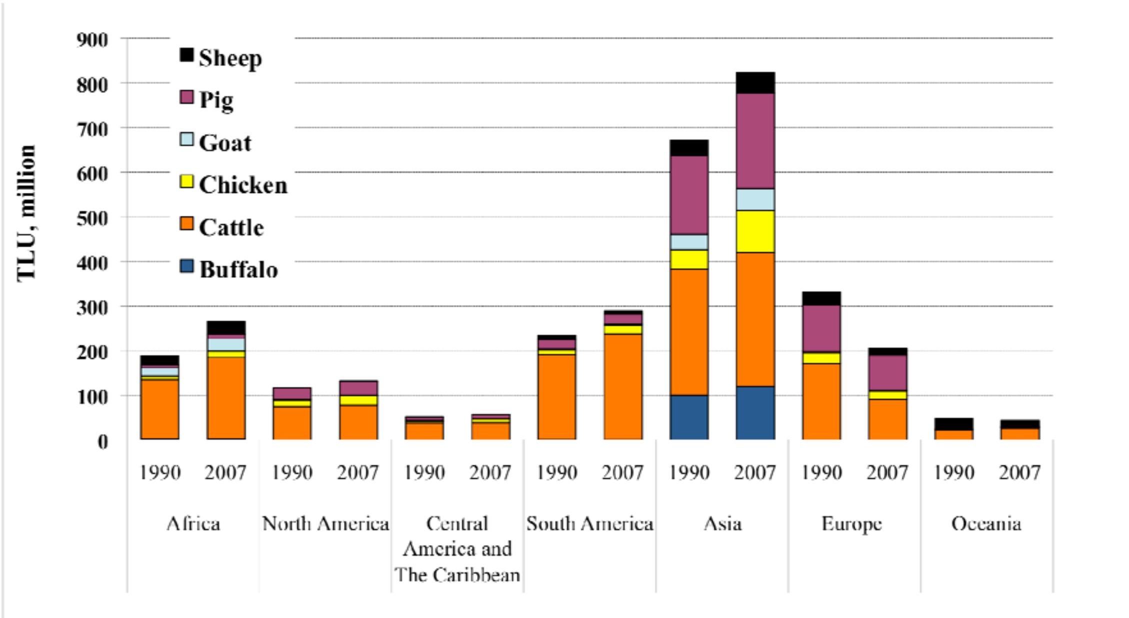

Figure 6. *Trends in livestock numbers given as total tropical livestock units (TLU) by region. Conversion factors: Buffalo and cattle 0.7; Pig 0.4; Sheep and goat 0.1; Chicken 0.01.* Source: FAO (2009).

4 Livestock revolution underway

People in developing countries consume more meat and milk, but still on average only 35% of the meat and milk respectively per capita compared to the developed countries (FAO, 2009). While the consumption of meat and milk per kg per capita from 1990 to 2003 has been almost the same in the developed countries of the world, it has during the same period of time changed with an increase of 21% for milk and 36% for meat in the developing world (FAO, 2009). Poor people everywhere are eating more animal products as their incomes rise above poverty level and as they become urbanized.

By 2020, the share of developing countries in total world meat consumption is projected to expand from 52% currently to 63% (Delgado, 2003). By 2020, developing countries will consume 107 million tons more meat and 177 million tons more milk than they did in 1996/1998, with highest increases in Asia, specifically East Asia for meat and South Asia for milk. Developed countries, however, will have much smaller increases of 19 million tons for meat and 32 million tons for milk. The projected increase in livestock production will require annual feed consumption of cereals to rise by nearly 300 million tons by 2020. In the long run

Figure 8 shows the positive projection for Asia, whereas a continued increase in the gap between sub-Saharan Africa and the industrialized world is noted.

