Sustainable Intensification and the Conservation of Farm Animal Genetic Resources

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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 the twenty-first century demands of a much larger and more affluent human population.

Key Words: Genetic Resources, Farm Animals, Sustainable, Conservation

INTRODUCTION

Awareness of the roles and values of animal genetic 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 realise genetic improvement of livestock in the lower-input, higher-stress production systems; and to service country conservation strategies.

This is particularly so for enabling sustainable action in developing countries, with these countries also being responsible for most of the world's animal genetic resources. Development of FAO's Global Strategy for the Management of Farm Animal Genetic Resources is supported by the Secretariat's 180 member countries, as offering a framework for planning and implementing the necessary management action.

THE NEED

Food, agriculture and animal production

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 range 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 employment throughout the year; and
- Supplying a range of cultural needs.

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

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.

Since traditional feed resources are limited and animal numbers cannot expand to meet 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.

In much of the developing world the animal species mix is also changing rapidly, favoring the smaller, shorter-cycle animal 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, demand for product range and for consistency of each product in the range will continue to increase, and the drive to retain competitiveness will continue to demand productivity gains in the production and processing chains.

So, the pressure for world livestock development will continue to intensify. Whilst the development will also include major production system shifts, the broad range of available production environments must continue to be sustainably used and developed. Genetic as well as non-genetic interventions will be required to meet the projected demand for product and to realize sustainable production systems in each production environment. A challenging question, particularly for most of the developing world production systems, is: How will the necessary substantial genetic interventions be met?

Of course, to realize sustainable use and development, all resources must be well managed, over time. Livestock are no exception. When animals are poorly managed, particularly in fragile production environments in which they are used becomes an important consideration for sustainable intensification of these production systems. Hence, the very meaning of "genetic superiority" differs amongst production environments, and the difference can be substantial.

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.

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-lifecycle 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.

The conservation of genetic resources at risk of loss often generates strong debate. Public and private good perspectives vary substantially, particularly when the future is being considered. Healthy debate also continues at the technical level. In addition to the ethical and aesthetic arguments associated with conservation, at stake are whether there is need to conserve genetic variation additional to that being maintained in the animal populations currently favored by farmers and used widely, how such conservation could best be done, and who pays - see, for example, Barker (pers. comm.) and Franklin (1997). Motivations for and against conservation of animal genetic resources are summarized in Table 1.
Table 1. Motives for the conservation of animal genetic resources

<table>
<thead>
<tr>
<th>Motive for</th>
<th>Motive against</th>
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<tr>
<td><strong>Section 1. Retain AnGRs as a matter of principle:</strong></td>
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<tr>
<td>Custodian of Earth's resources</td>
<td>Consumer of Earth's resources</td>
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<tr>
<td>Why eliminate in generations what has developed over millennia?</td>
<td>Evolution is dynamic: loss and generation of diversity are continuous processes</td>
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<td><strong>Section 2. Pragmatic motives:</strong></td>
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<td>Genetic material underpins production, productivity, product quality and</td>
<td>Non-genetic manipulation is of overwhelming importance</td>
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<td>subsustainability gains</td>
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<td>Genetic variation within populations increases resilience to</td>
<td>Homozygous and cloned lines will be the best</td>
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<tr>
<td>environmental changes</td>
<td></td>
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<tr>
<td>Countries are becoming increasingly dependant on new genetic material</td>
<td>We have all we need to remain competitive now and in the future</td>
</tr>
<tr>
<td>World agriculture will continue to comprise a wide spectrum of</td>
<td>All production environments will be high input, high output, low stress, low</td>
</tr>
<tr>
<td>production environments</td>
<td>risk</td>
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<tr>
<td>&quot;The Market&quot; produces the wrong results</td>
<td>Let &quot;The Market&quot; decide</td>
</tr>
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<td>City folk wish to experience variety in farming</td>
<td>Profit margins require farmers to use the most cost-effective approaches</td>
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<td>The current and future traits of primary importance are</td>
<td>Molecular Genetics will ensure all future needs are</td>
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<td>quantitative genetic; trait combinations are</td>
<td>met cost-effectively for all production</td>
</tr>
<tr>
<td>important and costly to realize in time and money.</td>
<td>environments.</td>
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<tr>
<td>About 50% of the quantitative genetic variation in each species is</td>
<td>Quantitative variation is rapidly renewed</td>
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<tr>
<td>breed-level</td>
<td>&quot;Modern&quot; breeds are sustainably best in all environments</td>
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<tr>
<td>A net loss of unique sets of genes is underway</td>
<td>Future environments + nutritional needs will be best</td>
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<td>Will best meet short- and long-term needs</td>
<td>met using only the &quot;modern&quot; breeds.</td>
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<td>Can dramatically reduce the size of the AnGR management task</td>
<td>Fancier and Rare breeds have no place</td>
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<td>Costed correctly, the least-cost scenario for humankind is</td>
<td>More synthetics are being formed than are breeds being lost</td>
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<td>conservation</td>
<td>Can't afford it</td>
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<td>Developing and using breeds wherever possible is low-cost</td>
<td>Too ambitious</td>
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<tr>
<td>conservation</td>
<td>Financial and human resources are inadequate</td>
</tr>
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<td>A key constraint: our high level of ignorance of AnGR</td>
<td>Can't maintain effective animal-breeding programmes in developing countries</td>
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<td>Sustainable rural production modalities are required</td>
<td>Most of important research has been done</td>
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<td>Food security helps achieve peace &amp; satisfaction for all</td>
<td>Farming profits are too low</td>
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<td>Let them care for themselves</td>
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Establishing the principles and procedures of sustainable use and conservation, 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).

