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CONSERVATION STRATEGIES FOR ANIMAL GENETIC RESOURCES

by

David R. Notter
Virginia Polytechnic Institute & State University
Department of Animal and Poultry Sciences
Blacksburg VA 24061-0306 USA
drnotter@vt.edu

The first Report on the State of the World's Animal Genetic Resources will provide a comprehensive review of the current status of global livestock diversity and direction for better future management of that diversity. This document contrasts opportunities, challenges, biological characteristics, institutional infrastructure and operational considerations influencing management of plant and animal genetic resources. It also summarises main threats to livestock genetic resources and outlines areas of greatest opportunity for better management of these resources.

Dr. Notter is Professor of Animal and Poultry Sciences at Virginia Polytechnic Institute and State University. He conducts research in quantitative genetics and animal breeding with emphasis on small ruminants and meat cattle. Specific areas of interest include the management and use of livestock genetic resources, the genetic control of reproduction in sheep and the genetic evaluation of animal performance. He teaches graduate courses in population genetics and undergraduate courses in animal breeding.

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1. Executive Summary

The forthcoming Report on the State of the World's Animal Genetic Resources (SoW-AnGR) will provide both a comprehensive review of the current status of global livestock diversity and direction for better future management of that diversity. Development of a Report on Strategic Priorities for Action is required to build upon country reports and provide coordination for high-priority activities. The 1998 Report on the State of the World's Plant Genetic Resources for Food and Agriculture provided impetus for a variety of agreements and legal instruments, including a Global Plan of Action, the International Treaty on Plant Genetic Resources, and the Multilateral System. While this model has informed the SoW-AnGR process, the specific approaches adopted for better management of global AnGR must recognize that significant differences exist between livestock and crops in management of genetic resources.

This paper will:

- Compare and contrast opportunities, challenges, biological characteristics, institutional infrastructure, and operational considerations influencing management of plant and animal genetic resources;
- Summarise main threats to livestock genetic resources;
- Outline areas of greatest opportunity for better management of AnGR.

The focus will be on the fewer than 10 globally important livestock species and the 25 to 30 annual plant species that account for over 90% of the world's calorie intake.

In both plants and animals, optimal programs for Genetic Resources (GR) use should result in deployment of an array of GR that can increase food production and improve animal and plant productivity across the full spectrum of global production environments. In plants, this goal has been addressed by development of a strongly centralised and institutionalised seed production sector. The institutions of the seed sector rely on professional plant breeders for development and distribution of improved crop varieties; have strong ties to, and support for, extensive *ex situ* collections of PGR; and provide a focus for international collaboration. This structure is facilitated by the generally high reproductive rates and short generation intervals of annual crops and by the relative ease of distribution and long-term storage of seeds. In contrast, the process of livestock GR development and use is far more participatory, with less institutional focus and more farmer involvement in maintenance of loosely organised "seedstock sectors". Low reproductive rates, long generation intervals, use of breeding males as the vehicle for genetic change, maintenance of breeding herds within the production system, and high-costs of *ex situ* storage combine to retard development of strong institutional capacity to manage AnGR.

Main threats to AnGR, and possible responses to these threats, include:

- **Failure to match genetic resources to the production environment.** High cost of AnGR development for specific environments has favored the spread of a few highly productive but often poorly adapted global breeds. More attention to specification of clear development goals, development of comprehensive livestock improvement strategies, and critical assessment of benefits and risks associated with use of local *versus* imported GR are needed.
- **Inadequate infrastructure for improvement of AnGR.** Public sector ownership of AnGR and investment in AnGR development is declining. New investment in training and capacity

building is needed to establish and empower farmers' organisations to take greater responsibility for better use and further development of AnGR.

- **Limited capacity to develop *ex situ* collections.** High costs of collection and limited use of preserved material will restrict development of extensive *ex situ* collections of AnGR. An alternative would be to implement a global program to assess genetic relationships among breeds following the pattern proposed by FAO Project MoDAD (http://dad.fao.org/en/refer/library/guidelin/project.pdf) and use this information to identify "core collections" of breeds that encompass a high proportion of global diversity for each species. These key GR could then be monitored *in situ* and collected for *ex situ* storage as required.

- **Inadequate institutional capacity to manage AnGR.** Institutional capacity to manage AnGR lags far behind that available for plants and will make implementation of action plans and legal agreements challenging. Methods to better coordinate, mobilise, and enhance existing institutional capacity should be identified.

