



Will African Animal Breeds Withstand the Challenges of the 21st Century?

If market forces push farmers to adopt high productive breeds, why should we conserve the low productive ones?

1. Introduction

Livestock represent an important resource for the economic development and livelihoods security of the African continent. The most obvious contribution of livestock is as a direct source of food. Livestock products are an important source of proteins and amino acids and also contain vitamins and minerals. Livestock help to alleviate seasonal food variability. Milk and eggs are produced almost year-round while animals, particularly small stock, can be slaughtered for food or sold for income as the need arises.

In many parts of the world, farmers now find it cheaper to feed grain to their livestock rather than depend upon pastures and forests for grazing. This has led to more capital-intensive techniques in livestock farming. Highly productive breeds have also been developed through years of intense selection or use of biotechnology. The combination of high yield breeds and more capital-intensive techniques has made production systems based on indigenous animals and more traditional techniques economically unviable and less attractive for our farmers. The high rate of adoption of exotic breeds by farmers therefore raises serious questions about the changing ways of life, changing landscapes, and the loss of animal genetic resources (AnGR) and biodiversity.

Farmers that live in low potential and unfavorable agricultural areas depend directly on ecosystem biodiversity for their livelihoods. In many regions AnGR are a vital component of this biodiversity. Conservation of livestock genetic variability is thus extremely important, especially when considering possible future changes in production environments.

The increasing demand for livestock products pushes against a traditional resource base for livestock production that cannot expand at the same pace. The agricultural biodiversity contained in the world's domesticated livestock is disappearing at an unprecedented rate. At stake is nothing less than the animal basis for the world's food security. Economics may not be the only explanations for the loss of indigenous animals as a wide variety of factors also contribute to the loss including lack of genetic resources management schemes and strategies and inadequate Government policies.

Animal genetic diversity needs to adapt food production systems to changing conditions in the coming decades. African livestock breeds offer a wide and unmatched diversity, the loss of which threatens food security and environmental stability. Having described the causes of AnGR decline, we

tackle the challenges to the conservation of animal genetic resources including the investments and the legal framework to be put in place; thereafter we shall discuss strategic options for policy makers.

2. Threats to animal genetic resources

Indigenous livestock breeds are under various types of threat. Breeding programs, by both Governments, non-Governmental organizations, and the private sector, have favored the use of exotic breeds for crossbreeding, upgrading, or replacement. These programs have mostly been implemented without strategic thinking and a long term view and were only motivated by the objective of rapid productivity gain. Although such programs often fail to achieve their short term objectives (because in many cases, the low genetic potential was not the main/only constraint for productivity improvement), they have also led to the dilution of indigenous genotypes, or even to their complete extinction.

Wildlife sanctuaries, national parks and other types of protected areas almost always deprive livestock keepers of their pasture. Combined with efforts to persuade farmers to adopt high-input breeds, this contributes to the pressure on local breeds. Conflicts have also contributed to the disappearance of indigenous breeds.

Changes in production systems are a major factor leading to the elimination of indigenous farm animals. The switch to certain cash crops eliminates crop residues that used to be an important component of fodder. Irrigation makes two or three crops a year possible, eliminating the possibility of grazing on stubble or browsing on trees in the fields. Replacement of draught power by tractors for agricultural works or transportation is a prime cause for the gradual extinction of many draught livestock breeds.

Making a living from keeping livestock is hard work that ties people down day in and day out and many young people succumb to the attractions of city life. Animal-handling skills are disappearing very quickly, within one generation. Village based breeding institutions, such as keeping a community bull, also deteriorate rapidly once economic returns are not sufficient or social networks break down. Once such institutions have disappeared, they are very difficult to resurrect.

3. Why do we need to conserve and sustainably use African farm animal genetic resources?

Very often, decisions regarding the improvement of animal genetic resources hence, which breeds should be conserved and how this should be done, have increasingly emphasized the development of just one or a few breeds in each species¹, at the expense of others. Most of this genetic development is often a result of Government policy/programs and has been done in the minority high-input, high-output production systems without considering the long term consequences of such programs, and without envisaging them in the scope of a holistic genetic resources management framework.

