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Animal Breeding and Animal Genetic Resources

edited by
Eildert Groeneveld and Peter Glodek

Proceedings of Workshop 7 on Sustainable
Animal Production, organized by the Institute for
Animal Science and Animal Behaviour,l
Federal Agricultural Research Centre (FAL), Mariensee,
and the Institut für Tierzucht und Haustiergenetik
der Georg-August-Universität, Göttingen,

held at Hannover, July 17 - 18, 2000

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Workshop Series „Sustainable Animal Production", June - October 2000

Foreword to the Proceedings

How can agriculture provide a reliable source of food of animal origin for the world's population without compromising the basis of life of future generations? In view of the rising demand for food of animal origin in industrialized, emerging and developing countries, how can animal production on a global scale become sustainable?

These were among the key issues under scrutiny in a series of international workshops on sustainable animal production conducted during the world exposition EXPO 2000 by a consortium of scientists from four north German research institutions: the School of Veterinary Medicine Hannover (coordination), the Federal Research Institute for Agriculture (FAL), the Institute for Structural Analysis and Planning in Areas of Intensive Agriculture (ISPA) at the University of Vechta, and the Agricultural Faculty of the University of Göttingen.

A broad spectrum of current issues and problems in modern livestock production were covered: animal production and world food supply; globalization, production siting and competetiveness; product safety and quality assurance; the environmental impact of livestock farming; animal welfare and health; biotechnology and gene technology; animal genetic resources; animal nutrition: resources and new challenges; safeguarding animal health in global trade.

The individual workshops were organized by local coordinators and moderated by international discussion leaders. In all 142 scientists from 23 countries worldwide participated as speakers. The workshops produced a differentiated, inclusive and holistic vision of the future of global livestock farming without national bias and free of emotionally-tinged concepts or ideology. The results of the workshops were summarized and presented to the public in a final plenary session including a roundtable discussion with representatives of agricultural policy, public life and the media.

In addition to the publication of proceedings of the workshops as special issues of *Landbauforschung Völkenrode*, abstracts of the papers and summaries of the results are now documented in the Internet at www.agriculture.de, where a preparatory virtual conference was conducted from October 1999 until October 2000.

Volker Moennig
School of Veterinary Medicine Hannover

Workshopserie „Nachhaltige Tierproduktion", Juni – October 2000

Vorwort für die Tagungsbände

Wie kann die Landwirtschaft in Zukunft weltweit Menschen nachhaltig mit Lebensmitteln tierischer Herkunft versorgen, ohne die Lebensgrundlagen künftiger Generationen zu beeinträchtigen? Wie kann eine nachhaltige Tierproduktion global und angesichts wachsenden Bedarfs an Lebensmitteln tierischer Herkunft in Industrie-, Schwellen- und Entwicklungsländern aussehen?

Diese und ähnliche Fragen waren Anlass zur Organisation einer internationalen Workshopserie zum Thema „Nachhaltige Tierproduktion/Sustainable Animal Production" zur EXPO 2000. Veranstalter waren Wissenschaftler aus vier norddeutschen Forschungseinrichtungen: Die Tierärztliche Hochschule Hannover (federführend), die Bundesforschungsanstalt für Landwirtschaft (FAL), das Institut für Strukturforschung und Planungen in agrarischen Intensivgebieten der Hochschule Vechta (ISPA) sowie die Agrarwissenschaftliche Fakultät der Universität Göttingen.

Ein breites Spektrum von Themen, wie Tierproduktion und Welternährung, Globalisierung, Standortorientierung und Wettbewerbsfähigkeit, Umweltverträglichkeit der Tierproduktion, Tierschutz und Tiergesundheit, Produktsicherheit und Herkunftssicherung, Tierzucht und genetische Ressourcen, Sicherung der Tiergesundheit bei globalen Handelsströmen, Tierernährung: Ressourcen und neue Aufgaben, Bio- und Gentechnologie spiegeln die gesamte Bandbreite der modernen Tierhaltung und ihrer Probleme wider.

Die einzelnen Workshops wurden jeweils durch lokale Koordinatoren organisiert und von internationalen Diskussionsleiter moderiert. Insgesamt 142 Wissenschaftler und Wissenschaftlerinnen aus 23 Ländern weltweit haben als Referenten an der Serie teilgenommen. Die Workshops haben ein differenziertes und umfassendes, ganzheitliches Bild von der Tierhaltung der Zukunft ergeben, das frei von nationalen, teils emotional und ideologisch gefärbten Konzepten ist. In einem Abschlussworkshop wurden die Ergebnisse der Workshops mit Vertretern aus Politik, öffentlichem Leben und Presse diskutiert. Die jetzt vorliegenden Proceedings der Workshopserie in der *Landbauforschung Völkenrode* werden ergänzt und weltweit verfügbar gemacht durch die Veröffentlichung im Internet unter der Adresse www.agriculture.de. Unter derselben Internetadresse hatte vor den Workshops eine virtuelle Konferenz als Vorbereitung von Oktober 1999 bis Oktober 2000 stattgefunden.

Volker Moennig
Tierärztliche Hochschule Hannover

Introduction

Eildert Groeneveld[1] and Peter Glodek[2]

During the last few years biodiversity has gained much public attention increasing the awareness that its current rapid loss should not go unchallenged. Animal breeding operates within the realm of biodiversity and depends on genetic variation as the basis for future genetic progress. While much of the loss in biodiversity can be attributed to the eradication of species, in animal agriculture the most conspicuous loss of genetic variability is the disappearance of breeds. Loosing a breed may be considered less irrevocable than loosing a species. However, animal breeders should be concerned and carefully consider its potential impact and take – where needed – counter measures.

As part of the World Exposition 2000 in Hannover/Germany a series of Virtual Internet Conferences was organized by a group of research institutions in the Hannover area under the heading "Sustainable Animal Production". One of the nine conferences dealt with "Animal Breeding and Genetic Resources".

The objective of this conference was to discuss the impact genetic erosion on animal breeding. The focus was on potential future problems or losses in efficiency which breeding programs may incur if breeds vanish at the current rate. Likewise, potentially changing environments and other conditions were to be considered.

It quickly became clear that the impact of breed loss may be very different for various species and different parts of the world. Here, the global mandate of a World Exhibition helped to assemble a truly worldwide group of animal scientists to discuss the issue from as many perspectives as possible. With contributors from Asia, Africa, North and South America, Australia and Europe, we have hopefully not omitted any important region of the world.

When comparing animal production on the world wide scale differences in intensity of inputs are very prominent with far reaching consequences. Accordingly, it was attempted to assess the impact of genetic erosion with low and high input systems. As can be seen from the papers in this booklet, genetic erosion is expected to have very different impact for these two groups.

Principles of genetic improvement are independent of the species they are applied to. Nonetheless, the structure of the animal breeding industry is substantially different among the species. Therefore, representatives for chicken, cattle and pigs were asked to explore the relevance of genetic resources to animal breeding at present and in the future.

As can been seen from their contribution, the fault line is not so much along species but rather along intensity of production systems.

While conservation of genetic resources in animal production was generally considered an important issue for high intensity production systems which tend to be located in the first and second world, it was made clear that conservation through utilization and improvement of indigenous breeds was of crucial importance to low intensity production environments which are often to be found in the developing world.

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The Relevance of Plant Genetic Resources in Plant Breeding

Th. Gladis[1] and K. Hammer[1]

Summary

The total number of plant species, which are cultivated as agricultural or horticultural crops, can be estimated to be close to 7,000 botanical species. Nevertheless, it is often stated that only 30 species "feed the world", because the major crops are made up by a very limited number of species. The latter is also the major reason that 6 million of accessions collected and conserved in gene banks belong to a very limited number of species compared to the total number of species, which contribute to food security. About half of all accessions maintained in collections *ex situ* are advanced cultivars or breeders' lines, while just over a third of them are made up by landraces, or old cultivars, and about 15 % are wild relatives of crop species, weedy plants or wild plants. Only a third of all accessions are characterized. There is obviously a gap in the collections regarding minor crops and underutilized species, in particular landraces and wild relatives of crops from the respective crops' centres of diversity and cultivation are underrepresented in gene banks.

Therefore, the further exploration of minor and underutilized species, the collection of these genetic resources and the assessment of genetic diversity within and between landraces should have priority in gene banks' activities. At the same time it is necessary to develop better methods of characterization and evaluation of germplasm collections, to improve strategies for conservation and collection of germplasm, and to increase the utilization of plant genetic resources.

The most effective methods for conservation of diversity for the respective plant groups considered, i.e. crops, their wild relatives, weeds and wild plants, are different. In some cases a combination of different strategies is the most effective way. The strategies include *ex situ* conservation (management of gene banks), conservation and management on farm (monitoring and protection of agro-ecosystems), *in-situ*-conservation (monitoring and protection of natural ecosystems). The most effective way of assessment of genetic diversity within a given taxon is also a combination of different methods, combining morphological, agronomic and molecular characterization of genetic diversity. The ongoing process of gene-erosion requires clear decisions for future strategies.

To promote the work with animal genetic resources, a proposal is made to collect information about domesticated or at least reared animal species and to edit a manual in analogy to the dictionary of cultivated plants by Rudolf Mansfeld.

Introduction

There has been a significant loss of diversity during the last 100 years and the process of extinction and advanced gene erosion continues. Crops and cultivated plants, today named plant genetic resources for food and agriculture (PGR or PGRFA) include all species, which contribute to peoples livelihoods by providing food, medicine, feed for domestic animals, fibre, clothing, shelter, energy and other uses. Forest plants and ornamentals are excluded in this view as well as in the following tables. PGR are subject to cultivation by man as well as their wild relatives are for breeding research and studies about evolution, domestication and co-domestication. However, in comparison to the total number of species of higher plants which have been identified world-wide, PGR comprise 40 % of these species, while the crop plants themselves cover only 2.8 % of the species (Table 1).

Table 1
Number and relative amount of botanical species of higher plants, plant genetic resources (PGR), and crop plants in Germany, Europe, and world wide (estimates according to Hammer 1995a, Moore 1982)

	Higher Plants		PGR		Crop Plants	
Germany	2,500	(100 %)	1,055	(42.2 %)	150	(6.0 %)
Europe	11,500	(100 %)	4,730	(41.1 %)	500	(4.3 %)
World	250,000	(100 %)	100,000	(40.0 %)	7,000	(2.8 %)

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Agrobiodiversity, Steinstr. 19, D-37213 Witzenhausen, Germany

The irreversible loss of species - cultivated as well as wild -, the loss of subspecies, land races, formerly modern varieties, characters, "single" genes and combinations of them during the last 100 - 150 years is of major concern. Polymorphism is the primary source for variation in morphological and physiological appearance of plants. Diversity is the basic result but even an important factor of the evolution within and among species. It made it possible for plants as well as animals to be adopted to the most different environments and uses. Diversity will allow them to respond to the challenges of the future.

Adaptability acts as a buffer against harmful environmental changes and economic challenges. The erosion of character results in a severe threat to the world's long term food security. Although often neglected, the urgent need to conserve and utilize this diversity and to protect the processes resulting to diversification as a safeguard against an unpredictable future is evident. The complexity of serious ecological problems, partly also caused by agricultural science, now to be solved with the help of agricultural sciences, is a great challenge. The disciplines of soil sciences and the search for renewable resources from animals and plants as raw materials are important issues, which are related to research in genetic resources.

The future development of agriculture must become much more aware of ecological and environmental impacts. External effects, which have so far hardly been part of economically based decisions, have to be taken into consideration. This requires renewed approaches, for the management of and research in biodiversity (Hammer and Gladis 1996). These changes are more substantial than other changes in biological sciences, which can be observed today, and can be compared to what is called a paradigm shift (Kuhn 1970, Anonymus 1986). It will be necessary to better understand the threats to biodiversity, including the consequences of introduction of new species, genetically modified organisms, changes in agricultural practices and land use, or disturbance, fragmentation, isolation and pollution of ecosystems. A substantial change in approach or even a paradigm shift regarding conservation of agro-biodiversity and ecosystem-management from conservation *ex situ* to a management on farm resp. conservation *in situ* (FAO 1996b) can be observed. A similar change is ongoing regarding the strategies for most effective study and utilization of *ex-situ*-collections of plant genetic resources e.g. (Tanksley and McCouch 1997). The impact of modern biotechnology on agriculture, breeding and, thus, agro-ecosystems also causes severe changes.

Crops and cultivated plants versus PGRFA

The terms PGR and PGRFA present a breeder's view to the entire concept of plant diversity. Specialized plant breeders exist since about 200 years. They feel themselves as the primary improvers of primitive plant material, used and maintained by unspecialised farmers elsewhere. But just these farmers grew and carefully selected their plants over many generations, altogether about 10,000 years following their own experience and intention. The progress regarding yield, homogeneity, nutritional value etc. was slow. But the adaptation to special climatic and soil conditions was perfect. These local land races were lowest input varieties, the harvest was stable and nearby sure even under extreme conditions, just thanks the variation between as well within the plant populations. The annual harvest was comparably low but there was space between the individual crop plants, used by weeds and animals, the soil was fertile without other fertilizer than manure. Watering was reduced to kitchen gardens with vegetables and spices. Field crops had to be draught resistant enough to survive without irrigation. Salt was not yet a problem in agriculture at that time. At the end of this period, there existed a giant diversity in animals and plants and human begun to dominate the world with more and more individuals of his species as well as accompanied animals and plants. Industrialization started, progress in research yielded in better and better understanding of nature and exploitation of the resources. Nowadays, we have a nearby perfect exploitation of nearby all the available resources of the world, not living as well as living, including human resources.

The definition of the purpose would fill as separate paper, but coming back to the diversity of PGR we have first of all to be aware of things we have lost in these days. One of them is the diversity of land races in the landscape, resulting in the establishment of gene banks, nowadays called *ex-situ*-collections. They exist since about 100 years. Other things we have completely lost are the tight relation between plants and culture, and the loss of respect to life in general. The value of everything is automatically reduced to the economic today, to the marketing value of, in this case, the crop for the present marketing season, nothing else. There is no space in the fields for weeds, no use recognized any more for fallow land and since the complete harvest is marketed, evolution only may happen in the hands of breeders. But even their number decreases dramatically. Is the application of modern techniques able to compensate the loss of evolutionary options in general?

From the viewpoint of a cultivated plant species or population, its chances to be maintained and used by farmers increases, the lower its marketing value is. Dominant crops have no chance, underutilized or neglected crops on the other hand are in danger to be lost for ever. The more important, the more breeders work with the respective resource and its relatives, the space for all the other decreases dramatically. Before genome research and genetic engineering were established, PGR belong, according to Harlan and de Wet (1971), to the primary or to the secondary gene pool of the respective species. The native living beings and virus might be included into tertiary gene pool. It is enlarged more and more, depending from the development and application of new techniques and at the end perhaps unlimited. This third pool is just used as source for establishing "new", e.g. transgenic crops. A fourth gene pool is postulated here, composed of organisms or organismoids[1] with cells or celloids, containing partly or completely synthetic strains with nucleic acids, i.e. DNA or RNA frequencies, not occurring in nature, incorporated into chromosomes or the organells of living animals and plants for animal and crop design in future (Figures 1 and 2). This should not be confused with the term nano-technologies.

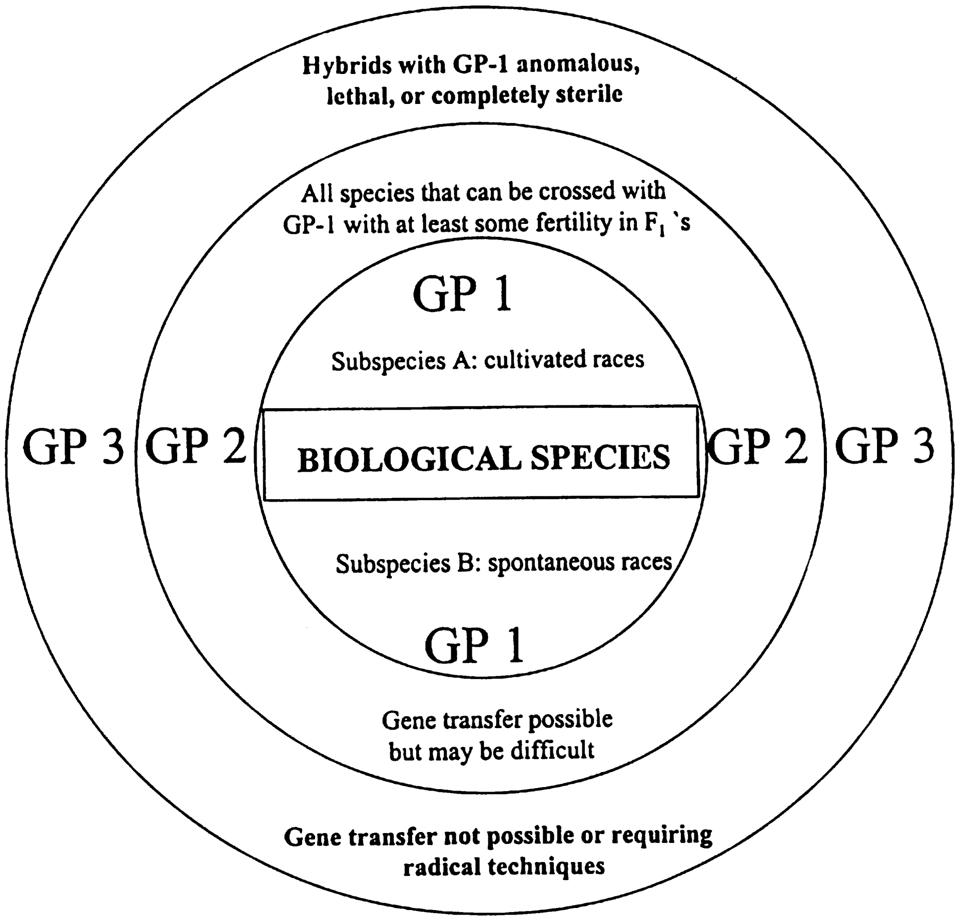

Fig. 1
The gene pool concept, established by Harlan and de Wet (1971), modified.

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[1] That are combinations of organisms or parts of them with components of artificial origin, not occurring in nature or at least not in the concrete combination: e.g. synthetic proteins, nucleic acids, incorporated instruments from the IT branch or other developing technologies up to complete organism like constructed machines.

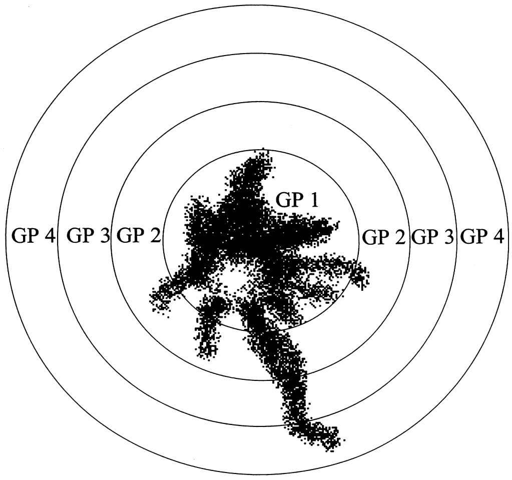

Fig. 2
Example for an organismoid or an - at present hypothetic - designed crop with a genome, composed of different gene pools and synthetic genes

Explanations:
GP 1 - The biological species with wild, weedy and cultivated races
GP 2 - All species that can be crossed with GP 1 with at least some fertility in individuals of the F1 generation; gene transfer is possible but may be difficult
GP 3 - Hybrids with GP 1 do not occur in nature, they are anomalous, lethal, or complete sterile; gene transfer is not possible without applying radical techniques
GP 4 - Any synthetic strains with nucleic acids, i.e. DNA or RNA frequencies, not occurring in nature

About thirty crop species are told to feed the world. The most important of them are listed in Table 2. These species provide more than 90 % of calories or protein to human nutrition, including vitamins and other essential components of our food and that of our domestic animals. Therefore, food improvement by modern plant breeding and molecular biology are demanded to guarantee food security e.g. by better resistance to diseases and to compensate nutrition gaps of the growing human population by higher yielding varieties. The conservation of plant diversity has always received attention in respect of food quality and diversification of products.

Table 2
Thirty crops with the highest number of accessions represented in ex-situ collections (after FAO 1996a)

Crop	**Total accessions world-wide**	**Crop**	**Total accessions world-wide**
Wheat (Triticum)	784,500	**Chickpea** (Cicer)	67,500
Barley (Hordeum)	485,000	Prunus	64,500
Rice (Oryza)	420,500	**Clover** (Trifolium)	61,500
Maize (Zea)	277,000	Capsicum	53,500
Garden Bean (Phaseolus)	268,500	**Cotton** (Gossypium)	49,000
Oat (Avena)	222,500	**Grape** (Vitis)	47,000
Soybean (Glycine)	174,500	Triticale	40,000
Sorghum	168,500	**Alfalfa** (Medicago)	33,000
Brassica	109,000	**Sweet poatato** (Ipomoea)	32,000
Apple (Malus)	97,500	**Potato** (Solanum tuber.)	31,000
Millet (Eleusine, Panicum,…)	90,500	**Faba bean** (Vicia faba)	29,500
Cowpea (Vigna)	85,500	**Sunflower** (Helianthus)	29,500
Groundnut (Arachis)	81,000	**Lupin** (Lupinus)	28,500
Tomato (Lycopersicon)	78,000	**Cassawa** (Manihot)	28,000
Pea (Pisum)	72,000	**Rye** (Secale)	27,000

However, the number of species used for peoples' livelihoods is much larger than these thirty and is estimated to be close to 7,000 botanical species (Table 3). The amount of PGR accessions in *ex-situ* collections world-wide is estimated to be 6.1 million accessions (FAO 1996a, see also Table 4). The 30 species listed in Table 2 already cover 4,036,000 accessions, or 2/3 of all genetic resources in these collections. But nobody knows the total number of accessions maintained on farms and in gardens. And there exist scarcely concepts for monitoring the process of evolution within cultivated plants, and their migration in connection with migrating people. This is an important point to have in mind when discussing plant genetic resources for food and agriculture. Several crop species are completely neglected by agricultural science or breeding efforts.

Conserving and evaluating agro-biodiversity

The *ex-situ* collections of PGR contain approximately six million accessions (Table 3). However, there is an unknown rate of duplication within and between collections. The total number of unique accessions in collections, which have been established to preserve diversity, is estimated to be one or two million only. 40 % of all accessions in gene banks are cereals. More than 1 million accessions belong to the three main crops wheat, maize and rice. Food legumes comprise about 15 %, vegetables, roots and tubers, fruits, and forages account each for less than 10 % of the global collections. Spices and medicinal, aromatic and ornamental species are rarely found in gene banks.

Table 3
Number of ex-situ collections and conserved accessions, by region. (FAO 1996a)

Region	Gene banks		Accessions	
	Number	%	Number	%
Africa	124	10	353,523	6
Asia	293	22	1,533,979	28
Europe	496	38	1,934,574	35
Near East	67	5	327,963	6
North America	101	8	762,061	14
Latin America and Caribbean	227	17	642,405	12
Total	1,308	100	5,554,505	100
CGIAR			593,191	
Total			6,147,696	

Weeds, wild relatives of cultivated plants, crops running wild and introgressions between wild and cultivated material are scarcely noted or collected, but just the latter are of highest interest for studying evolutionary processes and plant domestication. This is demonstrated in figure 3. Weeds, which have been subjected to co-evolution or co-domestication with cultivated plants in agro-ecosystems, developed also a wide range of diversity and sometimes have potential value for cultivation. But they are hardly collected systematically (Hammer et al. 1997).

There is a lack of knowledge about the diversity and geographical distribution of less utilized species in agriculture. The need for more attention to such crops and crop-weed complexes in conservation and utilization programmes is evident. The knowledge about the species cultivated world-wide for food and agriculture is still increasing. Therefore, the estimated number of species of cultivated plants has increased considerably. This is revealed by the figures presented in Table 4.

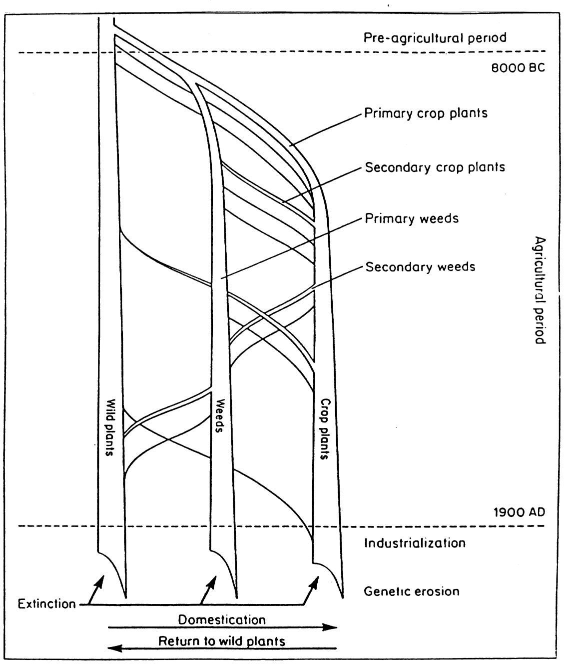

Fig. 3
Plants under human influence (Sources: Gladis 1996a and Hammer et al. 1997).

Table 4
Number of plant species cultivated for food and agriculture according to different inventories published in the 20th century (Hammer 1995b)

Source	Year	Number of species	
		Reported number	estimated total number
Mansfeld, 1st ed.	1959	1430	1700-1800
Vul'f (before 1941)	publ. 1987	2288	-
Vul'f and Maleeva	1969	2540	-
Mansfeld, 2nd ed.	1986	4800	-
Mansfeld, 3rd ed.	in prep.	-	6000
General estimation	2000	-	7000

Rudolf Mansfeld (17.I.1901-30.XI.1960), the first director of the Gatersleben gene bank, translated his dream into reality, to edit a dictionary of all the cultivated plants of the world, excluding forest plants and ornamentals in 1959. This manual is continuously actualised. The third edition is in preparation now and will be available as a book and in an electronic version in 2001. The first as well all other editions present the following information about each cultivated plant species as well as the most important infraspecific taxa up to the level of varieties:

– position of the respective plant species in the botanical system
– complete scientific name and most important synonym(s)
– vernacular names in the languages of the distribution area(s)
– origin and distribution as far as known
– short description of all known growing purposes and practises including the age of cultivation
– literature

As much as the authors know, there is no comparable dictionary available for domesticated animal species except Scherf (1995) which merely remains on the level of races of the most important mammals and bird species, just some reptiles are mentioned. It would be a fascinating work to complete the zoological part to the view on the existing agro-biodiversity in a world, dominated by human activities, which are mainly destruction of natural habits and extinction of species.

This list should be worked out with the help of as many specialists as are willing to contribute. The edition will be supported by the department of Agrobiodiversity of the University Kassel-Witzenhausen together with the department Information Centre for Genetic Resources (IGR) of the German Centre for Documentation and Information in Agriculture (ZADI, Bonn). In vertebrates, a first check after Monnerjahn et al. (2000) gave the following numbers of species reared by human for the groups of purposes proposed here (excluding decorative animals, i.e. pure ornamentals, without any economic utilization in this first step and wild animals used anyway). Rearing and breeding are the minimum criteria for listing here, keeping without reproduction should not be sufficient:

– Accompanied (economic value as currency, pats, traditional reasons etc.)
– Clothing, fibres, hides, skins, textiles
– Experimental (laboratory animals, research work)
– Fodder animals (including fishing bites)
– Introduction and release for collecting, hunting, influence on environment etc.
– Medicinal (drugs, poisons, production of sera etc.)
– Nutrition and food for humans (mainly meat, eggs)
– (Ornamental, decorative)
– Plant protection and pollination
– Religious
– Sports and transport
– Technical (products like biogas, bones, cheese, horn, oil, manure, wax)
  Vectors of human and animal diseases
– Zoological Gardens including protection and reintroduction programmes

Table 5
Preliminary list of vertebrate species reared and used by human (world-wide)

1.	Mammals	40
2.	Birds	24
3.	Reptiles	11
4.	Amphibians	7
5.	Fishes	18
	Total	100

The example of Reptiles (1 Boa sp. + 2 Asian + 1 European turtle species + at least 1 sea turtle protected and utilized officially + 4 crocodiles + 2 iguanas) may illustrate exemplarily the difficulties to initiate such an inventory. Literature is wide spread within many specialized journals, and the zoological experts have merely interest in protecting wild animals in their native habit or doing research on their ecology and behaviour there. Domesticated and pre-adapted animals or even the biological situation on markets are scarcely of interest to them. One of the few recent exceptions are the articles of Meier (2000a) and Valentin (2000). In China there are living 35 turtle species. Most are used as food or for medicinal purposes. Meier pointed out that 5-6 of them are reared in farms only. But the farms can not offer the quantities requested from the market. Valentin reports 26 turtle species with together more than 10 000 individuals per day on two regional markets in China without having visited the storing halls. His list contains just 2 of the species where successful farming is reported in the previous article. 445 individuals out of the above mentioned 10 000 individuals are coming from these two species only - but there is no evidence that they are originating from one of these farms. About the other species science does not know anything, neither about their biology nor about the native habits, many are only known from these regional markets. There has just started a project to study, breed and to maintain rare Asian turtle species at a Zoological Garden in Germany (Meier 2000b). This example illustrates the giant risk of extinction and loss of potentially usable species at an exotically seeming example. It will never be possible to maintain all the endangered species in Botanical and Zoological Gardens or gene banks - but these institutions can contribute to increasing awareness about erosion and may supply individuals as well as initial populations to reintroduction programmes if these are established. Just in this century a lot of knowledge about rare and endangered species has to be collected and listed, at least to measure the dimension of the losses human beings cause every day.

As shown above, zoologists tend to neglect utilized and domesticated species. The same is known for botanists since Darwin (1879 cited after Schultze-Motel 1986). Even in developed countries cultivated plants may exist, never noted or described by taxonomists (Gladis 1996b). Very recently, Botanical Gardens detect Plant Genetic Resources as a task and start to develop concepts (Rauer et al. 2000) which exist for a long time in crop plant research. Even literature dealing with long term experience in managing large collections of cultivated plants *ex situ* is ignored frequently up to now.

To compile the manual of domestic animals seems to be an urgent need in this context. But it should not be limited to vertebrates. Otherwise it can not be an useful tool for scientists and farmers. Evertebrates and other groups of animals are even used and reared for different purposes by man. Besides honey bee, e.g. a lot of beneficial arthropods are known in plant protection. The 24 *Trichogramma* species (Insecta, Hymenoptera), reared at the German Federal Biological Research Centre for Agriculture and Forestry, should be mentioned exemplarily here (Klingauf et al. 2000).

Further needs

Exploration of selected minor and underutilized species for germplasm collections and assessment of genetic diversity of landraces has priority in the field of crop plant research. The exploration, collection, conservation and identification of potentially valuable plant genetic resources for food and sustainable agriculture, which are endangered by extinction, as well as other plant genetic resources, which have potential value for future development, are primary obligations for all countries and institutions adhering to the FAO International Undertaking on Plant Genetic Resources. The Global Plan of Action for the conservation and sustainable utilization of Plant Genetic Resources for Food and Agriculture (FAO 1996b) emphasises, besides the *in-situ*- and on-farm conservation, the importance of *ex-situ* conservation. The figures presented in Table 3 show that the total number of accessions in collections is very large. But, besides the mentioned problem of duplication, the security of conservation *ex situ* is also questionable. About half of all gene bank accessions worldwide urgently require rejuvenation, and in several countries this amount is even larger. In Albania 80 % of the accessions conserved *ex situ* require regeneration, which is alarming, since gene erosion in agro-ecosystems in Albania is still observed, while other industrialized countries already lost most of this on-farm-diversity during industrialization (Hammer and Gladis 1996). Lack of funds is a general complaint of gene banks, and political instability also threatens *ex-situ*-collections.

Although there are high numbers of accessions for some important crop species in the collections, it is difficult to estimate, which proportion of the entire diversity of such a species is really preserved *ex situ*. Under on-farm-conditions the diversity is always subjected to evolutionary changes and adaptations, while gene banks usually try to exclude genetic shift and drift during rejuvenation and long term conservation of germplasm. The definition of three different categories of biological diversity should not result in neglecting the existing strong interactions between these categories. These are: (1) genetic (or better the infraspecific) diversity, (2) diversity of species, and (3) diversity of ecosystems (Akeroyd 1996, Wilkes 1989). From the viewpoint of plant genetic diversity for food and agriculture it has within each category to be differentiated between diversity of (1) cultivated plants, (2) wild relatives of cultivated plants, (3) introgressions between cultivated plants and their relatives, and (4) weeds.

It has to be analysed, which strategy for conservation of biodiversity is the most appropriate one for each of the mentioned categories and for each specific group within these categories. The conservation strategies can be categorized into: (1) *ex-situ*-conservation (gene banks, botanical gardens), (2) conservation or management on farm (agro-ecosystems, gardens), and (3) *in-situ*-conservation (natural ecosystems). Table 6 scores the advantages of each conservation strategy according to the respective category of biological diversity and the specific groups within them. Complementary action between these strategies is necessary. This needs increased cooperation in times of general reduction of budgets for such work, which can be more effective, if the relative superiority of the different conservation methods are taken into consideration (Diederichsen 1998).