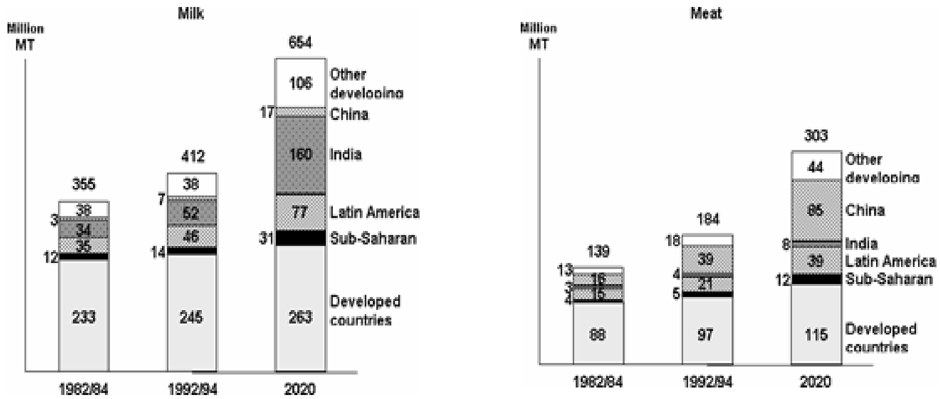

Figure 7. *Total milk and meat consumption during 1983 and 1992 and projection for 2020.* Source: Delgado et al. (1999).

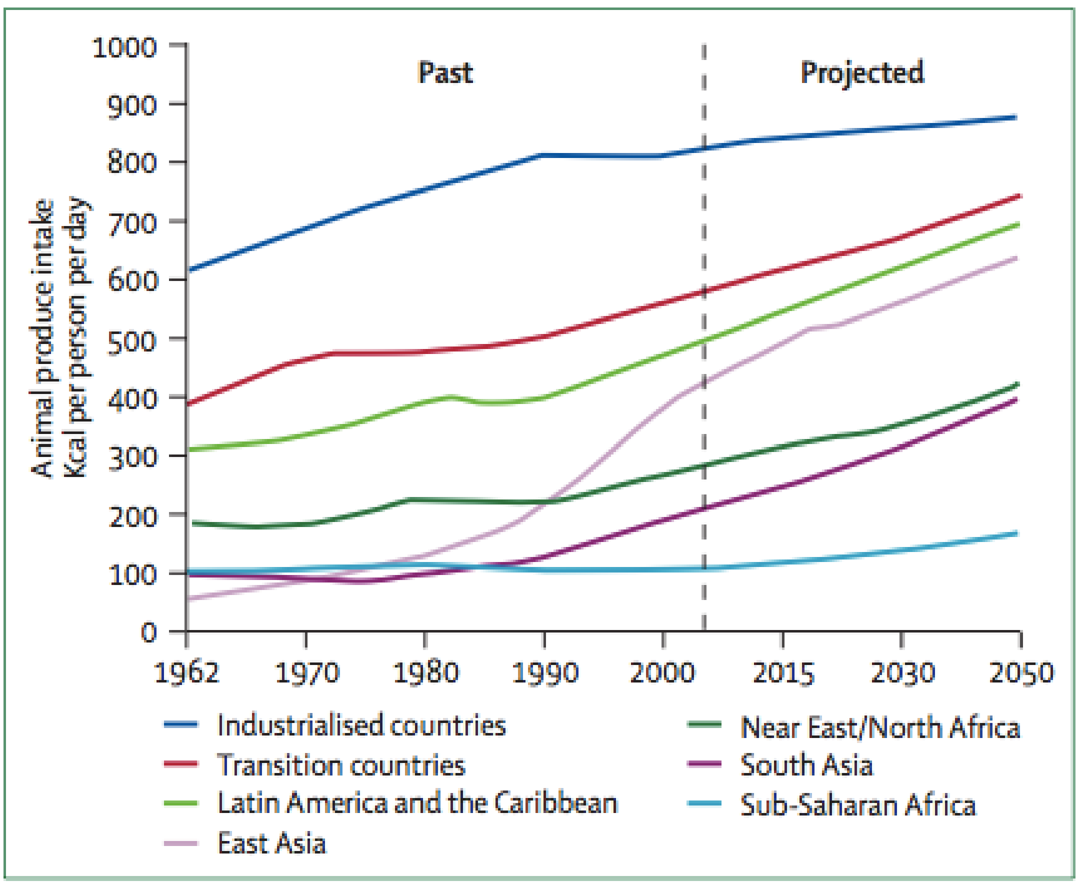

Figure 8. *Trends in consumption of livestock products per person in different regions*. Source: McMichael et al. (2007).

The demands for increased animal products are higher than for cereals because of changing consumption patterns following urbanization, population growth and projected income growth. Diets with more high-value protein and micronutrients will improve human health and the livelihoods of many poor people. The implications of the demands for 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, which 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 realized. 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 industrialized 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). 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 industrialization will continue, especially for pig and poultry production, but also for dairy production. This process may 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 recent bird flu and swine flu outbreaks, favourable domestic trade support and policy environments may further favour industrialized 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.