2. Introduction

The world is in the midst of the most comprehensive assessment of global animal genetic resources ever attempted. Country reports have been received from more than 150 nations, and preparation of the First Report on the State of the World's Animal Genetic Resources (SoW-AnGR) is well underway. A critical part of this process is development of a Report on Strategic Priorities for Action to increase food security, support global economic development, promote sustainable utilization of genetic resources, and ensure maintenance of domestic animal genetic diversity. Development of this Action Plan and refinement of the Global Strategy for the Management of Domestic Animal Diversity are required to maintain momentum generated by preparation of country reports and realise the expectations of the SoW-AnGR process.

Organisation and execution of SoW-AnGR relied heavily on the model used for global assessment of plant genetic resources (PGR) which resulted in the 1998 Report on the State of the World's Plant Genetic Resources, development of a Global Plan of Action, and the International Treaty on Plant Genetic Resources for Food and Agriculture. With one major variation, namely the preparation of a Report on Strategic Priorities for Action before negotiating the First Report on the SoW-AnGR, a similar set of outcomes has been proposed for SoW-AnGR. Yet it is imperative that these outcomes also reflect the unique realities involved in management of animal genetic resources.

3. Scope of the Work

This report will:

- Compare and contrast opportunities, challenges, biological characteristics, institutional infrastructure, and operational considerations influencing management of plant and animal genetic resources;

- Summarise main threats to livestock genetic resources;

- Outline areas of greatest opportunity for better management of AnGR.

This report will focus on the globally important livestock species that dominate world animal production and the 25 to 30 annual crops that are responsible for over 90% of the world's calorie intake. Regionally important livestock species (e.g., old and new world camels, yak, etc.) will not be directly considered, but their local importance and the risks to these genetic resources that may arise from excessive emphasis on global species are acknowledged. Likewise, focus on annual crops recognises that these are the main species involved in both plant breeding and PGR conservation.

4. Developing Strategic Priorities for Management of Animal Genetic Resources

Development of a Report on Strategic Priorities for Action for Management of AnGR and associated legal and policy documents requires clear understanding of current status and potential opportunities for better AnGR management. The model used by the PGR process provides important lessons, but differences in the utilization and conservation of PGR and AnGR must be acknowledged.

4.1. Genetic resource utilization

The proper use, further development, testing, and deployment of plant and animal GR is essential to enhancement of food security and sustainable intensification of food production. In both plants and animals, the goal is to deploy an array of GR that can increase food production and improve animal and plant productivity in economically and environmentally sustainable production systems across the full spectrum of global production environments.

In traditional production systems, utilization of animal and plant GR is broadly similar. Locally adapted breeds and landraces predominate, seed for planting and breeding animals are drawn from the farmers' fields and flocks, and genetic diversity within breeds and landraces is substantial. Most breeding and development activities are "participatory" (FAO, 1998b) in the sense that breeding decisions (which seeds to plant; which animals to retain for breeding) are made by farmers rather than professional plant and animal breeders. However, intensification of agriculture has been accompanied by changes in patterns of GR utilization and development. In plants, intensification of crop production has generally been accompanied by emergence of a strongly institutionalised and centralised seed production sector (Figure 1). The institutions of this "seed sector" include both publicly funded national and international centers and private firms.

In contrast, intensification of animal production generally occurs only after establishment of intensive crop production, is currently much less advanced, and has been a result of, rather than a prerequisite for, economic development. The animal "seedstock sector" (Figure 2) is far less centralised and institutionalised than the plant seed sector. Direct involvement of farmers in the seedstock sector is substantial, and AnGR utilization and further development remains strongly "participatory".

4.1.1. Plant GR Utilization and the Seed Sector

Figure 1 provides a model of PGR utilization, including variety development and testing and the distribution of seed to farmers. Saving seed for replanting remains important in traditional production systems. As recently as 1998, fewer than one tenth of farmers in developing countries used the formal seed sector as their main source of seed. However, development and testing of new varieties increasingly occurs within the institutions of the seed sector, and active involvement of farmers in development of PGR has correspondingly declined.

Relatively little genetic diversity is present within modern plant varieties. This genetic uniformity supports escalating demands for product uniformity in national and international markets, but increases vulnerability to diseases and other stresses. Replacement of existing varieties is an accepted part of PGR utilization. Most new varieties have useful lives of perhaps 5 to 20 years. New plant varieties often include contributions from diverse sources and are seldom developed solely from pre-existing varieties. For example, nearly three quarters of the rice varieties developed by national programs between 1986 and 1991 had at least one imported parent (FAO, 1998b).

Concerns from the SoW-PGR Report of 1998 included needs to broaden the genetic base of materials used in variety development and deploy greater genetic diversity to reduce overall crop vulnerability. Despite calls for greater participation by farmers in variety development, responsibility for these activities was clearly focused on the institutions of the seed sector, with farmer participation mainly involving development goals, breeding objectives, and testing.