The type of genetic material required to meet the challenges of the 21st Century must be determined by the nature of the production environments, which differ greatly within countries and regions. For example, climatic conditions and climatic risk, the type and digestibility of feed resources, disease stresses, the level of management. Local breeds may produce less milk or meat than improved breeds, but they usually fulfill a wider range of functions for their owners, and are much easier and cheaper to manage.

¹ The world dairy sector for instance is largely dominated by one breed (Friesian/Holstein) which enjoys a quasi monopoly and has contributed to eliminate or absorb , many local breeds in the planet

Genetic material has been introduced, often too rapidly, into the medium-to-low input and high-stress agro-ecosystems in Africa, often to the detriment of local highly adapted and, commonly, highly variable genetic material - the very thing that is needed to underpin and further develop production, productivity and sustainability in these production environments. A crossbred or exotic cow may give a high amount of milk, but its offspring will be often poorly adapted to local conditions. A local cow, on the other hand, may produce high value offspring that are well -suited for work under harsh conditions or for meat, as well as providing enough milk to cover family needs. The local cow needs fewer inputs and is less susceptible to disease, drought or heat, making it lower-risk for its owner.

The range of production environments requires an equally diverse range of biological types to enable sustainable production. Many marginal areas, such as deserts, scrubland and mountainous zones, can be exploited only by locally adapted breeds or minority species, adapted to climatic, epidemiological conditions and to long distance trekking. For instance, camels are the only livestock that can exist in areas with less than 50 mm of rainfall.

In pastoral areas, crossbreeding jeopardizes the ability of herds to move and to profit fully from the scarce resources and climate variability. The genetic diversity they embody enables breeders to respond to changes in production, marketing and the natural environment. With the advance of functional genomics, scientists have begun to systematically screen indigenous livestock breeds for genetic traits that confer disease resistance, provide special production characteristics, or influence the processing of animal products.

Disease-causing agents such as internal parasites and bacteria are becoming increasingly resistant to medicines such as anthelmintics and antibiotics respectively. “Breeding for disease resistance” is an emerging trend in disease control. Indigenous breeds typically have not been subjected to strong selection for productivity, but exhibit disease-resistance traits. That makes them of interest to the livestock industry and scientists.

4. How do we increase the productivity of our AnGR to meet the increasing demand?

Genetic improvement of livestock breeds in developing countries remains a challenge. Breed improvement programs provide key entry points for increasing productivity in cattle populations, especially those plagued by animal diseases. However, breed improvement programs have tended to focus on single, market-driven production traits in isolation of broader livestock system functions. Genetic improvement can be done using within breed selection programs based on proven approaches and importation of exotic breeds for breed replacement and/or crossbreeding.

Table 1: Structured breeding activities for the main livestock species



	Cattle	Buffalo	Sheep	Goat	Pig	Chicken
	[percentage of countries]					
Africa	31	0	10	10	6	2
Asia	58	38	30	32	19	16
Near & Middle East	14	33	57	43	0	14
Europe & the Caucasus	74	9	59	54	62	23
Latin America & the Caribbean	36	14	23	9	9	14
Caribbean & Central America	17	0	17	8	8	8
South America	60	50	30	10	10	20
North America	100	0	50	50	100	50
Southwest Pacific	13	0	40	0	18	9
World	47	22	33	27	27	14

(Source FAO, 2007)

Straight-breeding

The most powerful tool available to the breeder to bring about changes in the genetic composition of a population is selection. The purpose of animal breeding is to improve animal populations, to improve future generations of animals. To this task breeders bring two basic tools: selection and mating. Both involve decision-making.

In selection, it is decided which individuals become parents, how many offspring they may produce, and how long they remain in the breeding population. In mating, it is decided which of the males selected will be bred to which of the females selected.