Table 6
Conservation methods and their relative superiority for different categories of diversity scored by their importance for specific groups of diversity (changed, after Hammer 1998)

Method of conservation	**ex situ** (gene banks)	**on farm** (agro-ecosystems)	**in situ** (other ecosystems)
Category of diversity		**developed countries**	
infraspecific diversity	C** R* W**	C** R* W*	C^{o} R*** W*
diversity of species	C* R* W**	C** R* W**	C^{o} R** W*
diversity of ecosystems	C^{o} R^{o} W^{o}	C* R** W***	C^{o} R** W*

Explanations:
The relative importance of the methods to the specific groups of diversity is indicated by the number of stars
C = **C**rop species — * = low importance — *** = very important
R = Species of wild **R**elatives of crops — ** = important — 0 = no importance
W = **W**eeds

Ecogeographic surveys of the ranges of distribution of a species as they have been initiated by N. I. Vavilov (1926), are still the basic tool for developing adequate strategies for monitoring and collection of relevant diversity of a plant species. Such studies deliver basic information about: (1) the geographic distribution of a particular species, (2) patterns of infraspecific diversity, and (3) the relationship between survival and frequency of variants and associated (agro-)ecological conditions. In cultivated plant species such studies are essential to understand the process of domestication and diversification on the infraspecific level.

The identification of primary and secondary centres of diversity is based on such studies, which are still important. As an example in this direction Pistrick (1987) presented the range of distribution of wild radish, *Raphanus raphanistrum L.* ssp. *raphanistrum*. He could show for the same species, how the historical exchange of crop genetic diversity over far distances has led to the development of secondary centres of diversity for this subspecies.

A number of methods are available to analyse genetic diversity. Since each of these provides different types of information, the choice of the appropriate method or methods depends upon the information required as well as the resources and technological infrastructure available. Diversity can be studied, measured and quantified at different organisational levels, which are subject to research on ecosystem, plant sociology, species, infraspecific, cellular, subcellular, or molecular levels. Whatever the level of analysis may be, the purpose is to detect and quantify diversity. The basic questions are: What are the suitable units for quantifying diversity at the respective levels? What kind of variation is of importance for the question to be investigated? For research in cultivated plants, for handling and utilisation of diversity of plant genetic resources for food and agriculture, measurements of the extent of variation, i.e. the polymorphism, can easily be made by observing the phenotypes of plants. If such characterization uses clear-cut qualitative traits, like colour, morphology or enzyme variants, it already reflects to high degree the genetic diversity by being relatively independent from environmental influences. More technical methods are needed to analyse genetically complex quantitative traits that vary continuously over a scale. These included agronomic traits such as yield or plant height, which are more typical for evaluation data in the PGR context.

Morphological and agronomic characters are often used for basic characterization, because this information is of high interest for users genetic diversity of PGR. Such characterization requires human labour and organizational skills as well as an elaborated system of data documentation. It can be done using simple techniques and is capable to reach a high sample throughput. The data are not only of interest for users of the collection, but allows interpretation of the relations between the genotype and the environmental conditions, and, thus, conclusions on the evolutionary responds of the given species to selection pressures. This is essential for understanding the evolutionary pathways of cultivated plants. Taxonomical treatments of infraspecific variation tend to favour qualitative traits in the analysis of diversity. The basic units for measurement of diversity taxonomy defines are infraspecific taxa like subspecies and botanical varieties. Breeders, however, to large extent have to focus on quantitative traits in reaching their breeding goals. Quantitative agronomic traits measure the differences between individuals and populations with regard to genetically complex traits such as yield potential and stress tolerance. The diversity of a population with regard to such a complex trait can be described by using its mean value and genetic variance in statistical terms. The traits detected are of high interest but frequently subject to strong environmental influence, which makes their use for defining units for measurement of genetic diversity difficult. Formal taxonomical classifications are not based on such characters, while informal classifications, which are sometimes used in agriculture, are frequently based on such traits. The relationship between the curators and users of PGR is a key issue in the management of *ex-situ*-collections. The analysis of genetic diversity is necessary to monitor genetic erosion, to guide collecting priorities, to investigate the evolutionary history of crops, to support breeding strategies, to guide the management of germplasm collections, and to recognize genetic erosion.

The major advantage of molecular methods for characterization is their direct investigation of the genotypic situation, which allows them to detect variation at the DNA level and thereby excluding all environmental influences. Furthermore, it can usually be done at early growth stages. The advantages and disadvantages of some commonly used molecular techniques for characterization of PGR are summarized in Table 7. According to the chosen method, they can be very sensitive to any genetic differences and, thus, detect much more genetic diversity than the classical morphological methods. Molecular marker techniques have become powerful and accurate tools for the analysis of genetic diversity. If molecular markers are correlated to characters of interest in breeding programmes, they are invaluable and help to accelerate breeding progress considerably. Also for quantitative traits of interest in plant breeding molecular markers (quantitative trait loci) have been found in some cases. Tanksley and McCouch (1997) stated: "New findings from genome research indicate that there is tremendous genetic potential locked up in seed banks that can be released only by shifting the paradigm from searching for phenotypes to searching for superior genes with the aid of molecular linkage maps". The tendency to use molecular marker techniques to assess diversity has already marginalized other methods used for this purpose. Nevertheless, markers useful to characterize the plant genetic diversity and in particular PGR are not only molecular ones. It is important to identify as many markers as possible of different nature, which support analysing and quantification of diversity and genetic erosion. This will help to develop scientifically improved units for measurement of genetic diversity. The classical infraspecific taxa have been a first approach for creating an overview by establishing systems, and these system are open for addition of further information, which results from molecular research. A broad approach is required to analyse diversity and to support conservation, management and development of plant genetic resources. Better methods for quantification of biological diversity are essential in order to describe diversity and to get a clear picture of the ongoing gene-erosion.

Table 7
Advantages and disadvantages of some currently used methods of measuring genetic variation (FAO 1996a)

Method	Variation detected	Sample throughput	Loci analysed per assay	Reproducibility between assays	Type of character analysed	Inheritance of character analysed	Technology level required
Morphology	Low	High	Low no.	Medium	Phenotypic trait	Qualitative/ Quantitative	Low
Pedigree analysis	Medium	n.a.	n.a.	Good	Degree of co-ancestry	n.a.	Low
Isozymes	Medium	Medium	Low no.	Medium	Proteins	Co-dominant	Medium
RFLP (low copy)	Medium	Low	Low no. (specific)	Good	DNA	Co-dominant	High
RFLP (high copy)	High	Low	High no. (specific)	Good	DNA	Dominant	High
RAPD	High to medium	High	High no. (random)	Poor	DNA	Dominant	Medium
DNA sequencing	High	Low	Low no. (specific)	Good	DNA	Co-domin./ Dominant	High
Seq tag SSRs	High	High	Medium no. (specific)	Good	DNA	Co-dominant	High
AFLPs	Medium to high	High	High no. (random)	Medium	DNA	Dominant	High

Conclusions

From the very beginning the number of domesticated plant species comprised only a small proportion of species of the plant kingdom as a whole. Within each species domestication narrowed the genetic diversity to useful genotypes, which where adapted to local conditions. After industrialization the genetic diversity of domestic crops decreased dramatically. At the same time the need for a reserve of germplasm for developing new and improved varieties is recognized and is expected to increase in future. Meanwhile the diversity collected and maintained *ex situ* is limited and only a third of all accessions are characterized. There are gaps in the collections regarding minor crops and underutilized species. In particular landraces and wild relatives of crops from their centres of diversity and cultivation are underrepresented. The need for more attention to such PGR in conservation and utilization programmes is evident.

A clarification of the strategies for characterization of existing collections of PGR is necessary. At the same time the different strategies for the most effective conservation of the different categories of diversity have to be strengthened. To recognize their relative superiority for the different levels and categories of plant genetic resources will help to reasonable allocate the limited financial resources for their conservation. This will lead to complementation of work in the different areas. The instability of gene bank conservation due to their dependence to political and economical circumstances has to be taken into consideration. The reduced number of breeders and breeding companies shows nowadays comparably low interest to use gene bank material for recent breeding work since it is more time consuming to make long distance crosses than to include exotic and well defined genes into optimised crop genomes. As a result of this, the access to and the knowledge about biodiversity of cultivated plants is decreasing in many countries, developed like developing. Non Governmental Organisations (NGO's), agricultural institutions, museums, schools on the other hand are more and more interested in this material, even interpretable as living human heritage. The CBD approach of national sovereignty contradicts farmers' and consumers' rights on the plant material they are living from. The higher the public awareness about losses in biodiversity, the higher the demand for a broad spectrum of utilized biodiversity, genetic resources of animals and plants will be.

The conservation *ex situ* has relative superiority in preservation of diversity for specific groups and diversity conserved in gene banks, Botanical and Zoological Gardens has always been easily accessible to the world-wide community of researchers, breeders and all the other groups of users. Further research for morphological and molecular markers will be the best contribution to quantification of genetic diversity and gene-erosion. Taxonomy has to become more involved in these activities and has to pay more attention to the specific needs in the field of domesticated animals and cultivated plants. Further explorations to fill gaps in present holdings and human knowledge in this field of research are necessary.

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Relevance of Animal Genetic Resources and Differences to the Plant Sector

J. S. F. Barker[1]

Introduction

The most pressing problems facing the human species can be summarized in the fewest words as "population, food security and the environment". The world's population is forecast to rise from 6.0 to 8.7 billion by the year 2030. At the same time, the area of arable land per person is decreasing - because of loss of land due to human activity (currently 1 million hectares of arable land is lost per year), as well as the increasing number of people. Feeding more people from less land will require massive increases in agricultural production (amount of product) and productivity (output per unit input), while at the same time the sustainability of production systems must be improved.

Further, the increase in demand for animal products is projected to outstrip that for plant products (Delgado et al. 1999), so there will be even more pressure on the animal sector. Satisfying these demands will require effective and integrated action in many areas (e. g. political, sociological, economic and trade), quite apart from directly increasing animal production.

The present global animal genetic resources (AnGR) are what we have available to better meet the animal product needs of the current human population, and to meet these increasing demands. We need to utilize them as efficiently as possible, while any loss of these resources will restrict our options for livestock improvement, both now and in the future.

My focus here will be on current perceptions of animal genetic resources and inherent differences relative to the plant sector. First, however, some historical background should put the current situation in perspective, and I will conclude with some exploration of possible futures.

Historical background

Role of FAO

Concern about loss of animal genetic resources was I believe first publicly expressed at a meeting of the then existing Standing Advisory Committee on Agriculture, in Copenhagen, in 1946, which led to FAO (the Food and Agriculture Organization of the United Nations) being given the role of cataloguing, maintaining and using animal genetic resources. Initial efforts were devoted to publications describing types and breeds of cattle in various parts of the world, and to meetings on animal breeding under tropical and sub-tropical conditions, and related topics. Some attention was given to the conservation and use of animal genetic resources at these meetings, but it was not until 1966 that FAO convened the first study group on the evaluation, utilization and conservation of animal genetic resources (FAO, 1967). One must give credit to the members of that study group - they raised many of the issues that we are still discussing, and recommended actions that are still being recommended as urgent!

Concern about loss of AnGr - particularly in the developing world - was very clearly expressed at the FAO/UNEP Technical Consultation on Animal Genetic Resources Conservation and Management, which was held in Rome in 1980, and attended by Government delegates from 46 countries and observers from four international organizations (FAO 1981). This Consultation was a real milestone for AnGR, in recognizing that loss of AnGR was a global problem, in defining what needed to be done to facilitate development of a global program for their conservation, and in recommending to FAO that it establish such a global program. Methodologies for such a program were researched (Hodges 1990), but it was not until 1992 that FAO launched a new global program (Cunningham 1992), later designated the Global Strategy for the Management of Farm Animal Genetic Resources. In November 1995, the FAO Conference of member governments made two major decisions in relation to animal genetic resources: (i) it provided an intergovernmental mechanism for animal genetic resources by broadening FAO's long-established Commission on Plant Genetic Resources to a Commission on Genetic Resources for Food and Agriculture, and (ii) it supported as a priority activity for FAO the Global Strategy for the Management of Farm Animal Genetic Resources.

Other organizations

While FAO has concentrated activities on the developing world, NGOs and some governments in the developed world have, since the 1960s, emphasised the need for preservation of their rare breeds (Alderson 1990). Private organizations with this objective were founded in the UK, France and Holland, and in the USA in the 1970s. In 1991, these and organiza-

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tions in other countries were internationalized, in the formation of Rare Breeds International with founder membership in 30 countries. Scientific organizations, such as EAAP (Ollivier 1998a), have developed successful activities (breed surveys, data bank development), while others (e. g. SABRAO, WCGALP) have provided for extensive review and discussion. In countries such as Hungary, China and some South American countries, government agencies have had major responsibility for conservation programs, many of which have been very effective. Overall, progress has been made, but the primary effect of all these activities has been a broader awareness and recognition of what needs to be done.

Reasons for concern

The reasons why animal genetic resources should be conserved have been discussed extensively (e. g. Mason 1974; Simon 1984; NRC 1993), and can be summarized as economic, scientific, cultural and historical. This concern about animal genetic resources stemmed from two main factors - one in the developed world, one in the developing. In the former, where livestock improvement programs have been initiated over the last 50 years, and where market forces prevail, improved breeds that fit market requirements dominate, while breeds that are perceived as less suited to current needs are reduced in numbers and may be lost. The scale of this potential loss of variation is not trivial. For example, Maijala et al. (1984) found that about one-third of the 737 recognized livestock breeds in Europe were in danger of extinction. Today one breed, the Holstein-Friesian, probably accounts for 80% or more of all milk produced in the developed world.

In the developing, mainly tropical world, efforts to improve livestock performance, again over the last 50 years, often have relied on importation of these "improved" breeds from the developed, temperate world - breeds that were selected for performance in high input, low stress production systems. In most cases, the aim was to produce crossbred animals, by importing males only or semen to be used with indigenous breed females. The F1 crossbreds generally were superior in performance to the indigenous breeds (FAO 1987; Bondoc et al. 1989), and crossbreeding programs have been successfully developed in some cases. However, most such programs failed, because of inadequate infrastructure to maintain the indigenous breed or production of F1 animals, or failure to develop a breeding program beyond the F1, or eventual recognition that the F1 were not superior in life-cycle productivity. As a result, various indigenous breeds have lost their genetic integrity, and consequently are endangered.

Current perceptions

Some 40 domesticated mammalian and avian species are used to meet our demands for food, clothing, draft power and manure, and to satisfy various cultural, religious and recreational purposes. Within these species, there are in total about 5,000 breeds. The best available information indicates that about 30% of all livestock breeds are now at risk of extinction (FAO 1995). As about 50% of the total genetic variation within a domestic species is between breeds (Hammond and Leitch 1996), and because between breed variation is more accessible, the primary focus in the conservation of domestic animal diversity is on the conservation of breeds.

I do not believe that anyone would now argue that there is no need for any form of direct conservation, i.e. that market forces alone should prevail on a global scale. However, there is still, and there should be, further debate on the magnitude and nature of the effort. Although loss of breeds provided the initial stimulus, consideration of and action on AnGR today encompasses much more than saving rare or endangered breeds.

What I see as the current status and important issues for AnGR can be treated under three headings - management of diversity, use of adapted breeds, and setting priorities.

Management of diversity

We need to manage AnGR for the benefit of present and future generations. But the resources we have to work with fall into two classes - those that are perceived to have little or no current utility, and those that do have current utility or seem likely to have in the near future. The necessary actions then are preservation and genetic improvement respectively, both of which are critical elements in the global management of animal genetic resources (Notter et al. 1994). In addition, differences between the developing and developed worlds need to be recognized.

In the developed world, breeds that have little or no current utility presumably have been evaluated, at least to some degree in the context of today's markets, and have been found wanting. These breeds will be rare already or declining in numbers. Preservation is thus the issue - should the breed be preserved, and will it be preserved by existing organizations (see Notter 1999). On the other hand, breeds that do have current utility will have a secure place in the livestock industry, and many will be in planned genetic improvement programs. Management of these resources generally is not of wider concern.

The developing world, however, stands in stark contrast. The majority of breeds and the majority of endangered breeds are to be found there, but they are also the breeds about which we know the least (FAO 1995). Breeds that are not numerically small may be endangered because of ill-advised crossbreeding or replacement policies. Others may be numerically small, but not endangered because they are in a specific production environment or fill a particular market niche. Many could be utilized more efficiently, and genetic improvement programs or planned crossbreeding programs generally are lacking. The primary management requirement then is characterization and comparative evaluation. This characterization must be of total life-cycle performance in the relevant production system, including comparisons with other breeds. Where appropriate (depending on species and production system), crossbreds with other indigenous breeds or exotic breeds should be included in the evaluation. But until that information becomes available, subjective decisions on choice of breeds for preservation, or for development and better utilization will have to be made.

Use of adapted breeds

A major advance in recent years has been the wide recognition of the importance of adaptation in livestock production, and the need for better utilization of the indigenous breeds of the developing world. On a global scale, these breeds occur in an extremely diverse range of production systems and environments. Most of them have evolved over millenia under conditions of low input and high stress (due to climate, poor nutrition and parasite/pathogen exposure), with natural selection maximizing the fitness and adaptation of each to its particular environment, i. e. adaptive gene complexes will have evolved.

As noted earlier, many are endangered because they were (or are) perceived to have "poor" performance for production traits, yet where evidence is available, they have superior productivity when the level of input and overall life-cycle performance are taken into account. Many of these breeds are being used in production systems that are already sustainable, or which could be made sustainable with relatively small changes, but which are not likely to be changed towards medium or high input systems. Further, they occur in those parts of the world where the need for massive increases in production is crucial. In terms of the global management of AnGR, development and better utilization of these breeds is of the utmost importance.

The genetic basis for adaptation and fitness traits is primarily non-additive (dominance and epistasis), while that for production traits is more additive (Barker 2000). Thus highest immediate priority for the use of these adapted breeds should be given to the development of breeding programs, with selection for production traits based on appropriately defined breeding objectives (Amer et al. 1998). Later, when evaluation is completed, it may be found for a particular breed that it is best used either as a purebred, or in a particular structured crossbreeding program. In either case, of course, some genetic improvement of the indigenous breed will have been made, and the selection program should be continued.

Setting priorities

With some 5000 livestock breeds, a majority of them in the developing world, and about 30% currently at risk of extinction, not all can be, should be, or will be maintained. As the overall rationale for conservation is to maintain the maximum possible genetic diversity of each species, and as the primary unit of concern is the breed, the goal should be to maintain as many breeds as possible. However, rather than lose breeds effectively at random, as has largely been the case to now, the most effective conservation action must entail the setting of priorities, as already indicated, for the choice of breeds for (i) genetic improvement programs, (ii) for comparative evaluation, and (iii) for conservation of endangered breeds. These three situations need to be considered separately, as the criteria used, or their relative weighting, may differ substantially among them. Even given specific criteria to be used, application may not be possible, e. g. breeds not characterized for performance in traits of economic importance. Further, the weightings for criteria, and hence the breeds chosen, could vary depending on who is doing the choosing.

An FAO Expert Consultation on the management of global animal genetic resources (FAO 1992) recommended that a "breed should be evaluated for conservation according to whether it is: threatened, not being efficiently utilized, unique in important characteristics, likely to have potential impact in a large geographical area, especially important to a particular region, and whether adequate infrastructure is available to develop and conserve the breed." This Consultation also recommended that studies of genetic distances among breeds should be done (i) to avoid duplication of conservation efforts, and (ii) for populations not well identified genetically, to identify those most appropriate for conservation/development programs. As part of the development of the FAO Global Strategy, a Working Group in 1993, recognizing that adequate characterization data were not available for the majority of breeds, argued that " maintenance of maximum genetic diversity could be achieved by conserving that sub-set of all breeds in a species that show the most genetic differentiation among them, including those that contain unique alleles or unique combinations of alleles" (FAO 1998). Genetic distances between breeds, using microsatellites as the genetic markers, were recommended as the best available objective description of genetic differentiation. However, the Working Group emphasised that such distance measures should be used only as an initial guide, and that final decisions should also take into account any available information on traits of economic value, specific adaptive features, presence of unique genes or phenotypes, local or regional importance of a breed in production systems, and availability of resources and infrastructure in the region where a breed is located.

More recently, Ruane (1999a) and Barker (1999b) have discussed criteria to be used in selecting breeds for conservation. Ruane specifies degree of endangerment, adaptation to a specific environment, traits of economic importance, unique traits, cultural or historical value, genetic uniqueness and the species a breed belongs to, while Barker gives breed divergence, risk of breed extinction, measure of merit (adaptive, production and quality traits, traits unique to the breed, socio-cultural and ecological value) and within breed variation (allelic richness). The obvious differences are the species a breed belongs to in the former, and within breed variation in the latter, but there is also a difference in emphasis with regard to genetic uniqueness (= breed divergence). Ruane (1999b) in expressing concern about the reliability and relevance of genetic distance studies, argues that there is currently over-emphasis on such studies, and that the limited resources (personnel and financial) should be devoted to characterization. Questions about the reliability and relevance of genetic distance studies are recognized (Barker 1994, 1999a,b), but again given the limited resources available, and the time and effort required for characterization, genetic distances provide an initial guide to the choice of breeds that should be given highest priority for characterization.

Ruane (1999a) also discusses how the different criteria might be weighted. This is a major area for further work and development. However, in considering this question, I would re-emphasise the point made earlier - that the weightings of the criteria may be different when choosing priority breeds for genetic improvement, for comparative evaluation, or for conservation of endangered breeds. A decision making tool with capacity to vary the weightings, both for these different situations and to allow sensitivity analysis within each of them, would be invaluable (see also Woolliams and Meuwissen 1999).

Differences relative to the plant sector

Any unbiassed external observer would surely claim that action on the conservation and utilization of plant genetic resources is far more intense and advanced than for animal genetic resources. The differences between the two sectors have their basis in four areas: organizational, historical, biological and economic.

Organizational

I use this term to mean the structure and control of breeding operations and use of genetic resources. At least since early last century, most plant breeding has been done by publicly (or industry) funded national agricultural research (and after World War II, international) centres. Following the outstanding example of N. I. Vavilov and his colleagues in the 1920s and 1930s in collection, characterization and conservation, these centres also assumed, to varying degrees, responsibility for collection and maintenace of genetic resource collections - including landraces as well as improved varieties. More recently, private companies and international corporations have become increasingly active in plant breeding, but relying on existing collections.

In contrast, animal breeding has been primarily the province of individuals - breeders maintaining their own stock and selling to other breeders and to commercial producers. With the advent of artificial insemination and progeny testing in dairy cattle from the 1950s, and the application of quantitative genetic principles in breeding programs, particularly in poultry and pigs, breeding in these species (in the developed world) has become controlled predominantly by companies. To my knowledge, these companies have shown little interest in maintaining collections of breeds or stocks, apart from trying to obtain genetic material from their competitors.

Historical

This difference in organizational aspects has been a major factor in the history of development of genetic resources activity. Because genetic resource collections and use were an integral part of plant breeding, publicly funded scientists working in plant breeding influenced government policy in a number of countries, and through them, international activity.

Conferences convened by FAO in 1961 (Whyte and Julén 1963) and by FAO and the International Biological Programme in 1967 (Frankel and Bennett 1970) led FAO in 1972 to appoint a Panel of Experts on Plant Exploration and Introduction. The work of this Panel in turn led to the formation, in 1974, of the International Board for Plant Genetic Resources (IBPGR) as one of the centres of the CGIAR. Many of the CGIAR centres had major plant breeding programs, and these were thus supplemented by the IBPGR, an autonomous international scientific organization to promote the collection, evaluation and use of plant genetic resources. This Board, now the International Plant Genetic Resources Institute (IPGRI) states it is "devoted solely to the study and promotion of agricultural (sic - essentially read 'plant') biodiversity" (http://www.cgiar.org/ipgri).

Subsequent to the formation of IBPGR, FAO in 1983 established a Commission on Plant Genetic Resources - a permanent inter-governmental forum. As noted earlier, this was expanded in 1995 to a Commission on Genetic Resources for Food and Agriculture. As such, this Commission "develops and monitors the Global Strategy for the Management of Farm Animal Genetic Resources; and the Global System for Plant Genetic Resources" (http://www.fao.org/WAICENT/FAOINFO/AGRICULT/cgrfa). As names are generally carefully defined in international organizations, the "Global Strategy" versus "Global System" suggest to me that member governments, and thus FAO itself still give greater significance to plant genetic resources.

Biological

The most obvious biological difference is the number of species involved - some 7000 plant species (Hammer et al. 1999) used for food, forestry, medicines, forages, fibres, oils, tannins, waxes and spices, as compared with some 40 domestic farm animal species. For the majority of plant species, collection, characterization and conservation by seed storage (*ex situ* conservation in genebanks) are relatively simple and cost-effective, as compared with equivalent procedures for animals, frozen semen, oocytes and embryos, which are possible for only a few species.

Breeding techniques for plant species commonly involve crosses of commercial varieties or breeder's lines with landraces or wild relatives, in order to introgress from the latter desirable genes for pathogen resistance or agronomic characters. A single plant then may be the basis of an improved variety. Crossing among livestock breeds, and among highly selected commercial strains of poultry and pigs, also is practised, but with the objective of combining desirable quantitative traits. That is, there has been greater emphasis on traits controlled by single genes in plant breeding, and on polygenic traits in animal breeding.

Thus for plant genetic resources, it is claimed (Eriksson 1994) that the primary objective is to save all alleles with a frequency > 0.01, although Holden et al. (1993) argue for the importance of general adaptation, and the collection of representative samples of adapted gene-complexes from populations in distinct ecological or agro-ecological habitats. I am not aware of any claim that conservation of animal genetic resources should conserve all alleles, rather the emphasis is on breeds and genotypes, including adapted gene-complexes.

As compared with the some 5000 livestock breeds and a few wild relatives, the number of accessions in plant genetic resources collections is staggering - some 6.1 million (Hammer et al. 1999), with more than one million just for the three main crops wheat, maize and rice. These collections are primarily *ex situ*. For animal genetic resources, details of conservation methods are still being debated (Oldenbroek 1999), but *in situ* conservation, supplemented by cryo-conservation, is considered optimum. Given the long term emphasis on *ex situ* collections of plant genetic resources, there has been a recent significant shift in emphasis to *in situ* conservation. The Global Plan of Action adopted by representatives of 150 countries (FAO 1996) has *in situ* conservation and development of plant genetic resources as its highest priority activity, while IPGRI has recently initiated as a new project on farm *in situ* conservation of plant biodiversity.

Economic

While no figures can be quoted, I would draw attention to the vastly greater funds currently devoted to plant genetic resources as compared with animal genetic resources, and to the relative efforts devoted to each in the CGIAR system.

Finally on this topic, there is an interesting contrast. In the public concern and debate over biodiversity and threatened species, much more attention is given to animals, particularly mammals and birds, than to plants. Can we convince the public that domestic animals need their concern just as much?

Possible futures

The preferred mode of animal genetic resources conservation is currently *in situ*, with a backup of cryo-conservation where possible. To what extent will current and likely developments in biotechnology affect the perceptions of and attitudes towards animal genetic resources and the effectiveness of their conservation? One of the arguments for conservation that has been challenged (e. g. Franklin 1997) is that rare or endangered breeds and those of little or no current utility may carry alleles or genotypes that would be useful in meeting future unforeseen needs.

Even with an *in situ* conservation program, genetic diversity will certainly decrease due to inbreeding accumulation, or the live animal population even may be lost. Cryo-conservation then should be a high priority for such breeds, and for efficient regeneration of the breed at some future time, embryo freezing would be optimum. But given possibly hundreds of such conserved breeds, would they in fact be regenerated in the future and then characterized to determine if they carry genetic material useful for the production systems of that future time? Given today's knowledge and technology, almost certainly not.

While there are other potential biotechnological developments that may impinge on animal genetic resources, such as embryo production, embryo transfer, and semen and embryo sexing (see Ollivier 1998b, Cunningham 1999), the above scenario emphasises the two issues that I believe are most critical.

There is no question that embryo freezing would be the best technique for cryo-conservation, since complete genotypes are conserved, and breed regeneration is direct. For cattle, embryo freezing is well established, and it is reasonably successful for sheep, goats and rabbits. Among other species, some limited positive results have been obtained for pigs and horses, but I know of no successes for poultry, buffalo or camelids. To maximize the efficiency of animal genetic resources conservation, research on and development of successful long term embryo cryo-conservation must have the highest priority for all species.

The second question is what developments in biotechnology would increase the probability of future evaluation and possible use of those breeds that are currently rare, endangered, or of little current utility. The development of genome maps, using molecular markers, offers the most immediate potential. Such maps are well advanced for humans and mice, and the numbers of markers in farm animal maps are rapidly increasing. Sufficiently dense genetic maps will facilitate the search for (i) single genes controlling traits of economic importance, and (ii) quantitative trait loci (QTL) which contribute substantially to the quantitative genetic variation for most traits of economic importance. Once such single gene loci or QTL are identified, allelic effects in the conserved breeds could be studied. Early evidence (Notter et al. 1999) suggests that alleles of large favourable effects may be found in low producing, high fitness breeds. Undoubtedly further into the future, genomics (the sequencing and functional analysis of entire genomes) should allow not only the identification and analysis of genes, but also the epistatically interacting gene-complexes now considered most important for adaptive and fitness traits.

While the only SURE way to conserve agro-biodiversity is to use it sustainably, the new biotechnologies will surely expand our options for conservation and use of animal genetic resources in the development of sustainable animal production systems. However, enthusiasm for the potential benefits of biotechnology for the future management of animal genetic resources should be tempered by the real need for a detailed analysis of those benefits for each animal species, specifically accounting for the time frame of their likely impact, and differences in their application in the developed and developing worlds.

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Breeding Strategies for Sustainable Layer Breeding

Rudolf Preisinger[1]

The breeding of agricultural livestock is aimed at efficient food production and thus makes a major contribution towards feeding the world's population. Against the background of rapid population growth, with a current rate of increase of four people every second, or 345 600 per day, and a decline in the amount of arable land available for the production of animal feed and foodstuffs, the term "sustainability" encompasses a multitude of issues of increasing significance which need to be addressed both in the breeding and management of farm livestock.

In this paper I propose to examine efforts to increase the efficiency of feed conversion in commercial laying hen production with a view to reducing environmental pollution, the sustainability of breeding programmes and the preservation of the genetic diversity of the existing chicken populations.

Feed conversion

Measurement of the feed intake of individual breeding hens has been a routine component of breeding programmes for more than two decades. Feed efficiency, along with a continual increase in daily egg mass performance and the partial reduction of bodyweights, is employed as a direct selection criterion. From the multitude of different conversion coefficients, the feed input per day, per egg or per kg of egg mass is minimised in relation to the pricing of eggs and table hens. Enhancing feed conversion efficiency has the effect of improving nutrient utilisation, thus reducing manure output and the nutrients bound to it. Phase feeding, which is widely practised and designed to match the birds' changing requirements at each stage of development and production, mainly with regard to dietary nitrogen, phosphorus and calcium, makes an important contribution towards reducing environmental pollution and hence securing the sustainability of the entire ecocycle.

As Figures 1 and 2 show, marked improvements in feed conversion have been achieved both in white and brown lines. This process is continuing at a linear rate. According to German performance testing data with uniform management and feeding conditions, there are as yet no indications that this trend is levelling out.

The world demand for eggs is about 700 billion pieces or 42 million tonnes of egg mass per annum.

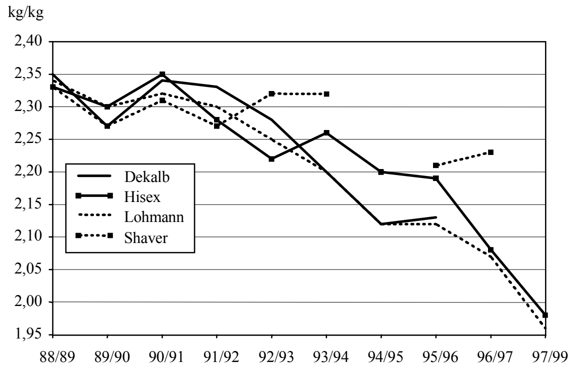

Fig. 1
Trends in feed conversion of white-egg layers based on German random sample tests (1988/89 - 1997/99)

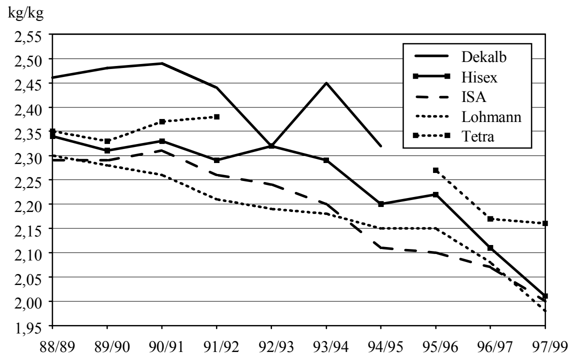

Fig. 2
Trends in feed conversion of brown-egg layers based on German random sample tests (1988/89 - 1997/99)

An improvement in feed conversion from 2.4 kg feed per kg of egg mass to 2.2 kg reduces the feed requirement by 8.4 million tonnes of cereal. Based on an average yield of four to five tonnes per hectare, this would save about 2 million ha of arable land for the same volume of egg production. The saving represents about 20 % of the entire agricultural land area of the Federal Republic of Germany.

