Module 1
Animal Genetics Training Resource (CD-ROM)
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ILRI-SLU

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

Jan Philipsson

Swedish University of Agricultural Sciences (SLU),
Dept of Animal Breeding and Genetics, Box 7023, S-750 07 Uppsala, Sweden

This first Module provides some insight to the needs for better use of animal genetic resources (AnGR) in the context of projected demands for food in developing countries until 2020. Note that 800 million people suffer from hunger and that a livestock revolution has to take place to meet the nutritional needs for improvement of the livelihood of poor people. The module provides the background, facts and reasons that call for increased attention to improve the utilisation as well as the maintenance of AnGR in developing countries. It is also supplemented by a list of some key literature. References and links to the internet [burgundy] and to parts of this resource [blue] are made to some case studies, breed resources and all other relevant components of this CD-ROM that illustrate the issues presented.

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1 Summary

Livestock play important roles for production of food and for many other purposes. They represent great socio-economic and cultural values in various societies around the world. The present 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 food, especially of animal origin, against a shrinking animal genetic diversity. A livestock revolution has to take place to meet the demands of more than doubled meat and milk consumption in developing countries over the next 20 years.
- The potentials of indigenous breeds in developing countries are largely neglected in the name of improved breed selection for better livelihood of people.
- The value of AnGR conservation is generally underestimated, as the indirect values are often neglected and future option values are yet difficult to accurately predict.
- Global initiatives must be accompanied by local activities to implement conservation programmes that increase animal productivity while maintaining necessary genetic diversity. Previous programmes have largely failed. Simple, yet effective methods, that take into account environmental, socio-economic and infrastructure constraints must be developed.
- The most efficient way to sustain a breed is to continuously keep it commercially or culturally viable.
- Research, in combination with capacity building at all levels, to improve the knowledge on indigenous AnGR, are instrumental for increased awareness on the roles of livestock and their genetic diversity and for implementation of sustainable breeding programmes.

2 Food security—The key to poverty alleviation

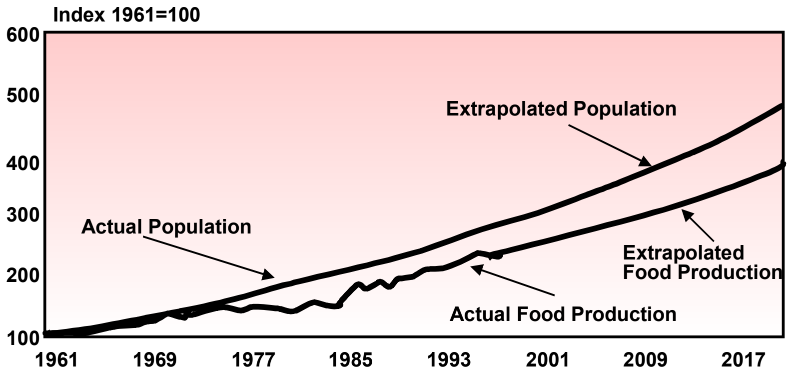
At the dawn of the 21st century more than 800 million people do not have enough to eat. Most of these people are found in sub-Saharan Africa (SSA), and South and East Asia. Of the 40,000 people that die each day of malnutrition, about half are infants and children. Throughout the developing world, poverty is linked to hunger, and every other person in SSA is considered poor, i.e. lives on less than one US dollar a day. The challenge to feed the people in the future is jeopardised by the fact that the global population annually climbs by some 90 million people. 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 Box shows the changes in the past three decades (1960–90) of population figures of humans as well as of different domestic animal species in the developing world. Most of the increase in animal production result from increased animal numbers rather than from better productivity per individual animal [Delgado et al. 1999]. Such changes in animal populations require resources that conflict with future sustainability of the agricultural systems.

Population increase 1960-90 in developing countries

Humans	+ 97 %
Large ruminants	+ 48 %
Small ruminants	+ 53 %
Pigs	+ 200 %
Poultry	+ 280 %

The increasing disparity between population growth and food production for SSA is 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.