The institutions of the seed sector include national and multinational firms that dominate seed production in the most developed nations, publicly supported national institutions, and the international institutions of the CGIAR. All these entities hold extensive collections of PGR and, at different levels, contribute to development and release of new plant varieties. Interactions between these institutions and the various national and international *ex situ* PGR collects are likewise substantial, providing linkages to, and benefits from, ex *situ* collections.

Issues involving farmers' rights to share in the benefits from use of PGR in variety development have been extensively debated and addressed in documents arising from the SoW-PGR process. The right of farmers to retain seed for planting is now widely acknowledged and has had an impact on materials released by plant breeding firms

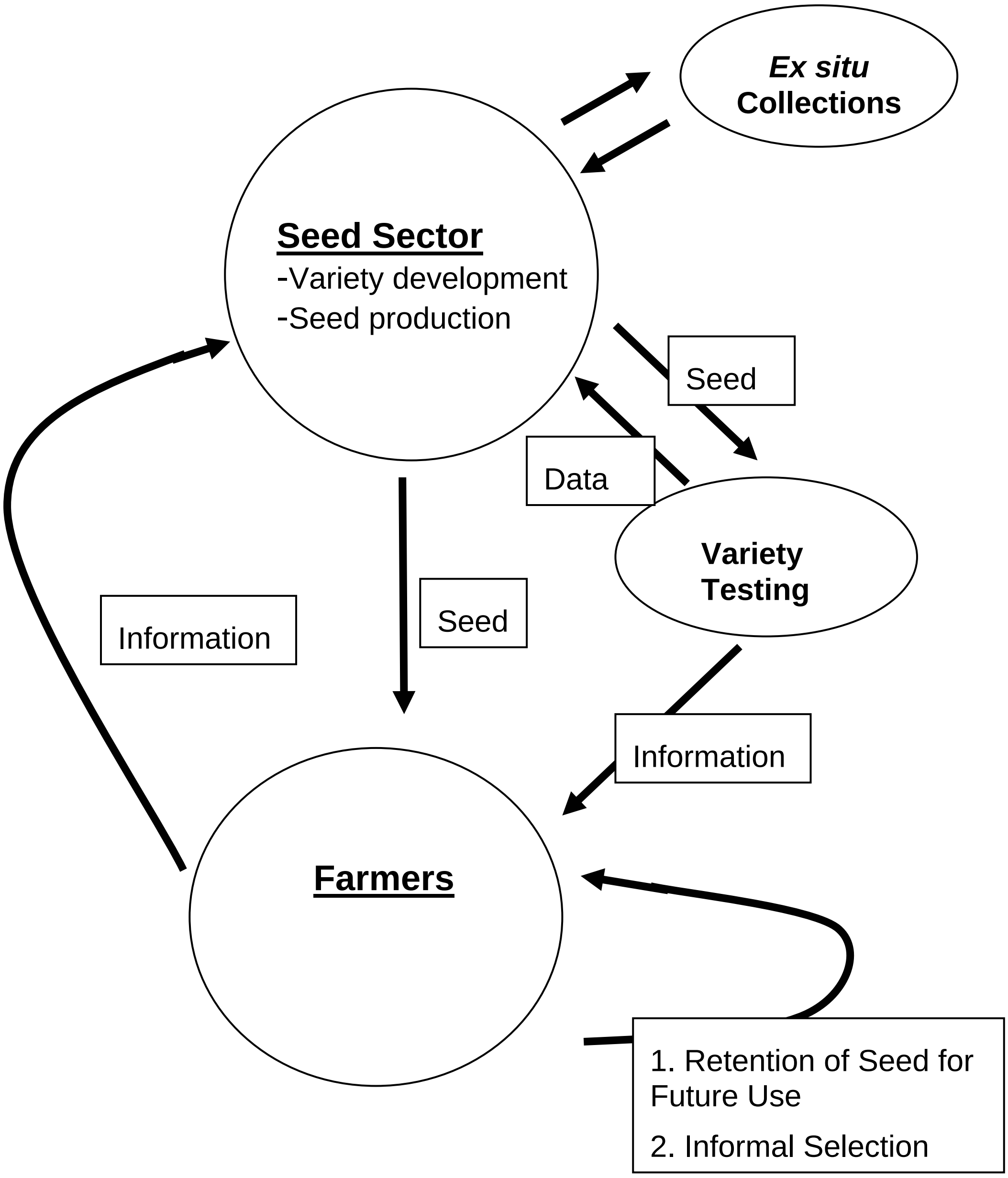

Figure 1. Organization of the plant genetic resources seed sector and relationships with *ex situ* genetic resource collections, variety testing, and commercial farms. Arrows show movement of data from variety testing activities back into the institutions of the seed sector, and feedback to and from commercial farmers (“information”, rather than “data”).