In addition to the potential burden on the environment through manure spreading, ammonia emissions in the layer house also represent a not inconsiderable pollution potential. While manure belt ventilation has become standard practice in cage rearing systems and is gaining popularity in aviaries, this facility is very often lacking in floor rearing systems because of the considerably higher cost involved.

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Rapid drying of the manure is essential for reducing emissions because ammonia release declines with increasing dry matter content.

Table 1
Relationship between subjective scoring offaecal onsistency and its dry matter content

Score 1 – 9	Mean dry matter content
1	65 %
5	40 %
9	15 %

Source: Preisinger et al. (1994).

A highly promising breeding approach is the subjective assessment of faecal consistency as an aid for estimating the dry matter content of fresh manure. The figures in Table 1 show that a good correlation exists between subjective faecal consistency and faecal dry matter content. With heritabilities of .17 to .34 (Table 2) on recurrent scoring, the dry matter content can be increased in each generation, thus making a long-term contribution towards lowering emissions because faecal consistency is also positively correlated with feed conversion (Preisinger, 1995).

Table 2
Heritability for faecal consistency scoring

Scoring method	Line A		Line B	
	h^2	r_g	h^2	r_g
Single cage	.25	.87	.13	.91
Continuous manure belt	.26		.10	
Mean of both	.34		.17	

Source: Preisinger (1995).

Genetic variance

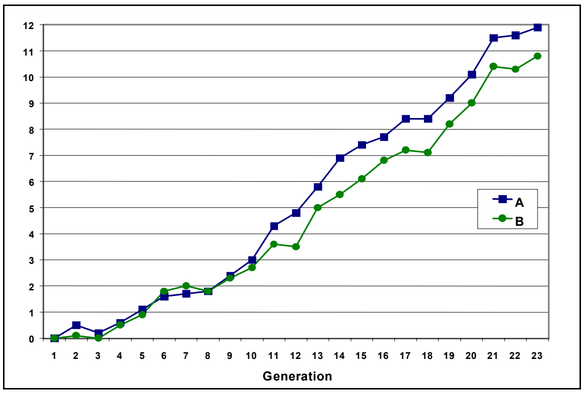
Individual breeders of laying hens work with a closed gene pool. Intensive selection over several generations poses the danger of reducing the genetic variance. As the latter is directly proportional to breeding progress, the rate of breeding progress is likely to decline if selection is focused on the same traits throughout the entire period. Although individual lines have been studied for more than 30 years as closed populations, the heritability for rate of lay has declined markedly only at peak lay. As peak lay is the point at which the biological maximum of one egg per 24-hour day is reached, this trend is not surprising. Both onset of lay and persistence show sufficient genetic variability for a medium- and long-term improvement (Table 3).

Table 3
Heritability for rate of lay at different stages of the laying period

Rate of lay in different weeks of age	Heritability 1977	1998
21 – 28	.58	.28
29 – 36	.23	.11
37 – 44	.21	.23
45 – 52	.24	.25
53 – 60	.25	.25
61 - 68	.25	.26

1977: Flock
1998: Savas

The increase in the rate of inbreeding in closed populations is often used as a critical measure of the sustainability of a breeding programme. In addition to the inbreeding coefficient, which describes the probability that genes are identical by descent, inbreeding depression is of major significance.



Source: Ameli et al., 1991

Fig. 3
Cumulative inbreeding over 23 generations for two lines of White Leghorns

Recent analyses have shown that the inbreeding coefficient derived from the effective population size rises at a much faster pace than that actually resulting from the degree of relationship (Savas et al., 1999; Preisinger and Savas, 2000). As sib matings are avoided in each generation in the practical implementation of breeding programmes, inbreeding is reduced to a minimum. Moreover, a sire is only mated with hens that are unrelated to each other. Over a 25-year period the average inbreeding coefficient for all individuals of a population only rose by 0.7 % per annum (Ameli et al., 1991). **Figure 3** shows that the increase was linear over the entire period, thus permitting a reliable prognosis to be made for subsequent generations. Similar values have emerged for laying hens from brown lines (**Table 4**, Savas et al., 1999).

With a maximum inbreeding coefficient of 12.3 and 15.8 % respectively in the population, the extreme values are also at a very low level. The cumulative maximum over 10 generations is comparable to a simple half-sib mating (inbreeding coefficient of 12.5 %).

Table 4
Average inbreeding coefficient after ten generations

Lines	**Inbreeding coefficient, %** $\bar{X}$	**min.**	**max.**
A	4.8	1.1	15.8
D	3.9	0.8	12.3

Table 5 shows that more than 50 % of the individuals in both lines have an inbreeding coefficient of less than 4.5 %. As line D contains more individuals than line A, the overall level is much lower.

Table 5
Distribution of individual inbreeding coefficients in lines A and D

Classes for inbreeding coefficients	**Line A**		**Line D**	
%	**Number**	**%**	**Number**	**%**
< 3.0	629	24.4	2081	36.5
3.0 - 4.4	700	27.2	1925	33.8
4.5 - 6.0	633	24.6	963	16.9
> 6.0	616	23.9	728	12.8

Estimations of inbreeding depressions in the literature are often based on the regression of the performance trait resulting from an increase in inbreeding by 10 %. The figures in Table 6 (Savas et al., 1999; Sewalem et al., 1999) show that the regression of the trait was not significant in the vast majority of cases.

Table 6
Inbreeding depression per 10 % increase in inbreeding coefficient

	Line[1)]		**Line**[2)]		
Trait	**A**	**B**	**Egg number**	**Egg weight**	**Egg mass**
EN 20 – 24	- 0.88	-1.07 **	- 0.86 *	- 1.08 *	- 0.83 *
EN 25 – 32	- 0.59 **	- 0.39			
EN 33 – 44	- 0.17	- 0.15	- 1.75	- 3.84 **	- 0.31
EN 45 – 60	- 1.99 *	0.74			
EN 20 – 60	- 3.65 **	- 0.88	- 2.75 *	- 1.67 *	- 1.86 *
Egg weight	- 0.47	0.28	- 0.61 *	- 0.51	0.18
Egg mass	- 3.63 **	3.90	- 0.72	- 0.94	0.00
Feed intake	- 0.54	1.70			

1) Savas et al. (1999).
2) Sewalem et al. (1999), selected by egg number, egg weight, egg mass .

* (P<0.05)
** (P<0.01)
EN = egg number

The absolute amounts for a 10 % increase in the rate of inbreeding are below the annual level of the breeding progress. As more than 15 generations are needed to increase the mean inbreeding coefficient by 10 %, the inbreeding depression remains at an insignificant level for the existing population structure and mating system. If we compare these values with zoo animals or pet breeders (Sölkner, 2000), the effects calculated for laying hens are marginal.

Allele frequencies

The allele frequency for polymorphic microsatellites can be adopted as a further measure of the homozygosity of a population. The mean allele frequencies for four lines of a breeding programme with brown-egg layers are presented in Table 7. In the case of all four commercial lines the degree of homozygosity is still very low, with a maximum proportion of only 14 % fixed alleles, which must not be equated with genes.

Table 7
Comparison of allele frequencies for microsatellites in pure lines for a breeding programme and that of an experimental line

Line	Number of markers	Proportion of fixed alleles	Number of alleles/marker
A	89	4	3.06
B	92	10	2.59
C	87	14	2.60
D	97	14	2.32
Exp.	103	80	1.20

Based on a set of about 100 microsatellites several lines were analysed from a representative sample (equal number of descendants of all current paternal families).

The experimental line was used in the 1960s for specific inbreeding experiments. In order to identify genetic defects with a view to selecting against them, sib matings were performed over several generations. For more than 25 years now sib matings have been avoided in this line, too. Both the number of fixed alleles and the small number of alleles per marker highlight the difference from commercial lines, where a low rate of increase in inbreeding was a deliberate strategy. Despite the large proportion of fixed alleles, this line exhibits sufficient genetic variance for breeding progress to be attained within the line.

In addition to assessing the similarity between individuals within a line, comparisons between breeds on a molecular genetic level are of major significance for estimating genetic diversity. As the number of commercial breeders of laying hens declines, the issue of genetic impoverishment is increasingly becoming the focus of critical debate. The decision on whether a breed is worth preserving cannot be based on phenotypic appearance alone. Rather, the genetic similarity or distance between different populations is a valid measure of the significance of the gene pool. This issue is currently being explored in a European research project coordinated by Weigend (Mariensee). Initial pilot experiments have shown that a very large molecular genetic similarity still exists between pure-bred poultry stocks and selected commercial lines. The extent of the actual differences cannot be anticipated ahead of the ongoing, extensive study. In addition to microsatellite-based comparisons, the phenotypic appearance and the history of the various breeds and lines are also considered (Weigend, 1999).

History of shifting selection criteria

Prior to the introduction of group cages in commercial layer management, laying hens were reared in floor pens and selected for performance criteria by the use of trap nests. With the advent of single cages for breeding hens it became possible to include individual feed intake data in the breeding programme as a direct selection criterion, along with laying performance and egg quality. This greatly improved the efficiency of egg production. As the demand for brown-shelled eggs increased, uniform shell colour was incorporated in the selection process in addition to shell stability. The number of saleable eggs in the desired weight classes per hen housed with minimal feed input defines the current breeding goal for laying hens. More recently, the growing debate about beak-trimming and the proposed changes in housing systems have shifted the selection focus to behaviours such as feather pecking, cannibalism and nesting behaviour. In order to cater for this altered requirement profile, new line combinations have been introduced in the market. This has extended the range of hen types on offer and hence the genetic diversity among laying hens.

The gradual shift in the selection focus and the extension of the range of available hen types are definite moves away from a restriction of genetic diversity. As markets become increasingly sophisticated and globalised, leading breeders are forced to offer more products. The high adaptability of laying hens to a variety of climatic and management conditions proves that sufficient genetic variability exists to satisfy these demands.

Growing population sizes and an increase in the number of lines being studied provide more assurance than ever of the sustainability of laying hen production. The different assessment approaches demonstrate that genetic variability is not at risk. The use of new biotechnological procedures facilitates a more quantitative estimation of genetic variability. As a result, negative effects, which can occur within closed populations, can be identified much earlier and specific countermeasures initiated more effectively.

Irrespective of requirements with regard to management and reproduction, the production of high quality protein with minimal use of resources remains the primary target parameter for securing the world's food supply. Even single- or dual-purpose hens kept under bio-guidelines must allow economic egg production so that farmers can generate an adequate income. If that is not the case, both breeding and farming of poultry will move abroad. The impact this would have on the sustainability of laying hen management and breeding is difficult to assess.

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Animal Genetic Resources in High Input Systems Meat Production in Pigs

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1ntroduction

Meat production in pigs in the developed countries is characterised by relatively small breeding nuclei serving a multiplication level which in term provides sows and boars to the producer's level for the production of fattening pigs. On the breeding level various systems exist in the different countries. They range from internationally operating breeding companies to traditional herdbook associations. In almost all countries, there is strong competition between different companies on the pig sector. However, the majority of the successful systems are organized in a pyramidal structure which is characterized by a relatively small (100 - 400 sows) nucleus undergoing intense selection. In this setting the loss of genetic variability is previsible. The question is whether the loss of genetic variability in these high-input systems is relevant from a global perspective. This paper will give some different perspectives on genetic variability and will try to evaluate the role of high performance breeds in the developed countries as a future genetic resource.

Perspectives

The topic of this paper is *not* the conservation of rare pig breeds. For this purpose there are plenty of activities in different countries in order to preserve those breeds. However, even in those cases the question "what to preserve" arises and there is still a considerable lack of objective criteria (Ollivier, 1998). This paper deals with relatively large, economically important breeds that are the basis of pig production in the developed countries. These breeds or lines are not at the risk of extinction. The questions relevant to these breeds are:

– In what respect are those breeds relevant for the global biodiversity of pigs?
– Is there a need for preservation of the quantitative genetic variation of these breeds/lines within the frame of high input pig production?

The two questions already illustrate that the subject can be seen from many different perspectives. These can be described as the global perspective, developed countries' vs. developing countries' perspective, national perspective, enterprise view and the view of a breeding line within a company.

From a global perspective the variability between breeds dominates the variability within breeds. Consequently, the genetic variability between all available lines in the high input meat production systems of the northern hemisphere appears to be very small. As a consequence there is no sense in preserving for example several subpopulations of Landrace pigs or Large White pigs. Maybe that from a global perspective it would even be sufficient to preserve a pool of genes from white sow lines?

From a national perspective, there are usually some "rare" breeds which are supported by public funding. In many cases there is no evaluation of the usefulness of these resources in an international or global context and even if there was some evaluation, the national budgeting rules usually do not allow to support projects in other countries.

From the breeding companies' point of view genetic variability is good when it occurs within and between its own lines. Genetic variability is bad when a competitor has a higher genetic variability or when it occurs in the marketed products. For a breeding company in high input systems 99% of the genetic variability available in the world is not of interest, because it cannot improve the performance of the own products or because it would be too expensive to make use of this variability.

(Why) do we need genetic resources?

Many reasons are claimed why we need genetic resources (FAO, 1998). These include the conservation of useful genes or gene combinations, to take advantage of heterosis, to overcome selection plateaus, cultural reasons and research activities. None of these apply to meat production with pigs in high input systems under the present conditions. Consequently, the remaining reasons for conservation of genetic material in high input systems could be:

– to avoid a significant loss of additive genetic variation and
– to prepare for changes in economical, political or social conditions.

Maintenance of genetic variation

There are no general formulae how genetic variance changes in the process of selection. Hill (1998) gives an approximation for a population without selection, constant population size, and purely additive gene action:

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$$V_{A(t)} = V_{A(0)} \exp\left(\frac{-t}{2N_e}\right) + 2N_eV_M\left(1-\exp\left(\frac{-t}{2N_e}\right)\right)$$

where $V_{A(t)}$ is the additive genetic variance in generation t, $V_{A(0)}$ is the additive genetic variance in some initial generation 0, N_e is the effective population size, and V_M is the additive genetic variance gained by mutation.

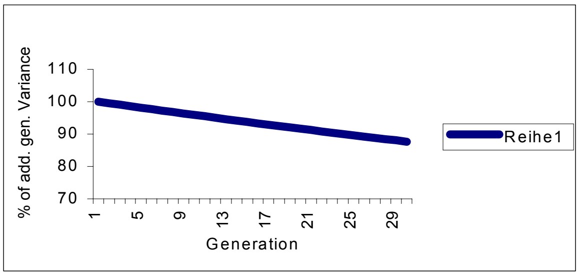

Fig. 1
Decrease of additive genetic variance in a population with N_e=75, h^2=0.33 and V_M=0.00066

Fig. 1 shows that when this function is assumed, the additive genetic variance decreases only very slowly. Of course formula (1) does not consider the effects of selection, variation in population size and the prevalence of genes with large effect. However, Hill (1998) concludes from numerous selection experiments that "substantial progress can be maintained for very many generations, even with populations of effective size well under 100".

In real world pig populations there is even less concern about the loss of genetic variation, because selection is for several, partly antagonistic traits, there is no strict truncation selection and breeders are trying to avoid inbreeding. Thus, inbreeding coefficients in commercial lines are far below the expectations calculated from the effective population sizes. For example, in the Bavarian herdbook association the average inbreeding level for the Pietrain breed is 1.06% and for German Landrace it is 1.15%. Even in breeding companies with moderate effective population sizes, the average inbreeding coefficient ranges from 1 to 2.5% after 25 years of operation (Henne, pers. comm.).

Prepare for changing conditions

The political and economical conditions for pig production are subject to change. Thus, the major reason for the conservation of genetic resources in European pig production is to provide an insurance against possibly changing conditions. With the previsible use of marker assisted selection in pigs there will be a new argument for the conservation of genetic material: to provide an insurance against selection errors.

Two major sources for changing conditions for meat production can already be identified:

1. environmental changes. This includes potential shortages of grain or soy beans due to the general growth of the world's population as well as climatic changes caused e.g. by the greenhouse effect.
2. social changes. These effects are much more likely to occur in the near future driven by the animal rights movement or changes of nutritional habits.

Changes of the first group are not relevant for Western pig breeding companies. Hardly any breeding company would survive climatic changes that would lead to an extreme change of environmental conditions. Most likely, this would result in a substitution of pig production by sheep or goat production. Furthermore, this situation could not be resolved by using conserved genetic material from European pig breeds. In that situation one would go back to breeds that have been kept under extensive conditions.

Social and/or political changes are much more likely to occur. The ban of growth promotors is one example, others can be found in preferences for meat from outdoor pigs, preference for meat with high intramuscular fat content etc. As can be seen from the examples, social changes will cause only slight differences in selection goals as compared to the environmental changes. Probably most of the present breeds used in high input systems will still have enough genetic variability in order to respond to such changes of selection goals. However, if there is insufficient genetic variability, one will need genetic resources that are similar to European breeds in their performance level.

The breeding companies' perspective

The point of view of the breeding company has to be purely economic. Smith (1985) calculated that for a breeding company it is much less attractive to develop lines with different characteristics than on the national level. He also showed that for time horizons between 10 and 20 years 1 to 4 different lines are sufficient. This corresponds well to the number of lines used in commercial pig breeding programmes. Only if the time horizon is 50 years or more, a larger number of lines is recommended. Hardly any pig breeding company has time horizons exceeding 10 to 20 years of operation.

A breeding company can only conserve genes from its own strains. If it does so, it will predominantly decide to use cryogenic conservation of genetic material instead of living animals. From a global perspective this has all the disadvantages of cryogenic resources like no adaptation to current conditions, no genetic progress etc.. In addition it is not clear how long a genetic resource is maintained and whether it could be saved in case of extinction of the enterprise.

Economically it is not easy to decide whether maintaining genetic resources is a profitable measure. Table 1 gives the four different cases. In analogy to statistics, one could call the situation in the upper left quadrant the "power" of genetic resources. Unfortunately, there is no example that under the conditions of high input systems anyone ever needed genetic resources from his own enterprise. Consequently the power of the system is low. The situation in the upper right quadrant is analogous to a type-I error in statistics. One conserves genetic material that is not needed.

Table 1
Decision matrix for conservation of genetic resources from an enterprise's point of view

	Real world situation	
	Resource needed	**Resource not needed**
Conservation	Very favourable economic situation that increases competitivity.	Annual cost reduces profit and genetic progress. In the long run this may reduce competivity.
No conservation	Enterprise is no longer viable and will vanish from the market immediately.	Economically optimal situation. No cost, all financial resources can be used for maximum genetic progress.

The most critical situation is in the lower left quadrant (type-II error). Although the situation is not very likely under the present conditions, its consequences are so dramatic that it should be considered as the driving force for decisions on conservation of genetic resources in enterprises.

However, it is more likely that changes of economical and/or environmental conditions will only be of moderate size. This means that the profile of the optimal breed (cross) will also change only moderately. Consequently breeding companies will require resources that are genetically not too far from the current lines.

Need for a public conservation policy in high input systems?

From a national or even international perspective, genetic resources maintained by the breeding companies themselves are not a good alternative. First of all the resources are not safe in the sense of a long term guarantee for conservation. In addition some enterprises might decide not to maintain any resources at all, while others will perhaps maintain strains with insufficient effective population sizes. Krieter (1996) claimed the need for cooperation between breeding companies in order to reduce the cost for maintaining genetic resources. Several German herdbook organisations decided in 1997 to cooperate in maintaining the genetic variability in German Landrace pigs. However, until today no actions have been taken in order to preserve genetic material.

This clearly shows that there is a need for the participation of the public sector in the conservation of genetic resources. This participation should not only focus on the few "rare" breeds in each country but should include systematic conservation of genetic material from productive populations. As Hill (1998) puts it: "Populations maintained just to increase the total variation present among and within populations remain unlikely to be able to contribute usefully". However, the question "what to preserve" is even more difficult to answer than in the case of rare breeds. At present there are no scientific concepts for the management of a gene-pool for a sample of breeds that are not endangered. Possible aims are

– preservation of genetic variability,
– preservation of "blood-lines" or ,
– preservation of certain alleles.

Preserving the genetic variability *within* lines is not a public task, but is in the interest of the breeding companies. This conservation can be done by keeping frozen samples of the semen of boars that have been used in the past. For the conservation of genetic variability on a national level this is not an efficient way. New methods will have to be developed in order to do this efficiently. A successful (inter-)national conservation program must address the following topics:

– How does the conservation programme obtain information on which animals' genetic material should be preserved?
– How can the access of the conservation programme to sperm of these animals be guaranteed?
– What are suitable criteria for the characterisation of the conserved genetic material?
– Under which conditions is it possible to make use of the conserved genetic material?
– What should be the financial contribution of the breeding companies or herdbook organisations?

Especially the question on when to give access to genetic resources to interested parties is a critical point. It must be guaranteed that public genetic resources will not be abused to obtain genetic material from competitors.

Practical breeders are frequently talking about the preservation of "blood-lines". However, what they really mean is the improvement of certain families that are relatively rare in the population because they are inferior in the traits of the selection index but superior in one or more secondary traits. Strictly speaking this is not a problem of maintaining genetic resources but of upgrading certain families with deficits in important traits.

Finally, every conservation programme should keep copies of alleles that are going to be removed by the selection process if they can be detected by means of DNA assays. Examples are the MHS-gene (Fujii et al., 1991) or the RN-gene (Milan et al., 2000). In theory it would be sufficient to keep a single copy of the allele in question, because in case of emergency its introgression could be monitored on the DNA level. However, the allele's effect might depend on the genetic background or epistatic effects so that several copies should be conserved.

Summary

The genetic variability represented in the high performance lines of western countries is small as compared to the worldwide variability in pigs. This implies a limited public interest in the conservation of genetic resources in high performance populations from a global perspective. Consequently public funding should support globally operating programmes for the conservation of genetic resources instead of spending money for the maintenance of national breeds that are genetically not very distinct from the productive breeds.

The creation of genetic resources within the framework of high performance breeds is in the interest of breeding companies and herdbook organisations. In order to be efficient, the management of genetic resources should be organised on an international level and financed by the participating organisations. However, there are many open questions remaining.

This twofold strategy can be considered a safeguard against both the dramatic changes that might arise from global climatic changes as well as smaller changes in economic conditions caused by social changes.

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Genetic Resources for Current and Future Development of Holstein-Friesian Dairy Cattle

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Abstract

The Holstein-Friesian dairy cow is undergoing rapid genetic change. Annual increase in genetic merit for protein yield is over 1% of the phenotypic mean in the United States. Those gains are achieved through intensive selection both within and across countries. Although selection goals vary somewhat among countries, the same top bulls have been used globally. The international popularity of a few bulls has led to increases in inbreeding and a rather small effective population size. This trend has been accelerated by recent improvements in international comparisons of bulls. Strategies to preserve genetic diversity and slow the rate of increase in inbreeding are being developed. Analysis of DNA provides an opportunity for more accurate selection decisions and parentage verification. New genes for the Holstein-Friesian population may be obtained through crossbreeding and, in some limited cases, through transgenics. However, mass selection will continue to be the most important method of change. In the future, genetic evaluation systems are expected to become more accurate through better modeling and inclusion of DNA marker information. Mating programs will be more widespread so that inbreeding can be minimized and dominance relationships used. Further consolidation of breeding companies may lead to a change in the structure of the genetic improvement program. Adoption of new reproductive technologies such as semen sexing, cloning, and improvements in oocyte recovery also may cause changes in the dairy cattle industry.

Introduction

The world's human population relies on dairy cows as sources of milk for fluid consumption and manufactured food products; meat; draft labor; and, in the near future, pharmaceuticals after the introduction of exotic genes. High input systems are characterized by high production per cow in a tightly controlled environment. Cows are valuable in the food chain because they can produce a high protein pr oduct, including many essential amino acids, from a high forage diet. Dairy products also are an important source of calcium.

A cow's performance is influenced by genetics and environment. For any particular level of performance to be expressed, the genetic ability and adequate environmental conditions both must exist. The degree to which a trait is genetically controlled (heritability) varies greatly among traits (Goddard and Wiggans, 1999). For example, coat color and pattern are determined almost completely by genetics (Becerril et al., 1994). Although most traits of economic importance have a large environmental component, the genetic ability still must exist for the animal to achieve the desired performance.

Dairy cattle are under continuous pressure to change. Producer goals might include increased efficiency of production, development of resistance to disease, and elimination of genetic defects. Additional reasons for change might include improvement in animal welfare, environmental concerns, response to a change in consumer preferences, improved quality of products, and generation of new products.

The goal of this report is to consider the source of the genes that enables such changes and the consequences of recent intensive selection for high yields. Related to those issues is the conservation of genetic diversity as a source of genes that may be required in the future.

Gene sources

The current generation of animals is the primary source of genes for the next generation and would be the sole source except for mutation, crossbreeding, and transgenics. The population can change even without the introduction of new genes by changing the frequency of existing genes; i.e., improvement can be accomplished by increasing the frequencies of desirable genes in the next generation by favoring the reproductive rate of animals with those genes.

Natural mutation is an ongoing source of renewed genetic variation. Although most mutations are harmful (Notter, 1999), mutation also is the raw material for natural selection. Experiments with artificial mutations that were induced through radiation have not proven to be effective in generating beneficial alleles.

Crossbreeding incorporates genes from other breeds. This approach is most beneficial if the two breeds are similar in their economic productivity. Crossbreeding reduces homozygosity, and this reduction provides relief from inbreeding depression and is the primary contributor to heterosis. If one breed is

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substantially inferior to the other for a desired trait, the first generation of progeny may still be inferior to the superior pure breed for that trait even with the benefit of hybrid vigor. Crossbreeding generally results in improved fitness and is most beneficial for traits with low heritability (Falconer and MacKay, 1996). However, crossbreeding requires maintenance of purebred lines or careful use of mating systems to maintain hybrid vigor.

Transgenics is the transfer of genes from one species to another (Hospital et al., 1992). Although transgenics have been commercially successful in plants, such as insertion of pesticide resistance genes ("roundup-ready" corn and soybeans) and BT (Bacillus thuringiensis) corn, similar successes with animals have been less visible and less frequent. Transgenic technology in animals originated with the random process of DNA injection into the pronucleus of an embryo (Gordon et al., 1980) and has progressed to targeted modification using homologous recombination (Piedrahita, 2000). Pinpoint insertion of genes may enable the addition of specific characteristics, such as disease resistance. Some work on the use of transgenics for disease resistance has been in support of human health. Organs for transplantation across species might be grown if proteins that cause organ rejection were eliminated (Piedrahita, 2000). Another active area of research is production of pharmaceuticals in milk, with the producing animals designated as "bioreactors." An example of such a bioreactor success is the insertion of the gene responsible for production of alpha-1-antitrypsin, a blood protein associated with lung function, into sheep milk (Carver et al., 1993). Using this process, the cow may become a low cost way to produce some specialized proteins.

DNA analysis

The rapid advances in DNA analysis have many potential applications to milk production in intensive systems, and analysis costs should decline as improvements in equipment continue. Several international efforts (Van Tassell and Ashwell , 2000; Gomez-Raya et al., 1998; Spelman et al., 1996; Velmala et al., 1995; Zhang et al., 1998) have been conducted to locate chromosomal regions that are associated with differences in productivity. Because of the structure of the dairy population, a granddaughter design has been used (Weller et al., 1990). This design requires genotyping of families of bulls, the sire with many sons, and his sons. Granddaughters contribute to the analysis through genetic evaluations of their sires for yield traits. For a sire that is heterozygous for a marker (a genetic polymorphism), information from his sons with known alleles from the sire can be analyzed to determine whether or not a marker and a trait are associated (Weller et al., 1990).

Information from DNA analyses can be used to make better breeding decisions through marker-assisted selection (MAS). Production information is necessary first to establish the connection between a marker and a quantitative trait locus (QTL). A QTL may be a particular gene, promoter, or other regulatory element that affects the expression of a quantitative trait, such as milk yield. Marker information can be combined with production information to improve the accuracy of genetic evaluations. Because of the abundance of genetic markers, marker information should be combined and applied using an index.

The possibility of recombination between a marker and the QTL requires that many markers be available in the region of the QTL of interest and that sophisticated estimation tools be used. If DNA analyses are performed within family, then estimates of allelic differences must be re-estimated with each generation. If QTL allele estimates are obtained across families, then updating of allelic differences is less critical. In either case, new markers may be needed because of the loss of informativeness of markers over generations as the result of identical genotypes in parents and progeny, which is a function of population frequency, and homozygosity in animals of interest.

As the genetic code becomes better known, particular QTL's may be identified. Then the problems of recombination and the limitation to analysis within family would be reduced. An immediate application of markers is to select full siblings in a family for which allelic effects have been estimated. However, even in this situation, an index must be used to combine marker information if more than one marker is considered.

A different approach to detect QTL's is through candidate genes (Gengler and Druet, 2000), which are known genes that are suspected of being QTL's. The success of this approach is dependent on previous knowledge of the genes, their DNA sequences, and their relationship with physiological functions. Additive effects for different alleles for candidate genes are compared with each other to establish allele substitution effects on a population or family level.

Another important application of DNA analysis is for verification of identification and determination of parentage. Such determination is extremely accurate with sufficient markers (Marshall et al., 1998). Identification errors reduce observed heritability and decrease the accuracy of detecting animals with outstanding genetic merit. Technology that allows more accurate identification of animals may result in large improvements in the rate of genetic improvement. In a simulation, Israel and Weller (2000) found that a 10% error rate depressed annual genetic gain by 4.3%. The Livestock Improvement Cooperation in New Zealand (C. Deadman, 2000, personal communication to R. Powell, USDA) found an error rate of approximately 13% from a field study of identification errors. If a low-cost system can be developed to extract, to label, and to collect DNA samples, large-scale parentage validation should be possible. Parentage validation may be more economically advantageous in areas where a single organization provides all genetic services because the benefits of increased accuracy can be dispersed throughout the system.

Inbreeding and effective population size

Intensive selection can lead to an increase in inbreeding and an associated decrease in effective population size (Ne) while increasing genetic merit for desired traits. Hansen (2000) reported that selection has become progressively more intensive. In the United States, the annual increase in Holstein genetic merit for protein yield is over 1% of mean. However, inbreeding in U.S. Holsteins has been increasing at .181% annually in recent years. At this rate, inbreeding would increase from 4% to 5% in 5.5 years.

During 1995, approximately 1 million Holstein cows that provided information for genetic evaluations were born in the United States, and 6047 Holstein bulls entered artificial-insemination service from 1995 through 1998. The mean ages of the parents of those animals were 7.2 years for sires of cows, 4.1 years for dams of cows, 7.1 yr for sires of bulls, and 3.9 years for dams of bulls. The mean for those parent ages of 5.6 yr is the current generation interval for U.S. Holsteins.

Effective population size (N_e) is the number of animals that, when mated randomly, would produce the sampling variance or rate of inbreeding of the subject population. Falconer and MacKay (1996) defined the relationship between the rate of increase in inbreeding per generation (DF) and N_e as DF = $1/(2N_e)$, which is equivalent to N_e = .5DF or .5/(.0181 H 5.6) = 49.4 animals for U.S. Holsteins. The actual N_e may be even fewer animals because of the high ratio of females to males and the nonrandom distribution of family size for dairy cattle populations (Falconer and MacKay, 1996). A similar estimate of 46 animals was found for N_e for French Holsteins by Maignel et al. (1996). Boichard et al. (1997) presented methods to estimate effective number of ancestors as an alternative expression of genetic variability. Meuwissen and Woolliams (1994) discussed the N_e required to maintain fitness.

The primary concern about a low N_e is the loss in ability to adapt to change. For example, susceptibility to an epidemic increases as the animals in a population become genetically more similar. If national populations are isolated from each other, then new genes are available from other countries. However, for dairy cattle, especially Holstein-Friesians, international trade in semen and embryos has been extensive over the last 20 yr.

An increase in inbreeding permits expression of deleterious recessive genes, which reduces production and fitness (inbreeding depression). Smith et al. (1998) reported the magnitude of inbreeding depression as 27 kg of milk, .9 kg of fat, and .8 kg of protein for each .1% increase in inbreeding. The effect of inbreeding on reproductive efficiency may be of greater importance.

The Interbull Centre (Uppsala, Sweden) has been active in facilitating the comparison of bulls across countries, which has led to the international use of popular bulls as sires of sons. Of 5543 Holstein bulls that were born during 1994 and evaluated by Interbull in May 2000, 45% were sired by the top 10 bulls worldwide for number of sons; 11% were sons of Ronnybrook Prelude. Of the 370 sires of sons, less than half (154) had only one son.