In order to design a sustainable breed improvement program, farmer preferences for traits need to be integrated into the breeding objectives and selection criteria developed based on them, should be the primary step in the development of structured breeding programs. Policies supporting selection are also required. This entails the creation of incentives that encourage farmers to keep traditional animals. The structure of a breeding program is relevant to two aspects of an improvement scheme:

- 1) The genetic improvement aspect: how do we determine the genetically superior animals?
- 2) The dissemination aspect: how do we ensure that the superior animals disseminate their genes quickly through the whole population of production animals?

Breeding works done at the International Trypanotolerance Center (ITC) in the Gambia have revealed the special qualities of the N'Dama, Djallonké and the West African dwarf goat breeds, an example being adaptability to local climatic conditions.



Crossbreeding

Crossbreeding offers two primary advantages: heterosis (also called hybrid vigor) and the opportunity for breed complementarity. When the performance of crossbred offspring exceeds the performance of the purebred parents, the difference is called heterosis. In other words, the whole can be greater than the sum of the parts. Works done at ITC have also demonstrated that the N'Dama productivity can be increased by crossbreeding with foreign sire breeds.

The N'Dama breed has been crossed with Jersey in Côte d'Ivoire since 1955, it has also been crossed with the Sokoto Gudali in Ghana, after its introduction in 1923 and it has been crossed with the West African Shorthorn in Togo. Since 1986 some N'Dama have been exported from Senegal to the Virgin Islands where they have been crossed to the Red Poll and a new breed, the Senepol has resulted.

Crossbreeding must be planned. If crossbreeding is indiscriminate and uncontrolled, it may result in reduced productive advantage. In most situations, crossbreeding has been applied in isolation and in an indiscriminate manner. It should involve sire evaluation and selection with the aim of stabilizing the crossbred population at the desired level of combination of different breeds. Simply mixing breeds at random will not produce the benefits that a well organized, thoughtful crossbreeding system can provide. Crossbreeding programs should be accompanied by measures ensuring the conservation of animal genetic resources. A question that would then have to be answered is how the desired combination could be continuously produced and utilized? This question centers both on genetic and logistic aspects.

Table 2: Strategies and tools used in cattle breeding

	World	Africa	Asia	Near & Middle East	Europe & the Caucasus	LAC*	Southwest Pacific
n	67	24	8	3	21	10	1
Total number of breeds							
Local	505	143	71	12	112	166	1
Exotic	476	143	34	10	159	125	5
Breeds with							
Breeding Goal	22%	18%	28%	14%	44%	4%	0%
Strategy Implemented	19%	13%	24%	9%	44%	1%	0%
Individual Identification	34%	11%	12%	9%	44%	58%	0%
Performance Recording	31%	12%	16%	9%	42%	45%	0%
Artificial Insemination	42%	23%	12%	23%	48%	69%	0%
Genetic Evaluation	22%	9%	12%	5%	38%	24%	0%
Breeds with system of use specified							
Pure-breeding	27%	33%	42%	60%	44%	11%	20%
Cross-breeding	25%	36%	17%	20%	16%	26%	0%
Both	49%	31%	42%	20%	40%	63%	80%

(Source: FAO, 2007)

Regional averages calculated on the basis of information from the subsample countries.

*Latin America and the Caribbean.

n = number of countries providing information.

5. Conservation of animal genetic diversity

Conservation of animal genetic diversity is a global issue, as all countries benefit from the use and development of domestic animals and their many products. Variations in environmental conditions such as disease outbreaks, drought, floods and climatic anomalies, as well as changes in consumer preferences, are inevitable.

Conservation of animal genetic diversity over the long-term will enable African countries and their farmers to better respond to these changing environmental conditions and consumer preferences, to pursue new economic opportunities and to reduce their vulnerability to food shortages. Conservation of animal genetic diversity will offer opportunities to utilize this diversity to meet present and future market demands, to serve as an insurance against environmental changes such as changes in production, socio-economic, and cultural conditions.

Conservation of local breeds also ensures preservation of genetic diversity in a more general manner and will ensure access to a large gene bank than could be used for any other purposes, including human health (animal genes, for instance, could be used for human genetic therapy). It is for these reasons that enabling policies are required to improve food security and to alleviate poverty through the conservation of AnGR in Africa.