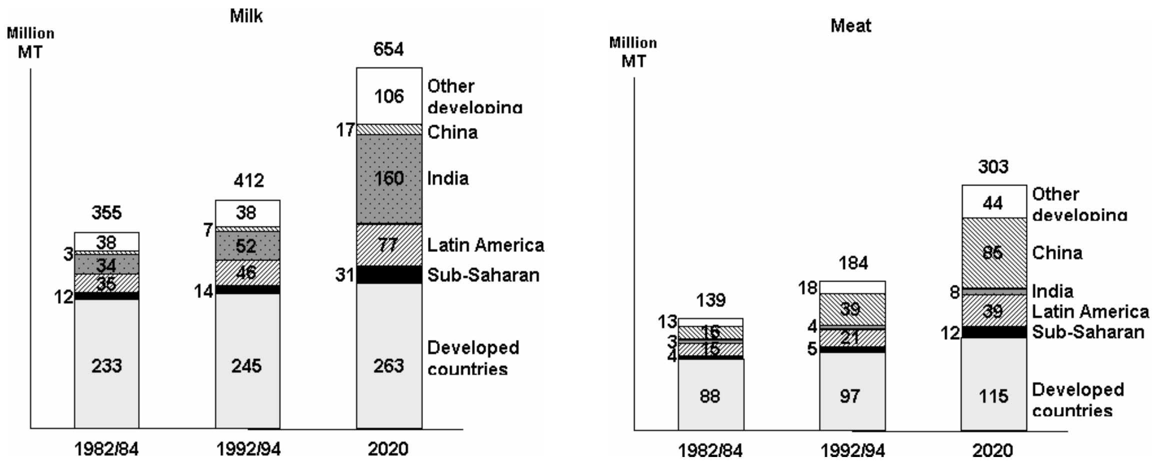


Source: CGIAR (1999).
Figure 1. *Trends in human population growth and food production in sub-Saharan Africa.*

Enhanced food security is a key factor for poverty alleviation. The overwhelming challenge to improve the well-being of people in developing countries is highly dependent on the realisation of increased food production in the coming decades. 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 with utilisation of complementary feed and management technologies for increased production had been introduced for smallholders. It was shown that women in households with access to crossbred cows earned nearly 7 times more dairy income than women in households with local breed cows due to the same division of work, but have larger opportunities with increased output. 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; Tangka et al. 2002).

3 Livestock revolution ahead?

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 2) 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 demands for increased animal production are bigger than for cereals because of changing consumption patterns following urbanisation, population growth and projected income growth. Diets with more high-value protein and micronutrients will improve human health and the livelihood of many poor. 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. Contrary to the familiar green revolution that started in plant production thirty years ago, a livestock revolution is taking place because of 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 poor.



Source: Delgado et al. (1999).

Figure 2. *Total milk and meat consumption during 1983 and 1992 and projection for 2020.*

ILRI, in its strategy to 2010 (ILRI 2000), 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. Results of a study conducted by ILRI's Livestock Policy Analysis Programme in the Ethiopian highland, to asses the impact of improved dairy technology introduction on household income, expenditure and nutrients intake demonstrate that adoption of market-oriented dairy technology significantly raises per capita income and income effect extends positively to expenditure and consumption. The study indicated that doubling the number of crossbred cows of the household may increase household income by 46.5% (Mohamed et al. 2002). The mean income of an adopting household was 41% higher than a non-adopting household. The higher the income level, the higher was the expenditure on food and non-food items and farm inputs. On the other hand, household expenditure was directly related to household nutrient intakes. A 100% increase in expenditure on food may result in about 32%, 33% and 19% increase in calorie, protein and iron intakes, respectively. Households with dairy crossbred cows consume 22% more milk than households without crossbred cows due to the perceived lower cost of own production.

The current ILRI's strategic plan (ILRI 2000) includes a substantial programme on characterisation of indigenous AnGR, and development of strategies for sustainable utilisation of the diversity in livestock species for the livelihood of people in developing countries [see ILRI Strategy to 2010].

4 Diversified use of livestock

Domestic animals have, for more than 10 thousand years, contributed to the human needs for food and agricultural products, such as meat, dairy products, eggs, fibre and leather, draft power and transport, manure for fertilisation of crops and for fuel. Livestock also play an important economic role as capital and for social security. The many-sided contributions of livestock are also emphasised by their cultural role 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 enormously differ.