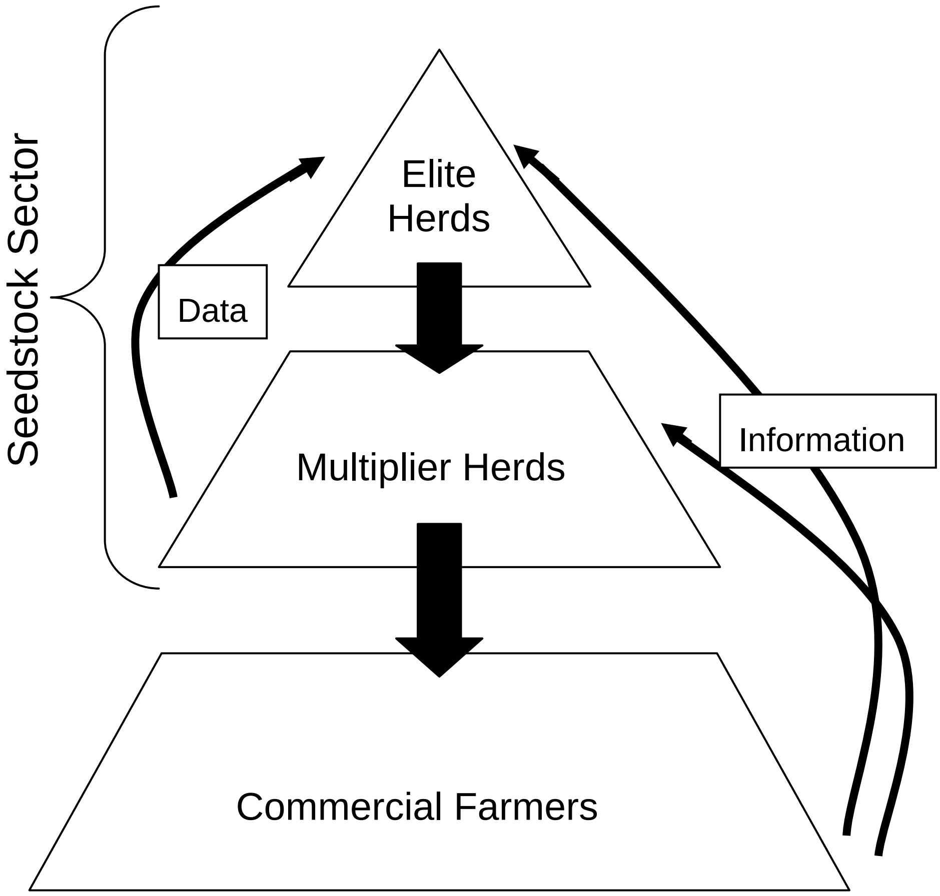

Figure 2. Genetic improvement pyramid portraying the movement of improved livestock genetic resources (block arrows) from elite breeding herds through multiplier herds and on to the commercial sector. The elite and multiplier herds represent the “seedstock sector” responsible for generation and multiplication of superior animals. Testing of selected animals (shown as contributing “data”) occurs in both elite and multiplier herds, with results contributing to further genetic improvement. Less formal feedback (shown as “information”) flows up the pyramid from commercial farms, but rarely involves the actual recording of animal performance. The size of the multiplier layer depends on the fecundity of the species and the organization of the elite breeders. Thus in poultry the multiplier layer is often small and closely associated with the elite breeders whereas in small ruminants, the multiplier layer is much more extensive and much more loosely associated with the elite breeding herds.

4.1.2 .Animal Genetic Resources Utilization and the Seedstock Sector

The process of genetic improvement in livestock in the commercial sector is shown in Figure 2, where the well-known genetic improvement pyramid is exploded to emphasise the different groups involved in the process. Elite herds at the apex of the pyramid and multiplier herds directly below them constitute a “seedstock sector” analogous to, but far less consolidated than, the seed sector of Figure 1. Multiplier layers are required because relatively low reproductive rates in livestock do not allow elite genetic resources developed by a small number of firms or institutions to be multiplied quickly enough to immediately serve the needs of commercial farmers. Instead, genetic improvement involves transfer of breeding stock (usually males) from elite herds through potentially several layers of multipliers and on to commercial farmers.