Utilization of animal genetic diversity will further depend on the ability of local communities to decide on and implement appropriate breeding strategies. It is therefore essential to ensure that farmers and breeders have access to the widest possible range of animal genetic resources so that they can effectively respond to change. It is impossible to predict the nature of the change, but change is certain, and the livestock sector must not be left without its animal genetic diversity insurance policy. Making sure that local breeds and their diversity continue to contribute to the livelihoods of their keepers may be the most effective way to ensure their conservation. The process should encourage and support the participation of farmers, pastoralists and breeders, governments, regional and international organizations, scientists and researchers, local communities, organizations and institutions, the private sector and the civil society.

6. How to conserve indigenous livestock breeds and farm animal genetic diversity

Conventional approaches to conserving indigenous animal breeds include *ex-situ* and *in-situ* conservation.

In-situ conservation involves maintaining breeding populations of live animals in the agro-ecosystem where they developed (or where they are now normally found), along with appropriate husbandry activities. *Ex-situ* conservation can be either:

- *Ex situ in vivo* Conserving living animals outside the environment where the breed developed or is now normally found.
- *Ex situ in vitro* Conserving genetic material in an artificial environment outside the living animal. This usually involves cryoconservation (ultra deep-freezing). Semen, oocytes, embryos, cells or tissues can be conserved in this way.

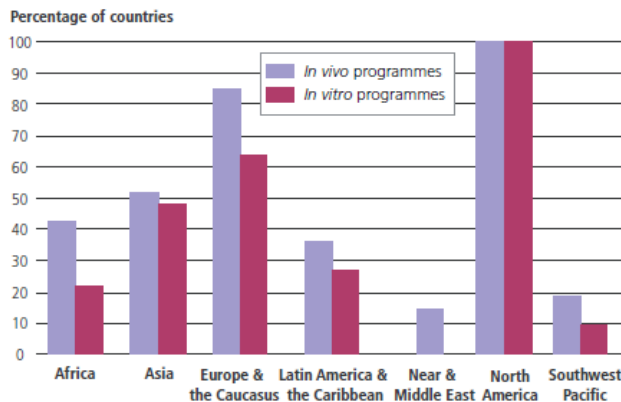


Figure 1: Regional distribution of conservation programs (Source: FAO, 2007)

In recent years, a widespread consensus has developed that the best way to conserve breeds is by maintaining them as part of functional production systems in the social and ecological contexts in which they were developed (and continue to develop). Thus there is a strong rationale for community-based conservation of livestock breeds. Community-based management of animal genetic resources is “the management of animal genetic resources in which decisions on defining, prioritizing and implementing actions on animal genetic resources are made by the local communities who own these resources”.

This is the process by which most of our domestic animal diversity has evolved. Community-based management of animal genetic resources is supported by such organizations as GTZ and FAO for the following reasons: the multitude of local breeds results from the indigenous knowledge of many local communities which manage their animals according to local ecological conditions, production requirements and their own cultural preferences. Such communities are the natural candidates for managing these animals.

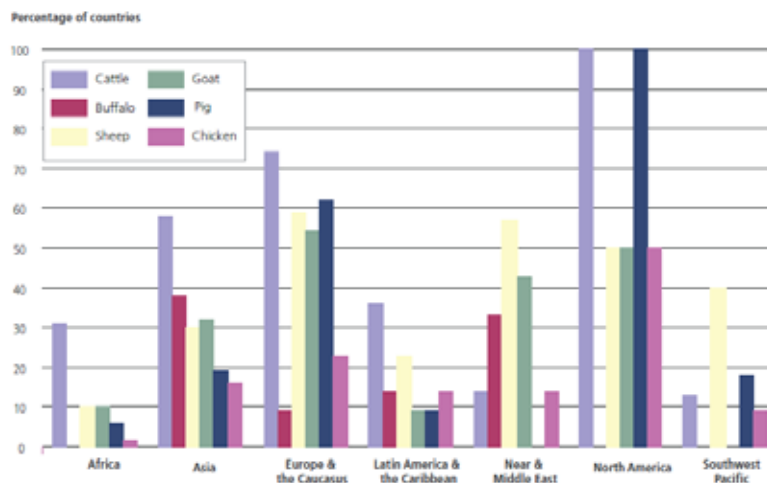


Figure 2: Regional distribution of structured breeding activities for the main livestock species (Source: FAO, 2007)