Of the world's total agricultural output it is presently estimated that about 30% is produced by its variety of livestock. 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. Here, much of the crops produced are fed to livestock and converted to high quality food for human consumption. High yielding breeds of a number of species have been developed genetically to fit different markets and environments [CS 1.4 by Mpofu]. Such genetic changes, combined with continuously better feed and management, have in a few decades doubled the food production in a number of breeds and species. This increase in agricultural produce has required high technology and large inputs of feed, labour, energy and capital, as well as good disease control and management practices. However, only limited considerations regarding total efficiency in nutrient cycling and pollution may have been made. Without such considerations, these production systems will not be sustainable.

4.1 Adaptation to environment a necessity

In most parts of the developing world environmental conditions and availability of capital, technology, infrastructure and human resources have not allowed such an intensification of agriculture, including development of the genetic resources. Instead, harsh climate, less nutritious feed and irregular feed availability, diseases, as well as traditions and lack of education and infrastructure, have for long kept the agricultural output per animal at a low and rather unchanged level. On the other hand, livestock breeds in the tropical parts of the world have during thousands of years been adapted to cope with harsh environments, including disease challenges, and produce under conditions in which breeds developed in more favourable environments will not even survive [CS 1.1 by Mpofu & Rege]. 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 as well as human selection of animals for performance in different environments. That is why we have such a variety of indigenous breeds.

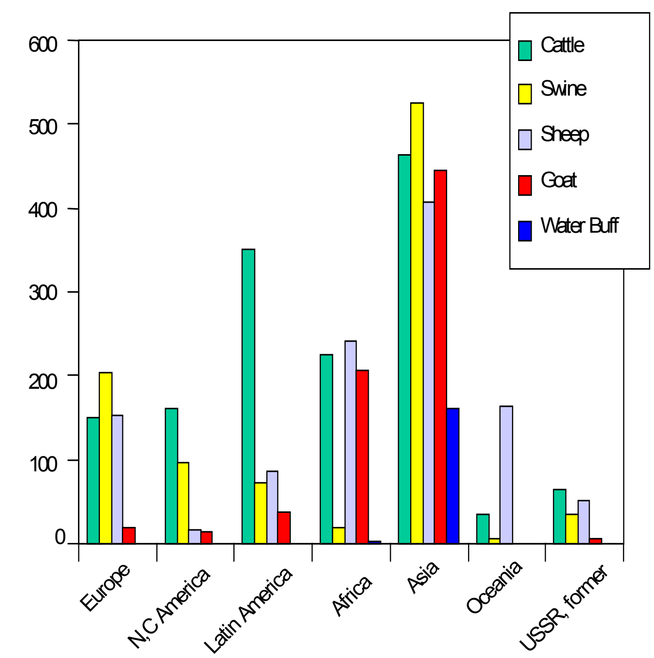
4.2 Increased productivity to avoid degradation of natural resources

The issue 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. Otherwise, we will not be able to produce what is needed for the people of the developing world to survive. Hitherto demands for increased livestock production has largely been met by increasing the number of animals without improving yield or efficiency per animal or area used. This development cannot continue. Land degradation and increasing amounts of resources required to only 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. For sustainability, these systems must emphasise effective resource input/output ratios and more integration of livestock and crop production rather than industrialised mono-cultural production systems that seriously challenge the wise use and care of our natural resources. Thus, the role of the smallholder farmer will be as important as ever, but the production will need to be intensified, yet diverse, and be located in rural, peri-urban and urban areas. The interaction between genotypes and environments would continue to be a key element in developing the future breeding stocks, while some environmental changes, such as improved feeding, including concentrates, will also have to take place.

5 World animal populations increase, but not everywhere

In analysing the distribution of species by world regions, there are some striking differences, which, likely, are the results of different natural resources, climate, culture and socio-economic conditions (FAO 1993-2002). Whereas cattle and sheep together dominate the animal populations in all regions, the swine populations are more or less confined to the western parts of the world and Asia (Figure 3 and Table 1).

Asia keeps more than half of the world's swine population, of which 80% is found in China. Goats are primarily found in Asia and Africa. Chickens are not included in the statistics shown, but the estimated world population of some 11 billion is rather well distributed across regions, although Asia has the largest share and Africa the smallest. The most remarkable changes in the past decade concern the former USSR, where several species populations have been halved. Europe generally shows decreased animal numbers of all species, yet there is a surplus in production. Africa and Asia show steadily increased population numbers, except for sheep in the latter region. Among small ruminants, goats increase relatively more than any other species, whereas sheep decrease in all regions except for Africa.



Source: FAO (2002).