The problem of a small global N_e may not be as serious as the limited number of sires of sons suggests. Not all countries and breeders have identical breeding objectives. The genetic correlation between countries (r_g), which reflects those differences in breeding objectives, has a large effect on N_e. If r_g <.8, then local bulls often will be selected as sires of sons (Goddard, 1992), which greatly increases N_e. Local differences in breeding objectives and interaction of genotype with environment both are important in affecting N_e, even if their magnitude is small.

Holstein-Friesians have become the dominant breed in high input systems for dairy cattle, which is justified when Holstein-Frieisans are clearly superior based on economic considerations. In New Zealand, where the breeding worth index includes maintenance costs, differences between Holsteins and Jerseys are small on a farm profitability basis (Harris et al., 1996). Breeders should resist converting to Holstein-Friesian genetics because of fashionability. If other breeds are and remain competitive, use of their germplasm increases N_e. However, if Holstein-Friesians improve faster than other breeds for economically important traits, those other breeds will have little to contribute genetically and, therefore, will likely decline in number.

One approach to slow DF is to account better for inbreeding when making breeding selections. Optimum contribution selection (Sonesson and Meuwis-

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sen, 2000) is a procedure used to maximize genetic response while restricting coancestry among parents. Although this method is computationally challenging to accomplish, particularly if all possible matings are considered, inbreeding in the next generation can be reduced without sacrificing genetic gain. Alternatively, Meuwissen (1997 and 1998) and Meuwissen and Sonesson (1998) described mating plans and algorithms for maximizing genetic gain while limiting DF.

Another approach to managing inbreeding of dairy cattle is to select a group of bulls that are as unrelated to each other as possible to progeny test. The main determinant of future inbreeding is how closely sires are related to each other. An alternative is to predict the genetic composition of the future cow herd so that estimated inbreeding of future daughters can be considered during the selection of progeny-test bulls. A routine statistic generated by the U.S. genetic evaluation system is the expected inbreeding coefficient for future progeny of bulls, which is half of the mean relationship of a bull with a random sample of 600 cows that were born during the last 3 yr (VanRaden and Smith, 1999). The expected inbreeding coefficient is useful in identifying less related bulls.

Access to genetic diversity

With the worldwide trend toward fewer animals in high-producing food species, maintaining the genetic diversity of existing populations becomes increasingly important as those populations may contain the genetic material needed to resist a future calamity or to provide a characteristic that has been lost from commercial populations. Small populations that are not economically competitive are expensive to maintain. Some species can be maintained as exhibits, such as zoo populations, and should be managed so that their genetics are preserved. Semen storage is the most economical method of saving genetic material and should be continued both to provide a source of genes and to support research. Although semen is an extremely valuable genetic resource, it is not complete because it lacks maternal factors, such as mitochondrial DNA (Schutz et al., 1994). Long-term preservation of embryos and ova also is desirable and may become more practical as procedures are improved.

Breeding programs

The breeding program is the practical implementation of reproductive technologies and genetic information. Depending on the scope of the organization, the planning horizon may vary greatly in length. Scope also affects an organization's ability to undertake projects that may only be profitable at a population level.

The recent trend is for organizations that implement breeding programs to be combined into larger units. For artificial-insemination companies, this consolidation may result from mergers of domestic companies, purchase of foreign companies, development of marketing alliances, or development of joint sampling programs for young bulls. Another type of integration is a combination of industry functions, such as CR-Delta (Coöperatie Rundveeverbetering Delta, Arnhem; http://www.cr-delta.nl) in The Netherlands and CRI (Cooperative Resources International, Shawano, WI; http://www.crinet.com) in the United States, which include bull studs and dairy records processing centers.

The dairy cattle breeding industry was an early participant in the globalization that is such a common concept today. The European black-and-white population has been transformed through the use of semen imported North America and embryos over the last 25 yr. The trends toward international and multifunctional organizations will continue because of the intensification of dairying and the rapid flow of information about dairy techniques around the world. Changes in technology accelerate those trends by improving the availability and quality of genetic materials.

Multifunctional national organizations have the advantages of being able to set national policy and to exert greater control over various program aspects from animal identification through milk recording and young sire sampling. For example, LIC (Livestock Improvement Corporation Ltd., Hamilton; http://www.lic.co.nz/index.html) in New Zealand would be able to make DNA parentage verification economically feasible before other breeding companies because LIC can realize the general benefit of improved accuracy on all bull evaluations.

Calculation of genetic evaluations by organizations that are separate from AI businesses helps to avoid potential conflicts of interest and to maintain high credibility internationally. For other species such as swine and poultry, large companies operate separate breeding programs and deliver live animals, often crossbreds, rather than sperm or embryos. With this structure, those companies can retain ownership of their genetic materials across generations. The dairy industry could move in this direction if cloning becomes a popular way of delivering genetics. However, commercial female clones are not likely in the near future. Dekkers (1992) showed that inbreeding is the limiting factor for genetic improvement through cloning technology.

In addition to cloning, other reproductive technologies, including semen sexing and improvements in oocyte recovery, may lead to changes in the structure of breeding organizations. With current technology, sexed semen is more practical for use with *in vitro* fertilization because of the much smaller amount of semen required. Sexing of embryos also is promising for commercial application.

Sustainability

As dairy cattle are bred to be productive in today's high-input environments, they are less likely to be able to survive in harsh environments and to maintain efficient production. Some genetic differences have been found between the best cows in grazing and concentrate environments. Correlations are <.8 between Australian and New Zealand bull evaluations and those from the United States (International Bull Evaluation Service, 2000).

More accurate determination of each animal's economic contribution should be facilitated by collection of more reliable information on more traits, which may become possible because of the intensification of dairy production. This increased accuracy will allow better selection decisions and, therefore, more rapid increases in genetic improvement (Misztal and Lawlor, 1999). However, the dairy industry will need to adapt to realize the benefits of recent changes. Mating plans can consider inbreeding and charge each potential mating with the short-term and perhaps long-term costs of the inbreeding. A breeding program will fail if the resulting animals cannot reproduce or are susceptible to diseases.

Summary

Dairy cattle must change to meet changing requirements in product characteristics that are desired by consumers and to decrease the impact that animal husbandry has on the environment. Change also is essential to maintain the competitiveness of dairying as a food-producing enterprise. Because genes determine what is possible phenotypically, retention of genetic diversity is critical so that desired changes can be achieved.

More efficient selection of animals with desired genes can be accomplished by using information available from DNA analysis. Because intensive selection and existing (AI) and potential future reproductive technology (e.g., cloning) can reduce further genetic variation and increase inbreeding, introduction of genes from other breeds and species also are potential genetic resources for Holstein-Friesians. Germplasm from preservation efforts may be a rich source of diverse genetic material.

Predictions

Future changes in the genes of Holstein-Friesian populations will result primarily from the continuation of current breeding practices. Selection within the current population will be the primary tool for change. Breeding decisions will become more accurate through the use of information generated by better statistical models and the use of genetic marker information. Mating programs will become more important as the value of avoiding inbreeding becomes more clear. Crossbreeding programs or methods that consider dominance effects within breed may be implemented to obtain benefits from existing genes from contemporary populations. The dairy cow may become an important source of pharmaceuticals after introduction of genes from other species.

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Economic Valuation of Animal Genetic Resources with Special Reference to Subsaharan Africa

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Introduction

Valuation in the context of biodiversity is the process of determining the importance of consequences of economic activity that are not taken into account in market transactions (chapter 12 of Heywood and Watson, 1995). Valuation might in principle help with deciding the allocation of resources to conservation of Animal Genetic Resources (AnGR).

There are two aspects to this issue; one seeks to place a valuation on AnGR so their priority for conservation can be compared with other ventures. The other seeks to establish the relative importances of different breeds as candidates for conservation.

Current market signals worldwide are leading to loss of AnGR. Discussions on AnGR in Africa must bear in mind that introgression often comes not from the exotic (i.e. non-African) breeds such as the Holstein-Friesian that have so often been seen as a cause of loss of genetic variation. A local breed may receive genetic introgression from another breed of the region. Introgression from exotic breeds will however be important in pigs and poultry. Introgression can lead to breed replacement in that the local breed is 'graded up to' (acquires in an asymptotic manner the genotype of) the other breed; sometimes grading-up is incomplete and the result is a hybrid swarm resulting from matings among crossbred animals.

In many parts of west central Africa, the indigenous humpless shorthorned cattle (the west African Shorthorn breed group: WASH) are being replaced in their traditional range (the humid forest and certain parts of the savanna) through crossbreeding with zebu genotypes (Jabbar et al., 1997; Blench, 1999). Although the WASH can tolerate trypanosomosis and presumably, like the Ndama (Mattioli et al., 1995) other local diseases, developments in husbandry and environmental changes are permitting the trypanosusceptible zebu genotypes, which the market prefers (Jabbar et al., 1997, 1999), to colonise these areas. As the grading-up proceeds, the WASH breeds will lose their distinctiveness and their trypanotolerance is reduced stepwise (Achukwi et al., 1997). Market prices favour the graded-up genotype and the economic value of this breed replacement, to the farmer, can in principle be calculated directly. But loss of the purity of the WASH genotype would deprive future generations of the option of using it. Use might be in crossbreeding schemes that exploit additive and heterotic effects sustainably, or as a source of genes conferring specific adaptations which are much easier to retrieve from the pure genotype than from a hybrid swarm.

Two questions arise. How can the opportunity cost, imposed on future generations, of the loss of this AnGR be calculated? Can breeds be ranked for conservation priority on the basis of a valuation process?

Placing a value on a lost breed

If breed A is replaced by breed B, this is because the market value of breed A is less than that of breed B. In matters relating to biodiversity, as in environmental matters, there is often a gap between the market price of resources and the value of these resources to other individuals, society and to future generations. A valuation exercise establishes the financial extent of the corrective measures that are needed, if the interests of the whole of society are to be taken into account (chapter 12 of Heywood and Watson, 1995). Two methods of valuation are calculation of the opportunity cost of losing the AnGR, or the cost of a "shadow project" that would effectively restore the lost AnGR later.

Opportunity cost of loss of AnGR

1. As an export commodity or as a source of patentable genes

If a breed is lost, its home country loses the opportunity to export it as a genetic resource for use elsewhere. There has for example been a significant international trade in trypanotolerant cattle (Shaw and Hoste, 1987), but the prices paid for these animals for export have probably been the current market prices.

Domesticated animals and plants differ in the nature of the patent and intellectual property protection that countries are required to accept (Day et al., 1994). Plant patents mean that farmers are not necessarily allowed to sow seed harvested from patent-protected plants, but there is no restriction on breeding from patent-protected animals. The process of genetic engineering of animals, as of plants, is however patent-protected. Local breeds may carry genes that could be

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of economic value and patentable once defined and engineered, but once exported to a new country, the country of origin has no further rights in the genotype.

No information is available on whether African breeds are being investigated as sources of useful genes. The value of AnGR for this kind of exploitation is difficult to estimate. As part of the FAO Domestic Animal Diversity Information System, it is intended to characterise production environments of individual breeds to facilitate this kind of utilisation. Unless breeds can be characterised in such a way as to demonstrate their commercial potential the price they command will continue to be only modest. Perhaps international development funds could be directed towards characterisation work for this reason.

2. As a genetic resource for national agriculture

More importantly in economic terms, loss of a breed means the country loses a source of genes for introgression into other local breeds. As pointed out by Smith (1984) the financial benefits of even a small proportionate improvement in animal production arising from use of a genetic resource can be very large. A major part of the value of an AnGR may be as a source of such genes rather than as a specifically adapted genotype.

3. As a genetic resource for regional agriculture

A locally adapted breed may be the key factor in persistence of livestock husbandry in a challenging environment. An obvious example would be the Kuri cattle of Lake Chad (Tawah et al., 1997). These animals appear to be uniquely adapted to the area. During the 1990s the Lake almost dried out and newly-available grazing areas were being heavily exploited by herders who used zebu breeds. The Lake has become flooded again over the last three years (R.M. Blench, pers. comm.). If in the future this pattern is repeated livestock farming in the area may prove to be very difficult if the Kuri has been crossbred out of existence while the Lake has been dry. In this case the opportunity cost of losing the Kuri could be calculated from the cost of the extra veterinary and husbandry inputs needed to maintain the same level of production in that area using a different genotype of cattle.

Shadow project approach

The cost of a project that would rectify the loss of a breed, can be calculated in very approximate terms. Here are two approaches.

1. Valuation of a breed characteristic

Assume that introgression leads to a replacement of a national population of WASH, by a modified genotype which lacks trypanotolerance. How much would it cost to reinstate trypanotolerance in the population? Biological feasibility must be assumed. The cost and necessary duration of an introgression programme, which in this case would use some other trypanotolerant breed as a source of a small number of genes, can be calculated (van der Waaij et al., 1997). Genotyping of breeding stock throughout the programme is assumed and the economics of the operation are sensitive to female reproductive capacity and to the number of genes to be introgressed. Calculations on poultry by Hillel et al. (1993) show that a specific genetic modification originating in one heterozygote could yield lines homozygous for the trait in 3 or 4 years.

2. Valuation of a breed as an entity

If it is desired to restore a breed that has been lost through grading-up to another genotype, this could be done to a certain extent by grading-up using either stored germplasm or a closely related substitute breed from elsewhere. The practical problems would be considerable. While new genomic techniques would probably enable the optimum substitute breed to be identified, the restored breed would not have the same mitochondrial lineages or epistatic combinations of genes as the lost breed. For characteristics determined by major genes it might be a replica of the lost breed but for quantitative characteristics and for characters where background genotype is important it probably would not.

The costs might be estimated thus. In the case of muturu cattle (the Nigerian form of WASH) the national population in 1990 was about 115,000 (Blench, 1999). If these were graded-up to another type and it was then decided to restore the original breed, bulls of related WASH breeds could be imported from nearby countries and distributed. Perhaps around 2,000 bulls would be needed. The programme would take at least eight years (four generations of upgrading) to be completed. Basic costs can be estimated from the data of Shaw and Hoste (1987); the total cost of purchase, transport and installation of an imported bovine is about five times the village purchase price. Using the village purchase prices of young breeding WASH cattle in Ghana, given by Hall (1999) as between US $87 and $103, the cost of the importation would be between $870,000 and $1,030,000. Costs of running the programme over eight years would be the major cost and probably add $4 million to give a total of about $5 million. If cryoconserved muturu semen were available, or if imported WASH semen could be used, the costs would be reduced considerably but the necessary stores, infrastructure, training and husbandry systems do not exist.

However, the breed restoration programme concept is not applicable for breeds such as the Kuri cattle which have no obvious close relatives though an affinity with the Ndama is revealed by microsatellites (Meghen et al., 2000). In the absence of stored semen only a very imperfect restoration programme would be possible and the replacement cost of their genetic identity cannot be estimated.

Valuation of breeds for conservation

Valuing breeds according to their replacement cost would have disadvantages in that some breeds, i.e. the most distinctive, would have infinite value and economic appraisal would therefore be difficult or impossible. Numerically small breeds would have a low value in that they would be easier to restore than common breeds. The concept could be harmful in that it could foster the notion that extinct genotypes can be recreated, and thus devalue efforts to prevent extinction. Nevertheless the concept of including genetic distance measurements in economic assessments of priority for conservation requires further investigation.

At least in some circumstances a rare breed could be of greater potential value as an AnGR through being genetically close to a more numerous breed. Introgression of a conserved, useful gene may be more likely to succeed when the background genotypes are relatively similar between the rare and the numerous breeds. Following May (1990) breeds separated by high genetic distances should be at a premium if conservation is to be for maximising *existence values*, but there is also a case for low genetic distances being considered as possible criteria for conservation, because of high potential *use values*.

Extinction and depletion

A given amount of money will buy more today than it will be able to buy at some time in the future. The rate at which money loses value is the discount rate and a major issue in the economics of conservation is how to deal with the 'iron law of the discount rate' (p. 831 of Heywood and Watson, 1995). This states: 'Harvested species with a population growth rate less than the rate of discount will be optimally driven to extinction'. This means that for maximum financial benefit and with no negative feedback from the market a species with a low population growth rate should be exterminated as quickly as possible and the cash proceeds invested elsewhere. This law also applies to within-breed genetic variation (Hill, 2000). Under realistic discount rates, in economic terms it is best to select very intensively in the early stage of a breeding programme, which means that genetic variation would be rapidly depleted.

Policy background

The cost to society of loss of AnGR can only be calculated when the policy framework is defined, as this enables the social value of this biodiversity to be deduced. In the context of the developing world assessment of social equity may differ between governments and aid agencies. The UK Department for International Development (DFID), for example, emphasises 'elimination of poverty and encouragement of economic growth which benefits the poor' (HM Government of the UK, 1997). This is to be done 'through support for international sustainable development targets and policies which create sustainable livelihoods for poor people, promote human development and conserve the environment'. Other agencies may concentrate on other sectors of society. It can be argued that support for in situ conservation and development of AnGR will advance DFID's mission more than many other kinds of development activity. Locally adapted breeds will foster economic and environmental sustainability and promote human development through fostering indigenous knowledge, skills and resources.

Design of sustainable livestock projects is a separate subject but it must be touched upon here in order to illustrate the problems of deducing social value. AnGR development and conservation projects must be more carefully designed than has been the case in the past if such aims as those of DFID are to be met. For example projects relating to cattle will concern, directly, only a minority of the rural population while those on poultry will have a much broader direct relevance. In a study of 178 households in two villages in northern Ghana, 59 households owned cattle (of whom 11 kept pairs of bullocks), while 87 had sheep, 114 had goats, 113 guineafowl and 161 chickens (Brinkmann, 1991). Jabbar et al. (1997) surveyed 377 villages in Nigeria; of 41,321 households only 292 were settled cattle farmers.

Changes in livestock systems may jeopardise conservation of AnGR, yet may advance other social aims. In one region of Benin (Hall et al., 1995) the traditional cattle husbandry system depends on children to herd the animals. Now that children tend to go to school, the herds are entrusted to Fulani herders and the management system is now more extensified, with use of bulls of Fulani breeds and retention of animals in herds rather than marketing of surplus stock. There is a greater risk of environmental degradation under the Fulani herding system, but on the other hand the education of children may be facilitated. These examples illustrate how AnGR issues cannot be considered in isolation from considerations of social equity.

Breeding schemes in relation to livestock development and genetic conservation

Livestock owners in SSA exert varying degrees of control over the mating of their animals but there is little or no information on the extent of within-breed selection. In some breeds field evidence, and comparison of 'traditional' and 'commercial' husbandry systems, may suggest this selection operates. One example is traditionally farmed Mashona cattle in Zimbabwe (Hall, 1998). It is probably much more common for owners to introduce stud males from other breeds and practise grading-up; this is detectable by field livestock interview surveys, for example (Blench, 1999), and by genetic studies, for example (Achukwi et al., 1997) and could easily be quantified (Bradley et al., 1994; Nijman et al., 1999; Meghen et al., 2000). The appeal of crossbreeding is obvious (Cunningham and Syrstad, 1987). In Australia, it was found that by intense within-breed selection it was possible to increase the overall tick resistance of a herd of taurine cattle (Australian Illawarra Shorthorn) to the same level as that of zebu x taurine cattle, but it took ten years and the same result was achieved by one mating of the herd with a zebu sire (Utech and Wharton, 1982). As market requirements and technology are changing at a faster rate than genetic variation is being lost (Hill, 2000) it is difficult to make an economic case against such crossbreeding.

Animal breeding programmes are generally a good investment provided they are properly designed, capitalised and carried out (Hill, 1971; Mitchell et al., 1983; Simm, 1998). Initial investment (in testing facilities and other infrastructure and research) is heavy and returns in the early years are predicted to be erratic (Hill, 1971). In the context of SSA, nucleus breeding schemes are theoretically attractive (Hodges, 1992) and have been operating (Yapi-Gnaoré et al., 1997a,b), but practical problems may limit their applicability. Few people who have carried out field work on livestock in SSA would expect livestock owners, especially pastoralists (Blench, 1999) to part with their best female stock, a basic requirement of such schemes. (van Wyk et al., 1999) consider that because of the intensive husbandry practised in nucleus flocks and herds these schemes are an excellent way of spreading anthelmintic-resistant parasites ('stud worms') around the environment.

The key to the conservation and sustainable utilisation of AnGR in SSA and probably elsewhere is the development of practicable breeding schemes that conserve genetic variation and also permit within-breed improvement. If biodiversity is not utilised, it will cease to exist.

Before anything is done the benefit of animal breeding components of livestock development projects needs to be properly compared with the benefits of improvements in husbandry and veterinary care and within the context of appraisal of the social and economic role of livestock within the community.

Allocation of conservation expenditure

In the early 1990s FAO proposed a list of breeds deemed particularly worthy of development and conservation (Hodges, 1992). Criteria for inclusion in the list were not clear which is one reason why Hall and Bradley (1995) advocated the prioritisation of breeds for conservation on the basis of their genetic distinctiveness. This was an extension of the proposal of May (1990) that evolutionary history is the commodity that conservation should concentrate upon. At the same time, transparency in such a programme would seem to be desirable though discussion has been limited.

Much genetic distancing work has been done and this has led to a new appreciation of the scientific interest of domesticated animals. However, it can be argued that the resources could have been better applied to direct phenotypic characterisation and simple conservation measures (Ruane, in press). Certainly, no list ranking breeds in order of priority for conservation on the basis of genetic distancing alone has yet appeared and almost certainly any such priority list will have to use multiple criteria (Ruane, 1999).

Conclusions

The main cause of loss of AnGR in Africa is probably genetic introgression leading either to grading-up of one breed to another or to theemergence of a hybrid swarm. This loss has an opportunity cost which is probably most significant in terms of the farming of a specific region. In principle a replacement cost can be calculated for a breed that has been lost. The social cost of loss of AnGR depends on how costs and benefits relating to livestock farming are distributed within the community. Comparative economic valuation of breeds could add to the criteria available for determining the allocation of conservation expenditure.

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Experience from Asia

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The basis for much of the opinion expressed in this paper is the experience gained from managing the activities of the Japanese government funded Trust Fund project operated by FAO from late 1993 until August 1999, coupled to earlier duties within Asia when based in FAO Headquarters in Rome. The project 'Conservation and Use of Animal Genetic Resources in Asia and the Pacific' covered twelve countries of Asia, was the first regional project and, as such, was used in many ways as a pilot project for the development of the Global Strategy. Indeed, the project was first discussed during the Committee On Agriculture (COAG) meetings in FAO, Rome in 1992 just at the time when the Expert Consultation on the Management of Global Animal Genetic Resources met and developed a series of recommendations to FAO. The countries and their known populations both prior to and at the end of the project are shown in Table 1. In fact, the twelve countries have about one third of the known breeds of livestock in the world which presented the project with some problems given the stated objectives (Table 2) and the limited ($1.8 million total) project budget.

Table 1
Participating Countries and known breed numbers

Country	**Breeds in 1993[1)]**	**Breeds in 1998[1)]**
Bhutan	1	6
China	174	280 (596)
India	108	199
Indonesia	28	175
Laos	1	15
Malaysia	6	36
Myanmar	4	18
Nepal	20	36
Pakistan	76	115
Philippines	17	31
Thailand	8	22
Vietnam	16	41
Total	459	974 (1,290)

[1)] Figures as submitted to FAO - figures in parenthesis include the total reported in Chinese internal report.

Table 2

Project Objectives
The long term objective was to evaluate thoroughly the particular characteristics of the different breeds and strains; to strengthen, by appropriate breeding programmes, and by adjustments to the husbandry systems to which they are particularly adapted, their prospects for survival; and to contribute to the balanced evolution of the farming systems which are the basis of human food production in Asia. The Development Objective was to identify, characterize and conserve Animal Genetic Resources so as to maintain biological diversity for sustainable agriculture.
The Immediate Objectives: -
1. To identify and monitor the animal genetic resources of 12 countries in Asia and the Pacific.
2. To preserve and simultaneously enhance the productivity of those indigenous breeds at risk of disappearing or being replaced in breed substitution or upgrading(continuous crossbreeding) programmes
3. Training of national experts on techniques for description of breeds, data handling and in situ and/or ex situ preservation.
4. Analyze and publish all information related with Animal Genetic Resources collected or created during the project, including materials prepared for or produced by workshops.
5. Establish the Asian Network on Conservation of Animal Genetic Resou

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From the onset, it was obvious that the stated objectives in the project document were not achievable within the budget and that the major objectives would be a summary of the stated aims. The aim would be that, by the end of the project, there should be better awareness of the value and use of indigenous genetic material. In addition, there should be much better data about the resources available from all countries and that each country should have developed a National plan (this was later called a National Animal Genetic resource Management Action Plan ('NAGMAP').

The project worked through a National Coordinator (NC) who was nominated by each participating government and had total responsibility, as far as I, as manager, was concerned, within the country, in the context of the project operation. How the National Coordinator selection was decided and how activities were achieved was up to each individual country but the general aim was to have a Coordinating institution (usually but not necessarily the organisational group to which the NC belonged) giving full technical and administrative support. The role of the NC was to coordinate and to mobilize whatever expertise was available to assist in doing the activities - it was not the NC's function to try to do everything. The project held a meeting for NCs each year and, in most years, also invited a second person from each country. These annual meetings were used for discussion and for training as well as for planning activities. These meetings also showed the similarity of the problems and led to sharing of experiences. In addition, they also led to the development of a proposal for an Asian Programme for Animal Genetic Resources identifying the essential elements for the region to become self sufficient in the human resources capable of managing this valuable world asset held in Asia. This will be discussed in more detail later.

The first common problem is the general lack of knowledge of the breeds which exist within a country and even where breeds were known, the lack of detailed information either on population size and/or performance parameters. There are exceptions with the Chinese having reviewed their breeds in 1993 - concluding they had at least 596 rather than the 250 or so registered on the FAO database (DAD-IS) at present. During the project lifetime, several countries have done surveys - some nationally, some limited to certain regions within country but all are in a better position in terms of possessing relatively good information. India had been carrying out surveys for some time having had a specific Animal Genetic Resource institution for about ten years. China has now recommenced a 'national' survey by doing specific provinces - the last survey was done in the late 70s and reported early in the 80s. NCs can update the national data in DAD-IS as necessary although, at present, the database does not include information on the normal environment in which a breed is performing. This seriously limits the value of the data.

Another common element, albeit at different stages, is the use of 'exotic' breeds (usually as semen) in almost all species. In most cases, the exotic breed was crossed with the local and the resultant F1 was very successful. However, either political interests or technical experts (or both) have generally misinterpreted this initial success so that, in many places, there has developed a policy of so-called 'upgrading' by continuous backcrossing to the exotic breed. In almost all cases, the predictable has happened - the continued crossing has resulted in poorer performance (the level varies according to conditions but usually a maximum of either 50% or 75% exotic gives the best overall performance). The desire to continually backcross is understandable at farmer level and probably for the initial political reaction but there is sufficient data and knowledge worldwide for this to have been avoided. The general policy seems to have been based on the worship of the exotic rather than any logical evidence. Referring to smallholder dairy projects, S.R. Na Phuket (1999) reports that 'many of these projects were classified as unsuccessful or partially successful under donor's respective criteria'. 'The common problems of these multi- and bi-lateral assisted projects and programmes are that they have focused on larger project size with a high proportion of foreign exchange components. Therefore these projects involved investment in large importation of animals ...'. He continues ' However, in all of these unsuccessful projects, there are project components which could be classified as successful ones.'

The general picture is that the desire to use exotics is also accompanied by other biased strategies. Examples are the introduction of subsidised Artificial Insemination (usually free) to encourage uptake and no offer or availability of local breed semen. Given the poor financial state of the farmer, naturally the preference is for free insemination and, in the first instance, this provides a good animal which performs better than the local purebred. However, feed is usually a major limiting factor and the larger F1 requires both more intake for maintenance and then feed for production. Given the lower feed value of many forage crops in Asia, the solution has been to use compounds - again these (or their ingredients) are imported and subsidised, encouraging reliance on them rather than on locally available feeds. The recent disaster for the Indonesian poultry industry was due to its total reliance on imported feed, indeed the whole production system, which became far too expensive. Thailand would have suffered the same fate if it had not had such a good poultry export trade, which, because of devaluation, became even more attractive to importing countries. In addition, many countries are happy to receive aid in terms of heavily subsidised agricultural equipment (up to 80% in some cases) which again puts pressure against local livestock used for draught purposes which leads to the loss of the manure and treading value of the animal.

One of the common situations in Asia is that local resources which cannot be used for other purpose become wasted as the 'new' breed is provided with new feed. New and better feed is obviously desirable to a certain extent but must be used to provide more efficient use of the whole local (national) resource which includes, for example, forest and hill grazing. . For example, it is estimated that such forest resource contributes about 30% of Bhutan's total feed availability for ruminants. Nations, indeed, the world, cannot afford to throw away resources in the context of long term sustainability

Yet another common element is the development of industrial livestock production and this can be attributed to several factors. These can be summarized as a combination of the ease with which production can be increased without investment in good extension services coupled to the fact that capital investment is open to some adjustment of funds or is private and the state does not have to provide funds. There is some improved 'efficiency' (since the criterion is usually only a partial evaluation of efficiency) or there is direct subsidy either as such or in the provision of services by the government. The reference to efficiency is due to the false impression often given that feed conversion is the best criterion whereas cost per kilo of desired product would be a better measure. For example, FAO, in a study some years ago, found that efficiency of energy use was quite different from efficiency of feed conversion - countries have to decide what is in their best interests for long term sustainable production. There are other concerns in relation to increased urban industrialized animal production - the movement of nutrients to urban areas and the lack of return of waste products to the growing land for example (de Haan et al, 1997). However it would appear that the move to further industrialization will continue (Steinfeld et al, 1997; FAO, 1999).

Another major component of the situation in Asia is what can be regarded as the adoption of dubious 'economics' - as passed down from the "developed" world accompanying the rather narrow biological view of the developed world just exemplified. There is continuous reference by the donor world to the use of 'market' economy without any proper description of how this is manipulated by the adoption of practices to 'externalise' costs as economists would have us believe. Essentially 'externalising' costs is another description of a subsidy i.e. getting someone else to shoulder the costs which should be part of the production costs of a particular product. Good examples are the car industry's ability to get cities to provide the entire infrastructure required at no or little cost to the car manufacturer by promising good employment for that city. It is followed by the total lack of any charge for the pollution caused by their vehicles. Similarly, industrial pollution of the atmosphere is about twice that due to cars and lorries and yet there is usually no tax. Within the Livestock industry, the processing of effluents was, until recently, a free service to industry and, indeed, to industrial agriculture with the latter creating heavy burdens on sewerage treatment or simply allowing it to pollute land and water courses.

A common factor across all countries was the fact that local farmers had a wealth of experience and, in many cases, a better overall judgment than was apparent at higher administrative levels but their views were often neither sought nor welcomed. Rarely did farmers not appreciate the different abilities of the different crosses and the implications for management and for resource use. Not all developed the same conclusions as some preferred to rely on outside inputs but almost all appeared to recognise the limitations and advantages. Various discussions indicated levels of perception that would benefit policy makers and planners if there was some way of transferring the information! Clearly farmers follow the immediate financial forces since they have no other option - survival is their basic criterion. They may well be aware of the unsustainability of the system but there is no real choice for them.

In considering the various elements in more detail, it is clear that scientific evidence has often been ignored. For example, the results of dairy crossing in India was documented many years ago and the Brazilian results have been available for some years now but still programmes appear to ignore such information. It is as if every country believes that, against the odds, it will be different from all others. The lack of good records is not new (Trail, 1986). However, a useful review by Rege (1998) made some telling points - mainly that while first crossed provide improvement, subsequent crosses do not, that Friesian crosses are no better than crosses involving Jersey, Brown Swiss, Ayrshire or Red Dane and that F3 and F4 generations were no worse than the F2. Madalena (1990 and 1998) provides excellent evidence from Brazil on the various levels of Holstein crosses in different environments and on a system to provide a continuous supply of F1 heifers to the dairy industry. While not fully documented as far as I am aware, the difficulty of the Brahman to produce when feed is restricted is known but was not properly acknowledged /dealt with when the breed was imported to Thailand (and similar experience may well occur in Philippines). Indeed it is interesting to note that a recently made FAO video records the efforts of one group in Thailand trying to eliminate the Brahman blood from their animals to return to the pure Kao Lamphun. I am not sure that pure breeding only is the most efficient but the farmers believe that it is more productive than the Brahman in their circumstances and offers much lower risk. In a review on sheep and goats in Asia, Khan and Taneja (1996) confirm the recent emphasis on crossbreeding with exotics and refer to the inconsistent results. They comment ' there is now a growing realization for the importance of indigenous sheep and goats because of their suitability and adaptation to specific agro-climatic and socio-economic situations.' There are several examples of the use of exotic pig breeds in Asia - mainly in industrial type units. Again local resources have been ignored. In many situations, local farmers state that the feed requirements of the exotics are too high (especially in the breeding animal) - some countries have proposals to move away from such breeds (e.g.Bhutan, where farmers have clearly stated their preference for black pigs which withstand solar radiation much better). In addition, there is further scientific support for the contribution which can be made by indigenous breeds - e.g. Frankham, 1994; Hammond and Leitch, 1995.