7. Investment in conservation of the African indigenous breeds

Conservation/improvement programs require long-term strategic investments and incentives. Genetic resources can be considered as a global good and their conservation can be very costly. The financial burden of conservation, including in situ conservation, cannot therefore be supported by the livestock keepers alone. Because there are many breeds at risk and only limited resources available for their conservation, it is necessary to set priorities to address this.

Establishing economic values for genetic resources can help in making policy and management decisions. Valuation can support decisions with respect to resource allocation between biodiversity conservation and other socially valuable endeavors or between various types of conservation research and development. It can also assist with determining the nature of economic incentives and institutional arrangements for the livestock keepers involved in conservation programs. Inadequate or lack of sustained funding is a major limitation to the implementation of animal genetic resources improvement programs.

It may be that, there are other more profitable or less risky private investments that can be made in African countries other than in breeding operations, although investment is growing along with market developments. Whereas in some regions governments often do not have difficulties in starting projects usually funded under donor agreements, there appears to be a lack of a long-term commitment on the part of the decision-makers to secure funds on a sustained basis to run these programs. Breeding programs are driven by investment and management decisions.

Private investment is slowly but steadily increasing in some regions and may be accelerated by demonstrating to the producers the economic benefits of using truly improved stock, which requires teaching them to keep and use accounting records. Large private firms take care of managing their own breeding programs but the smaller ventures may profit from joint programs with institutions providing scientific expertise.

Getting an active involvement of the breeders and producers and the continuous co-participation of scientists and breeders are essential components of realistic programs. The vast majority of smallholders will not be able to buy improved stock and will not attract investment from private companies in animal breeding for their systems, so funding for this is needed from other sources, such as cooperatives, governments and international organizations. In view of past experiences, programs run on public funds should avoid the many vices mentioned (and unmentioned), perhaps by implementation through NGOs. At any rate, funding must be adequate for the long-term nature of breeding operations. An efficient legal framework is needed for the operation of the programs and the dissemination of the improved genetic stock and materials.

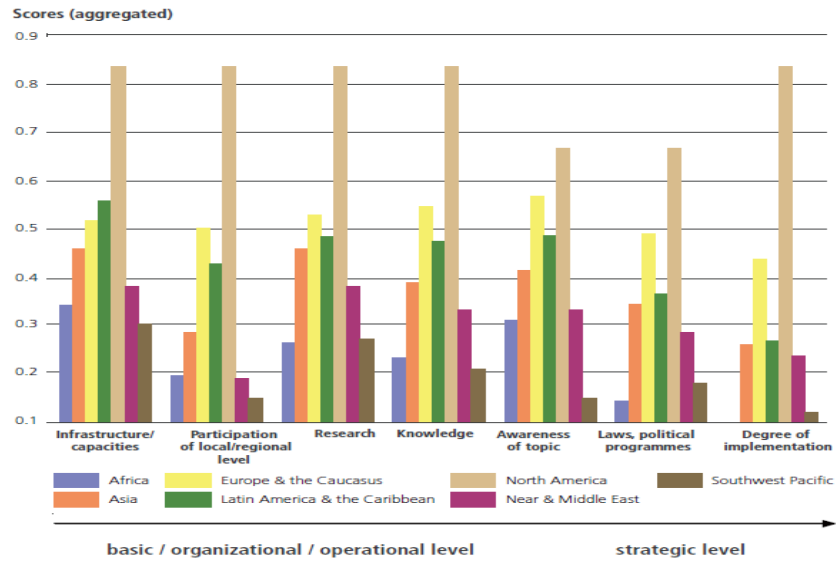


Figure 3: State of institutions - regional comparison (Source: FAO, 2007)

8. International legal frameworks and Legislation to deal with access to African AnGR and the sharing of their benefits

Since food production is increasingly becoming an international area and market, there is a web of relevant regional and global agreements. In the field of genetic resources a substantial amount of law-making goes on in the international arena and at a regional levels. International and regional law may be totally new or target the harmonization of national laws (e.g. veterinary regulations). There are no comprehensive international regulations or policies that specifically address the management, sovereignty, ownership and sharing of benefits for AnGR, although they can without any doubt be considered as a global good.