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 characterization of indigenous AnGR and development of strategies for sustainable utilization 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 globalization in trade of agricultural products is going to wipe out less competitive production systems in favour of products from industrialized ones in other parts of the world. See [ILRI Strategy to 2010].

5 Diversified uses of livestock

Domestic animals have, for more than 10 thousand years, contributed to human needs for food and agricultural products. These products include meat, dairy products, eggs, fibre and leather, draft power and transport, and manure to fertilize crops and for fuel. These animals have always played a large cultural role for livestock keepers. 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; Olson 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. Consequently, the use of animal resources varies considerably in different 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, little 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 to 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. This 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 there is such a variety of indigenous breeds. However, when appropriately utilized in pure or cross-breeding 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 to exploit 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, it will not be possible 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 industrialization is predicted to continue at a higher pace, especially for pig and poultry production, using mainly genetically improved breeds and composites. Non-structured cross-breeding 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 emphasize effective resource input/output ratios and more integration of livestock and crop production rather than industrialized mono-cultural production systems that seriously challenge the wise use and care of our natural resources.

Consumer concern and consumer perceptions in light of the increasing global push for product standardization and wider impacts of production systems on environments are 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 organization, in terms of product quality assurance, standardization 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 (Kirchgeâner et al., 1995; McCrabb et al., 2003). Hence, 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. This intensification must, however, 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 such as those in Malaysia, increased resource utilization 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, and good disease control and management practices. However, in high input and resourceful industrialized 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 utilizing 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 organized 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 and the Murray and Nili 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 in many Asian countries. Strategic use of such breeds as dam-lines/breeds in terminal cross-breeding programmes presents 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 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 (see Anderson, 2003; Rege and Gibson, 2003; 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 characterization, 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 cross-breeding systems could help save the desirable genes, even when the livestock breeds that once possessed 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 Shreeram and Prakash]. 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]. Cross-breeding for rapid improvement of traits, such as milk production, requires even more consideration in the choice of breeds and the design of both the cross-breeding 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 that normally cannot support them adequately. The short-term economic benefits of replacing low yielding but well adapted breeds could be seriously challenged if the 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 cross-breeding 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 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. Generally, 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 utilization 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 of natural and artificial selection, it may be difficult to restore 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 specialized 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 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 minimizes genetic diversity losses is discussed by Simianer et al. (2003). Economic valuation methodologies are presented elsewhere (see Anjani-Kumar et al., 2003; Scarpa et al., 2003b; Gianni et al., 2003).

Furthermore, beyond economic evaluation of alternative breeding schemes within a breed or cross-breeding programmes, it seems even more important to value the variation in genetic resources, especially such resources that 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 one 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 and 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 globalization 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, Sweden, recognized the need to consider biodiversity as an essential resource for humankind's future well-being. Since then, the 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, 2007a) are important achievements at global level. At the UN Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, 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 (CBD) (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 also supported by many national and regional activities, e.g. by the International Livestock Centre for Africa (ILCA) collecting and publishing all kinds of 'grey' literature on local AnGR. The foundation of Rare Breeds International (RBI) in 1989 was another milestone that has proven its value in raising important issues of AnGR in collaboration with many non-governmental organizations (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 9).