Ironically, even a study of data entered into DAD-IS by each country shows up some interesting aspects that require further consideration and investigation. For example, using data on milk yield, calving interval and average life span, indigenous buffalo in Indonesia appear to produce more milk per Kg of mature bodyweight than do imported Murrah buffalo. It would also appear that adopting a strategic programme of using pure breeding and crossing for early and late parities respectively, goat production in several countries could improve by some 30 to 50% without the involvement of massive importation either of stock or other resources(Indonesia, Philippines, Nepal). Without environmental/management information within DAD-IS such study is limited to within country/region where such data is known. Nevertheless, it is clear that local evidence has not always been considered fully even when available. This is a serious omission both from a national point of view and from that of donors who could have provided funds more effectively - even if this did not include some trade with the donor country.

The need for better extension services cannot be over emphasized unless one is aiming at an industrialized livestock industry with no real involvement of the majority of the population i.e. farmers! In many countries, extension is at a low level - often simply a person trained to vaccinate but with no formal educational background. Often, extension is basically regarded as instruction on government policy and certainly the local culture does little to encourage the exchange of ideas and information between farmer and an extension person (with university education). Much of the graduate and postgraduate training is based on developed country scholarships and people are trained with 'western' attitudes. ' New science' is regarded as the only solution and, often, simple, but no less scientific, solutions are ignored. Examples are the lack of use of data already available to show the direction of policies and strategies to produce more efficiently in a sustainable manner - the examples of the potential for improving efficiency of goat production in several countries and buffalo in Indonesia have already been mentioned. To give another example, in Vietnam, on one of the best managed dairy cow units seen in the region, the owner - a classic entrepreneur who would be the epitome of what donors want to see - had no real idea what to do since only Holstein Friesian semen was available. He complained that was already finding additional problems with animals of over 75% HF genes. Eventually, via the government, local AI stations were encouraged to obtain Sahiwal and/or Red Sindhe semen (which they had stopped stocking a decade or more ago!) and he is able to criss-cross with good results and animals which do not suffer stress problems. However, even he was not aware that the progeny colour would not be a factor in indicating milk yield and expressed concern about the brown animals. Apparently, the local extension had offered no advice.

There is another difficulty in resolving the problem of extension services (or, rather, the absence!) which is the present, popular 'donor' opinion that such services should be self-supporting. Given that the developed world cannot achieve this status (except perhaps with one or two exceptions, it is nonsense to insist that this is an immediate objective. Whatever the correctness of the philosophy, it must be recognized that the developed world has had subsidized extension services for at least 40-50 years and is only now moving slowly towards a self supporting service. It cannot be reasonable for the developed countries to expect those regarded as developing to achieve what the former cannot achieve for themselves.

There has to be much more effort from the developed world to create more correct economic principles - there is some movement but it is very slow and marked by considerable reluctance - especially by the large (international) companies who benefit most from 'externalized costs'. There can be no real excuse for the exclusion of costs - these need to be more properly linked with the causal agent rather than simply accepted by an agency further down the line (as is the classic case for water pollution). There are examples of attempts at more direct costing (in the UK, for example) and of other excellent schemes to create more sustainable production. The types of regulations on stocking rates and linkage to land area in Scandinavia and parts of Europe would be of interest and assistance to many other countries.

There appears to be no good reason for developing countries to go through the whole experience that Europe has undergone when the problems and potential avoidance policies and procedures are already known. Perhaps the more cynical might believe that there is a political view held that the better way is to allow the problem to occur and then provide (sell?) the solution at that stage.

While hindsight can provide indications of errors and of successes, e.g. S.R. Na Phuket (1999), it does not itself provide all the solutions. Some solutions clearly come directly out of the study of the past but others are not so obvious. While the improvement of extension will assist, what is the timing of this relative to the development of industrialized production? - What are the regulatory mechanisms in place? - Do they encourage an incorrect long-term response and, if so, can they be changed or avoided?

A classic question is that concerning the use of breeds, the use of pure breeding and of crossbreeding. While there are some good examples of the sustainable use of cross breeding these appear not to be well known in the developing world. The situation in the UK particularly regarding beef cattle and sheep production shows how cross breeding can be used in a sustainable manner even with large numbers of pure breeds being available (and continuing to be so although with some minor reduction). While such cross breeding strategies are relatively easy to adopt if the necessary structural organization is put into place, it is rather more difficult with the low reproductive species like cattle and buffalo. Most countries shave not started to consider the solution but are staggering from one problem to the next. There is s crucial need for models (desk studies) to be undertaken to look at the options for these species. In dairying, should the approach be to have a simple criss-cross? To upgrade and hope that management 'keeps up? To develop a synthetic at some particular level of HF genes and have a progeny testing programme? Or to try to provide a continuous supply of F1s as in Brazil? (Madalena, 1998). There is no easy way in which the dairy industry can itself provide adequate numbers of F1s and keep a large purebred population to do this in tropical environments. Brazil uses the beef industry to do this and this could be a possibility elsewhere. Clearly, biotechnology has a potential role - given existing techniques of In Vitro Maturation (IVM), In Vitro Fertilization (IVF), semen sexing and embryo transfer, in theory it is possible to foresee a guaranteed supply of F1 Female embryos to dairy farmers. This potential has been improved by Ova Pick Up (OPU) techniques allowing the local purebred to be kept alive as well as contribute the necessary large number of ova. It has to be said that, at present success rates, this is not yet a feasible economic proposition but, in my opinion, this could soon become so IF sufficient effort was put into it. For example, surely biotechnology could find a simple way in which a farmer can ascertain that the cow (or more especially the buffalo) is in oestrous thus alleviating a major constraint on better conception rates. However, the effort in 'new biotech' has been put in at the top end of genetic improvement where the Laws of Diminishing returns are already operating and the techniques have not been supported to the level needed because, at that particular level, the returns cannot justify investment. On a world scale, the provision of guaranteed F1 females at a reasonable price could revolutionize the dairy industry in the developing world and provide a massive boost to real efficiency and to the alleviation of poverty. However, this is not the only component of successful smallholder dairy production - for a better review of the whole subject, see the recently published '*Smallholder Dairying in the Tropics*' [Falvey L. and Chantalakhana C. (Eds). 1999].

The technical aspects of selection for improvement are well documented but there is still very little operational experience of selection programmes in medium and low resource base systems. FAO and the International Committee on Animal Recording (ICAR) have taken some useful steps in attempting to find solutions (ICAR, 1998). Nevertheless there are several situations in which relatively little input could result in major gains - the proper structuring of goat schemes to involve local small but highly prolific breeds and larger, fast growing breeds by judicious crossing for slaughter is a good example. The missing ingredient appears to be the small amount of funding coupled to the close cooperation of an experienced applied animal breeder with local participants and extensionists.

In ensuring that local people are closely involved and get adequate experience for future use, the use of more computerized systems and making such programmes available and accessible to a wider audience is crucial. The potential for desk studies and the use of programmes for modelling different breeding systems is immense but there needs to be coordination of efforts if the best is to be obtained for least cost. Regionally based schemes such as the one recently operated in Asia on Animal Genetic Resources could be used for this purpose with considerable advantage. The sharing of common experiences in Animal Genetic Resource Management should obviously include operational experiences in recording and breed improvement.

There has been much written about the value of Open Nucleus Breeding Schemes (or Systems) (ONBS) and the inclusion of Multiple Ovulation and Embryo Transfer is frequently advocated in developing countries - especially for dairy selection. In many such comments, there is, in my opinion, a lack of awareness of the full implications and demands of such systems. This is not a criticism of ONBS itself - indeed the UK initiated several such schemes in which I had an involvement -but it is essential that the complete picture is seen by those considering whether to use the system. It is not the purpose of this paper to list all pros and cons - simply to confirm that ONBS offers some advantages but that, in certain circumstances, these can easily be changed into a loss of progress compared to a normal closed breeding system (Steane, Guy and Smith 1982). A crucial element in ONBS is the cooperative nature involving all parties in the whole system - this aspect is not strong in several Asian countries and could provide real difficulties. MOET is quite a different matter - it is interesting to note that there is, perhaps, one scheme in the world that has managed to achieve the technical control needed to gain the advantages of MOET as first outlined (Nicholas and Smith,1983). Most schemes have failed in this respect and have been adapted to achieve less spectacular advantage. Clearly, the biotechnology used needs to achieve better, more reliable results before it can be of any real value in the context of rate of nucleus genetic change.

There is now considerable debate about the use of Genetically Modified Organisms (GMOs). This term is unfortunate since the human race as all others has undergone genetic modification over time. The need to differentiate is justified since the traditional methods did allow time for most aspects to be considered and for problems to be exposed before major expansion could take place. However, even the advent of AI has meant that this no longer occurs - hence the problems with crossing programmes trying to 'upgrade' as they call it. In the past, keeping the exotic pure breed locally did give some indications of the likely difficulties ahead! Embryo transfer has made the problem even greater since the full purebred can be transported at minimal cost - and in fairly large numbers too.

Genetic engineering does have the potential for some spectacular gains - for example, if stress genes could be transferred to the most highly productive breeds in all species - consider the possibilities for reduction in numbers if animals. However, unless and until genes can be placed precisely where they should go within a 'foreign' genome, the need to do a full and proper evaluation has never been greater. Unfortunately, it is highly unlikely that, without full legislative and regulatory control, those investing will carry out the necessary tests. Financial investment is such that the aim will be/is to identify the required benefit - such tests are likely to be much smaller than those required to check on the many other aspects of the production systems which may be affected by the same engineered gene(s). It is crucial that the present debate does not prevent the proper research, development and evaluation taking place. Indeed those involved either as consumers or as scientists should use the opportunity to ensure that proper and fully responsible science is practiced and that full evaluation is carried out and reported independently in each specific case. There is no justification for generalised opinions whether research based or not. The recent moves to maximise industry funding of R & D (and to minimize government inputs) carries with it serious dangers some of which are now being publicly identified as a result of the GMO debate.

The regional Animal Genetic Resource project in Asia ended last August but the activities continue, although on a much lower scale, through the Animal Production and Health Commission for Asia (APHCA) which is embedded within FAO but partly funded by the member countries. The Secretariat is based within RAP in Bangkok. This arrangement will not allow all the crucial activities to be undertaken but at least gives a contact forum for continued sharing of ideas/experiences and a base for trying to get further funding for the better management of the region's animal genetic resources.

However, during the last two years of the project, the National Coordinators worked with the CTA to develop a Programme for Asia. The objective was to identify the crucial areas of work essential if the region was to be in a position to be self sufficient in terms of human resources to manage the AnGR of the largest livestock region in the world. Due to the large area of common problems and needs, NCs were quite clear that the major work required was at the Regional level. This would to a common base for work, facilitate the use of data and people more effectively and to ensure that the region, as a whole, obtained the greatest benefit from its resources. Tables 3, 4 and 5 summarise the main aims, objectives and beneficiaries of the proposal entitled 'Programme Document for Farm Animal Genetic Resources in Asia'.

It is interesting to note that the most crucial element was not identified as high technology input but as straight forward, proper and relevant training.

Table 3

Immediate objectives, outputs and activities
1. Strengthen the Regional Focal Point to ensure the necessary coordination of Activities that can be effectively delivered at the regional level, provide a mechanism for developing regional animal genetic resources policies, and to provide an interface between the region and the Global Focal Point.
2. Enhance capacity building in the management of farm animal genetic resources to ensure the sustainable use and conservation of these resources, through training, technical assistance, and development of guides and guidelines; and provide support for in-country policy development for animal genetic resources.
3. Improve capacity to prepare regional and country-based strategies and plans, and strengthen mechanism for developing regional and national policies for farm animal genetic resources.
4. Improve communications and data and information collection and sharing among farmers, scientists, managers, countries and interested organizations.

Table 4

This programme will:
1. Address the rapid loss of indigenous breeds and develop and implement conservation strategies for breeds most at risk.
2. Address the lack of management capacity in farm animal genetic resources
3. Lead to the development of sustainable livestock utilization strategies and projects, which are based on both short and long-term impacts.
4. Lead to improved agricultural and economic policies, which support the conservation and sustainable use of farm animal genetic resources.
5. Increase awareness of the roles and values of animal genetic resources and the need to fully consider both indigenous and exotic genetic resources.
6. Increase communication among farmers, scientists and policy-makers which will enhance planning, policy making and livestock management.

Table 5

Specifically, the Programme will benefit:
a) Farmers and rural communities through enhanced management capacity which will improve their ability to produce farm animal agricultural products for their families, community and country.
b) Scientists and managers, from training programmes and improved communications with other scientists and managers.
c) Senior policy makers whom will have improved mechanisms for identifying policy issues and needs, and in formulating both national and regional policies for animal genetic resources.
d) International organizations involved in/with animal genetic resources, as the Programme will identify research priorities and provide a means to coordinate research in the region, and will contribute to the development of a Global Plan of Action for Animal Genetic Resources.
e) Countries that have ratified the Convention on Biological Diversity, as the programme will help them to meet their obligations to conserve agricultural biodiversity, and will facilitate development of measures to provide access to genetic resources on mutually agreed terms.
f) Indirectly, countries outside Asia region will benefit, as conservation of the region's diverse animal genetic resources means that these resources may be made available to other countries on mutually agreed terms, for research, commercial and other uses.

The essential elements start with the aim of strengthening the Regional Coordination by more formal involvement of countries in the management of the focal point. Three aspects all directly concern management practices that the National Coordinators consider to be in short supply within the region and yet crucial to the future use of resources in the best way for long term livestock production. The detail of the Programme has been widely distributed to donors. It provides a useful set of aims, objectives and activities which would not only be valuable on a regional basis but could well serve as a guide both to national and to global priorities and strategy.

Essentially, the NCs recognised that countries, in general, have not properly considered their resources and the optimal way of exploiting these in a sustainable way. They also consider that it is crucial that this is tackled as a matter of urgency if long term programmes are to be achieved in the most effective manner. (In this respect, the various recent decisions within FAO to give priority to the Report on the State of the World are most welcome). The NCs also recognised that, in general, the region lacked the technical experience and expertise and that this matter had to be rectified as a priority. Obviously each country has to consider these points and to take any action deemed necessary to best utilize its resources and to maintain those resources which still exist. The proposed Programme for Asia provides a most useful summary which merits detailed consideration, not only at regional level, since the crucial areas of need are likely to be repeated elsewhere.

There is a danger that a country, in addressing how to conserve its genetic resources, fails to review the overall livestock programme and future sustainability. Some countries have developed good conservation schemes which fail to use the breeds maintained and these may well become a burden on society in the longer term. Governments are always looking for cost cutting items so these programmes then become vulnerable. Conservation and genetic improvement are but two sides of one coin - without both, the value of the coin is effectively zero.

This paper has, so far, discussed breeds on the basis that, looked at in an overall sustainable systems approach, most will have benefits to offer. Conservation in the context of maintenance per se has not been discussed. The assumption that most breeds are useful appears to be contrary to the present popular view which clearly accepts the continuing dramatic reduction in the number of breeds. Given that "sustainability" is now accepted by governments as the way forward, the present trend must cease - unless such acceptance is only for reasons of respectability. However, even in a situation where more local breeds are recognised for their value in an overall system, there will be breeds which do not/cannot contribute usefully. The principle of maintenance of diversity is generally accepted but that does not mean the maintenance of all breeds. Developments over the last ten years have provided the objective means by which the genetic similarity can be estimated with acceptable precision. Such measures can enable strategies for the maintenance of diversity to be developed (Barker et al,1993; Nardone et al 1995). However measures of genetic distance have limitations - no additional value is given to major gene effects, none to religious, cultural or heritage considerations. Hill (1998) suggests that knowledge of breed evolution itself may well be of value. The importance of individual genes has come into even greater prominence given the announcement of the new technique for placing new genes into a genome. Clearly, developing countries cannot play a major role in carrying out these new technologies although most would appear to wish to do so. However developing countries do have much of the genetic variation - how is this best used for the benefit of all? Amazingly, there are still countries which have not ratified the Convention on Biodiversity and, therefore, are not bound by it - the USA and Thailand for example. There must be serious pressure brought to bear for all to ratify - until such time, countries should not cooperate with non-ratifiers - that is if they want to be relatively secure in the knowledge that the law is on their side. It is crucial that the CBD is not regarded as secondary to the World Trade Organization (WTO) since there are clearly common areas of interest but with quite different approaches. This latter point is true too for the method of governance of the two bodies and the implications need more public debate. Globalization is here and will stay with us whatever the reactions of different interested parties. It is incumbent upon us all to work to ensure that the 'Global Village' has a properly structured, transparent 'Village Committee' to regulate it. The present system which appears to many to consist of a series of disjointed and unconnected groups of people, all apparently representing their 'nation' is NOT the way forward - it can only lead to further strife. It is an unfortunate, but nevertheless important reality that the most effective measures for the best management and exploitation of Animal Genetic Resources are political and not scientific - the future global food security and poverty alleviation depends upon the politics of the first five years of this Millenium.

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Animal Genetic Resources in Low Input Systems: The African Perspective

S.H.B. Lebbie[1] and J.E.O. Rege[2]

Introduction

The theme of the World Expo 2000 Workshop on Animal Breeding and Animal Genetic Resources (AnGRs). "Sustainable Animal Production" highlights the major issue facing AnGRs conservation and utilization pondits today - sustainability. No more can we limit our attention to productivity-oriented strategies without giving due consideration to economic, social and environmental implications of livestock conservation and utilisation (Lebbie, 2000; Rege, 1997), particularly in low input production systems. In the context of these systems, our contribution in this workshop with reference to African AnGRs will focus on: the major low input systems within which the exist; a review of their role, diversity and distribution; the current conservation and utilisation strategies and actions; the challenges and constraints, and the strategies for enhancing their conservation and utilization. These discussions, while attempting to cover Africa as a whole, will draw most examples from Sub-Saharan Africa as well as the ruminant livestock.

What Are Low Input Livestock Production Systems?

Low input systems are those in which the production systems depend largely on the maximisation of the utilization of locally available inputs and minimum external inputs. They are also largely closed systems that tend to internalise their environmental costs. The production systems themselves epitomise the extent to which livestock are integrated with crops and land-use patterns. The degree of integration is determined by several factors including demographic pressures, policy, resource endowment and the availability of delivery systems and support services. In this context, the low input systems are classified into three broad production systems, viz., grazing, mixed farming and small-scale commercial systems (Tables 1 and 2). The following discussion takes an overview of these systems in Africa.

Table 1
Characteristics of four major Ruminant Production Systems in Sub-Saharan Africa

	Grazing			
	Pastoralist	**Agro-pastoralist**	**Mixed crop/ livestock**	**Small scale commercial**
Zones	**A-SA**	**SA-SH**	**SA-SH-HL**	**SA-SH-H-HL**
Density (km^2):				
Persons	4-8	10-40	20-100	100-300
Ownership (% of total)				
Camels	90	10	-	-
Cattle	30	20	40	10
Sheep	40	20	30	10
Goat	40	20	30	10
Mobility	XXX	XX	X	X
Major strategies:				
Cash income	XX	XX	XX	XXX
Milk & Blood	XXX	XX	X	X
Meat	XX	XX	X	X
Manure	X	XX	XXX	X

Zones: A = arid; SA = semi-arid; SH = sub-humid; HL = Highlands.
Score: XXX = High; XX = Medium; X = Low.
Source: Adapted from Lebbie et al. (1996).

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Table 2
Strength of Livestock-environment Interactions By Production System

Interaction	Production Systems: Landless		Grazing			Mixed (rainfall)		
	Monog-astrics	Rumi-nants	Cool High-lands	Humid/ Sub-humid	Arid/ Semi-arid	Cool High-lands	Humid/ Sub-humid	Arid/ Semi-arid
Range Utilization	-	***	***	***	***	***	***	***
Forest Utilization	*	***	*	***	**	*	***	**
Waste Manure	***	***	*	*	*	*	**	*
Waste from Processing	***	***	*	*	*	*	**	**
Methane	***	***	**	***	***	**	**	***
Mobility	*	*	**	**	***	*	*	**
Wildlife Bio-Diversity	-	*	*	***	***	*	**	**
Concentrate Feed	***	***	**	*	*	***	**	*
Input to Cropping	***	***	**	**	**	***	***	***

*** = Strong interaction.
** = Moderately strong interaction.
* = Weak interaction.
Source: FAO (1996).

Grazing Systems

Extensive grazing systems are essentially based on livestock production on rangelands with minimum external inputs. Both humans and their livestock depend on this resource base for their sustenance. These systems are generally constrained by limited but highly variable rainfall and there is only limited or no integration with crops. The systems can be described as closed systems where farm wastes (e.g. manure and occasionally crop residues) are utilised within the systems, with little or no pollution of the environment (de Haan et al., 1997)

In the hyper-arid or near desert conditions, extensive grazing systems are characterised by pure pastoralism that may be either transhumance or nomadic with increasing dependence on frequent and long distant movements in search of feed and water for the survival of their livestock and their own well-being. These systems are common in countries in the northern fringes of the sahelien belt.

In the arid zones, one finds a mix of pure pastoralism (long-range transhumance in the drier areas), agro-pastoralism (short-range transhumance in the wetter areas) and some sedentary domestic pastoralism. Grazing systems in semi-arid zone are more diversified, including "cattle posts" or traditional ranches and occasionally, integrated wildelife-livestock farms (promoting eco-tourism) in countries like Kenya, Botswana, Namibia, Zimbabwe and South Africa (Cummings, 1993; de Jager, 1996; Lebbie et al; 1996).

Grazing systems in the cool highlands, humid and sub-humid zones are largely sedentary, with limited mobility. Strict herding and tethering are the variations of grazing systems here, especially when crops are still in the fields, thus making them very labour intensive. Unlike pure pastoral and agro-pastoral systems, flock/herd sizes tend to be small, ranging from 1-10 animals per flock/herd.

Traditional or subsistence grazing, unlike ranching, is based on communal grazing systems (Winrock, 1992; Danckwerts, 1996). The limited and highly variable rainfall characteristic of arid and semi-arid grazing areas, result in major intra- and inter-seasonal variation in the quantity and quality of available forage and water in the rangelands. This phenomenon is largely responsible for the seasonal mobility of pastoralists in search of forage and water. In the dry season, pastoralists move their animals from the wet season grazing areas in the flood plains to the higher potential river valleys, crop land or mountain meadows for dry season grazing (de Haan et al, 1997). Concomitant with this high mobility of herds/flocks is extreme flexibility in herd/flock size. The livestock populations tend to expand when rains are abundant and decrease with long dry spells or drought. This highly flexible and mobile nature of the systems allows for adjustment of grazing pressure to the quality of feed available (de Haan et, al, 1997; FAO, 1996). These opportunistic management strategies are largely responsible for the resilience and the efficient use of the natural resource base with capacity to regenerate rapidly when the conditions are right (Behnke et al; 1993; Scoones, 1994; Thomas and Middleton, 1994).

Grazing systems, particularly pastoral systems, raise and conserve most of Africa's indigenous domestic and wild ruminant genetic resources and the livelihoods of the people in these systems are basically tied to their animal genetic resources. These systems also provide the best opportunities for the development of productive wildlife-livestock systems, as exist in Namibia, South Africa and Kenya, inter alia (Ellis, 1991; Lebbie et al; 1996). The traditional practice of mixed species grazing systems (cattle, small ruminants, camels and wildlife) also helps to maintain biodiversity and the resilience of the systems.

Mixed Farming Systems

Mixed farming systems integrate crops and livestock production on the same farm. The systems utilise mostly indigenous genotypes. Some, however, do take advantage of cross bred genotypes developed and provided by either the National Agricultural Research Systems (NARS) or development agencies including Non-Governmental Organisations (NGOs). Most of the meat (54%) and milk (92%) produced in Africa come from these systems (FAO, 1996). They form the backbone of smallholder farming systems in Sub-Saharan Africa and West Asia and North Africa (WANA). As closed or near closed systems, mixed farming systems provide opportunities for better natural resource base utilisation through nutrient recycling between crops and livestock and use of animal draught power. It is predicted that intensification of agriculture in SSA will evolve from mixed crop-livestock systems (Mclntire et al; 1992; Winrock, 1992; de Haan et al; 1997). Mixed farming systems also provide opportunity for diversification of risks and add value to both livestock and crop waste.

The main challenge of mixed farming systems, however, is how to maintain their environmental equilibrium and at the same time allow sustainable productive growth.

Small Scale Industrial Production Systems

These are semi-intensive to intensive small-scale urban or peri-urban livestock production systems (dairy, fattening of small ruminants, and pigs and poultry production) in most countries. These systems account for the largest proportion of the eggs and pork and poultry meat produced in SSA. They are largely open systems and depend to a certain extent on outside supply of inputs including, medicants, feed and fuel. Because they are largely open systems, these systems, especially the monogastric subset, tend to externalise and therefore neglect their environmental costs (de Haan et al., 1997).

The systems tend to normally keep-improved breeds, mostly crossbred animals (dairy cows and goats) and few of pure indigenous breeds of goats and sheep. For the monogastrics only exotic breeds of pigs and poultry are raised. Because they tend to be kept in relatively large numbers per unit area, monogastrics produce large volumes of waste which when not properly managed could cause environmental pollution and expose the animals to high health risks.

The systems' dependence on external inputs, especially for feed grain, has an indirect effect on arable land us. As the urban and peri-urban systems grow there will be a growing need for cut-and carry or production of fodder forages and feed grains. This has the potential effects of mining nutrients from the supply base and causing land degradation, which inturn could lead to the erosion of biodiversity, when waste is not returned to the exploited lands.

Compared to grazing and mix farming systems, the small-scale commercial systems have great growth potential. The systems, however, pose several challenges, including the development or adaptation of appropriate technologies and establishment of policies that will address the problems associated with their intensification such as infectious diseases (particularly the zoonotics), high feed demand, need for better marketing services and environmental concerns (pollution mainly).

The African Animal Genetic Resources - Diversity and Distribution

Africa is a storehouse of unique animal genetic diversity, largely made up of indigenous AnGRs. Various estimates have been made. According to Hodges(1993), 450 (13.4%) of the 3,350 breeds from the 10 main domesticated species of animals in the world are from Africa (Table 3). Among the developing countries, Africa accounts for 30% of the 150 breed from these major domesticate animal species. The FAO global Domestic Animal Diversity

Information System's (DAD-IS) data on buffalos, cattle, goats, sheep and pigs indicates that Africa has 381 (29%) of the 1744 documented breeds and breed varieties (Table 4). Current estimates of ruminant breeds/strains from data coming from the National Agricultural Systems (NARS) in SSA indicates that there about 50-60 sheep and 30-40 goat "breeds/strains" (Lebbie and Ramsey, 1999) and at least 100-150 cattle "breeds/types" (Rege, 1997). However, it is worth noting that except for the exotic and the synthetics or composites, the real genetic distinctiveness of most of these major indigenous "breeds" and their varieties or strains is not known. This is obvious as one looks at the names given to these animals. The names are in most cases related to specific ethnic groups (e.g. the Red Maasai sheep; the Boran cattle) or geographical locations (e.g. the West African Dwarf Goat; the Mpwapwa cattle). Similarly, the classification of the major types is largely based on morphological or physical characteristics including the type and size of ears and horns. This situation holds because of limited systematic and comprehensive characterisation of these indigenous AnGRs, particularly in terms of their genetic population status or production/adaptability traits. In the FAO data referred to above (Table 4) only about 18% of the 381 African breeds and breed varieties had some information on population size and or production traits.

Table 3
The Distribution of Breeds throughout the World

Geographic Regions	Number of Breeds
Development Countries	1,500
Republic of Farmer USSR	350
Developing Countries	1,500
Africa	450
Asia	900
Latin America	150
Global Total	3,350

Same: Hodges (1993).

Table 4
Distribution of Breeds and Breed Varieties By Geographic Regions and Species

Geographic Region	Species[1]					
	Buffalo	Cattle	Goats	Sheep	Pigs	Total
Former USSR	1 (1)	62 (38)	20 (7)	135 (51)	35 (21)	253 (118)
Africa	8 (1)	173 (38)	59 (11)	133 (18)	8 (1)	381 (69)
N&C America	1 (0)	67 (2)	12 (1)	48 (5)	35 (1)	163 (9)
Latin America	2 (0)	45 (12)	11 (2)	17 (5)	17 (2)	92 (21)
Asia	63 (1)	200 (36)	147 (29)	231 (80)	142 (12)	783 (154)
Oceania	0 (0)	21 (0)	6 (2)	39 (2)	6 (0)	72 (4)
Total	75 (3)	568	255 (48)	603 (6)	243 (37)	1744 (375)

[1] Numbers in brackets shows the number of breeds with some information on population size and or production traits.
Source: Adapted from Hodges (1993).

This diversity of AnGRs is a result of millions of years of natural selection. About 80 - 90% of these AnGRs are indigenous and are predominantly associated with traditional farming practices. Thus they are widely and variably distributed across the major geographic regions (Table 5). In SSA, East Africa and West Africa overall hold the largest proportion of AnGRs, with Ease Africa dominating in all the ruminant species and the west dominating in monogastric species. There are, however, variations between countries within geographical regions. For example, among the SADC member states, South Africa, Namibia and Lesotho have more sheep than goats while Malawi, Tanzania and Zaire have more goats than sheep. The regional distribution of African ruminant biomass by species reflects the same pattern as their proportional distribution (Table 6). Among agro-ecological zones (Table 7), the drier and fragile zones (arid and the semi-arid zones) hold about 60% of the total African ruminant biomass. The humid zone seems most unsuitable for livestock farming, accounting for a mere 6% of the total African ruminant biomass. Species differences are noted, with cattle over represented in all zones and regions. Camels are found almost exclusively in the arid zones of the eastern and northern regions.

Table 5
Distribution (%) of African Livestock populations by Geographic regions, 1995

Region	Camels	Cattle	Sheep	Goats	Pigs	Chicken1)
Eastern Africa	78	52	34	41	15	20
Southern Africa	0	16	16	10	6	13
West Africa	5	20	20	33	53	30
Central Africa	4	7	4	7	16	6
North Africa	13	5	26	9	0	31
Africa %	100	100	100	100	100	
-x 1000 head	14.151	196.393	211.611	14.905	21.555	1.061

1) Figures for chickens are in millions.
Source: Rege (1997).

Table 6
Distribution (%) of Africa's ruminant biomass by species and region, 1995

Species	Eastern Africa	Southern Africa	West Africa	Central Africa	North Africa	Total %	Number of TRLUs (millions)[1)]
Camels	5.5	0.0	0.3	0.3	0.9	7.0	14.2
Cattle	35.5	11.3	14.0	4.8	3.1	68.7	137.4
Sheep	4.6	2.1	2.6	0.5	3.5	13.3	26.4
Goats	5.4	1.1	3.6	0.8	1.0	11.0	21.9
Total (%)	50.1	14.5	20.5	6.4	8.5	100	
Number of TRLU(millions)	110.1	29.0	41.0	12.9	16.9	199.9	
TRLU/caput	0.48	0.27	0.20	0.18	0.13	0.27	
Area (km^2) /TRLU	0.07	0.21	0.12	0.42	0.42	0.15	

1) Tropical ruminant livestock units (250 kg): cattle 0.7; sheep and goats 0.125; camels 1.0.
Source: Rege (1997).

Table 7
Distribution of sub-Saharan Africa's ruminant biomass (in millions) by agro-ecological zones and species

	Cattle		Sheep		Goats		Camels		Total	
Zone	TRLU [1)]	% [2)]	TRLU	%	TRLU	%	TRLU	%	TRLU	%
Arid	24.2	48.3 (20.3)	5.3	10.6 (32.7)	7.1	14.2 (37.6)	13.5	26.9 (100)	50.1	100 (29.8)
Semi-arid	36.7	80.6 (30.7)	3.8	7.1	5.0	11.1 (26.5)	0.0	0.0	45.5	100 (27.1)
Sub-humid	27.4	83.3 (22.9)	2.3	5.0	3.2	9.7 (16.9)	0.0	0.0	32.9	100 (19.6)
Humid	7.1	68.9 (5.9)	1.4	3.2	1.8	17.5 (9.5)	0.0	0.0	10.3	100 (6.1)
Highlands	24.0	82.2 (20.2)	3.4	1.8	1.8	6.2 (9.5)	0.0	0.0	29.2	100 (17.4)
Total	119.4	71.1 (100)	16.2	18.9	18.9	11.3 (100)	13.5	8.0 (100)	168.0	100 (100)

1) Tropical ruminant livestock units (250kg): cattle 0.7: sheep and goats 0.125: camels 1.0.
2) Figures outside parentheses expressed as % of row (zone totals). Figures in parentheses expressed as % of column species totals.
Source: Rege (1997).

The Role of Animal Genetic Resources in Low Input Systems

Farm animal genetic resources are critical to the economic development and the well-being of the people of most countries in Africa, especially those in the rural communities. About one-eight of the world human population resides in Africa and about a similar proportion of world livestock is raised on the continent. In general, however, livestock contribution to food supply is not up to half of the world average and it is believed to be declining as is the overall per capita food supply. This general decline in per capita food supply may be largely due to widespread land degradation and poor management resulting in massive erosion of biodiversity, especially in the arid and semi-arid ecosystems (Fitzhugh, 1993; Lebbie, et al., 1996).