FARM ANIMAL GENETIC RESOURCES

The state of animal genetic resources

Over the past 12000 years, some 40 mammalian and avian species have been domesticated and developed by humans to form those farm animal genetic resources (AnGR) remaining today, with 14 or so of these responsible for approx. 90 percent of the world’s food and agriculture production.

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 Breeds 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 favorable.

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 medium-to-high input, low-stress production environments. Whilst negative outcomes to this international collaborative effort have not been well reported, evidence is accumulating which 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 the developing countries. Trials done have frequently been brief, involved poor design, with feeding and management biases favoring 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, 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.

The relevance of ‘indigenous’ breeds

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 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 favored. 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.
It is also interesting to note that the relative variability for production traits of interest in these populations is commonly more than double that in the highly improved breeds of developed countries, indicating high potential for genetic improvement if well-planned breeding programmes could be executed and sustained in these developing-country breeds.

To replace or to develop?

When rapid intensification of animal production can be reliably implemented, 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 and cost pressures. During this process of genetic improvement of the traits identified by the farming community involved 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 steadily develop the production environment to suit the genetic improvement being generated within the breed. When unadapted exotic breeds are 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 medium input and perhaps also even to low-input, higher-stress areas of these countries, will be essential.

This remains a challenge for, whilst developed-country experience 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 substantial public-sector support in the early implementation years, and on substantial technical and operational capacity. These requirements are in short supply in the world’s developing countries. Does this infer that the current rapid development of genetic information and bio-technologies 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?

Which breeds to use? Which to conserve?

While some loss of animal genetic resources is inevitable, and should be planned, the process of intensification at all input levels is not 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 their 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.

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 costs 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 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.

Natural disasters, wars and other forms of socio-political instability also contribute to loss of local animal genetic resources. Most of the recently war-torn and drought-stricken countries of the world have lost the majority of their indigenous resources. In these situations only early warning, emergency plans and response may help, but to date no such action has been taken for animal genetic resources. The re-establishment of national herds and flocks based on genetic material from neighbouring countries alone, which meets the demand of local people, has repeatedly proven extremely difficult.
Having ratified the CBD, it is the sovereign prerogative of countries to establish their conservation strategy for animal genetic resources at risk. Several *in vivo* and *in vitro* conservation approaches have been used to stop or reduce breed decline; these often serving as mutually supportive forms of short and longer-term insurance. Maintenance of a breed in the environment in which it is developing satisfies the requirements of Article 8 of the Convention on Biological Diversity, which gives priority to *in situ* conservation. But *in situ* conservation may not always be feasible and may be very costly and risky, e.g. breeds of larger species in developing countries. Neither is *ex situ* *in vivo* conservation particularly useful where the objective is to be able to re-establish the breed at some future date; so the European Union combined with Member Countries to introduce low-cost, per-head incentive payments for pre-identified, endangered breeds of some species, with positive results to date. Development and promotion by local communities and governments of niche markets for products of some breeds is proving quite effective in some countries. In Thailand, for example, the meat of the local black-legged chicken is again favoured. The current *in vitro* technologies which enable re-establishment of animals are not particularly robust, either at field sampling, during transport, in long-term storage, or at re-establishment, when compared with *ex situ* storage of plant genetic resources. A number of *in vitro* animal genome banks have failed, with the loss of all material. Nevertheless, cryo-conservation may form a useful adjunct to *in vivo* conservation. Regional-level *in vitro* conservation approaches are also not without difficulty, but the Nordic countries have decided to follow this route, as being more cost-effective. Detailed protocols for conservation of animal genetic resources are given by FAO-UNEP (1998).