The process of AnGR utilization and development differs considerably from that of PGR. Thus PGR utilization mainly involves annual decisions about what seed to plant. The crop is harvested at the end of the growing season and new (and potentially totally different) seeds are acquired for next year. In animals, this model is approached only for intensive and semi-intensive poultry production, where chicks can be purchased from hatcheries, grown out, marketed, and replaced with new chicks. In larger mammals, however, GR utilization involves maintenance of herds of breeding females and the purchase of breeding males (or, occasionally frozen semen) as the agent of genetic change. While most offspring may be marketed, some of the female offspring are also commonly retained to replace females culled from the breeding herd. Breeding females and market animals usually coexist on the farm for at least part of the production cycle, and costs and returns from both affect profit from the livestock enterprise. Breeding females often remain on the farm for several years, so long-term effects of an AnGR utilization decision are not fully evident for some time and are not easily reversed; replacement of the entire breeding herd is not normally possible. Also, when breeding males are the main agent for genetic change, the full impact of a GR utilization decision is not immediately evident, even in market animals, because offspring express only 50% of the inheritance of their newly introduced sires. Several generations (up to 20 years for cattle) may be required to fully evaluate the introduction of a new livestock breed.

In most cases, genetic diversity in livestock breeds is much greater than that in crop varieties. Development of highly inbred, genetically uniform lines of livestock is not possible because of lower fecundity and greater sensitivity to negative effects of inbreeding. Even within highly selected and superficially uniform industrial breeds of poultry, pigs and dairy cattle, within-breed genetic diversity far exceeds that present in most crop varieties. In striking contrast to the situation in plants, there have been no convincing examples of a popular and apparently well-adapted livestock breed becoming threatened by a newly introduced or newly evolved pathogen and rescued by introduction of material from an unrelated breed. Thus in animals, emphasis has been placed on further development of a few popular breeds and the perceived need for maintenance and conservation of landraces, wild relatives, and other threatened AnGR has been correspondingly reduced.

Successful AnGR utilization generally requires some sort of seedstock sector to create, multiply, and deliver improved breeding animals. Establishment of a highly organised seedstock sector has occurred only in industrial poultry production where the reasonable prolificacy of poultry females (50 to 250 offspring per year) has allowed genetic improvement to be consolidated in a small number of multinational breeding companies. Multiplication of breeding stock occurs in flocks that are owned by or contracted to the parent firm, and chicks are delivered from hatcheries to farmers. Global expansion in industrial poultry production and consumption of poultry meat in part reflect establishment of this global seedstock sector. Similar structures for intensive pig breeding are emerging but are less efficient and widespread than those for poultry.

In ruminants, lower fecundity and generally more extensive production retard establishment of a centralised seedstock sector. A substantial multiplier layer can only be avoided through extensive commercial use of artificial insemination (AI) with frozen semen, but this approach has, to date, proven feasible only in industrial dairy cattle production, with very high total receipts per animal unit. In meat cattle, use of artificial insemination varies among countries, but AI usually accounts for less than 5% of total matings. Commercial use of AI with frozen semen in sheep and meat goats is virtually nonexistent. Strategies for development of seedstock sectors that rely on the extensive, unsubsidised use of AI and embryo transfer must thus be viewed with skepticism.

In some cases (e.g., Western Europe, the Americas, Australasia), strong seedstock sectors already exist. Ownership of GR is almost exclusively in private hands, ranging from multinational firms to individual farmers. Public ownership of AnGR is increasingly rare. Instead, the public sector increasingly emphasises either basic research in biological mechanisms underlying animal performance, including, in particular, biotechnology and animal genomics (Annex 2), or development of methodology to support programs for animal recording and genetic evaluation. The latter activities commonly involve interactions with farmers' organisations.

If a seedstock sector does not already exist, establishment of mechanisms to distribute improved AnGR has proven difficult. Attempts to establish elite herds in public institutions have often failed due to inadequate resources, failure to establish multiplier herds, and the small size of livestock production units. Given this history, an important outcome of SoW-AnGR will be identification of effective AnGR utilization strategies to support sustainable intensification of animal production and establishment of functional seedstock sectors.

Legal documents addressing farmers' rights and privileges with regard to AnGR must be developed carefully to ensure protection for those that maintain AnGR without stifling AnGR characterisation, development, and utilization. In plants, the institutions of the seed sector have a long history of use of conserved PGR in variety development and take primary responsibility for distribution of seed from resulting varieties. Global movement of AnGR is already limited by strict sanitary regulation designed to protect the health of national herds, and collection and testing of AnGR from the developing world is rare. Attempts to develop guidelines for benefit sharing must therefore first address how to better generate benefits from existing AnGR.

4.2. Ex situ conservation of GR

The global *ex situ* PGR collections contain approximately 6 million accessions (FAO, 1998b). After accounting for duplication and considering only material maintained primarily for conservation, the number of unique accessions is estimated to be 1 to 2 million. Of these, seed storage accounts for about 90% of the total, and cereals and food legumes account for nearly two thirds of the total. Wheat, rice, and maize are each represented by 250,000 to over 500,000 accessions.