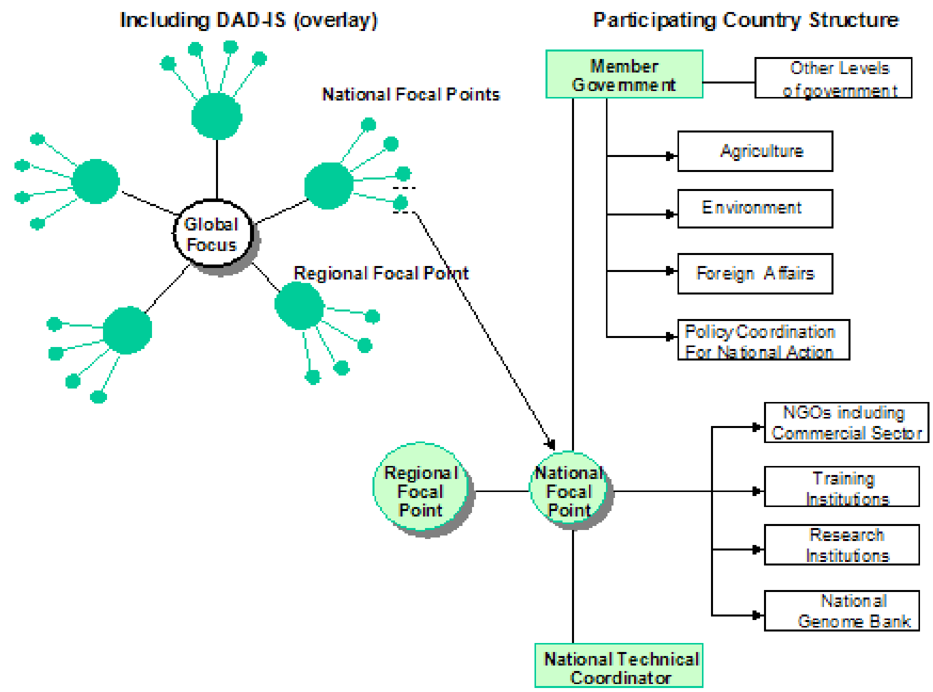

Figure 9. *Structure of the FAO management of Global Farm Animal Genetic Resources.* Source: FAO (1999).

This framework assumes the participation of government organizations to provide information on AnGR in each country and to establish operational action plans for conservation and utilization of their AnGR. One important outcome of the implemented global strategy is that an information system called the Domestic Animal Diversity Information System (DAD-IS) has been established to facilitate the monitoring of AnGR at all levels. An overview of the structure and its integration with national organizations is given in Figure 9. As a basis for development of appropriate conservation programmes, FAO member countries have produced a report on the State of the World's Animal Genetic Resources for Food and Agriculture (FAO, 2007a). Drawing on 169 country reports, contributions from a number of international organizations and 12 specially commissioned thematic studies, it presents an analysis of the state of agricultural biodiversity in the livestock sector - origins and development, uses and values, distribution and exchange, risk status and threats - and of capacity to manage these resources (institutions, policies and legal frameworks, structured breeding activities and conservation programmes). The analysis also presents the needs and challenges in the context of the forces driving change in livestock production systems. It explores the tools and methods needed to enhance the use and development of animal genetic resources, which include characterization, genetic improvement, economic evaluation and conservation.

The reports and the other parallel efforts have provided a detailed assessment of roles and values of AnGR and the state of these resources. They reveal a 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. It identifies the 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 currently available to the country and the world livestock farming community and also to enable them to respond in future to inevitable changes in conditions (FAO, 2005b; FAO, 2007a).

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 organization with a comprehensive programme on AnGR research and development for developing countries. The ILRI programme aims to characterize 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 cross-breeding with other livestock breeds and genotypes, in appropriately designed breeding programmes. To date, ILRI has undertaken a comprehensive characterization of African and Asian cattle, sheep, goat, camel, yak and chicken populations at the molecular and phenotypic levels [CS 1.10 by Okomo]; [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 characterization 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 AnGR: [DAGRIS] the Domestic Animal Genetic Resources Information System (DAGRIS). This 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 characterization, 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. The Federal Government of India is working with the state governments to phenotypically and genetically characterize 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 to formulate and effectively manage breeding programmes.

6.7 Global Plan of Action and country initiatives on the management of AnGR

The Global Plan of Action (GPA), which comprises 23 strategic priorities aimed at combating the erosion of animal genetic diversity and at using animal genetic resources sustainably, was adopted in September 2007 (FAO, 2007b). It is a culmination of an extended process leading to the *Interlaken Declaration on Animal Genetic Resources*. The member countries of FAO confirmed in that document their common and individual responsibilities for conservation, sustainable use and development of animal genetic resources for food and agriculture; for world food security; for improving human nutritional status; and for rural development. They committed themselves to facilitating access to these resources, and ensuring the fair and equitable sharing of the benefits from their use.

Generally, the aims of the GPA are to support and increase the overall effectiveness of national, regional and global efforts for the sustainable use, development and conservation of animal genetic resources; contribute to the development of a comprehensive framework for the management of agricultural biodiversity; and facilitate international cooperation and the mobilization of resources. Country reports from the 169 countries formed the basis for the development of the strategic areas and priorities of the GPA. A review of the reports confirmed the significant and irreplaceable contribution that the diversity of farm animals makes to the food security and development of nations. It also revealed a serious erosion of genetic diversity and underutilization of AnGR. Consequently, a global strategy was necessary to guide national, regional and global efforts to strengthen the contribution of domestic animals to food security and rural development, and to prevent further erosion of important AnGR. The GPA addresses four main strategic areas and proposes specific strategic priorities for actions in each area (FAO, 2007b):

1) Characterization, inventory and monitoring.

