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Complementary Strategies for Conservation of Animal Genetic Resources and Global Innovation Challenges

Sipke Joost Hiemstra
Centre for Genetic Resources (CGN), Wageningen University and Research, Wageningen, The Netherlands

Global Challenges and Trends

The livestock sector is facing major challenges in order to reach global food security and to supply animal products for a growing global population (UN, 2012). At the same time, the livestock sector will have to anticipate climate change (Aby and Meuwissen 2014; IPCC, 2014) through both mitigation and adaptation strategies. Sustainable growth and sustainable intensification strategies are needed to meet the predicted future demands taking advantage of innovation and implementation of new technologies in the livestock sector. Genetic improvement of livestock has played an important role in enhancing the efficiency and sustainability of animal production during the past decades and will continue to be relevant in order to deal with future challenges.

International flows of animal genetic resources have continued to expand over recent years, driven by the increasing demand for higher-output animals and major developments in livestock management and reproductive biotechnologies. Introduction of new technologies in advanced animal breeding programmes has resulted in high genetic gains. Global distribution of improved genetics has accelerated, although the introduction of highly specialised, improved genetics to more extreme and variable production circumstances is not always sustainable. A still growing proportion of livestock products is produced by highly specialised livestock breeds, and local breeds have been gradually replaced by more widely used specialised breeds. The Second State of the World's Animal Genetic Resources (FAO, 2015) showed that 17% of the world's livestock breeds is classified as being at risk of extinction.

Complementary Conservation Strategies

Multiple publications have indicated that complementary *ex situ* and *in situ* conservation strategies are needed to support and to promote the conservation and sustainable use of genetic resources. Both type of strategies have clear advantages and disadvantages with respect to specific conservation objectives, and individual strategies can include a wide range of activities to support the conservation and sustainable use of genetic resources. And, very important, there is a variety and large number of actors, contributing to or leading particular conservation strategies.

In situ conservation strategies support the maintenance of livestock populations in the environment where the breeds have developed, and in this context it is important to establish and implement sustainable breeding and genetic improvement programmes. The complementary *ex situ/in vitro* strategy (cryoconservation and storage of frozen genetic material) is particularly an important back-up strategy for long-term conservation of between and within breed genetic diversity.

For animal genetic resources (AnGR) most of the European countries report *in situ* and *ex situ* conservation activities for livestock breeds, but there are also gaps in (the breed coverage of) conservation programmes (FAO, 2015). The Second State of the World's AnGR (FAO, 2015) shows that *in vitro* gene banks have been established by 64 countries and a further 41 countries are planning to do so. However, many of these gene banks are in early stages of development and most collections have gaps in their breed coverage.

An integrated *in situ/ex situ* conservation strategy requires a common understanding of conservation priorities at local, national and European level. However, often neither *in situ* nor *ex situ* conservation strategies may have a high priority in national policies; stakeholders or user groups may have different interests resulting in different conservation priorities. Coordination at national, regional and global level is needed to strengthen (linkages between) *ex situ* and *in situ* conservation efforts, as it was also indicated in the the Global Plan of Action for Animal Genetic Resources (FAO, 2007).

**Author for Correspondence: Email- sipkejoost.hiemstra@wur.nl*

Developments in Animal Breeding

Application of new technologies in animal breeding, including genomic selection and advanced reproductive technologies, will continue to play an important role in meeting future challenges for the livestock sector. Genomic selection, which enables prediction of the genetic merit of animals from genome-wide SNP markers, has already been adopted by dairy industries worldwide and is expected to double genetic gains for milk production and other traits. Use of whole-genome sequence data could further accelerate these developments (Hayes *et al*., 2012). Genomic selection reduces the generation interval and has clear advantages for traits that cannot be measured on the selection candidates themselves, for traits that are difficult to measure or traits expressed late in life. Genomic selection also has the advantage to start a genetic improvement programme in an un-pedigreed population, and has the potential to be applied across breeds, in non-mainstream breeds, or in cross-bred small-holder cattle populations in developing countries (Brown *et al*., 2016). However, extensive validation of the association between genotypes and phenotypes will always be needed first.

The livestock sector has entered the area of 'precision breeding' (Flint and Woolliams, 2008). Developments in genomics and the possibility of generating full DNA sequence information at low cost, will make it possible to unravel the genetic mechanisms of traits in livestock breeds. Detailed knowledge can then be used to make 'interventions' at DNA level, either through genomic selection, genomic introgression methodologies (Aby and Woolliams, 2014) or through emerging genome editing techniques (Jenko *et al*., 2015). Modification of the genome using genome editing techniques has the potential to introduce specific phenotypes in commercial livestock populations, on the basis of increased knowledge of genome function and genetic mechanisms. Expected growing demands for animals that are robust, well-adapted to climatic extremes, or to climate-related disease challenges, could trigger such developments. Genome or gene editing techniques – combined with advanced reproductive technologies may change the animal breeding landscape in the future.