Establishment or enhancement of national collections of PGR was accorded particularly high priority in the 1970's and 1980's and facilitated by the relative ease of collection and storage of seeds. While these collections may not provide complete coverage of the genetic diversity which exists (or existed) for many crops, they nonetheless represent a very substantial store of genetic diversity. Material from SoW-AnGR country reports will permit a rough accounting of the current state of *ex situ* conservation of AnGR. Results are not expected to be encouraging in terms of either numbers of breeds sampled or numbers of individuals represented within most breeds.

Ex situ conservation of livestock GR mainly involves long-term storage of frozen semen or embryos in liquid nitrogen. However, just as some plant species (whose seeds will not survive long-term storage) must be maintained in field genebanks or *in vitro* facilities, so some animal GR are maintained as living animals under *ex situ* conditions. These mainly involve poultry species for which use of frozen semen is inefficient and freezing of embryos is not currently possible.

Costs of collection and cryoconservation of semen and, particularly, embryos are many times greater per preserved genome than costs of collection and storage of seeds. The World Watch List for Domestic Animal Diversity (FAO, 2000b) lists nearly 4,300 breeds of buffalo, cattle, goat, pig, and sheep and over 900 breeds of chicken, duck, goose, and turkey. Only a few of these are well represented in *ex situ* collections and almost none have been sampled at levels consistent with FAO (2000a) guidelines for *ex situ* sampling.

Resources to develop *ex situ* collections including a substantial proportion of these 5,200 livestock breeds are not likely to become available. Nearly 1,300 breeds are listed as at risk, and FAO (2000) Guidelines for Management of Small Populations at Risk recommend collection of frozen semen from at least 25 males per breed and use of semen from these males on an additional 25 females per breed to produce frozen embryos. For cattle, this would involve 300 endangered breeds and require cryopreservation of semen from 7,500 males and of approximately 100,000 embryos.

Development of *ex situ* collections of AnGR must also address operational issues regarding use and replenishment of material. Cryopreserved gametes and embryos should remain viable in perpetuity if properly frozen and maintained, whereas stored seeds eventually lose viability and must be grown out under controlled conditions to produce new seed. In animals, direct replenishment of stored material is possible only from frozen embryos, and requires access to, hormonal preparation of, and maintenance through gestation of recipient females plus maintenance of offspring to reproductive age and subsequent collection of embryos, a costly, high-maintenance process. Frozen semen is ideal for many GR utilization activities, providing a sample half of the genetic material of preserved breeds in a form that permits convenient introgression into recipient populations. However, regeneration of a cryopreserved breed from frozen semen in one generation is possible only if living females of that breed are still available. If these females are not available, several generations of upgrading are required to permit reestablishment of a conserved breed. Regeneration of a cryopreserved breed would thus be very difficult, accounting, in part, for the very large numbers of doses of semen and embryos recommended for *ex situ* breed conservation (FAO, 2000). Developments in biotechnology may provide new opportunities for *ex situ* collections but have yet to be realised (Annex 2).

These considerations suggest that establishment of comprehensive *ex situ* collections of endangered breeds is unlikely for any livestock species without a major commitment of new resources. Yet action to secure and maintain global domestic animal diversity is desperately needed (Annex 1); over 50% of global livestock breeds are known to be endangered or have unknown status. An initial priority might be to identify “core collections” of genetic diversity for each species. In plants, *ex situ* core collections have been identified by sorting through material in existing *ex situ* accessions and targeted collecting of poorly represented materials. A similar goal could be adopted for livestock, involving a comprehensive global genetic and phenotypic analysis of breeds.to identify those that would contribute most and most efficiently to core collections. This analysis would be followed by strategic targeting of populations for maintenance or collection. It can be argued that targeting of activities to areas of greatest need and opportunity is less likely to result in losses of globally significant populations than current *ad hoc* approaches and may be the only approach that provides a reasonable likelihood of success in securing these core collections.

5. Main Threats to AnGR and Possible Responses

5.1. Failure to match genetic resources to the production environment

Use of poorly adapted breeds with high production potential but correspondingly increased requirements for supplemental feeds, veterinary services, and more intensive management has often resulted in erosion of local GR without measurable increases in production.

Possible Responses:.programs for AnGR utilization should be established in the context of clearly defined development objectives that take account of the stressors present in the production environment. These programs should be implemented as part of a coordinated livestock improvement strategy that clearly addresses patterns of use of animal products. Identification of new markets and marketing strategies are particularly important to help defer greater input requirements of high-production breeds.