   Strategic priorities of action suggested to improve the understanding of AnGR in this area are:

- Inventory and characterization of AnGR, monitoring trends and risks associated with them, and establishing country-based early-warning and response systems
- Developing international technical standards and protocols for characterization, inventory, and monitoring of trends and associated risks

2) Sustainable use and development.

   Activities in this strategic area would enhance sustainable use and development of AnGR relevant to all production systems, with a focus on food security and rural development. They include:

- Establishing and strengthening national sustainable use policies
- Establishing national species and breed development strategies and programmes
- Promoting agro-ecosystems approaches to the management of AnGR
- Supporting indigenous and local production systems and associated knowledge systems of importance to the maintenance and sustainable use of AnGR#

3) Conservation.

Strategic priorities in this area focus on the steps needed to preserve genetic diversity and integrity for the benefit of current and future generations. These actions are summarized as:

- Establishing national conservation policies
- Establishing or strengthening *in situ* conservation programmes
- Establishing or strengthening *ex situ* conservation programmes
- Developing and implementing regional and global long-term conservation strategies
- Developing approaches and technical standards for conservation

4) Policies, institutions and capacity building.

The priorities of action in this area directly address the key questions of practical implementation, through coherent and synergistic development of the necessary institutions and capacities. They include:

- Establishing or strengthening national institutions, including national focal points, for planning and implementing AnGR measures, for livestock sector development
- Establishing or strengthening national educational and research facilities
- Strengthening national human capacity for characterization, inventory, and monitoring of trends and associated risks, for sustainable use and development, and for conservation
- Establishing or strengthening international information sharing, research and education
- Strengthening international cooperation to build capacities in developing countries and countries with economies in transition
- Establishing regional focal points and strengthening international networks
- Raising national awareness of the roles and values of AnGR
- Raising regional and international awareness of the roles and values of AnGR
- Reviewing and developing national policies and legal frameworks for AnGR
- Reviewing and developing international policies and regulatory frameworks relevant to AnGR
- Coordinating the Commission's efforts on AnGR policy with other international forums
- Strengthening efforts to mobilize resources, including financial resources, for the conservation, sustainable use and development of AnGR.

The Interlaken Declaration was recognized that the essential role of FAO was to support country-driven efforts in implementing the GPA. One step in that direction was the ILRI-Swedish University of Agricultural Sciences (SLU)-FAO workshop held in Arusha, Tanzania, in September 2009 and with participants from different countries in the Eastern, Central and Southern Africa. An AnGR strategic outcome map derived from the GPA was examined and discussed during the workshop in order to better understand the goals and desired outcomes of the GPA. Through group discussions, outcomes and activities/actions were added to the strategic outcome map developed from the GPA (Figure 10).