International, regional and national laws, as well as customary laws at community levels, are all relevant for AnGR. There are, however, several international treaties not designed primarily for AnGR, with a general scope applying to AnGR. At the international level, two major agreements govern access and rights over genetic resources. These are the United Nations Convention on Biological Diversity (CBD) and the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs Agreement) of the World Trade Organization.

The CBD is a legally binding framework that confirms the sovereignty of States over their genetic resources and stresses the importance of *in situ* conservation. It stipulates that access to resources is to be granted on mutually agreed terms, and subject to prior informed consent of the contracting party and fair and equitable sharing of the research and development results and commercial benefits. The Convention recognizes the central role of indigenous and local communities in biodiversity conservation through their traditional and sustainable practices and knowledge systems. The TRIPs agreement obliges all member states to develop minimum standards for the protection of intellectual property rights and a mechanism for their enforcement. The Bonn Guidelines on Access and Benefit Sharing, The Karen Commitment, and other resources on intellectual property law and the World Intellectual Property Organization Treaties also apply to AnGR. Currently, the exchange of AnGR is mainly regulated by the transfer of private ownership (by private law contracts and customary law) and is also influenced by zoo-sanitary regulations. As the implementation of the above international treaties with a general scope

advances further, they may have an increasingly significant impact on AnGR exchange, use and conservation.

9. Intellectual property

Among the legal questions that have arisen with the advent of biotechnology and its increasing use in AnGR, the questions of intellectual property (IP) protection and their impact in the field are of great importance. IP rights that have been in use for decades in AnGR – patents cover the genetic material and its use as such. Unlike the former rights that cover the use of protected commercial signs and names, patents thus allow the rights holder to exclude others from accessing the material, namely the animal. The main impact of biotechnology on agriculture and thus AnGR today is found in the application of selection processes comprising certain biotechnological steps such as marker selection. The potential impact of the entry of patent law can be felt at several levels. It mainly affects the possibility of gaining access to genetic material and thus also to the animals. It influences the ownership structure and can provoke a shift in control from farmers to the rights holders or inventors.

The traditional rule that ownership of animals includes the right to the subsequent generations is reversed in relation to patent-protected animals. Here the owner of the individual animal will need authorization (license) of the patent holder to reproduce it. Whereas previously, genetic resources were accessible by owning the animal patent protected animal resources can no longer be used by an owner to reproduce new generations at will.

Livestock Keepers' Rights are a concept developed by Civil Society during the "Interlaken Process", the run up to the First International Technical Conference on Animal Genetic Resources held in Interlaken in September 2007. They are advocated for by the LIFE ("Local Livestock for Empowerment") Network, a group of non-government organizations (NGOs) and livestock keepers/pastoralists. The group attributes the loss of many breeds in developing countries to the loss of the traditional rights of livestock keepers to breed, keep and sustain their livestock on common property resources, and supports community based conservation of local breeds. "Livestock Keepers' Rights" are a set of principles that would enable and encourage livestock keepers to continue making a living from their breeds and thereby achieve the combined effect of conserving diversity and improving rural livelihoods.