Figure 3. *Animal populations (million heads) distributed by species and region*

Table 1. Animal populations (million heads) by species and region in 1999 and percentage change from 1993 to 2001.

	Region	Cattle		Buffalo		Sheep		Goat		Swine	
No.	%	No.	%	No.	%	No.	%	No.	%		
Africa		230	+19	3	0	250	+18	218	+18	18	+8
Asia		471	+8	160	+8	406	-2	465	+26	552	+15
Europe		144	–26	0.2	+45	145	–29	18	–5	194	–15
N&C America	161	–1	–	–	15	–14	14	–14	97	+5	
S America		309	+9	1	–23	75	–16	22	+2	55	+2
Oceania		38	+14	–	–	164	–13	0.7	–10	5	0
Ex-USSR		59	–45	0.4	+7	51	–58	6	–14	32	–47

Source: FAO (2002).

6 Diversity in animal genetic resources invaluable for future developments

The consistent contribution of animal production to human needs under different environmental conditions, as diverse as arctic and tropical, maritime and mountain, humid and, arid semi-desert eco-zones, has provided during thousands of years, stems from the development of some 4000–5000 breeds of different species. Of these, about 70% are found in the developing world. 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].

6.1 Considerable genetic variation among breeds

The diversity among breeds is usually known to contribute half of the genetic variation found among animals within species, while the other half is attributed to genetic variation within breeds. The latter variation is less vulnerable to loss, whereas breeds are easily irreparably lost when commercially non-competitive. That is why the maintenance of local breeds is of great importance for the genetic diversity [CS 1.17 by Drucker]. 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. 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 their interaction with environmental changes.

6.2 Within-breed variation for sustainable use and improvement

The sustainable use and improvement of indigenous breeds has been justified on grounds that they are already adapted to local conditions [CS 1.8 by Mpofu]. It is also a fact that a large genetic variation exists in productivity within these breeds in 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]. In order 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 material needed to develop appropriate genotypes as the environment and human needs change.

6.3 Rapidly 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 requiring high input and intensive care and management, also in environments which normally cannot support them very well. 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 practising crossbreeding with exotic breeds without any long-term breeding plans, has contributed to severe genetic erosion, including extinction of a number of breeds in the last few decades.

The rather recently started World Watch List of global animal genetic resources suggests that approximately 30% of all current livestock breeds are at risk of extinction. The erosion of animal genetic resources, that already has taken place, is anticipated to continue according to present trends in population statistics. Such a development threatens 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.

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, 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, for example, 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]. 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 so important to seriously consider both the present and future breeding programmes of all species and breeds.

The previously shown distribution of species by world regions may lead to the conclusion that ruminants, which today have the largest world coverage by a large number of breeds adapted to different environments, will also have the best opportunities to adapt to future environmental changes. Similarly, populations confined to 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.

6.5 Animal genetic diversity undervalued

In order to put the right emphasis on long-term genetic improvements, or the needs to conserve genetic variation for present and future use, it seems important to find ways of economic valuation of the genetic resources [CS 1.17 by Drucker] and their developments. Procedures are well developed for economic evaluations of the improvements of individual traits as well as 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 as well as 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]. 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 made between different breeds to be conserved when all are not commercially viable. Unfortunately, there is no single method to readily apply for such economic valuations, but a few important principles need to be understood.

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. However, 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 one, must therefore also include 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 animal genetic resources (AnGR) is generally underestimated.

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.