Livestock contribute to the national economies

In Sub-Saharan Africa, animal products - meat, milk, eggs, wool, hides and skins - contribute about 28% of the total value of agricultural output (Winrock, 1992). If animal manure and draught power are monitized, the average will increase to 35%. This contribution varies from country to country and from region to region. For example, in Eastern and Southern Africa, the contribution of the livestock sector to the agricultural output ranges from 5% in the Congo to 88% in Botswana (Table 8).

Table 8
Value of Agriculture and Livestock products in selected countries in Eastern and Southern Africa, 1988

Region and country	Value of sector (US$ millions)		Livestock share of
	Agriculture	Livestock	Agriculture output (%)
Eastern Africa:			
Burundi	739	42	6
Congo	2,74	143	5
Ethiopia and Eritrea	3,243	1,299	40
Kenya	2,202	826	38
Madagascar	1,765	472	27
Rwanda	645	70	11
Somalia	709	514	72
Sudan	3,261	1,901	58
Tanzania	2,837	642	23
Uganda	2,84	404	14
Southern Africa:			
Angola	632	201	32
Botswana	121	107	88
Lesotho	95	66	70
Malawi	831	98	12
Mozambique	796	160	20
Namibia	300	245	82
Swaziland	193	47	24
Zambia	527	169	32
Zimbabwe	1,137	260	23

Source: Winrock (1992).

The total estimated value of outputs of meat, milk, hides/skins from major indigenous ruminants in 1995 was about US$ 18,966 million (Table 9), with most of this attributed to meat (70.1%) and milk (27.9%) output. The regional differences observed in output value seem to reflect AnGRs distribution. Thus East and West Africa with the with largest total ruminant livestock populations and biomass (Tables 5 and 6) also accounted for most of the total output value of the assessed commodities (49.4% for Eastern Africa and 17.4% for West Africa) compared to Southern (14.7%), North Africa (12.8%) and Central Africa (6.1%). On species bases, the overall contribution of cattle to the total output value of the assessed commodities (Table 9) was considerably higher (68.8%) compared to contributions from sheep (16.8%) and goats (14.4%). In terms of specific commodities, cattle, sheep and goats accounted for 66.6%, 19.0% and 14.4%, respectively, of the estimated total output value of meat; 76.1%, 10.2% and 13.7%, respectively for milk and 43.6%, 31.3% and 25.1%, respectively, for milk. Sheep milk does not seem to be an important commodity in Southern Africa and to some extent, Central Africa. Goat milk, on the other hand, seems highly valued in all the regions, except for Southern Africa where the value of output seems very low.

Table 9
Estimated value of output of meat, milk, hides and skins from African ruminant livestock by region, 1995[1]

Species	Product	Value (US$ million)					
		Eastern Africa	Southern Africa	West Africa	Central Africa	North Africa	Total
Cattle	Meat	4,293.5	1,611.4	1,616.7	722.5	634.0	8,878.1
	Milk	2,647.1	534.5	424.2	144.4	277.0	4,027.2
	Hides[2)]	78.6	24.2	30.2	10.6	7.6	151.2
Sheep	Meat	740.6	391.8	422.2	101.3	878.1	2,534.0
	Milk	343.8	0.0	40.7	9.8	142.5	536.8
	Skins	36.9	17.4	21.7	4.3	28.2	108.5
Goats	Meat	732.5	189.1	598.8	146.5	251.2	1,918.1
	Milk	467.6	4.9	112.0	20.3	120.5	725.3
	Skins	35.6	8.7	28.6	6.1	7.8	86.8
Subtotal	Meat	5,766.6	2,192.3	2,637.7	970.3	1,763.3	13,330.2
	Milk	3,458.5	539.4	576.9	174.5	540.0	5,289.3
	Hides/Skins	151.1	50.3	80.5	21.0	43.6	346.5
Total		9,376.2	2,782.0	3,295.1	1,165.8	2,436.9	18,966.0

1) Estimated from national figures summarised by Winrock 1992.
2) Not available.
Source: Rege (1997).

The 1993 estimates of the import and export values of selected livestock products in the various African regions are presented in Table 10 (Rege, 1997). The region's total expenditure on importing these livestock products was a staggering US$ 2,485.5 million which was nearly six times the export earnings (US$ 436.2 million) from the same products. If the value of these same products from the indigenous livestock (US$ 18,966 million; Table 9) is considered, it becomes obvious that these livestock play a significant role in import substitution, thus contributing to foreign exchange savings, especially in a continent where most countries have perennial headaches meeting their foreign exchange commitments.

Table 10
Estimated value of imports and exports of selected livestock products and average contribution of livestock to value of agriculture in Africa, by region, 1993[1]

Region	Value of imports and exports (US$ million)						
	Meat Preparations		Dairy and Eggs Products		Hides and Skins		Value of livestock as % of value of Agriculture
	Imports	Exports	Imports	Exports	Imports	Exports	
Eastern	114.7	11.8	143.2	2.6	0.5	56.6	30
Southern Africa	240.9	163.8	103.7	48.0	2.4	97.6	43
West Africa	117.8	0.0	290.2	0.2	0.5	11.1	20
Central Africa	137.9	0.4	66.3	0.0	0.1	1.8	19
North Africa	236.7	15.6	1020.2	16.3	10.4	10.4	na[2)]

1) Estimated from national figures summarised by Winrock 1992. 2) Not available.
Source: Rege (1997).

Livestock provide food security

One of the critical problems facing Africa is that of food insecurity, especially in terms of food animal origin. The need for animal food to supply high quality protein and other essential nutrients including minerals, vitamins micro-nutrients in human diets in relatively undernourished developing countries (Table 11) could not be emphasised. It is envisaged that with the predicted increases in human population (3.2% per annum) and urbanisation (54%), demand for more food in developing countries will also increase and that with possible increase in annual income growth, there will be a shift from staple grains to livestock products (Fitzhugh, 1993). Among pastoralist and agro-pastoralist communities, food of animal origin (blood, meat and milk) could account for 90 - 100% of the daily household food supply. Thus, animal agriculture will become crucial to the enhancement of food security, poverty alleviation and sustainable agricultural development in the region.

Table 11
Relative per caput consumption of meat and milk in 1990 (kg/year)

Region	Commodity	
	Meat	Milk
World	33	75
Developed	82	200
Developing	18	37
Africa	11	28
Latin America	41	94
Near East	20	61
Far East	15	27

Source: Sansoucy et al. (1995).

However, current total animal production falls far below the projected demand. The Winrock (1992) reports predicted a shortfall of 3% for meat and 8% for milk by the turn of the century and that to feed some expected extra 800 million mouths by the year 2025, Africa will need to increase its meat and milk production by at least 4% per annum.

Indigenous African livestock have potential to provide high quality protein foods (meat milk and milk products and eggs) including essential nutrients, especially for pastoral and agro-pastoral communities that depend mostly on their livestock for their well-being. (Tables 12 and 13). The Butana and the Kenana of Sudan (Table 12), for example, could produce up to 10 kgs of fresh milk daily per lactation, which compares well with the average lactation milk yield of Friesian cows on an average smallholder dairy farm in Kenya (Rege, 1991). When lactation performance is adjusted for factors such as butter fat content and mature body, a Butana cow weighing 400kg could be as productive as, if not more productive than, a Friesian cow weighing 650 kg (Rege, 1997).

Very recent production and consumption estimates are difficult to obtain. Between 1990 to 1992, meat produced locally from ruminant livestock (cattle, sheep and goats) contributed about 70.5% (3.2 million tons) of the total meat (4.5 million tons) produced in SSA (Table 13). Beef accounted for about 71.4% (2.3 million tons) of the meat produced by ruminants only and about 50.3% of the total meat produced by both ruminants and monogastrics (poultry and pigs) in the sub-region. During the same period, meat produced locally by both ruminant and monogastric livestock accounted for about 96.7% of the total meat consumed in SSA, with cattle alone accounting for nearly half of the total meat consumed. Similarly, ruminant livestock (Cows and goats) produce a total of 11.3 million tons of milk, which accounted for nearly all (91.5%) of the milk consumed in SSA during the period. Again, cattle account for most (85.6%) of the total milk produced and about 78.3% of the total milk consumed during the period.

Table 12
Some Promising indigenous cattle breeds of Eastern and Southern Africa for dairy Production

Breed	Location	Milk production (kg)	BF (%)	Lactation Length (days)	Fat-corrected milk (kg)[1)]
Barea	Ethiopia/Eritrea	670-1,800	5.0	170-185	817-2,194
Butana	Sudan	1,000-5,600	5.5	190-580	1,299-7,272
Kenana	Sudan	700-4,600	4.5	220-400	798-5,242
Kenya Sahiwal	Kenya	900-2,700	5.0	270-320	1,097-3,291
Mpwapwa	Tanzania	350-1,600	4.9	92-285	421-1,925
Nkone	Zimbabwe	300-2,300	4.2	100-290	328-2,511

[1)] Corrected to milk of 3.6% butter fat.
Source: Rege (1997).

Table 13
Meat and Milk production, imports, exports and consumption in Sub-Saharan Africa, 1990-1992

Product	Production (000 t)	Net imports (000 t)	Consumption	
			Total (000 t)	Per Caput (kg)
Red Meat	3179	62	3241	6.0
White Meat	1329	85	1414	2.6
Total Meat	**4508**	**147**	**4655**	**8.6**
Milk	11324	1049	12373	22.9

Source: Calculations from FAO production yearbooks and data tapes.

In addition to these direct contributions to food security, livestock owners sometimes rely on income from livestock sales to purchase food grain and grain products, especially when crops fail due to late rains or drought. Some livestock owners exchange animals for food in times of need. The increasing trends predicted in offtake of livestock, especially among monogastrics and small ruminants (Table 14), indicates the increasing dependence of livestock owners on their livestock for their well-being.

Table 14
Estimates of off-take rates for ruminant and non-ruminant livestock in sub-Saharan Africa

Species and Zone	1995	2010	2015	2025
Cattle (total)	10.8	10.9	12.2	13.0
Arid/semi-arid	10.2	10.6	10.7	11.0
Sub-humid/humid	10.6	12.2	12.8	14.0
Highlands	12.5	13.2	14.1	15.0
Sheep and Goats	28.5	37.7	41.4	50.0
Pigs	82.6	90.9	93.8	100.0
Poultry	116.4	131.1	136.8	148.0

Figures for 2010 and beyond predicted from rates of growth in the 1980s and 1990s.
Source: Rege (1997).

It is important to note that nearly 80 % of the domesticated ruminant livestock and about 40 of the monogastrics in Africa are indigenous and hence play an important role in meeting the needs of those that depend on them for the well-being.

Livestock Bring Income Stability

The evolution and expansion of mixed crop-livestock and small-scale commercial peri-urban and urban production systems provide more employment and income generating opportunities. Smallholder dairying and peri-urban animal agricultural practices, especially smallholder poultry and pig production, are all labour intensive. For example, FAO (1992) analysis indicates that slaughtering and marketing of 30 head of cattle, pigs and small ruminants requires 20, 10 and 3 persons per day, respectively (Table 15). More labour is even required for the processing activities. Ruminant by-products (horns, bones, wool, hides, skins and offals) provide raw materials for local industries that also provide jobs and generate income (McCorkle, 1995).

Table 15
Labour needs for processing and marketing for 30 head of stock

Animal species	Labour need (person/day) Slaughter	Marketing	Further processing
Cattle	20	4	>80
Pig	10	2	>30
Small Ruminants	3	1	6

Source: FAO (1992).

Most rural communities that depend on livestock are isolated and do not have banking or any reliable financial institutions. Their livestock have therefore inevitably become their means of investment providing them with easily convertible assets and security against crisis such as crop failures, civil strife, wars, currency fluctuations and unstable commodity prices. In pastoral and agro-pastoral systems, income generated from animal assets is not only used to purchase food grains but to purchase animals for restocking during and after crisis situations such as drought, occasional floods and civil strife and wars. Farm inputs and other household needs are also purchased from these animal-based incomes. It has been reported (Rege,1997) that in 1986 in West Africa, cattle contributed about US$ 396 million to change in farm wealth or capital gains.

Animal agriculture also sustains agricultural output:

In addition their commodity and income stability functions, livestock can provide manure (all species) and farm energy (ruminants only), particularly in the mixed crop-livestock farming systems.

Animal Draught Power could be used for diverse operations. These include bush control, cultivation, threshing, transportation and transformation of farm resources of little or no direct use to humans into high value commodities. It is estimated that about 15% of the smallholder farmers in SSA use ruminant draught power (ILCA, 1987). The use however varies from country to country. Rege's (1997) has extensively reviewed this subject matter and revealed the following: about 10% of the national cattle herd in The Gambia are oxen and about 60% of the farming households use animal traction to cultivate their land; in Ethiopia, 64% of the 14 million acres under cultivation were cultivated using animal power; and in Kenya, about 32% of the 1.3 million ha under smallholder cultivation is cultivated using animal power. Other reports indicate that in Tanzania there are about 0.8 million draught animals with a potential to cultivate 1.6 million ha/year (Mgaya et al., 1994) while Botswana is estimated to have 0.35 million draught animals (Panin et al., 1994). ILRI's work in Ethiopia on cow traction shows potential for the use of crossbred cows in land cultivation in mixed crop-livestock systems in the wetter semi-arid and humid zones of Africa (Zerbini et al, 1994). This technology is particularly exciting because of its potential to promote sustainable natural resource use.

The contribution of animal energy to African agriculture cannot be underrated. In actual monetary terms, ILCA (1987) estimated that in 1975, the value of traction in SSA was around US$ 2,000 million. With the intensification of agriculture, decrease in farm sizes, land use policy changes and the high cost of mechanisation, the use of animal traction among smallholder farmers in rural areas is bound to increase, if this is not already the case. The use of animal energy for cultivation, transportation and processing adds value to agriculture in several ways including an increase in the amount of work done, accomplishing farming operations in time and is less time and reducing the labour stress on the household, particularly the women and the children. All these result in improved efficiency in farming and hence increased productivity and farm income.

Farm Animal Manure has been widely recognised as an important alternative source of soil nutrients for crop production, especially in the emerging mixed crop-livestock production systems in the wetter semi-arid and sub-humid zones of Africa. Dry cow dung also substitute fossile fuel for farm household use in rural areas (Fernandez-Riviera et al; 1993, Lebbie, 1996; Powel et al., 1994; Rege, 1997). For example in Nigeria, it has been reported that overnight dry season manuring in ginger fields and putting animals in cash crop plantations (mango, citrus orchads and oil palm) added fertility to the soils and improved crop yields (Rege, 1997). Manure is critical for sustaining soil productivity especially in these areas where access to commercial fertilizer is limited to a few well-to-do farmers. The amounts of manure available in a given location to support crop production depend on herd/flock size, daily faecal output per animal, efficiency of manure harvesting and preservation, spatial location of livestock during the manuring season and species competition (Tables 16 and 17). Diet quality and animal management both highly influence nutrient excretion by ruminant livestock. In stall fed sheep, those fed browse leaves had the highest faecal-N content followed by those fed cowpea and then millet leaves (Somda et al., 1995).

Table 16
Simulated faecal excretion by cattle, sheep and goat grazing under fluctuating feed supplies (kg DM)

		Season		
Productivity Level	**Total per year**	**Wet (July-Sept.)**	**Post-harvest (Oct.-Jan.)**	**Dry (Feb.-June)**
Low:				
Cattle	793	201	274	319
Sheep	155	38	56	61
Goats	124	32	45	47
Medium:				
Cattle	884	214	317	353
Sheep	175	42	62	71
Goats	134	35	48	51
High:				
Cattle	931	228	323	379
Sheep	184	44	66	75
Goats	141	36	50	56

Source: Fernandez - Rivera et al. (1993).

Tables 17
Tropical Livestock units (TLUs) per cultivated hectare and potential amount of manure collected in Sahelian countries (Medium Livestock Productivity)

Country	TLU/ha	Manure(kg/ha)
Burkina Faso	1.03	465
Tchad	3.60	1593
The Gambia	3.42	1521
Mali	2.70	1223
Mauritania	9.48	4524
Niger	0.70	317
Senegal	1.42	668
Weight mean	1.50	679

Source: Fernandez - Rivera et al. (1993).

When the contribution of form animal energy and manure are monetized , livestock contribution to total national agricultural output could be increased by as much as 10-15% (Winrock, 1992).

Beyond meat and milk

In addition to these commodity values income stability role of animal agriculture, the socio-cultural role of ruminant livestock cannot be over-emphasised. In pastoralists and some agro-pastrolist systems, the conventional products of meat and milk are actually by-products or secondary in importance. For pastrolists, cattle are their dearest possession and virtually the only store of value known to them. Their social life is impossible without them. They provide a useful link between relatives, dead and alive (MacMillan, 1995).

Current Status and Trends in AnGRs Improvement, Conservation and Utilisation in SSA

The prevailing strategies for livestock improvement, conservation and utilisation can be addressed at two major levels, namely, strategies targeting live animals and strategies targeting preserved gerplasm. These strategies in turn employ different techniques in their implementation.

Living Animals

The key players in this domain in SSA are both in the public and private sectors (de Haan et al., 1997). The degree and scope of involvement by these players vary within and across geographical locations.

In the private sector, the main players are the Farmers, Breed Societies, Industries Non-Governmental Organisations (NGOs) and inter-governmental development agencies. The main players in the public sector include the National Agricultural Research Systems (NARS), Government Ministries, Universities, International Research Institutions, and Regional Agricultural Research and Development Associations such as the Association for Strengthening Agricultural Research in Eastern and Central Africal (ASARECA), the West African Council for Agricultural Research and Development (WECARD) and the Southern African Centre for Co-operation in Agricultural and Training (SACCAR).

The efforts of the actors in this category are focused largely on the development, conservation and management of AnGRs in-situ and ex-situ. The successes of the active approach indicated below, is largely due to the fact that (a) the strategies are based on the indigenous animal populations in their adaptive environments and (b) the strategies have also been tailored to fit the production systems. A number of notable activities in SSA are highlighted below.

Smallholder Farmers

Smallholder rural farmers are the current custodians of the majority of the indigenous animal genetic resources in SSA. The conservative attitudes of most of these farmers, as demonstrated in their preference for their local animal genetic resources over those perceived to be superior, is largely responsible for the successful conservation of most indigenous genetic resources today. However, some of them who have adopted the use of new technologies related to, for example, feeding, animal health care and controlled breeding, have also gradually opted for the "improved" breeds and varieties, especially the crossbreds or the synthetics, which shift has serious implications for the sustainability of indigenous AnGRs.

Pastroralists have increasingly adopted opportunistic management strategies to conserve and manage their animal genetic resources under their dynamic and generally hash environments. Over the past two decades or so there has been an increase in the number of pastoral communities that have moved with their animals away from the extensive mobile range systems towards more intensive and sedentary smallholder agropastoral and mixed farming systems in the wetter semi-arid and sub-humid zones. The frequent occurrence of droughts and long dry spells in the region has also made some pastoral communities, who traditionally depended on cattle only, to diversify their animal agriculture by including small ruminants. A notable example is the near two-fold increase in the number of small ruminants (SRs) among Maasai herds in East Africa. Increasingly, population and food demand increases in the wetter semi-arid and sub-humid zones are putting pressure on the limited land for increased food production. This has prompted some local farmers to incorporate small ruminants into their farming systems in preference to cattle because, firstly, holding large numbers of cattle on their small farms will reduce the opportunity for them to put more land under crop production to increase food production; and secondly, SRs offer opportunity for fast turn-over on investment as a result of their short reproductive cycles and early attainment of market weight.

The use of crop-residues and forage trees (mainly cut-and-carry) for supplementary feeding of livestock, especially in the dry season (Fernandez-Rivera et al. 1993) has intensified in the sahel because of the limited grazing available most of time in the year in this region. In the sub-humid and to a lesser extent, humid zones, mixed farming systems are gradually adopting alley farming (Reynolds and Jabbar 1994) and fodder banks (Mohamed-Saalem and Von-Kaufmann 1991) technologies in sub-humid and humid areas of West and Central Africa. In eastern and southern Africa, smallholder mixed farming systems raising crossbred milk goats and cows are integrating pasture to a limited extent and fodder shrubs and forage trees to a large extent in their production systems to cater for their livestock (Ndlovu 1992; Abate and Abate 1994; Semenye et al. 1994;). These systems also feed spoiled grains and bran as concentrate.

In the humid zone of West and Central Africa, ruminant livestock owners are increasing their grazing opportunities by expanding grazing under forests and tree crops such as coconut, cacao and oil-palm plantations. This is particularly so when labour is scarce because of out-migration and the schooling of children who used to herd the animals. Similarly, farmers in South Africa are integrating goats and cattle into their fruit and tree crop plantations.

Small Scale Commercial Farms

This sector comprises the small scale urban and peri-urban (backyard) raising of few dairy cows, fattening of sheep and raising of goats in Central, East and West Africa. For the evolving peri-urban sheep fattening and backyard goat farming systems, the driving force has been the increased demand for rams for the "Tabaski" festival by the large Muslim urban communities in West and Central Africa and the Middle East. Similarly, there is a high demand for grilled mutton popularly known as "Suyah" in urban cities in West and Central Africa and grilled goat meat popularly known as "Nyama Choma" in East Africa. These evolving livestock enterprises have promoted the use of crop-residues, house waste and concentrate for feeding as well as green feed markets commonly seen in urban cities like Addis Ababa, Nairobi, Dakar, Abidjan and Kaduna. The operators mostly use cut-and-carry feeding methods and invest in animal health care and housing. Civil servants (mostly chief executives) and retired civil servants who have extra money to spend are the most important participants in these evolving animal production systems.

Research and Development

The need to characterise the African AnGRs cannot be over emphasised (Rege and Lipner 1992). As noted earlier, majority of the African AnGRs are indigenous but unlike the fewer exotic and the synthetic breeds, very little information exists on most of these important genetic resources.

Currently a reasonable number of these genetic resources are at risk, including those with a critical status (the Pafuri goat of Mozambique, Nungua Blackhead sheep of Ghana, the Pedi cattle of South Africa), the endangered (the Namaqua sheep of Namibia and South Africa; the Watende cattle of Kenya) and those with the decreasing number status (the Touare sheep in Mali, Niger and Chad; the Blended goat in Tanzania; and the Basuto cattle of Lesotho) to name a few. Comprehensive though not exhaustive accounts of these could be found in Rege and Tawah (1999) and Lebbie and Ramsey (1999) Many more could be at risk, but these can only be identified through an effective and systematic characterisation of these genetic resources.

The key actors in this domain are the International Agricultural Research Centres (IARCs), mainly the International Livestock Research Institute (ILRI) and the International Centre for Research in Agro-Forestry (ICRAF), intergovernmental international and regional organisation and programmes such as the Food and Agriculture Organisation (FAO), the Inter-Africa Bureau for Animal Resources (IBAR) of the Organisation of African Unity (OAU) and the Environmental Programme of the United Nations (UNEP), NGOs and donors including the USAID, EU, UNDP and SIDA. The potential and relative importance of the conservation actions and key players are as indicated in Table 11). It is obvious that the private sector has a major role to play though the ultimate responsibility for the characterisation and the conservation of AnGRs in SSA lies with the national Governments.

So far, ILRI in collaboration with its NARIs partners in SSA and the FAO, has embarked on a programme for the systematic characterisation of the African Animal Genetic Resources including cattle, goats and sheep on contract basis as well as in collaboration with the Animal Agricultural Research Networks in ASARECA, WECARD/CORAF and SACCAR.

A research planning meeting hosted by ILRI (then ILCA) in 1992 identified ruminant livestock as priority area for conservation and hence characterisation. To this effect, ILRI is working with its NARS partners to develop standard methodologies to ensure similar data sets are collected in characterisation studies. The AnGRs studies have focused on "breed" surveys and documentation, and on-farm and on-station breed characterisation. The information on "breeds" and their strains/varieties documented to date for sheep and goats can be found in Lebbie and Ramsey (1999) and Rege.(1997) and for cattle in Rege (1997). This information can be obtained from the ILRI- developed "Domestic Animal Genetic Resources Information Database" (DAGRID). This database provides information on the geographical distribution of the known AnGRs, physical characteristics, performance under different conditions, unique genetic characteristics and population trends. The phenotypic characterisation work is complemented by molecular characterisation involving (a) the use of microsatellite markers to estimate the genetic diversity and distances among populations of cattle, sheep and goats.

Other areas of current research focus by ILRI and its NARIs collaborators include studies on the genetics of adaptive characteristics including genetic resistance to gastro-intestinal parasitism in tropical small ruminants (Baker et al., 1993) and tolerance to trypanosomosis in cattle. This work involves searching for Quantitative Trait Loci (QTLs) for resistance to internal parasites and tolerance to trypanosomosis. The summary on the results so far obstained from these initiatives can be found in Lebbie et al. (1996).

Nucleus breeding schemes

Nucleus breeding schemes are centralised improvement programmes, which build their base populations ("elite nucleus flocks/herds") from superior animals supplied by willing farmers. Open nucleus breeding strategies (ONBS) have been used in Cote d' Ivoire (Oya 1992) and in Togo (Pessinaba 1992) for the improvement of indigenous Djallonke sheep since the early 1980s. Both programmes select and distribute Djallonke rams to participating and non-participating farmers for improved growth performance. Nucleus breeding schemes for indigenous SRGR are also notable in a number of Other countries including Botswana Ethiopia, Kenya, Lesotho, Malawi, Namibia, South Africa, Swaziland and Zimbabwe inter alia, breeding schemes at central breeding stations, like for the Ngone in Zimbabwe and the Nguni in South Africa and Swaziland, that provide improved germplasm to smallholder farmers.

Dairy goat cross breeding schemes

A number of well conceived dairy goat development projects have and continue to play an important role in the in-situ development and conservation of animal genetic resources in SSA, particularly for low cost smallholder milk production in the rural communities. The schemes generally involve planned crossbreeding of indigenous goats with "improver" breeds, mostly milk breeds including the Toggenburg, Alpine, Saanen and Aglo-Nubian inter alia. Some of the well documented cases in this are include the Farm Africa Dairy Goat Development Project in mixed farming systems in Eastern Ethiopia, Tanzania, Kenya and recently in Uganda (Peacock et al., 1990); the Ngozi Goat Development Project in Burundi that was supported by the German Technical Co-operation (GTZ), ILRI (ex-ILCA) and the Burundian Government (Rey and Jacob 1991); and the Small Ruminant Collaborative Research Support Programme (SR-CRSP) Dual Purpose Goat initiative between the Kenyan Government and US-AID (Boor et al., 1987; Johnson et al., 1968; Semenye et al., 1989). The main focus and impact of these projects was upgrading the milk production capacity of the indigenous East African goat by crossing it bucks from the exotic breeds. Studies with Saanen - local goats crosses by the Department of Animal Health and production in the Faculty of Veterinary Science at the Medical University of South Africa (Donkin et al., 1996) and the Animal Science Department of the Bunda College of Agriculture in Malawi (Cooper et al., 1996) have indicated a great potential to add value to indigenous goat genetic resources. These goat improvement initiatives use the adaptive characteristics of the indigenous goats (hardiness and disease tolerance or resistance) to exploit the productive superiority of the more fragile and disease susceptible improved genotypes. Because these efforts are largely community based, they have led to renewed interest in the indigenous breeds in the participating communities and there is potential for multiplier effects.

Development of new genotypes

An impressive number of synthetic or composite breeds of sheep and goats (Lebbie and Ramsey, 1999) and Cattle (Rege, 1999; Rege and Tawah, 1999) have been developed across SSA using indigenous genetic material and exotic genotypes. This strategy has tremendous potential for animal genetic resources development by providing new genetic combinations and expanding diversity.

Community based integrated wildlife-livestock systems

The emerging community-based integrated wildlife-livestock production systems in South Africa, Namibia and Zimbabwe have great potential for effective in-situ genetic resource conservation, management and utilisation (Cumming, 1993). This strategy has potential to boost eco-tourism in leading tourist countries like Kenya, South Africa, Tanzania and Zimbabwe and to a lesser extent Botswana, Swaziland and Burkina Faso.

Cryogenic Conservation and Management

The are has been actively mostly in the semen collection and use in Artificial Insemination (AI) schemes. AI is widely used in the dairy sector, particularly for producing crossbred cows for market-oriented smallholder schemes in most countries, notably in eastern and southern Africa. Though Ai is extensively used, it only covers a small proportion of breedable animal populations, at most 15%. Also the success rate has not been very high. A number of factors could be responsible for this. In a number cases, particularly in small ruminants AI is based on chilled rather than frozen semen. IN most case handling facilities are inadequate. The selected dams are sometimes poorly fed and of poor quality. Again, in most cases the technicians are not adequately trained.

The use of embryo transfer (ET) and multiple ovulation and embryo transfer (MOET) has not yet got on very well in most countries. Even where they used, such as in Namibia, South Africa and Zimbabwe, they pure for getting clean genetic material for export purposes. South Africa currently earns about US 1.0 million per annum from exporting embryos of sheep and goats only. Lack of adequate resources, including infrastructure and finances, has made it impossible for most countries and institutions in Africa to carry out major activities in this area.

Challenges and Constraints to Sustainable Animal Agriculture in Africa

Notwithstanding its tremendous importance and potential for the economic development of millions of poor people in the developing world, animal agriculture is potentially an "endangered" agricultural activity in the whole world, especially in the resource poor sectors of Africa. This is attributed to a number of reasons. These include: the limited knowledge about Africa's diverse AnGRs; controversies of the implication on livestock management and use for human health and the environment; the prevailing biased economic development policies; and inadequate resources for livestock research and development initiatives.

Lack of or Limited Knowledge on Indigenous AnGRs

As indicated earlier in discussing the diversity of the African AnGRs, there is very little or nothing known about most of the indigenous AnGRs. Where information exists as in the FAO global Domestic Animal Diversity Information System (DAD-IS) and the ILRI Domestic Animal Genetic Resources Information Database for Africa (DAGRID), it is fragmented and incomplete. Indigenous sources of disease and parasite resistance/tolerance and adaptation are poorly characterised and ineffectively used in breed improvement programmes. Basically there is a general lack of systematic characterisation of these diverse genetic resources.

Controversies

Livestock, particularly in the smallholder sector, have been variously associated with environmental degradation, cardiovascular problems in humans, global warming, environmental pollution, low internal returns on investment etc. etc. These matters have been well documented and debated without resolve at many fora (Scoones, 1994; Hooges, 1993; Winrock, 1992; Somida et al., 1995; Sansoucy et al., 1995; de Haan et al., 1997) and therefore do not require any further battering. Let it just be mentioned that we subscribe to the belief that " livestock do not set out to destroy the environment, it is the socio-economic-political context, defined by humans, which determines livestock's effect upon their surroundings" (de Haan et al.,1997) and those keep and use them. In short, livestock - environmental interactions are driven by humans and not his livestock.

Biased Economic Development Policies

In appropriate policies have continued to seriously hamper the development of the animal industry, particularly the smallholder sector.

In most countries in Africa, economic development tends to be biased in favour of urban development from the stand point of a range of policies that affect the livestock sector. These include, trade, microeconomic and sectoral policies as well as investment in post-production micro-enterprises, marketing facilities and marketing information dissemination, public infrastructure and animal health services delivery (Williams et al., 1995). The consequences of these biases have been differential economic developments that have disadvantaged the majority of the resource people in the impoverished rural areas and have lead to unprecedented high rate of urbanization and importation of animal and animal products to meet the ever increasing demand for animal protein.

Livestock development efforts have also promoted biases that should be of concern. With the exception of a few countries, like South Africa, Zimbabwe, Kenya and Ethiopia, most public institutions in Africa have focused almost exclusively on cattle for meat and milk production, thus causing distortions in livestock production and the marginalization of other livestock species like small stock. Similarly, public institutions have focused their research and development efforts on introducing exotic genetic material which have unsystematically diluting the indigenous genetic resources through inappropriate and untested crossbreeding or germplasm replacement strategies. The marginalisation of the indigenous genetic material if not checked or controlled will result in the disappearance of valuable local genetic resources.

Institutional Constraints

Funding for animal agriculture in the developing world, especially for SSA, has shown an unprecedented decline in the past decade or so. This situation is largely due to the controversies discussed earlier in this paper as well as the lack of the political will and ability in most countries to invest adequately into the livestock sector. Most Governments support huge staff salary bills and have very little operating funds to operationalise their livestock development and improvement strategies.

The implications of this trend are that less and less livestock research and development activities will be undertaken at international, regional and national levels. This means no appropriate technologies will be developed or transferred to impact livestock production. It is inevitable that under such circumstances, the livestock sector, especially the smallholder sub-sector, will remain under developed. This could even lead to loss of animal biodiversity for lack of improvement. Unless the situation is reversed, animal production will decline and importation will escalate to support demand, but in the long-term this is not sustainable as most the countries in Africa have foreign exchange problems.