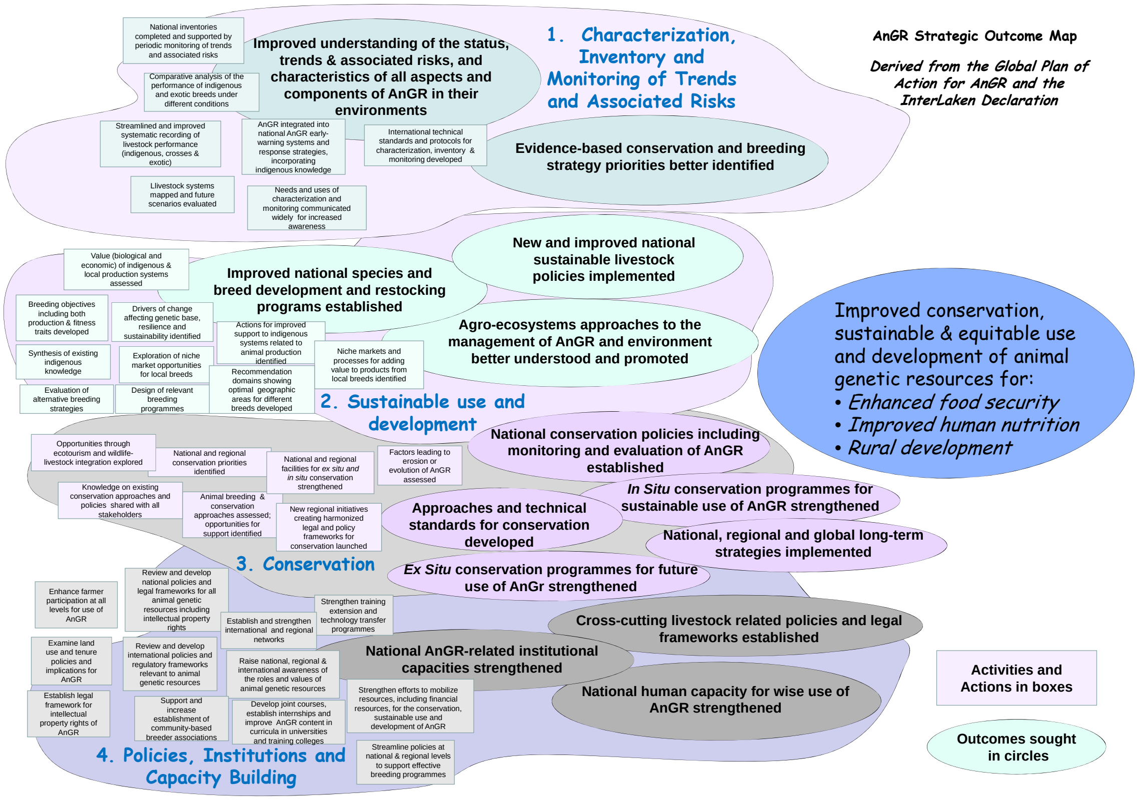

Figure 10. *AnGR Strategic Outcome Map - based on the Global Plan of Action for AnGR.* (Developed by participants at the ILRI-SLU-FAO workshop, Arusha, Tanzania, 2009)

The map shows the outcomes and joint actions that need to be considered in order to achieve improved use and conservation of AnGR throughout the region. Each of the main strategic areas has actions/activities, summarized in boxes, that were considered important and outcomes, in circles. The bigger circle at the far right-hand side of the figure is the desired outcome of the strategic map, which is in line with what the countries agreed upon in the Interlaken Declaration on AnGR. The main strategic areas and outcomes are not completely independent of each as illustrated by the overlapping circles. This reveals that the GPA contributes to creating synergies among the ongoing strategic priorities for action. It is also a comprehensive and coherent framework for enhancing management activities in relation to AnGR.

The information from the 169 country reports (FAO, 2007a) and the discussions on the strategic outcome map (Figure 10) clearly indicate that countries face organizational problems that, if not effectively addressed, would prevent effective implementation of GPA and management of the respective AnGR. Development of the necessary capacities and influence, and formulation of policies needed to sustainably manage AnGR in the respective countries and regions, is pegged to the pool of expertise and institutions that form the regional focal points. Currently, a number of activities joined to the GPA strategic areas in most of the countries are ongoing. However, these initiatives are still far below expectations. Lack of technical and infrastructural support is cited as a major drawback to this process, especially in the developing countries. In addition, policies and legal frameworks influencing the livestock sector do not favour sustainable utilization of AnGR. Policies, that promote conservation and sustainable use of farm AnGR, need to be urgently formulated and enforced to prevent further erosion and underutilization of AnGR.

A critical step in ensuring sustainable management of AnGR is the strategic development of a strong knowledge and skills base among farmers, frontline technical support staff, policy implementers, researchers and technology transfer agents through planned and concerted capacity building initiatives. Awareness has to be increased in order to obtain financial resources for improvement and conservation of AnGR. In addition, information and monitoring systems, livestock breed organizations, and subsequent establishment of livestock breeding programmes are urgently required to prevent further loss of important domestic diversity.

6.8 How could we ensure future diversity of Animal Genetic Resources?

Realizing 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 Mpofu]; [CS 1.7 by Khombe]. This sustainable use of AnGR imposes a tremendous challenge to 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, it is invaluable to capture ‘indigenous’ knowledge. 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 characterization 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 organization in revealing the new knowledge needed and to strengthen the national capacities in synthesizing and transforming such knowledge into sustainable programmes for conservation and utilization 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 recognized 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 Mpofu]; [CS 1.6 by Mpofu & Rege]. There are at least three primary reasons for these failures:

- Lack of domestic resources and enough trained staff with animal breeding backgrounds. 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 Mpofu].

- The introduction of cross-breeding 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 cross-breeding. 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 cross-breeding and formation of synthetic breeds has been successfully demonstrated in Brazil and is one way of combining diverse genetic attributes of the different breeds (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 cross-breeding 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 characterize the indigenous livestock breeds and their crosses to determine which are the most suitable ones for further improvement and to implement simplified, 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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