10. National Policies

In the area of AnGR international, regional, and national laws along with customary laws are relevant. Animal breeding happens within the territory of one country. Therefore, the point of departure for breeders, farmers and livestock keepers is the national legislation of their country. In most African countries, livestock breeding policies are embedded in the National Agricultural Policies. There is a need to build separate livestock breeding policies that would fulfill the following requirements: 1) recognize the role of indigenous breeds and local farming systems for conservation of animal diversity; 2) recognize that different ecological zones require different livestock management policies; 3) support not only the conservation but also the improvement of farm animal genetic resources; 4) provide for capacity-building of livestock keepers as well as livestock professionals; 5) regulate export and import establishing protocols for the guidance of donors and NGOs when importing exotic breeds; 6) embrace participatory approaches and place emphasis on them; and 7) address education and awareness raising about both indigenous and exotic breeds.

A regulatory mechanism for the imports of exotic AnGR to allow for better monitoring of their demand and use should be put in place. Institutional capacity for the conservation of livestock genetic diversity is limited. Those capacities need to be enhanced, with new institutional models and

collaboration among public institutions and between public institutions and private farmers. Making sure that these local breeds and their diversity continue to contribute to the livelihoods of their keepers may be the most effective way to ensure their conservation. This may require research to improve the breeds and their management and new economic models to assess the value of animal production.

The following types of policy-relevant questions can be addressed through the use of valuation methods and tools: a) which breeds should be conservation priorities (given that we cannot save everything)? b) How important are particular breeds to livelihoods and how can such values be harnessed to support poverty alleviation efforts? c) Which traits and functions (both marketed and non-marketed) are the most important and to what degree can they be traded off against each other? d) What are the costs of AnGR conservation programs and how can we minimize these? e) What are the related benefits?

Once the decision is made as to which breeds should be sampled, it is necessary to assign appropriate shares of the conservation budget to the different breeds. The total economic value that can be given to a genetic resource is composed of: direct use values: benefits from actual use such as sale of milk, meat, hides. etc.; indirect use value - refers to eco-system functions; option value - is derived from the value of safeguarding an asset for the option of using it in the future; bequest value - measures the benefit from knowing that others might benefit from an asset in the future; existence value - is derived from the satisfaction of knowing that a particular asset exists.

11. Strategic options and Actions to undertake to clarify, develop and implement AnGR

Local breeds are important elements of the genetic stock because they contain special qualities that will be useful for future breeds. The animals themselves might not be economically viable because their productivity is low. However, if they are capable of surviving in harsh climates or resisting local diseases (such as trypanosomosis), they may have genetic traits that could be combined with other animals to produce economically viable future breeds. Do markets protect local genetic stocks? Clearly markets provide some protection as owners of particularly productive animals can earn a great deal for semen or offspring. The issue is whether markets capture all the value of local genetic stocks? If the owners of breeds could reap all the benefits of potential future breeds that might be developed from their stock, there would be an incentive for markets to protect local genetic stock.

However, valuable genetic traits can be captured by purchasing only a few animals. If there are multiple owners of a particular breed, a potential buyer could buy a sample from any one of the owners. As the genetic material is effectively co-owned, there is an incentive for all the owners to underbid each other trying to get the sale. As a result, the generic genetic resource in the breed will tend to be undervalued. No single owner can obtain the value of the resource as long as the other owners exist. Competitive markets will therefore fail to preserve valuable local genetic stock.

Governments consequently have a role to play in putting up policies and regulations to preserve uneconomic species or breeds for future generations. The genetic value of the local stock is likely to be a public good, any genetic storage program is not likely to pay for itself. Revenues will probably be less than costs. However, one could argue that the social benefits of future breeds could easily outweigh the costs if the programs are efficiently designed. The facility that conserves the breed might not be able to reap these benefits, but society at large would enjoy them.

There is consequently a good economic argument for establishing a Government program to protect local breeds. Because the beneficiaries of this program are likely to be spread throughout the region, the continent and the world, there is every reason to argue that this should be an international responsibility.

Conservation programs must not only target the characteristics that local farmers want, they must also be available to local farmers. Community based breeding programs may be ideal because local farmers can have an input into what the breeders are seeking. Further, farmers are more likely to trust new breeds from local programs that they are familiar with. Breed conservation programs must also try to be economically efficient; the program should prioritize conserving species that best protect the local genetic stock. The motivation of this genetic program is the broadest possible genetic resource. Breeds that are more unique would consequently have a higher priority than breeds that are close substitutes for one another.