Institutions generally do not have the capacity to generate and transfer sufficient technology to fuel animal agricultural development. The Extension Agencies are weak and inefficient in delivering interventions to the end-users. Equally, the lack participatory approach culture has promoted very weak Researcher-Extension-User linkages. Public veterinary services lack the capacity to provide the much needed integrated animal health services to cater for the higher disease challenges. The outlook will be even more gloomy as more livestock are raised in wetter areas, more crop farmers with little traditional knowledge of livestock farming become involved in raising livestock and as livestock production intensifies.

Human resource development is key to the effective implementation of any national or regional strategies for improving livestock production at all levels. Must countries do not have the necessary scientific critical mass to drive a holistic and multidisciplinary approach to solving problem in a systems context. Training of animal scientist is deficient. Undergraduate curricular do not prepare the young professional to meet the challenges of contemporary agriculture, especially animal scientists and veterinarians. In the same vein, postgraduate education falls short of equipping researchers for development-oriented agricultural research.

The farmers themselves are not empowered to fully participate in taking decisions that influence agricultural policies and the technologies generated and delivered to them for use. This is largely because they are poorly organised.

Technical constraints

The major technical constraints hampering livestock development in low input systems include inadequate feed quantity and quality, animal diseases and parasites, and poor management.

The potential carrying capacity of agro-ecological zones differs. The arid rangelands are near maximum production and thus provide minimum opportunities for increase in production. While opportunities exist for farmers in the cool highlands to produce more feed by increased use of new technologies and inputs, it must recognised that feed resources in these zone are limited. They also form a small proportion of total land area The semi-arid and the sub-humid zones, on the other hand provide major opportunities for more food production that could support more livestock.

In addition to feed constraints, livestock farmers in the smallholder sectors experience great losses on account of large incidences of infectious, parasitic and non-infectious diseases. Estimates show that in sub-Saharan Africa, losses attributed to diseases amount to about US$ 4 billion per year, representing about one-fourth of the total value of livestock production in the region (Fitzhugh, 1993). As livestock production intensifies, diseases impact on productivity will become important.

Most of the smallholder farmers keep indigenous AnGRs. These resources are largely neglected and poorly managed thus resulting in low productivity. While one could argue that their genetic potential for the production traits is low, it must be equally agreed that their adaptability traits make them a better choice for the smallholders the pure exotic breeds. But the general tendencies to opt for improved genotypes and ill conceived crossbreeding programmes for livestock development further robes nations the opportunity to exploit the inherent within and between diversity provided by the indigenous germplasm.

Man-made (civil strife and wars) and natural (drought, floods and endemic disease outbreaks) have caused untold losses in livestock in many countries, particularly among livestock dependent communities like the pastoralists. The wars in Sierra Leone, Rwanda, the Democratic Republic of Congo, have decimated over 80% of the national animal populations. In Kenya, the current drought has resulted in the death of over a million ruminant livestock mainly cattle, sheep and goats in the descending of level of demise. The El-Nino and the floods in Mozambique and other countries in southern Africa have had similar effects on livestock in the region.

Strategies for Achieving Sustainable Animal Production

As indicate earlier, Africa is endowed with a wide variety of breed and strains of indigenous livestock. There is need to promote and popularise the use of these indigenous AnGRs with unique/adaptive genetic attributes such as resistance or tolerance to biotic and abiotic stresses. Work in ILRI (1994) has demonstrated that there are substantial between and within breed variations in susceptibility to endoparasitism and in nutrient partition and utilisation under stressful conditions. The identification and use of breeds with these unique attributes will enhance the conservation and use of these genotypes. This potential of the AnGRs has largely remained untapped. The region at the same time, like most other developing regions, is faced with new challenges concerning the fragility of its natural resource base and in particular the erosion of its animal biodiversity. To address these challenges, there is an obvious need for a comprehensive programme for the promotion of the conservation and utilization of the African AnGRs.

Commercialise indigenous animal genetic resources

The ultimate success and sustainability of any AnGRs conservation programme depends on the effective participation of the key players, individual farmers and breed societies. Conservation is appealing only if it results in economic benefits. Therefore it is important to commercialise the indigenous breeds to encourage farmers and societies to maintain them.

This could be achieved by diversifying the utilisation of the indigenous breeds and create niche markets. For example, the successful use of the Boer goat alone or in combination with cattle and burning in the control of bush encroachment in the Northern and Eastern Cape provinces of South Africa (Du Toit, 1972; Aucamp, 1976; Donaldson, 1979; Jordaan and le Roux, 1996) has resulted in renewed interest in the improved large Boer goat and its commercialisation. Another activity that could add value to indigenous AnGRs is the promotion of cottage industries such as those based on cottage cheese and cashmere. There is need to support the development of rural-based tannery and dairy industries that could convert AnGR raw materials such as skins and milk into quality products for sale.

Rapid genetic improvement through marker assisted selection for the major adaptive traits provides other opportunity to drive better use of indigenous livestock. The use of QTLs makes this achievable.

Broad-based economic development

The current focus on urban development to the detriment of rural development must be reversed and balance development policies advocated. Rural development will provide jobs and less rural dwellers will be attracted to the urban areas. This in turn will create prosperity for the urban populations Unless there is equitable distribution of efforts and resources, a nation cannot have broad-based economic growth. As already been mentioned, while exploiting the benefits of crossbreeding, attention should be given to the development and conservation of indigenous genetic resources.

Provision of reliable and adequate information

As indicated before, very little is currently known on most of the indigenous AnGRs in SSA. Adequate knowledge of their potential and unique attributes is essential to effectively utilise them. Information such as effective population sizes of available distinct genotypes will provide opportunity to initiate timely interventions to save populations at risk. Development of a well managed national as well as regional databases and information systems is required to collect necessary information for use by all involved. Therefore, systematic characterisation of indigenous AnGRs is a prerequisite for any effective AnGRs development and improvement strategies.

Intra-regional and inter-regional co-operation

The effective and sustainable conservation and management of national and regional animal genetic resources could have major financial and *infrastructural* implications, especially in the case of *ex-situ* conservation. Trans-boundary movements of animals have implication for conservation and improvement activities, especially as regards diseases and their effect on trade, whether external or internal.

Unfortunately, there are differences in the capacities of the various countries in the region in terms of expertise, money and infrastructure to undertake any meaningful animal genetic resources conservation activity. At the same time there is a general international economic contraction, which is likely to make the access to bilateral funds by nationals increasingly difficult. However, through inter-regional and intra-regional co-operation and initiatives, participating members can benefit from sharing resources including information, database, infrastructure, genetic material and expertise. Such integration also provides opportunities for harmonising policies on trade, natural resource management including the conservation or indigenous livestock. The international community needs to support such efforts, especially in their initial stages. The existing sub-regional associations (ASARECA, WECARD and SACCAR together with their newly formed Animal Agriculture Research Network provide the framework for regional collaboration. Also, the FAO/SADC/UNDP initiative on the management of animal genetic resources in SADC is another recent relevant initiative in this direction. Similar initiatives are underway for eastern and western Africa.

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The South American Perspective on the Use of Animal Resources

José Bento Sterman Ferraz[1] and Joanir Pereira Eler[1]

Introduction

South America is quite heterogeneous as related to environmental conditions and there are diverse sets of production-marketing systems that have to be considered. As the agribusiness is very important to South-American economy, but also to the world's economy, any improvement in economic efficiency will give substantial benefits and therefore would be very worthwhile (Smith, 1989).

The Brazilian Society of Genetics held a Conference on that subject in 1989, with several important papers that should be referred in any study on the use of genetic resources in Latin America. Some important papers on strategies in genetic resource utilization (Smith, 1989), crossbreeding performance (Eisen, 1989), evaluation of dairy and dual purpose cattle (Vaccaro, 1989), beef cattle breed resources utilization (Koch et al., 1989), sheep breeding programs (Cardelino, 1989); camelids improvement programs (Novoa, 1989), alternative genetic resources as capibara (Lavorenti, 1989), beef cattle breeding or crossbreeding programs in Argentina (Joandet, 1989), Venezuela (Plasse, 1989) and Brazil (Barbosa and Duarte, 1989); dairy breeding programs in Brazil (Madalena, 1989; Lôbo and Reis, 1989), Bolivia (Wilkins and Rojas, 1989), Cuba (López, 1989) and Argentina (Musi, 1989) and genetic resources conservation in Brazil (Mariante and Trovo, 1989) were published.

But things have changed a lot in the world's economy in the last ten years and more recently, the Brazilian Society of Animal Breeding (SBMA) had presented in it's 3rd Symposium actual overviews of beef programs in Venezuela (Plasse, 2000) and Brazil (Barbosa, 2000; Euclides Filho, 2000; Ferraz and Eler, 2000; Josahkian, 2000; Leachman, 2000; Pineda, 2000; and Pötter, 2000 and Schenkel, 2000), dairy programs in Venezuela (Vaccaro, 2000) and Brazil (Martinez et al., 2000; Melo and Penna, 2000; Menezes, 2000; Dürr and Rorato, 2000; Vercesi Filho and Madalena, 2000; Verneque et al., 2000 and Thaler Neto, 2000); swine breeding programs in Brazil (Freitas, 2000; Guimarães and Lopes, 2000; Nascimento, 2000), breeding programs in poultry (Figueiredo et al, 2000 and Michelin Filho, 2000), programs in goats and sheeps in Brazil (Gonçalves, 2000; Morais, 2000; Ollivier, 2000; Ribeiro, 2000; Vieira et al., 2000 and Araújo and Simplício, 2000) and also on horse breeding in Brazil (Bergmann, 2000). References on genetic resources on goats in Mexico can also be found in Montaldo and Meza (1999 and 2000). O lot of very important information is also at FAO's DAD (Domestic Animals Diversity System, www.fao.org).

Those references can give a good technical and scientific overview of a lot of programs that are being conducted in Latin and South America.

The objectives of this paper are to give an overview of South American animal production and discuss its perspective as related to genetic resources utilization and the possible impact of new technologies in production.

South American Animal Production - some statistics

To clarify the position on South America in the world scenario of animal production, some information and statistics are important to be known. South America is a sub-continent with 17,819,100 km2, 12% of the total surface of the planet. The distance between Caribbean Sea, its northern extreme and Cape Horn, its southern extreme is 7,400 km (Microsoft Encarta 2000(). It is linked to Central America through Panama. The countries that are located in South America are Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay, Venezuela, Guyana, Suriname and a French possession, French Guyana. Are also part of South America some Pacific and Atlantic Islands, like Galapagos (Colombia), Fernando de Noronha (Brazil), Juan Fernandez and Easter (Chile), etc.

South America lies from a latitude close to 14ºN to 50ºS, and longitude from close to 34ºW to 82ºW. Although 12% of land in globe is in South America it's population in 1990 was 304 million people, around 6% of the total earth people. Table 1 presents the estimated population to 2000 and its per capita income (Barsa Encyclopedia, 2000).

Topography, climatic conditions and soil fertility are quite variable in South America, which leads to a great variety of production systems in the agribusiness.

In South American countries, the major animal production is beef cattle. Table 2 presents the size of beef cattle herds, annual growth rate of herds, % of animals slaughtered, and t of carcasses produced per South American countries, compared to some European, North American and Asian countries.

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Table 1
Capital, population, Gross National Product and Per Capita Income of the South American countries

Country	**Capital**	**Population ($x 10^3$) 2000 (estimated)**	**Gross national product (US$ 10^6) 1995**	**Per capita income (US$, adjusted)[1)] 1995**
Argentina	Buenos Aires	36,648	278,471	8,310
Bolivia	La Paz	8,329	5,905	2,540
Brazil	Brasília	164,163	579,787	5,400
Chile	Santiago	15,086	59,151	9,520
Colombia	Santa Fe de Bogota	37,882	70,263	6,130
Ecuador	Quito	12,646	15,997	4,220
Guyana	Georgetown	780	493	2,420
Paraguay	Assumption	5,480	8,158	3,650
Peru	Lima	25,662	55,019	3,770
Suriname	Paramaribo	445	360	2,250
Uruguay	Montevideo	3,278	16,458	6,630
Venezuela	Caracas	24,170	65,382	7,900

[1)] Adjusted to international prices buying power.

Source: Barsa Encyclopedia (2000).

Table 2

Size of beef cattle herds, annual growth rate of herds, carcasses produced per South American Country, compared to some

Country	**Size of herd (10^3 animals)**	**N. of animals slaughtered/year (10^3 animals)**	**Off take rates (%)**	**Carcasses produced (kg x 10^6)**
Argentina	49,415	13,000	26	2,760
Brazil	158,435	35,743	23	7,322
Colombia	19,369	3,698	19	662
Paraguay	9,970	1,320	13	274
Uruguay	10,900	1,950	18	450
Venezuela	13,100	1,650	13	356
USA	96,447	35,470	37	11,432
Canada	12,650	3,700	29	1,178
Mexico	21,888	8,150	37	1,790
France	19,500	5,695	29	1,580
Germany	14,314	4,500	31	1,320
U.K.	11,440	2,608	23	709
Russia	24,815	10,300	42	1,800
China	143,000	21,000	15	4,580
India	319,724	13,000	4	1,700
Japan	4,560	1,285	29	255
Australia	26,300	8,360	32	1,860
New Zealand	9,290	3,557	38	580

Source: Adapted from Anualpec (2000); USDA, apud Anualpec (2000).

South American countries can be big beef exporters. Table 3 shows the beef exports, imports and per capita consumption of beef per South American countries, compared to some European, North American and Asian countries and also an analysis of the annual trend (rate of growth of production) in the last decade for those characteristics. Table 4 presents the amount of semen sold for beef cattle in Brazil in 1999, what gives a nice idea of how are the breeds being used in that country. It is important to say that the average cow used in the country is a Zebu (Bos taurus indicus) cow or a F1 (Zebu x Bos taurus).

Table 3
Beef exports, imports, per capita consumption and trend in the last decade, expressed as rate of growth per South American Country, compared to some European, North American and Asian countries (estimates for 2000)

Country	**Exports (kg x 10^6)**	**Imports (kg x 10^6)**	**Per capita consumption (kg)**	**Growth rate of beef production (%)[1)]**
Argentina	350	-	85.2	0.94
Brazil	600	36	40.9	1.27
Colombia	4	-	16.8	0.13
Uruguay	250	-	80.0	5.45
Venezuela	4	6	8.5	-0.31
USA	1,027	1,368	42.8	1.38
Canada	480	275	31.3	2.91
Mexico	5	237	19.8	0.84
France	335	315	26.9	-2.89
Germany	375	240	14.9	-5.54
U.K.	25	230	15.8	-5.93
Russia	75	505	15.9	-8.18
China	45	-	3.6	2.98
India	250	-	1.4	3.84
Japan	-	985	11.9	-1.83
Australia	1,235	-	33.8	0.97
New Zealand	450	-	33.8	3.78

[1)] Trend in the last 10 years, calculated as regression of production on year/mean.
Source: Adapted from Anualpec (2000); USDA, apud Anualpec (2000).

Table 4
Number of doses of semen of beef breeds sold in Brazil in 1999

Beef Breeds	**Number of doses**
Red Angus	799,270
Nelore	732,085
Simenthal	340,114
Limousin	277,387
Pooled Nelore	201,975
Aberdeen Angus	143,859
Pooled Hereford	63,067
Tabapuã	48,212
Charolais	47,614
Braford	42,652
Gir	41,839
Guzerá	36,830
Blonde D'Aquitaine	34,355
Santa Gertrudis	32,902
Brangus	32,893

Source: ASBIA (2000).

South American countries produce a great amount of other livestock also. Large production of milk, pork, chicken, eggs and some production of sheep and goats are available on those countries. Table 5 presents the actual figure for dairy in some South American Countries, compared to some other countries and Table 6 shows the amount of semen sold in Brazil per dairy breed. Table 7 presents the figure for chicken and egg production, while Table 8 refers to pork production and Table 9 presents the information on sheep and goat industry. Out of tables, is the information that the Water Buffalo herd in Brazil is 921,000 heads, and it is continuously growing at a rate close to 1%/year. Also fish production is growing in South American countries, mainly in fresh water species. Several projects of raising fresh water fishes are running today in Brazil.

Table 5
Number of dairy cows, milk production, milk yield/cow/year, per capita fluid milk and cheese consumption per South American Country, compared to some European, North American and Asian countries (estimates for 2000)

Country	Number of dairy cows ($x 10^6$)	Milk production ($kg x 10^6$)	Milk yield/cow (kg/lactation)	Per capita fluid milk consumption (kg/y)	Per capita cheese consumption (kg/y)
Argentina	2,470	9,750	3,900	64.77	11.59
Brazil	16,700	22,495	1,343	80.18	2.69
Chile	612	2,230	3,638	28.61	-
Peru	610	950	1,583	24.20	-
Venezuela	735	1,200	1,622	7.78	2.80
USA	9,134	72,650	7,934	97.94	13.44
Canada	1,242	8,340	6,726	95.28	11.25
Mexico	6,800	8,050	1,201	37.57	1.53
France	4,400	24,500	5,528	67.66	22.50
Germany	4,700	28,500	5,891	63.35	12.57
U.K.	2,000	14,550	7,167	117.69	9.91
Russia	12,500	33,000	2,444	93.30	1.97
China	2,280	7,600	3,423	2.88	-
India	35,800	36,000	1,014	32.93	-
Japan	1,000	8,500	8,433	39.01	1.73
Australia	2,152	9,930	4,682	101.60	10.79
New Zealand	3,295	11,460	3,489	115.42	9.52

Source: Adapted from Anualpec (2000); USDA, apud Anualpec (2000).

Table 6
Number of doses of semen of dairy breeds sold in Brazil in 1999

Dairy Breeds	Number of doses
Holstein	1,820,073
Jersey	292,149
Milking Gir	165,061
Brown Swiss	83,214
Milking Guzera	22,307
Girolando	15,872

Source: ASBIA (2000).

Table 7
Broiler production, per capita broiler consumption, broiler exports, egg production, per capita egg consumption per South American Country, compared to some European, North American and Asian countries (estimates for 2000)

Country	Broiler production ($kg x 10^6$)	Per capita broiler consumption (kg)	Broiler exports ($kg x 10^6$)	Egg production ($un x 10^6$)	Per capita egg consumption (un/y)
Argentina	835	23.5	22	-	-
Brazil	5,240	25.7	814	15,426	89
Colombia	638	-	-	8,868	206
USA	14,042	43.3	2,121	84,360	255
Canada	870	28.5	60	6,175	212
Mexico	1,730	18.2	-	30,984	304
France	1,150	12.9	300	17,200	263
Germany	395	8.2	17	14,250	227
U.K.	1,180	22.6	-	10,100	172
Russia	320	5.6	-	31,000	198
China	5,600	4.8	380	400,000	312
India	377	-	-	37,000	36
Japan	1,055	12.6	-	41,800	345

Source: Adapted from Anualpec (2000); USDA, apud Anualpec (2000).

Table 8
Sow herd, pork production, pork exports and per capita consumption per South American Country, compared to some European, North American and Asian countries (estimates for 2000)

Country	Sow herd ($x 10^3$)	Pork production (heads $x 10^6$)	Pork export (kg $x 10^6$)	Per capita consumption (kg)
Brazil	3,150	24,533	80	10.1
USA	6,472	97,950	544	30.2
Canada	1,285	20,174	610	33.6
Mexico	880	13,218	-	10.1
France	1,470	26,920	593	38.2
Germany	2,630	42,700	300	57.4
U.K.	665	14,047	201	23.5
Russia	3,000	26,934	-	12.0
China	31,000	495,000	100	30.1
Japan	930	16,980	-	16.6
Australia	306	5,000	-	18.9

Source: Adapted from Anualpec (2000); USDA, apud Anualpec (2000).

Table 9
Size of herd and number of animals slaughtered for goats and sheep per South American Country, compared to some European, North American and Asian countries (estimates for 2000)

Country	Size of herd (kg $x 10^3$)	Number of animals slaughtered (kg $x 10^3$)
Argentina	14,100	3,400
Brazil	22,722	-
Uruguay	14,500	3,400
USA	6,566	3,100
Mexico	15,438	8,900
France	10,540	8,315
Germany	2,290	2,143
U.K.	30,250	19,085
Russia	15,700	5,863
China	349,000	200,000
India	181,440	93,500
Australia	117,100	31,800
New Zealand	46,135	30,265

Source: Adapted from Anualpec (2000); USDA, apud Anualpec (2000).

The South American Perspective

Some comments on actual circumstances of South American animal production are needed. The analysis of Table1 1, 2 and 3 give a nice idea of how beef production is changing in these days of global economy. The key word is not production anymore, but costs of production. And here is one of the great advantage of South American countries over the other beef producers.

As the major part of South American countries is located in tropical or subtropical regions, they have very interesting pasture resources that have a very high productivity in rainy season, with a medium quality protein levels and high capacity of animal support, frequently over 1 A.U. (450 kg of liveweight). That, allied to very low labor costs, around US$5.00 to US$6,00/day for non-qualified workers, lead the costs of production in those countries very low, as compared to North American and European countries. Cost of production of Brazilian beef (US$0.99/kg) is around 1/3 of Irish costs (US$2,90/kg), 1/2 the costs of USA beef and lower than Australian (US$1.60/kg), New Zealander (US$1.23/kg) or Argentine (US$1.30) beef production costs, mainly because animals are produced in pastures, instead of under confinement (Josahkian, 2000).

However in dry season the amount and quality of roughage decreases significantly, what is a major problem to production. Several researches are being conducted to find cheap solutions to the problem.

The recent demand for "ecological", "organic" or "green" beef , specially for European countries, will cause some changes in the market, as an overprice will be available for those who raise animals under the roles for organic food (Paranhos and Cromberg, in Anualpec 2000, mpcosta@fcav.unesp.br).

Bovine breeds are not from America. The first Europeans that came to America introduced them. South American countries started to raise domestic animals for meat and egg production purposes in the 16th Century, after colonization started. Animals, mainly beef and dairy cattle, goats and sheep were brought from Portugal and Spain and originated the "local" breeds, naturally selected over centuries to adaptation characters like tolerance to heat stress, resistance to some diseases, a certain resistance to ticks, etc.

In cattle, those animals gave origin a some animals known as Criollos, like the Romo-Sinuano beef breed (Venezuela and Colombia), the Criollo en Bolivia (Wilkins and Rojas, 1989) and Paraguay, the Caracu and Mocho Nacional in Brazil, all Bos taurus animals. Those breeds were very important in all South American countries until the Zebu (Bos taurus taurus) started to be introduced from India, initially slowly, at the beginning of the 18th Century (maybe 1823), but strongly between 1870 and 1875 (Josahkian, 2000).

The introduction of Zebu cattle in Brazil was free until 1920 and controlled from 1920 to 1962, when it was forbidden. Around 6.300 Zebu animals were introduced (Josahkian, 2000). Those animals adapted so well and grading-up mating was adopted, using the "native" or "local" Bos taurus (Criollo type) cows. The first Zebu Herdbook started in 1919. Today, the estimate is that around 128 million cattle in Brazil has a major Zebu contribution (Josahkian, 2000), a very impressive example of a successful animal breed adaptation in World's history. Breeds like Gir, Nelore (the Ongole from India), Guzera grew a lot in number. The Indubrasil, a Zebu composite was formed from crosses between the other Zebu breeds and had a big importance until the 70's.

However, the most impressive growth was observed in Nelore breed, both horned and pooled varieties, that today respond for more than 75% of the Zebu animals in Brazil. The vast majority of the beef specialized cows in South America, from the Northern part up to parallel 25ºS are Zebu or Zebu crossed cows. In the Southern part of the continent, with latitudes greater than 25ºS, the cows are mostly Zebu crosses with Bos taurus, like Angus, Hereford, Devon, Simenthal, etc., or purebred or crossbred *Bos taurus.*

With the growth of Zebu cattle, mainly after the 40's and the expansion of Brazil's agricultural frontier to West and North (it was concentrated mainly in Southeastern region), the adapted *Bos taurus* almost disappear, taking with them all the results of natural selection to adaptation to tropical environment over centuries. More recently, in 90's there was a large interest for that type of animals, mainly to be used in crossbreeding systems, as they contribute with heterosis in growth, carcass quality and size. Those breeds are back to beef production again.

From the 60's, but mainly from the 70's, a large movement of development of crossbreeding production systems were introduced, with several experiences, some successful and some with not so good results. A large number of beef breeds were introduced in all countries, mainly the Continental breeds from 70's until middle 90's, switching to British breeds from middle 90's. Today Angus is the breed that sells the larger amount of semen in Brazil (Table 4), what also happens in other countries.

There were some trials to develop synthetic beef breeds in South American countries, with the larger success happening with Canchin, a 3/8 Zebu x 5/8 Charolais synthetic breed in Brazil (Barbosa and Duarte, 1989; Barbosa, 2000); Brangus (3/8 Zebu x 5/8 Angus) and Braford (3/8 Zebu and 5/8 Hereford) in Argentina, Uruguay, Paraguay and Brazil. Those synthetic breeds had some problems due to small number of animals, but are growing in the region. Some new ones, like Simbrah (3/8 Zebu x 5/8 Simenthal) are also growing. The mainly difference of those breeds to the ones developed in USA is that the Zebu part was mainly Nelore and Guzera, instead of Brahman, a Zebu beef breed developed in Mexico and USA, using Brazilian Nelore and Indubrasil bulls on *Bos taurus* cows from tropical areas of those countries.

Other synthetic breeds, like Santa Gertudis were introduced, but not formed in South America. They grew using grading up from Zebu cows. That also led to a big difference between animals from USA and Brazil, as the Brazilian animals had a larger proportion of very well adapted to tropical condition genes.

In middle 90's the concept of composites was introduced in Brazil and several South American countries. Based on Clay Center's crossbreeding experiments knowledge, several composite programs, some, like the so-called Montana Tropical® with herds over 60,000 cows. Those programs, that are being considered as a "revolution" in beef production systems, introduced other *Bos taurus* long term selected in tropical environment in Southern Africa (like Bonsmara and Tuli), Australia (like Belmont Red), Virgin Islands (Senepol), Southern USA (Barzona), but also are using South American-adapted *Bos taurus*, like Caracu and Romo-Sinuano.

Since middle 90's several genetic evaluation programs are being conducted in several countries, led by private companies or breeders associations. That is changing very rapidly the scenario of beef industry and words like EPD, genetic merit, selection indexes are spreading very fast among producers, with a very large impact in production. The portion of genetically evaluated sires that are being used in the production on calves, through artificial insemination or natural mating is growing very fast. One example of the success and impact of the evaluation programs, allied to the changes in world's economy is that the average age at slaughter in Brazil, that has the largest beef production in region, decreased from over 4 years of age to 3 years, in only one decade.

The analysis of Tables 1 to 4 show that the potential of beef production in South America is huge and as soon as sanitary problems, like foot and mouth disease (FMD), are solved (and the major part of Brazil was declared free of FMD, under vaccination in 2000), those countries will be in the beef market, with very low costs and increasing quality. The South American countries also have a very big and important internal market of more than 300 million people, with a very big growth potential, as they per capita income is still very low as compared to developed countries.

There are several diverse production systems in beef industry in South America, but the world's large scale economy is leading to a process were there will be only two very well defined processes: one, with very low input, low technology, used in subsistence conditions, with the use of Zebu or Criollo cattle, with very low productivity and very little impact in beef production. The other system is the one that has a large impact in beef production and uses improved Zebu under continued selection, crossbreeding systems and some use of improved Criollo type animals, mainly in crosses.

The situation of dairy cattle was quite different. There are also two very different production systems: one with very low input where Zebu or adapted *Bos taurus*, used as dual purpose animals, produce calves and also some, very few, liters of milk per day. That production system can be found in all countries and it is very important to subsistence economy. Is this scenario, the high productive European cows introduced, or their progeny born in South America, did not held productivity levels, being economically less efficient than dual purpose systems (Vaccaro, 2000). In those cases, the Criollo-like and Zebu breeds are very useful and are being broadly used in dairy production and several breeding programs are being developed with those breeds, and crossbred animals (*Bos taurus* x *Bos taurus indicus*, where *Bos taurus* can be both Criollo type breeds, like Caracu, Romo-Sinuano or Criollo or specialized dairy breeds like Holsteins, Jersey or Brown-Swiss cattle)with interesting results (Madalena, 1989; Vaccaro and Vaccaro, 1989; Wilkins and Rojas, 1989; Martinez et al., 2000). In some countries, like Venezuela, due to the finish of governmental subsides, the intensive specialized dairy production systems almost disappear (Vaccaro, 2000).

Some very interesting results in improvement dairy production were obtained in Gir breed (a Zebu breed, Verneque at al., 2000), Girolando (a 3/8 Gir x 5/8 Holstein synthetic breed, Menezes, 2000), Guzera (a Zebu breed, Melo and Penna, 2000) and even in Nelore, a beef breed, with a strain selected for milk (Martinez et al., 2000). In a 1995 Report to BBGA Project at Cenargem (Embrapa, Brazil), there is an information that one of the Criollo-like breed in Brazil, the Pé-Duro, raised in Mara Rosa, state of Goias, produces milk that has a higher yield in cheese production, when compared to milk from dairy cows. The report say that 10 l of milk are needed to make a kg of cheese, but with Pé-Duro milk, only 7 l are necessary. Such genetic material should be studied and maybe used in breeding programs. Also its meat is considered "of better taste" than beef of other breeds and also the animals are more resistant to diseases.

However, dairy industry is undergoing through a very deep change, with the need of scale gain to reduce the costs of production, both in production and industrialization/distribution parts of the economic chain (Anualpec, 2000).

The intensive systems use high input and highly productive animals, generally Holsteins, with some participation of Jerseys or Brown-Swiss, and they have a trend of concentration in larger producers. Genetically, this system is almost dependent of USA, Canada, Netherlands and Israel's genetic evaluation programs, do not considering genetic x environmental interactions. The Brazilian A.I. studs are not developing their progeny testing with bulls that have progeny in Brazil, using results from original countries' genetic evaluation.

As related to water buffaloes, they are some importance in some countries, mainly in Venezuela, Colombia and northern part of Brazil, where some research is being developed. But there are some cultural problems with the acceptance of buffalo meat. Water buffalo milk is normally used in fabrication of cheese and it's use as labor source is not very intense in South America.

From Tables 5 and 6 it can be observed that level of productivity of dairy cows is quite low in South America, exception to Argentina and Chile (also Uruguay, out of Table 5, but that also has a production level close to Argentina). In those countries a more intensive and specialized milk industry is carried out, with very little utilization of Criollo breeds or Zebu breeds. In the rest of the continent, those breeds are used in large scale, one of the reasons for the low productivity. Per capita milk consumption is low in South American countries and a huge market is available to the growth of that industry in the region.

Broiler and egg industry is very developed in some countries of South America, especially in Brazil, that ranks second in broiler exports in world. Brazil also leads the egg production in the sub-continent.

In the case of broilers, 80% the genetics of world is concentrated in 3 groups: **Avigen**, an European group led by BC Partners (include Ross Breeders, Lohmann Indian River, Arbor Acres and Nicholas); **Hubard-Isa**, a Merial Company that holds Hubard, Isa and Shaver; and **Cobb**, a Tayson Foods company, that also holds Avian Farms.

In Brazil Agroceres-Ross, a joint venture of Agroceres, a Brazilian company and Ross Breeders, has a program with line selection that today has close to 50% of the market (Michelin, 2000). Another program is starting within a large vertically integrated Brazilian food corporation, but is not in market. At research level, there are 3 programs being developed at Universities of Sao Paulo and Viçosa and also at Embrapa (Figueiredo et al., 2000), with some interesting results, using Leghorn, White Cornish, White Plymouth Rock birds.

Almost all the chickens used in egg production in the area are from imported genetics (grandparents imported from USA and Europe). A very small amount of birds come from Embrapa's Project, that uses White Plymouth Rock and Rhode Island Red bird breeds as original genetic source.

Analysis of Table 7 shows that poultry and hen industry has a very big growth potential in South America, particularly broiler production, that can be a very important way for the region to aggregate value to it's corn and soybean production.

Pork industry is well developed in Brazil, but not of great importance in other South American countries. Pork consumption is relatively low in Brazil, what indicates a large potential of growth. Brazil was more important as pork exporter in past, but lost it's position due to sanitary problems, that are being solved. In 70's, around 70% of pork producers had low technological level, what fell down to less than 30% in 2000 (Freitas, 2000). A very proportion of genetic material of the herds is now provided by Agroceres-PIC, a joint-venture of Agroceres, a Brazilian company and Pig Improvement Company (UK), and also by other foreign companies like Dalland (Netherlands), Seghers Hybrid (Belgium), JSR (UK), and Penarlan and Geneticpork (France). There are also breeders of Landrace, Large White, Duroc and Hampshire pigs.

Embrapa in its germplasm conservation program keeps some genetic material of "local" breeds, European pig breeds that were introduced with the first colonizers and are well adapted to tropical conditions. Although present in some subsistence areas, the impact of those "local" or "native" breeds is very low in pork production.