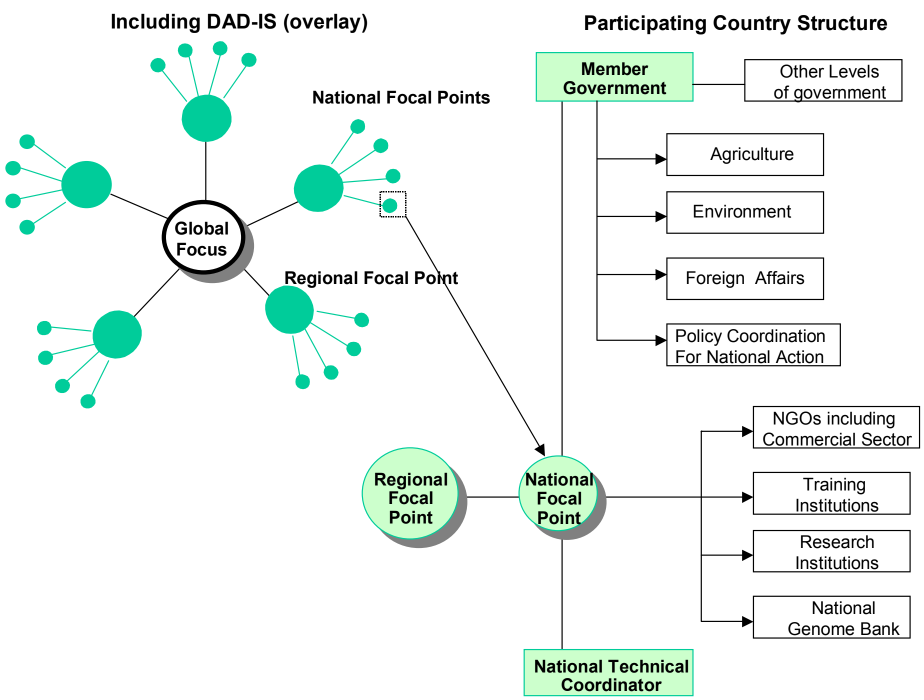
In 1972 the UN conference on environment in Stockholm recognised the need to consider biodiversity as an essential resource for humankind's future well being. The Food and Agriculture Organization of the United Nations (FAO) has ever since then had AnGR and their developments on its agenda. However, it was not until 1980 that a strong AnGR programme, funded by 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 very important step of AnGR development at the 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 (CBD

1992), which was ratified in 1993. 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 NGO's. The CBD has three main objectives:

- conservation of biological diversity
- sustainable use of its components and
- fair and equitable sharing of benefits arising from such use.

In other words, it 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.

The recognition of the importance of both conserving and efficiently using the AnGR as well as 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 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 4).



Source: FAO (1999).
Figure 4. *Structure of the FAO management of Global Farm Animal Genetic Resources.*

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. Figure 4 gives an overview of the structure and its integration with national organisations. 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'.

ILRI (International Livestock Research Institute) is the leading international research organisation with a comprehensive programme on AnGR research and development. The ILRI programme aims to characterise indigenous breeds in developing countries, to quantify the extent and rate of loss of diversity, to contribute to the use and conservation of indigenous breeds and to make them available for research and animal improvement programmes. To date, ILRI has undertaken a comprehensive characterisation of African cattle populations at the molecular level [CS 1.10 by Okomo-Adhiambo]; [CS 1.11 by Gwakisa]. Similar work in other regions and on more species is under way. At the same time ILRI is working with NARS on on-farm phenotypic characterisation of indigenous livestock. ILRI has also since 1999 been developing a web based electronic source of information on indigenous farm animal genetic resources, DAGRIS. It is backed up by bibliographic information and will support research, training, public awareness and genetic improvement and conservation programmes.

6.7 How could we ensure future diversity of AnGR?

Realising that 30% of all present breeds are at risk of extinction and that conservation programmes are lacking for more than 75% of these breeds [Breed information], one may ask how we could ensure the genetic diversity needed for the future. 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 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. That 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, the 'indigenous' knowledge is invaluable to capture. Facilitating the infrastructure needed, and application of adequate selection tools assumes also 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 a necessity, as well as research for characterisation of actual breeds and for design and implementation of sustainable breeding programmes.

Thirdly, as 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, policies are needed for supporting conservation and utilisation 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, but it is the responsibility of each country to see that its AnGR are given the right support to be sustainably used. In this context, ILRI's research and capacity building programme will play a significant role in revealing new knowledge needed and for strengthening the national capacities in implementing this 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 launched to genetically improve the livestock in the tropics. Although it should be recognised that improved livestock have been produced or 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]. 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, improvement programmes have usually been conducted by people from developed countries. 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 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. Too high upgrading has generally led to animals without resistance to withstand environmental stress.

The lack of analysis of the different roles of livestock in each specific area, usually leading to falsely defined breeding objectives and a neglect of 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 apparently better consider the potential of indigenous livestock breeds and realistic ways of improving this livestock in the context of environmental and socio-economic demands as well as within the resources available. For this purpose there is a great need to characterise the indigenous livestock breeds, in order to find out which are the most suitable ones for further improvement, and for implementation of simplified, but yet effective, breeding programmes [CS 1.7 by Khombe]; [CS 1.14 by Olivier]. Such programmes could e.g. 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].

8 Acknowledgements

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