5.2. Inadequate infrastructure to permit development of improved AnGR

Public sector investment in AnGR development is declining, with increasing emphasis on biotechnology and correspondingly reduced attention to more holistic breed improvement activities involving design of breeding programs, establishment and support of animal recording schemes, testing of alternative AnGR, and development of seedstock sectors involving local farmers and traditional breeds. The result is to abdicate AnGR development to the well-developed seedstock sectors of the (primarily temperate) global breeds.

Possible responses:.Policies are needed that foster more holistic approaches to AnGR utilization, including:

– More support for establishment of farmers' organisations, cooperatives, and collaborative breeding schemes that can support genetic improvement of local breeds and provide infrastructure for distribution, testing, and use of improved AnGR;

– Better integration of new techniques (*e.g.*, advanced reproductive technologies, biotechnology) with traditional approaches (*e.g.*, animal recording, crossbreeding) to establish practical breeding programs;

– Increased training and consultative capacity to empower farmers to better manage AnGR.

5.3. Limited capacity to develop ex situ collections

Capacity to collect and cryopreserve semen and, especially, embryos from large numbers of threatened breeds is inadequate. The forthcoming First Report on the SoW-AnGR will provide information on existing *ex situ* collections but is not expected to be encouraging. Current *ad hoc* approaches do not guarantee appropriate sampling of biodiversity.

Possible responses: Action is required to better understand genetic relationships among breeds globally and develop core collections of livestock biodiversity that encompass key genetic diversity of each species. These core collections could be maintained by monitoring *in situ* populations with *ex situ* conservation of the most unique and endangered breeds. Widespread assessment of genetic relationships among large numbers of global livestock breeds, following the prototype proposed by FAO Project MoDAD (FAO, 1998a) would do much to improve efficiency of management of global AnGR. Careful costing of alternatives for developing secure core collections of AnGR should be undertaken. .

5.4. Inadequate institutional capacity to manage AnGR

The institutions of the seed sector provide institutional capacity for management of PGR and implementation of the legal instruments and action plans that emerged from the SoW-PGR process. In contrast, institutional capacity for AnGR management is far more limited, involving two CGIAR institutions (ILRI and ICARDA) and generally very limited and poorly funded national *ex situ* collections. Ownership of AnGR is predominantly in the private sector and public-sector capacity for testing introduced AnGR is notably lacking.

Possible responses:.Increased support for institutions involved in management of AnGR is needed but at best will lag far behind that devoted to PGR. The Report on Strategic Priorities for Action that emerges from the SoW-AnGR process must focus carefully on the most critical activities and opportunities that maximise effectiveness and cooperation among existing institutions. Development of a Multilateral System and a Governing Body for AnGR analogous to those defined in the International Treaty on Plant Genetic Resources for Food and Agriculture would be challenging given current institutional capacity.

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Annex 1
Securing the Global Genetic Diversity in Livestock Species

The world's *ex situ* collections for major crop species such as wheat, rice, and maize contain several hundred thousand accessions, far in excess of anything imagined for major livestock species such as cattle, pigs, sheep, goat, and chicken. In the face of this disparity, one is led to ask how many "accessions" would be needed to adequately represent the diversity in a livestock species.

Unfortunately, the information to address this question in an objective way does not exist. Use of various genetic markers to derive measures of relatedness and genetic distance among accessions within *ex situ* plant collections was given high priority in the SoW-PGR report (FAO, 1998), but only modest progress has been made. Many studies to derive measures of genetic relationships among small groups of breeds have been conducted, but most did not use large enough numbers of markers, large enough numbers of breeds, or adequate sampling of individuals within those breeds to provide definitive results. Pooling results from different studies conducted in different laboratories and with different sets of genetic markers is not possible. Indeed, given our current knowledge of plant and animal diversity, attempts to somehow determine what sort of sample from a livestock breed is somehow equivalent in terms of diversity to a typical plant accession is largely a fruitless exercise.

The World Watch List for Domestic Animal Diversity lists over 5,200 livestock breeds reported to FAO. An additional 704 breeds have already disappeared in pure form. However, careful reading of the Watch List suggests that this estimate of the number of livestock breeds may adequately reflect current information, but likely underestimates of the total number of global livestock breeds and the extent of their endangerment. In addition to the 1,300 breeds listed as critical or threatened, the status of an additional 1,163 breeds is recorded as "unknown", and many of these breeds probably are also at risk. Reporting biases likewise clearly exist. Europe, with a land area of 10,517,000 km^2 and estimated populations of approximately 162 million cattle, 185 million sheep, and nearly 2 billion chickens, lists 482 breeds of cattle, 629 breeds of sheep, and 451 breeds of chicken. In contrast, Africa, with a land area of 30,259,000 km^2 and populations of approximately 175 million cattle, 127 million sheep, and 730 million chickens, reports 251 breeds of cattle, 148 breeds of sheep, and only 55 breeds of chicken. This discrepancy almost certainly does not reflect genuinely lower levels of genetic diversity in African livestock, but instead reflects more detailed reporting and a stronger tradition of breed development in Europe.