Goat and sheep production are not very important in South American agribusiness, except for Argentina, Uruguay and Southern Brazil, where animals raised are from European origin, imported from USA, Canada, Europe, Australia and New Zealand. The importance of "local" or "native" breeds in that industry is very low. However, in northeastern part of Brazil and some other tropical areas of South America, there are some very productive hairless sheep, like Santa Ines and Morada Nova and some goat breeds that are very important to local economy.

Sheep production had a big problem in 90's, with a large decrease on wool prices. That caused a switch of the market in the direction of sheep meat production, with use of some exotic breeds, like Suffolk, Hampshire Down, Ile de France and Texel. In this scenario, the hairless "Brazilian" breed Santa Ines is growing a lot , as animals are well adapted to tropical and arid conditions (Araújo and Simplício, 2000; Gonçalves, 2000; Morais, 2000; Ribeiro, 2000; Vieira et al., 2000).

Goat industry is growing in southern South America as related to milk and cheese production, using European breeds. In tropical areas, goat industry is concentrated in meat production, using a variety of types and breeds.

The Brazilian genetic resources conservation program

Embrapa, Brazil's federal agency for research in agricultural subjects has a large program of genetic conservation on bovine, water buffalo, swine, horse, sheep, goat and wildlife in a center called Cenargen (www.cenargen.embrapa.br).

That center is responsible for the maintenance and conservation of plant, animal and microorganism genetic resources. This conservation may be *in situ*, when the genetic resources are maintained where they originated and evolved, in genetic reserves for plants or in breeding nuclei for animals, or ex situ, when genetic resources are kept outside their natural environment, in collections, such as seed banks, *in vitro* and in field gene banks. A lot of information on their work can be found in papers, like Mariante and Trovo (1989) and Mariante et al. in FAO/DAD-IS Animal Genetic Resources Information, 25. Their work is really important and some precious information have been generated, like the resistance to infectious anemia in the Pantaneiro Horse, a brazilian horse breed raised in the swamp area of Pantanal (Central-West part of country).

Conclusion

South American animal production is very complex, as the sub-continent has a very large variety of environments, production systems, breeds and cultures.

The global world economy is causing a big impact in the region, but the low input systems, dedicated to subsistence is still important. That kind of system uses species and breeds adapted to tropical environments and need to be protected under government and international programs, as some heat tolerance, resistance to ticks and other diseases were found.

The high input-high productivity animal industry is also present in several parts of the sub-continent with some countries, like Argentina, Brazil, Chile, Colombia, Uruguay and Venezuela playing part of the international animal products market.

The potential of animal production in the region is very high, being the weather a favorable factor in many cases. International efforts should be put in region to develop animal production.

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Internet sites of Interest

Brazilian Association of artificial insemination	http://www.asbia.org.br/
CIPAV – Colombia (Sustainable Agriculture Research Center)	http://www.cipav.org.co
EMBRAPA – Beef Cattle Center	http://www.cnpgc.embrapa.br/
Embrapa – Brazilian Agricultural Research Intitution	http://www.embrapa.br
EMBRAPA – Cenargen – Center of germplasm conservation	http://www.cenargen.embrapa.br/
EMBRAPA – Dairy Cattle Center	http://www.cnpgl.embrapa.br/
EMBRAPA – Poultry, Hens and Swine Center	http://www.cnpsa.embrapa.br/
FAO – Domestic Animal Diversity System	http://www.fao.org/dad-is/
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A Global Strategy for the Development of Animal Breeding Programmes in Lower-Input Production Environments

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Abstract

Demand for the diverse range of livestock products will increase rapidly during the early twenty-first century, primarily in the large developing-world sector. Whilst much twentieth century activity disregarded most of the world's animal genetic resources, the use and the development of a broad spectrum of locally adapted breeds, in association with the intensification of animal agriculture in most available production environments, is required to meet these twenty-first century demands of a much larger and more affluent human population. The essential features are proposed for a strategy for country use in realizing sustainable livestock development for those many locally adapted animal genetic resources still being used by the farmers of the developing world's major lower-input production environments.

Introduction

Awareness of the roles and values of farm animal genetic resources, the lack of effective development of most of these resources and concern for their rapid loss, must be translated into effective action at the local, national, regional and global levels. Much more effective modalities are required to address the rapidly increasing demand for food and services from livestock this century, and in particular to realise the rapid genetic improvement of the majority of the world's livestock breeds of Earth's lower-input, higher-stress production systems. For the foreseeable future these production systems must continue to be responsible for supplying the majority of humankind's demands of farm animals.

This is particularly so for enabling sustainable action in developing countries. Development of FAO's Global Strategy for the Management of Farm Animal Genetic Resources is supported by the Secretariat's 184 member countries, as offering a framework for planning and implementing the necessary management action.

The Need

Food, agriculture and animal production

Animal production currently contributes between 30 and 40 percent of the total value of world food and services from agriculture, with some 1.96 billion people depending at least in part directly upon farm-animal species for their livelihood.

Human population growth, progressive urbanization and the increased purchasing power of the people of the world's developing sector will drive the increasing demand for animal products, outpacing that for plant products, over the coming decades. This demand-led process has been termed the "Livestock Revolution" in a recent joint report of FAO, IFPRI and ILRI (Delgado et al., 1999). The seven specific characteristics of this revolution were identified in the study as:

1. Rapid world-wide increases in consumption and production of animal products;
2. A major increase in developing country share of the world's animal production and consumption;
3. Changes in the status of animal production from a local multipurpose activity to food and feed production for global markets;
4. Increased substitution of meat and milk for grain in the human diet;
5. Rapid rise in the use of cereal-based animal feeds;
6. Greater stress on grazing resources, and more intensive animal production close to cities; and
7. Emerging rapid technological changes in animal production and processing in industrial systems.

Animals provide a broad variety of meat, milk and eggs, together with a spectrum of other public goods and services, such as:

- Animal power for transport of inputs, outputs, people; for irrigation, cultivation, harvesting;
- Fibre for clothing, and to supply a number of other community needs;
- Hides and leather meet a variety of material needs;
- Manure for fuel and fertilizer;
- Various medicinal and food-additive needs;
- Contributions to the generation of capital; and particularly to
- Assisting small farmers of developing countries to manage risk;
- Leveling out farm and villager employment throughout the year; and
- Supplying a range of cultural needs.

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In addition, with good management, livestock enable the sustainable use of large marginal areas of land for food and agriculture purposes, transforming otherwise unusable fibrous material into high quality protein and other important nutrients in human nutrition.

Since traditional feed resources are limited and animal numbers cannot expand to meet the expansion in product demand, the intensification of animal production in developing countries is gathering momentum. Whilst peri-urban industrial-type animal production is springing up around the large cities to meet the demand of rapidly increasing numbers of urban people, most future demand for animal products must be met from the resource-rich mixed crop-livestock environments, by intensifying the production systems to increase productivity (output per unit input) of both land and animals. As Chantalakhana (2000) points out, these mixed crop-animal systems, in addition to continuing to provide most of the food, also contribute strongly to social stability in developing countries.

Delgado et al., (1999) project aggregate consumption growth rates to 2020 for meat and milk at 2.8 and 3.3 per cent per year, respectively, in developing countries, and 0.6 and 0.2 percent per year, respectively, in developed countries. This would raise the demand for meat in the developing world from 65 million tons in 1990 to 170-220 million tons, and for milk an additional 224 million metric tons would be required. The dramatic demand increases for animal products are projected to outpace those for plant products.

In much of the developing world the animal species mix is also changing rapidly, favoring the smaller, shorter-cycle species, as women assume farm managerial responsibility, and enabling more rapid response to the changing demand for animal protein.

For the developed country sector, Delgado et al. (1999) reconfirm that demand for animal product will not change markedly. However, unless developed country policy is directed at down-playing local production in favour of meeting local demand from elsewhere, the continued development of the livestock of developed countries will also be important to enable farmers to respond to consumer demand for an increasing range of more consistent livestock products, and their need to retain competitiveness will continue to demand productivity gains in both the food production and processing sectors.

Sustainable Intensification

So, the pressure for world livestock development will continue to intensify throughout the early decades of the twenty-first century. Whilst this development will also include major production system shifts, the vast majority of the land area currently available to agriculture as well as the broad range of available production environments must continue to be sustainably used and developed, if we are serious about realizing 'food security for all'.

Some myths

To help realize the required livestock development several ingrained myths should be overcome.

Of course, to realize sustainable use and development of production systems, all resources must be well managed, over time. Livestock are no exception. When animals are poorly managed, particularly in fragile production environments, they become a destructive element in the production system with its surrounding environment. The issue in these circumstances is commonly not the livestock per se but the human capacity to manage.

Most plant production technologists appreciate the importance to crop development of both genetic and non-genetic, or environmental, interventions. However, some animal production technologists and policy-makers seem to consider that genetic interventions are of little value in livestock development. Yet the developed country poultry, pig and cattle production evidence from livestock development activity which incorporated well designed and executed within-breed genetic improvement programmes, shows that over the past half-century about half the realized improvement in production has been genetic and half non-genetic. Added to this is the relative permanency of genetic change, a feature also of disease eradication but not of disease amelioration or of, for example, feed ration improvements where the majority of the intervention cost is repeated annually. It is also important for technologists and policy-makers to appreciate that at each input level there will remain substantial variation amongst animals in their genetic potential to produce. The proposition that the genetic development should only be addressed following the non-genetic limitations being overcome is incorrect. It is also interesting to note that the between-animal relative variability for most production traits of interest in animal breed populations of developing countries is commonly more than double that in the highly improved breed populations of developed countries, suggesting high potential for genetic improvement if well-planned breeding programmes could be executed and sustained in the developing-country breeds. So, to meet the projected increasing demands on animal productivity over the coming decades both genetic and non-genetic interventions will be required in each production environment.

We often take for granted that agricultural biological diversity or Agrobiodiversity provides the biological capital for meeting our today's many needs as well as the longer term product-range of food and agriculture and resource use efficiency gains being demanded by the community. This diversity is maintained as genetic resources, which comprise the species and varietal populations of organisms used by farmers in the food and agriculture production processes. These resources also enable the diversity's continuous passage through time. In the process the diversity changes as the resources adapt in response to directional forces imposed by the surrounding environment, including the human-imposed forces. The seemingly obvious dictum, that response of genetic resources within and over time is environment-dependant, was often disregarded during twentieth-century agricultural practice, with people presuming instead that particular genetic resources were universally best in all production environments. This presumption of a universally-best genetic resource or breed is seriously flawed.

Marked differences amongst production systems in the important stressors operating, such as product needs and prices, disease occurrence and parasite spread and control methods, as well as climatic and resource availability differences, will often require the use of quite different genetic resources to realize sustained production of food and agriculture in each environment.

In addition to their genetic constitution for the production traits of immediate interest, the adaptive fitness of genetic resources to the production environments in which they are used becomes an important consideration for sustainable intensification of these production systems. In fact the sustainable use concept strongly implies that the microbial, plant and animal genetic resources being utilized for food and agriculture purposes within an environment will be well adapted to that environment. Hence, the very meaning of "genetic superiority" differs amongst production environments. A range of evidence is beginning to accumulate which indicates that these differences can be substantial.

The relevance of 'indigenous' breeds

A challenging question, particularly for most of the developing world production systems, is: How will the necessary substantial genetic interventions be met? The locally adapted indigenous breeds or landraces of developing countries commonly show low absolute production figures, whilst productivity may be remarkably high when proper account is taken of input level and of required production-lifecycle length. Indigenous breeds have evolved to survive, produce and reproduce in their environment! Commonly, developing-country production environments incorporate several intense stressors, frequently the result of pressure on the total resources base. Unless these stressors can be sustainably overcome, the locally adapted breeds should be highly favoured. These breeds may be an important asset to countries for the adaptive traits they have developed over time, such as:

- Tolerance/resistance to various diseases, including serious entero- and ecto-parasites;
- Tolerance to large fluctuations in availability and quality of feed resources and water supply;
- Tolerance to extreme temperatures, humidity and other climatic factors;
- Adaptation to low-capacity management conditions; and
- Ability to survive, regularly reproduce and produce for long periods of time.

To replace or to develop?

Where changes in animal production circumstances at particular locations occur steadily over time, locally adapted animal genetic resources possess the biological capacity to respond and become adapted to the altered conditions. To meet, for example, an increasing demand for increasing food and agriculture, it may be best to improve rather than replace these local breeds. This 'wise-use' approach (Notter et al., 1994) also incorporates a conservation element and, given the world's broad spectrum of major animal production environments, the potential to sustain into the longer term a broad spectrum of animal gene pools.

Alternately, where major production system shifts are made within just a few years, genetic resources from elsewhere in the country or from similar production environments of other countries may be required to maintain sustainable conditions, and the local community and country may benefit greatly from the careful planning and introduction of exotic material. For example, genetic material developed under the high-input, low-stress, short life-cycle production environments of developed countries may make valuable contributions to the small but expanding higher-input, 'softer' production environments of developing countries - although in the foreseeable future it will not be possible for the world's high-input, low-stress production environments to account for even half of the large and increasing livestock component of world food and agriculture production.

Where this rapid intensification of animal production can be reliably implemented, the environmental constraints to production will be substantially removed with more and better feed resources, housing and veterinary care combined with major husbandry changes. This process is inevitably associated with marked changes in the genetic resources used, since some other species, breeds and breed crosses will much better utilize the new higher-potential, much-less-variable production environment.

Of course, neither the continued use of an animal genetic resource nor its replacement by or introgression with another will negate the need for further genetic development of the resources in use, to respond to ongoing consumer demands, cost pressures and the need to better utilize finite feed and other resources. During this process of genetic improvement of the traits identified by the farming community as important breeding goals, traits contributing to the breed's adaptive fitness in that production environment will also respond slowly over time. Under these circumstances there is time to also steadily develop the production environment to suit the genetic improvement being generated within the breed. When unadapted exotic breeds are introduced and utilized as straightbreds, these long time periods required to establish levels of genetic adaptation to the new environment which are commensurate with sustainable systems are not available.

Developing countries host most of today's animal genetic resources. In these mostly-tropical countries, the costs of rapidly adjusting the production environment to the conditions required by high-input-demanding, high-output breeds of developed country origin, will be very high indeed. Future reliance on and development of genotypes adapted to the (majority) lower-input, higher-stress areas of the developing world, will be essential.

Who pays?

This need to actively develop adapted genotypes remains an important challenge for developing countries. Whilst developed-country experience of particularly the last half-century highlights the substantial benefits possible from well designed and executed straightbreeding and crossbreeding strategies, it also reminds us that farmer community uptake and the longer-term success of these programmes commonly depended upon provision of stable public sector enabling policy, substantial public sector resources in the early years of implementation, and on substantial technical and operational capacity. These requirements are in short supply in the world's developing countries; and are being further exacerbated by recent international pressures for early privatization of technological development in developing countries. In addition, international collaborative support projects are commonly of short duration, generally spanning less than one generation of a livestock breeding intervention. Based on substantial developed country experience, these approaches and time periods are seriously inadequate for realizing effective sustainable breeding programmes in the lower-input developing country systems.

Do these trends infer that the current rapid development of genetic evaluation, information and biotechnologies will continue to focus on the few high-input, high-output breeds and production systems of the food-secure developed countries? That genetic development of locally adapted genetic resources of the developing world will remain unaddressed? Or are technical, operational and policy modalities now feasible which could enable the sustained genetic development of these locally-adapted developing-country breeds for these very important lower input production environments of the world?

Which breeds to use? Which to conserve?

Preliminary surveying by 177 countries shows that most possess several of the 5600 or so remaining breeds of avian and mammalian farm animal species, with the majority of these breeds occurring only in one or another of the 160 or so developing countries (FAO-UNEP, 1995, 2000). Most are owned by small farmers, emphasizing the importance of private good to the sound management of animal genetic resources. 4182 breed records entered by countries in FAO's DAD-IS Animal Genetic Resources Databank possess at least some population-size data. 1686 of these are now categorized by FAO as endangered, with the 1995-to-1999 trend showing this number to be still increasing. Very preliminary data indicates that less than 10 per cent of those endangered are being maintained as a managed population in vivo or as cryo-conserved semen and/or embryos. Preliminary data from countries also indicates that at least 740 mammalian species breeds went to extinction during the twentieth century, at least 300 of these being over the past 15 years.

Whilst some 4000 of the remaining breeds are still popular with farmers, only about 400 are associated with designed genetic improvement programmes. Virtually all the latter are located in developed countries, where the evidence clearly shows that well planned and executed breeding programmes will realize cumulative gains in the breeding goal, with benefit: cost analyses universally being highly favourable.

It seems from Galal et al. (2000), who made an intense effort to document the range of experiences across the major farm animal species and regions of the world, that most of the comparatively small number of genetic improvement efforts made to date in developing country livestock systems have been ineffective and unsustainable. The issue for developing countries then is primarily not to refine local breeding programmes but to devise and implement sustainable breeding strategies.

The genetic material provided over the past few decades from these developed country successes to assist developing countries overcome their food security difficulties has primarily been developed under comparatively high input, low-stress production environments. Whilst negative outcomes to this international collaborative effort have not been well reported, the accumulating evidence suggests that much, not all, of this major animal genetic resource assistance effort has been in vain. Farmers gradually realize that this exotic genetic material is inferior in their environment - see for example Galal et al. (2000). Very different developing-country cost structures, shortages of quality feed resources and low technical and management capacity, mean that stock must survive, reproduce and produce for many years - a farmer whose stock first calve at 3.5 to 4 years of age cannot afford to have two-thirds or more of his herd pre-first calf. A further issue is that very few well-planned and executed comparisons of local and exotic breeds have been undertaken in developing countries. Trials done have frequently been brief, involved poor design, with substantial feeding and management biases favouring the exotics. Lifecycle productivity was not considered even though it is a critical element of sustainable intensification for medium-to-low input, high-stress production environments of developing countries.

A serious issue for good management of animal genetic resources in most countries is the extremely limited technical documentation available for decision making on breed use, highlighting the capacity limitations of these countries. Whilst communities generally possess extensive knowledge of the observable characteristics of their local breeds, there is negligible documented research data for some 85 percent of all breeds and even less sound breed-comparison information. Developed country research and publication modalities are not particularly conducive to enabling change in this predicament. A major challenge: Our level of ignorance about the vast majority of the world's animal genetic resources.

Neither is the process of intensification at all input levels always driven by rational principles. Frequently, policies and actions operate against the local breeds, favouring their removal beyond the rate which would occur without distorting the food and agriculture intensification process. Governments often incorrectly favour the introduction and rapid spread of particular breeds; farmers may preferentially feed and otherwise care for the exotic animals, sometimes for years before it is possible for them to appreciate the significance of the local breed loss. Comparative research is often done in environments where feed, water, disease control and management inputs are very different to those of the farming community.

Hence, the real value of genetic diversity may not be properly reflected in current choices of breeds and associated technologies. Breeds which utilize low-value feeds, or survive in harsh environments, or have tolerance to, or resistance against, specific diseases may realize large future benefits, depending upon developments and resource scarcities. The complete cost of exotic genetic material may not be considered. Genetic material is often donated free or at low cost to speed up genetic progress in developing countries; but progress for what breeding goal, and will this 'quick fix' development be sustainable? Semen from males progeny-tested under high-input production is provided to developing countries free of charge, without further progeny testing, and disregarding the production environment of use of the semen. Artificial insemination (AI) services to developing countries are often free of charge or real costs are not fully recovered; also providing local farmers access to exotic genotypes at lower cost than could apply for AI of the local breeds if the mechanisms were in place. Breed choice may also be influenced by economy-wide policies and pressures such as preferred credit schemes, exchange rates, producer prices, inflation and interest rates. In many countries, there are direct subsidies on feed and other inputs, which tend to favour exotic breeds; and indirect subsidies on production inputs, such as fuel and fertilizer to produce concentrate feed.

Establishing the principles and procedures of sustainable use and for that matter also of conservation of breeds not currently in favour with farmers, understanding the nature of the variation amongst production environments and amongst genetic resources, and developing programmes of sustainable use and conservation of genetic resources now must all occur simultaneously; at least for those 186 countries which have ratified the UN Convention on Biological Diversity, a legally binding agreement also supported by the UN General Assembly of countries (Resolution 53/190 of 15 December 1998, and 54/221 of 8 February 2000).

Changing Strategies for Livestock Development

The twentieth century

As the principles of the various disciplinary areas of Animal Science were established during the twentieth century developed countries initiated field trialing to evaluate and better understand how these separate disciplinary areas could be used to assist farmers needing primarily to increase production. For much of that century, payment systems tended to be simple, focussing on single products and few product categories. Farm accounting and cost structures were also simple, with farming being assumed a way of life rather than a business. Product marketing and processing operations and associated public sector regulation were simply configured; although during the latter part of the century much research effort was devoted to understanding the implications for farmers and consumers of the seemingly simple processing, marketing and regulatory activities. Research and extension for Agriculture were public sector based, for food production was viewed as important and in the public good.

Not surprisingly, these developments impacted in many ways on the organisation and evolution of animal genetic improvement programmes. As developed country farm community capacity increased so did farmer involvement in organized animal recording, in artificial breeding for species for which this had been developed, and in genetic improvement programmes. Where industrial production and marketing principles (large numbers of units requiring a service and the potential to (directly) return profit) were readily available, the private sector assumed increasing responsibility for breeding services. This included, for the more important shorter cycle species the supply of straight- and cross-bred parent stock, and for some other species commercialisation of artificial breeding services. In most developed countries a small number of genetic improvement initiatives based on the principles were begun mid-century for each of the important farm animal species. With reducing cost and speed of transport, genetic material particularly from the smaller number of reasonably well designed and executed breeding programmes was then spread rapidly internationally, aided in cattle, as the most important larger animal species, by frozen semen. Not surprisingly again, this apparently superior genetic material was also utilized by most developed countries as an aid element, to assist many countries in food deficit. Frequently, the genetic material was accompanied by technological packages, which were ready proving very beneficial in winning developed country production gains. Not surprisingly either, developing countries accepted this aid pretty much without question for several decades, reacting positively to high production being achieved by the use of these technological developments in the developed country production environments. Use of the strategy was further enabled by FAO, which until 1992 operated a cattle semen support activity comprising developed country provision of semen of particular breeds identified as desirable by developing countries to initiate genetic upgrading activity. Generally, the breeds chosen were those achieving high phenotypic performance in the high-input developed country production environments.

Into the twenty-first century

The past two decades in particular have heralded substantial change and the need to re-examine our strategic approaches to livestock development. For developed country food and agriculture, cost pressures and the various international policy initiatives associated with regional pact development and 'globalisation', together with the 1982 Den Bosch initiative for Sustainable Agriculture and Rural Development followed by the United Nations Conference on Environment and Development (UNCED) of 1992 and its associated agreements (Agenda 21) and conventions (Biological Diversity, Climate Control and Desertification), and implications of major information, communication and bio-technological developments, are beginning to impact all aspects of food and agriculture production.

For the developing world, because more than 80 countries and around 1 in 6 of the world's people suffer serious food insecurity, the Members Governments of FAO in 1996 negotiated the World Food Summit (WFS) Plan of Action, which focuses on achieving food security for all and sustainable agriculture and rural development. Then in late 1999 Members agreed on a Corporate Strategy for the FAO, on which the Organization's total programme of work is now based. Investment agencies and other international collaborative agencies are now directing their efforts at overcoming poverty. Livestock play important roles in the vast majority of the poverty stricken and food insecure countries.

Country recognition of the importance of animal genetic resources, of the need to sustainably use, develop and conserve these essential resources, and of the poor state of their current management, led the governing bodies of FAO to request the development of the Global Strategy for the Management of Farm Animal Genetic Resources (FAO, 1999). This priority action is aimed at enhancing awareness of the role and value of animal genetic resources; providing a frame work for local, national, regional and global efforts to better use, develop and conserve them; assisting with policy development; and with mobilising the necessary financial support to assist particularly the developing countries to utilize the Strategy.

The above referred 80 countries form an important sub-set of the developing world which, as earlier outlined, will need to cope further through the immediate future decades with the many issues arising with the projected Livestock Revolution. A challenge then is to assist these developing countries to establish substantial and sustainable livestock development initiatives.

Both the WFS Plan of Action and FAO's Corporate Strategy clearly identify the need for action in the sustainable use and conservation of plant and animal genetic resources, with genetic resources action being included by FAO's governing bodies amongst the Organization's 15 or so priority areas of work. However, the modalities for livestock development are moving to much more overtly emphasize the use of interventions which integrate the various disciplinary areas of the Animal and Social Sciences, to address more holistically the issues which farming communities face, thereby also improving the likelihood of sustainable development action. How should genetic improvement elements be integrated with disease control, social, feeding, economic, husbandry and institutional building elements?

Because of the transfer of both information and genetic material over time and space which are required to successfully implement and sustain some genetic improvement programmes, can the breeding element serve usefully as a 'carrier' for the non-genetic elements, the combination customized in each intervention to meet the needs and fit the capacity of the particular community?

Peculiarities of the lower input systems

Still we have the predicament of few effective genetic improvement programmes having been initiated and fewer sustained for the many locally adapted breeds of each farm animal species in the lower-input production environments of the 160 or so developing countries. Why is this so?

Lower-input production environments also exist in some developed countries. However, these lower-input production systems commonly are associated with a stable and comparatively comprehensive public and livestock sector enabling policy environment and well-developed markets and transport infrastructure. They also commonly comprise large herds and flocks, and include substantial technical capacity. With the added provision of low cost-effective animal identification, measurement, recording and genetic evaluation technologies, highly effective genetic improvement programmes are feasible.

The lower-input production environments of developing countries by comparison are generally characterised by:

1. Inadequate public sector enabling policy;
2. Poor market infrastructure with production commonly directed at meeting family needs and sale of surplus only;
3. Low technical and management capacity of available expertise, and low training and research capacity;
4. Poor transport infrastructure beyond village level for marketing, and for dissemination of superior parent stock for farm production; and
5. The need to maintain old herd/flock age structures, for farm viability.

In addition, these developing country production systems:

6. Often comprise very small herd and flock sizes; and
7. Commonly experience frequent crisis periods, either of shortage of water and feed or of other natural or human-induced disasters.

Item 1. requires resolution if effective and sustainable genetic improvement programmes are to be planned and executed. Inter alia, items 2. to 7. indicate the serious difficulties to be faced in attempts to involve all farmers directly in either crossbreeding or within-breed breeding herds and flocks, and strongly indicate the critical need for the use of two layer structures, a parent stock breeding layer and the food and agriculture production layer. To maximize farmer use of the breeding programme, develop farmer capacity, and enhance the programme's sustainability, from the outset the policy should be to firmly involve strong farmer representation from the food and agriculture production layer in the decision-making concerned with the parent stock breeding layer and with the development of the parent stock dissemination operations.

Item 5. creates somewhat of a production - breeding paradox for within-breed genetic improvement programmes. In these resource-scarce lower-input developing country production environments, the need to obtaining rapid genetic gains in farmer oriented breeding goals will generally mean the parent stock breeding layer will seek to cycle generations much more rapidly than will the food and agriculture production layer. Whilst rapid reduction in breeding value for longevity is unlikely, the breeding programme should consider options to monitor change in longevity.

The lower-input systems of the developing world also provide opportunities for the development of sustainable breeding programmes:

1. The willingness by many countries to create, with assistance, effective enabling policy environments;
2. The willingness to be involve in international collaborative research and development activity, which if well configured, can markedly upgrade capacity;
3. The direct involvement of the women of the family in virtually all aspects of livestock production, particularly for the shorter-cycle species;
4. A range of opportunities for configuring effective dissemination of superior genetic material within village communities, such as women marketing services of bucks they purchase using micro-credit; and
5. The possibility, with international collaborative support of introducing livestock development technical support to farming communities.

A strategy for developing sustainable breeding programmes

Whilst the impact on a production system of a successful animal breeding programme is commonly very substantial, the task of developing and maintaining an effective programme is sometimes underestimated. A very large number of decisions and actions both over space and time are required for a large community of farmers to realize the sound use of the readily accessible genetic variation associated with their development objective for the species. To assist all parties concerned to better understand the planning, implementation and further development needs of a breeding programme, a logical approach could involve the identification of all required decisions and actions and of all necessary sequencing of these. However, to characterise breeding programmes at this level of decision-support detail is obviously not possible. Nor is this desirable for there are many socio-economic and technical decisions of detail, which are unlikely to have major impact on the genetic outcome of the programme. Nevertheless, it is possible to identify and tease apart into decision steps those major processes involved in realizing successful breeding programme outcomes. These decisions are substantially generic for all species and production systems.

This approach to the planning, implementation and maintenance of breeding strategies is being developed by FAO during its detailing of the Global Strategy for the Management of Farm Animal Genetic Resources, as requested by countries to assist them in better managing their animal genetic resources.

The major processes identified for use in this breeding strategy decision support system are given in Figure 1. The steps within each of these processes have been drafted and the policy, technical and operational decisions are being teased out to enable all stakeholders concerned with the development of a breeding programme to better understand the processes involved and their roles, the policy-makers, the technical experts and the field operatives. The approach further teases out the decisions required into the 'Getting Started' and 'Further Development' phases, to differentiate critical foundation decisions and actions from those which can wait until the programme is underway. At each decision step the user is the user is assisted to do a SWOT analysis. The approach is being configured into a graphic decision support tool, DECIDE. Once the beta field-testing of the breeding strategy area of DECIDE is complete, the system will be extended to provide for the conservation and other areas of action involved in sound animal genetic resources management.

Identifying and understanding how to best use the enabling activities in breeding programme development

Some activities, when implemented, serve to speed uptake of a development initiative whilst others tend to slow overall activity; often for reasons not immediately apparent. So, for example, the use of the statistically and computationally complex multiple-trait animal model genetic evaluation has in some developed countries rapidly led to greater uptake of more effective breeding programmes, primarily because farmers involved in the breeding layer related well to how the system dealt with animal records. Further, the excellent contribution by Banks (2000) which demonstrates the use of animal model genetic evaluation to partition the costs of a breeding programme according to the level of benefit being realized by each major sector involved, breeder, food producer, processor and consumer, could show the way to convincing public and private sector policy makers of the need for and relevance of public sector support of genetic improvement interventions, and of the importance of utilizing more realistic time-frames for development. Earlier, it was considered that AI would provide a positive trigger for the development and uptake of more effective genetic improvement initiatives but in most situations this has not occurred - for an exception, see Trivedi (2000). The rapid developing of molecular genetic technologies also offer strong potential for a range of novel genetic improvement action in these developing country production systems. For example, realizing multiple-locus fingerprinting on low-cost, simple-to-use micro-arrays could be used to speed genetic progress. Of course, as with conventional animal technologies, applications of these new, potentially powerful technologies must be capable of close integration with the rest of the production system to realize sustainable benefits and a well managed environment within and about the production system.

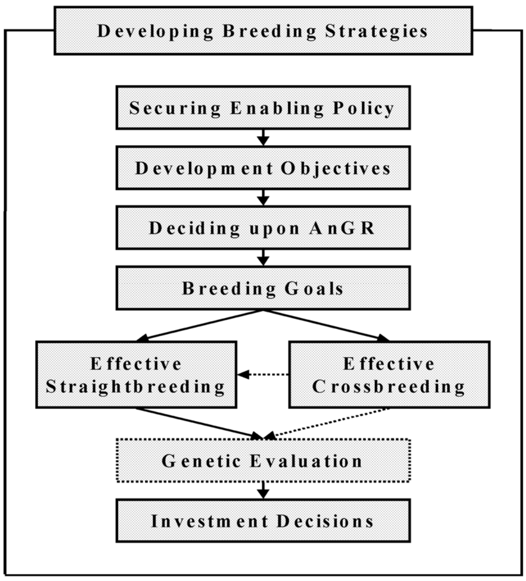

Fig. 1
The major processes identified for use in the Global Strategy's breeding programme development decision support system

The objective of the global strategy for the development of animal breeding programmes for locally adapted breeds in lower-input production environments of developing countries should be to stimulate the development of several hundred sustainable breeding programmes over the coming decades. This strategy is now being detailed by FAO to include:

- DECIDE, as a simple-to-use and readily available decision support tool for active use;
- Pilot breeding programmes formulated to trial and further develop the decision-support approach;
- Initial emphasis on the increasingly important shorter cycle, mutiparous animal species, to also rapidly determine the place of genetic improvement activity in developing world livestock development;
- Strong emphasis on countries establishing firm enabling policy;
- Novel approaches and suitably developed technologies to increase the rates of genetic improvement;
- Emphasizing the benefits to breeding programme development of the double-layered livestock population structure, the parent stock breeding layer and the food and agriculture production layer;
- A strongly developed gender element, in line with community culture;
- Efforts to convince countries, investment agencies and other international collaborators of the critical need for utilizing realistic development time frames, and more effective costing approaches if sustainable intensification is to be achieved; and
- Livestock development interventions which efficiently integrate genetic with the indicative non-genetic elements.

In this way also, the Global Strategy offers a framework for country use in breeding programme development, with the thrusts being to build understanding of the policy, technical and operational activity required for sound animal genetic resources management, and to further develop country capacity by providing tools for direct use in planning and executing action.

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