**Utilizing the information- and bio-technologies**

Recent developments in the information and biotechnologies offer important opportunities to both developed and developing countries to better characterize, utilize, conserve and access animal genetic resources. The possibilities are broad with most still quite immature, posing technical, operational and policy challenges. One of the likely impacts of these technologies will be to further increase country interdependency for animal genetic resources. Technical challenges include research and development of appropriate forms of these technologies for developing-country use, particularly for better developing and conserving locally-adapted breeds. There exist many possibilities for developed-developing country collaboration, to learn more about the biology of the locally-adapted breeds, and to contribute to developing-country capacity building and to food security for all.

**FAO’s role**

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 framework 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 countries to develop and implement the Strategy. It was resolved that the initial focus should be on the 14 or so most important mammalian and avian species, which account for over 90 percent of the world’s food and agriculture production.

The Global Strategy provides a comprehensive framework for country action sustainably to use and conserve domestic animal diversity. It has been designed to complement such international agreements as Agenda 21 and the Convention on Biological Diversity (CBD). Indeed Decision III/11 of the Conference of Parties to the CBD strongly supports the development of the Global Strategy and recognizes FAO as having a lead role in this process. The Strategy’s framework is configured to be applicable at all levels: within-country, national, regional and globally. The framework consists of four fundamental components and sets of elements:

1. **A country-based global infrastructure**, providing the enabling structure for country action and regional and global support, and comprising 3 elements: focal points and networks, a stakeholder’s mechanism, and a virtual structure known as DAD-IS (FAO, 1996a).

2. **An intergovernmental mechanism**, ensuring direct government involvement, continuity of policy advice and support; within FAO’s Commission for Genetic Resources for Food and Agriculture.

3. **A technical programme of work**, aimed at supporting effective management action at the country level, by providing guidelines and technical assistance; also working jointly with the CBD Secretariat. This component has 5 elements: characterization at the phenotypic, genetic and economic levels; sustainable intensification of production systems with genetic improvement; conservation of strategies; awareness generation through a communication programme; and emergency planning and response.

4. **A reporting and evaluation component**, to provide the critical data and information required for guidance, cost-effective planning and action. At its Eighth Regular Session, 19-23 April 1999, the Commission on Genetic Resources for Food and Agriculture resolved that FAO should coordinate the development of a country-driven *Report on the State of the World’s Animal Genetics*; adding a new major element to the strategic framework, which will require countries electing to participate, to develop and submit a substantial report covering five key areas: the state
of diversity, the state of the art and of capacity for managing the resources, and needs and priorities. The work is due to be done over 2000-05.

Desirable outcomes

The Global Strategy provides the basic mechanism and guidance for stakeholders’ use in achieving the following desirable outcomes:

- Country, regional and global co-operation and co-ordination in the development and implementation of management strategies and relevant policies, incorporating:
  - Identification, description and monitoring of all breeds, with attention to breeds most at risk.
  - Development of locally-adapted breeds currently used by farmers, and better understanding of the country’s primary-production environments for food and agriculture.
  - Effective and efficient conservation of unique animal genetic resources at risk, also ensuring ready access and integrating in situ and ex situ measures.
  - Programmes of research and training for the broad spectrum of areas associated with sound management of farm animal genetic resources.
  - Education and awareness generation to promote understanding of the roles and values of farm animal genetic resources in the immediate and longer term.
  - Maintenance of traditional knowledge and lifestyles; utilizing and conserving some resources.

The many opportunities for involvement in country action are outlined in the primary guidelines (FAO, 1998).

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