Gene Banks – Their Current and Future Roles

Countries are implementing the Global Plan of Action for Animal Genetic Resources (FAO, 2007) and are developing *ex situ/in vitro* conservation programmes (Paiva *et al*., 2014; FAO, 2015), complementary to *in vivo* conservation. Gene banks are important sources of genetic variation to ensure long-term conservation of within and between breed genetic diversity and to support the maintenance of genetic diversity in *in situ* livestock populations. Moreover, genebanks have shown to be a crucial resource for building reference populations and training sets for genomic selection. For the future, gene bank collections are expected to become increasingly relevant for research and development purposes.

Establishment of national farm animal gene banks often serves multiple objectives and gene banks differ in strategies, types and size of collections and organisation (Hiemstra *et al*., 2014). In general farm animal gene banks are organised by breed, and the concept of maximising/optimising genetic diversity stored for each breed is widely accepted. However, it can be argued that more emphasis should be put on characterisation and conservation of specific, unique phenotypes, across breeds (Leroy *et al*., 2015).

Gene bank collections could be better evaluated in terms of the genetic diversity currently present in genetic collections, for a range of traits. More research on functional genomics could provide a better understanding of the relationship between genotype and phenotype, for example to assess the adaptation of individuals to environmental variation, in particular in the context of climate change.

Whereas methods have been developed to optimise the management of genetic variability of *in situ* populations either under selection or under conservation, few scenarios have been tested in order to (re)introduce diversity or 'lost' alleles in animal production systems through the use of gene banks (Leroy *et al*., 2011). New techniques, including genomic introgression (Wall *et al*., 2005, Yazdi *et al*., 2008) and also gene editing could provide opportunities to (re)introduce rare or lost alleles or particular traits.

Long-term conservation of farm animal genetic diversity is primarily a government responsibility, but breeding industry is also interested in gene bank collections for future breeding and research, in particular to better understand the genetic background of traits across breeds and environments. Breeding industry will have to take responsibility for long-term conservation of genetic diversity in their own breeding populations or breeding lines, and at the same time they could contribute to the long-term conservation of farm animal genetic diversity in national gene banks. Further involvement of breeding associations, breeding industry, farmers' networks and other actors in the establishment of gene bank collections should be promoted, and more could be done with regard to the practical utilisation of gene bank collections in breeding and research (EC, 2016).

International Collaboration as a Network of Gene Banks

In Europe, the EUGENA initiative is developing the European Gene Bank Network, with the support of the European Regional Focal Point for Animal Genetic Resources (http://www.rfp-europe.org/). Currently there is limited information available about gene bank collections at national level and most gene banks are currently more active in storage than in distribution of genetic resources. At present, data on gene banks are scattered and incomplete. The current lack of information severely limits the transfer into current breeding programmes of genebank material which has been collected in the past. From this perspective there is a need for gene-banking data information systems that connect cryopreserved samples with a precise and comprehensive description of phenotypic and genomic information.

Groeneveld *et al*. (2016) also highlighted the importance of biobanks to meet future demands in livestock production. Well-established domesticated animal biobanks and integrated networks harbour immense potential for great scientific advances with broad societal impacts, which are currently not being fully realised.

IMAGE (Innovative Management of Animal Genetic Resources), a research project funded by the EU Horizon 2020 programme (http://imageh2020.eu), will support the development of the network of farm animal gene banks in Europe (EUGENA). The general aims of IMAGE are to enhance the use of genetic collections in Europe, to upgrade animal gene bank management, and to demonstrate the benefits brought by gene banks. IMAGE distinguishes two main types of genetic collections, germplasm collections (reproductive material) and genomic collections (DNA and tissues for research purposes). Both types of genetic collections are not very well connected. There is a need to facilitate access to (information about) genetic collections across Europe for research collaboration, conservation and breeding of transboundary breeds and for future breeding in general. IMAGE will take advantage of rapid developments in genomics and bio-informatics and will further develop reproductive technologies.

Conclusion

The global livestock sector is facing major global challenges and at the same time farm animal genetic diversity is under threat. Novel breeding approaches and complementary *in situ* and *ex situ* strategies are needed to deal with those challenges, and international collaboration and exchange of genetic resources has been important and will continue to be important for the future.

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