The considerable genetic diversity in livestock breeds.raises questions about the numbers of breeds and samples within breeds that must be included in *ex situ* collections to adequately capture the genetic diversity of a species. Preliminary results from many species now confirm that very few genetic markers are found in only a single breed. Even when large numbers of markers are screened, it is rare to find specific haplotypes that unambiguously define breed membership. We thus have a great deal to learn about the global distribution of livestock genetic diversity, and that knowledge is sorely needed to aid in the configuration of schemes for better management of AnGR.

Annex 2
Potential Impacts of Biotechnology on AnGR

Opportunities to use biotechnology to improve the effectiveness of AnGR utilization and conservation have been widely discussed but will require substantial technical and operational development. Thus:

- Artificial insemination (AI) using frozen spermatozoa and the transfer of frozen embryos are mature technologies in ruminant livestock but are widely applied only in intensive dairying or within elite seedstock herds where the potential value of each insemination or embryo transfer is high. Artificial insemination using fresh semen has been successfully applied on a commercial level in pigs and sheep. However, use of fresh semen in AI still requires that breeding males be deployed to the farms and villages where the females are located or that a transportation infrastructure exists that can support 1- to 2-day delivery of chilled semen. Increasingly, for zoosanitary and economic reasons, AI and ET are being used mainly for the initial delivery of imported GR and less as a vehicle for the better use of locally developed, superior males. In part this occurs because after the initial introduction of new GR, an animal recording infrastructure is required to continue to identify superior males and generate sustained genetic improvement. Unfortunately, far more resources are commonly applied to the initial AI or ET schemes than to the development of sustainable improvement programs.

- Gene mapping, the detection of quantitative trait loci (QTL), and the use of these QTL in selection schemes has potential to accelerate genetic improvement and provide new insights into control of animal performance. However, costs of detection and validation of QTL remain high. The identification of genes that impart disease resistance or improve product quality and their introgression into appropriate recipient breeds would be particularly attractive. However, many of the major QTL identified to date, such as the myostatin mutants leading to increased muscle mass in cattle or the various mutant fecundity genes associated with increased prolificacy in sheep, often have deleterious correlated effects on animal fitness. Attempts to detect and utilise the genes conferring resistance to trypanosomiasis in cattle represent a particularly cautionary tale. Although candidate QTL have been identified, the ability to control the disease by simple introgression of a few genes from resistant breeds has not been successful. To date, it appears that most useful QTL will have moderate effects on production and fitness and will need to be used in conjunction with classical methods for improvement of quantitative traits.

- Gene transfer:.the creation of new genetic diversity by the transfer of genes among breeds and, potentially, species has fired the imagination of animal breeders since the first “super-sized” mice appeared on the cover of Nature in 1982. Successful use of gene transfer in plants and the production of human pharmaceuticals by the introduction of human genes into animal models further raised expectations for comparable achievements in livestock production. Yet costs associated with gene transfer in animals remain high and there have as yet been no notable direct contributions of gene transfer to improving animal production.

- Cloning of livestock is not, today, a practical reality but would provide substantial benefits for both AnGR utilization and conservation. The development of totipotent cell lines would permit production and deployment of genetically identical individuals, with all the benefits and pitfalls inherent in the development of highly uniform plant varieties. If these lines could be readily established from adult animals, intensive selection and rapid multiplication of animals with desirable performance in specific production environments becomes possible. *In vitro* cryogenic storage of somatic tissue for future regeneration of living animals by cloning is sometimes put forth as a potential form of *ex situ* storage of AnGR. If feasible and reliable, this approach would allow establishment of AnGR collections that would rival seed collections in efficiency of storage and utilization. Utilization of preserved material would still be much more costly than use of seeds, but maintenance of an extensive *ex situ* collection would be possible. Individuals of several mammalian species have been produced by somatic cloning but success rates remain low and there is as yet no commercial application. Thus use of this strategy must await further developmental research and confirmation of its feasibility.

– Collection and storage of animal DNA for future genetic screening to identify sequence variants of potential interest has likewise been recommended, but living animals cannot be regenerated from DNA. However, DNA can be easily extracted from hair follicles or blood smears, even after long periods of low-cost storage. Thus widespread sampling of hair or blood as a DNA source for future research is recommended as a component of a comprehensive GR management strategy. Widespread DNA sampling within and among animal breeds would also facilitate clearer definition of genetic relationships among breeds and support development of more effective conservation programs.