Recommendations

- Recognize AnGr as a Global Public Good
- The conservation of valuable germplasm should be regarded as mandatory for future generations
- National breeding policies and programs should be developed or fine-tuned focusing on the biological and economic efficiency of livestock in the various farming systems
- Importation of exotic breeds or capital intensive technology requires a preceding detailed evaluation of the potential effects
- A livelihoods approach to AnGR management and conservation requires working directly with the poor to understand the complex interactions between AnGR and poverty, and to maintain or enhance the AnGR assets available to the poor
- Development of national policies on the rights of local communities, farmers and breeders and the regulation of, and access to, benefit-sharing of AnGR.

References consulted

- Agyemang K. and Fall A., 2002. Genetic improvement in medium to low-input systems of animal production. Experiences to date: the West African experience. In: Proceedings of the 7th World Congress on Genetics Applied to Livestock. Montpellier, France, p. 315-318
- Anderson S., 2003. Animal genetic resources and sustainable livelihoods. *Ecological Economics* 45: 331-339.
- Drucker A.G., Gomez V. and Anderson S., 2001. The economic valuation of farm animal genetic resources: a survey of available methods. *Ecological Economics* 36: 1-18.
- FAO, 2007. The state of the world's animal genetic resources for food and agriculture. Commission on Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations Rome, 2007. <http://www.fao.org/docrep/010/a1250e/a1250e00.htm>
- Kahi A.K., 2002. Crossbreeding systems and appropriate levels of exotic blood: examples from Kilifi plantations in Kenya. http://agtr.ilri.cgiar.org/agtrweb/index.php?option=com_content&task=view&id=80&Itemid=97
- Köhler-Rollefson I., 2004. Farm Animal. Genetic Resources. Safeguarding National Assets for Food Security and Trade. Animal Production and Health Division. GTZ, FAO, CTA. pp 54.
- Mendelsohn R., 2003. Analysis: The challenge of conserving indigenous domesticated animals *Ecological Economics*, 45: 501-510.
- Tvedt M.W., Hiemstra S.J., Drucker A.G., Louwaars N. and Oldenbroek K., 2007. Legal aspects of exchange, use and conservation of Farm Animal Genetic Resources. FNI Report 1/2007. ISBN 978-82-7613-504-6. pp 34.
- Philipsson J. and Okeyo A.M., 2006. Global perspectives on animal genetic resources for sustainable agriculture and food production in the tropics. In: Animal Genetics Training Resource, version 2. Ojango J.M., Malmfors B. and Okeyo A.M. (Eds). International Livestock Research Institute, Nairobi, Kenya, and Swedish University of Agricultural Sciences, Uppsala, Sweden. <http://agtr.ilri.cgiar.org/module/module1/Module1.htm>
- Sabine B.R-M., Awudu A. and Henner S, 2006. Optimum allocation of conservation funds and choice of conservation programs for a set of African cattle breeds. *Genetic Selection and Evolution* 38: 99-126.
- Sansthan L.P-P. and Köhler-Rollefson I., 2005. Indigenous Breeds, Local Communities. Documenting Animal Breeds and Breeding from a Community Perspective Edited and designed by Paul Mundy, Bergisch Gladbach, Germany. Sadri, Rajasthan, India. pp 80.
- Spotlight, 2006. Sustainable management and genetic improvement of local breeds are essential if countries are to meet their future food needs and respond to changing production environments. Farm animal biodiversity. <http://www.fao.org/ag/magazine/0609sp1.htm>
- Wollny C.B.A., 2003. The need to conserve farm animal genetic resources in Africa: should policy makers be concerned? *Valuing Animal Genetic Resources. Ecological Economics* Volume 45, Issue 3, July 2003, Pages 341-351.
- Zerbe N., 2005. Biodiversity, ownership, and indigenous knowledge: Exploring legal frameworks for community, farmers, and intellectual property rights in Africa. *Ecological Economics* 53: 493- 506.