



# Use of Modern Genetic Approaches in Conservation of Farm Animal Genetic Resources (FAnGR): A Review

Shweta Sachan\*, Babu Lal Saini and Ashish Bhaladhare

PhD Scholar, Animal Genetics and Breeding Division, ICAR-Indian Veterinary Research Institute, Izatnagar, Uttar Pradesh, INDIA

\*Corresponding Author: [shwetagb24@gmail.com](mailto:shwetagb24@gmail.com)

**How to cite this paper:** Sachan, S., Saini, B., & Bhaladhare, A. (2021). Use of Modern Genetic Approaches in Conservation of Farm Animal Genetic Resources (FAnGR): A Review. *International Journal of Livestock Research*, 11(1), 13-21. <http://dx.doi.org/10.5455/ijlr.20201018071309>

**Received** : Oct 17, 2020  
**Accepted** : Nov 29, 2020  
**Published** : Jan 31, 2021

Copyright © Sachan *et al.*, 2021

This work is licensed under the Creative Commons Attribution International License (CC BY 4.0). <http://creativecommons.org/licenses/by/4.0/>



## Abstract

*Farm animals supply 30 percent of total human requirements for food and agriculture and 70 percent of the world's rural population rely on livestock as a component of their livelihoods. On the basis of policy developments, climate change and diversifying market demands, livestock conservation practice is changing rapidly. Selective breeding and exchange of farm animals or germplasm among users within and across countries are most commonly used strategies of enhancing livestock production but it resulted in the reduction of the bio-diversity of breeds. The selection pressure strongly increased, and therefore the reproduction among breeds was seriously reduced, resulting in the fragmentation of the initial gene pool. The selection pressure further increased due to the use of artificial insemination, leading to a few industrial breeds with very high performances, but with low effective population sizes. Beside this performance improvement of industrial breeds, genetic resources are being lost specifically indigenous and local breeds, because of the replacement of traditional breeds by high performance industrial breeds at the worldwide level. Many breeds are already extinct, and genetic resources in indigenous cattle, sheep, and goats are thus highly endangered, particularly in developed countries. Based on sound genetic characterization, urgent conservation measures must be taken to avoid an irremediable loss of livestock genetic resources, integrating economical, sociological, and political parameters. The livestock genomic sector therefore needs to make a concerted effort in the coming decade to enable to the democratization of the powerful tools to ensure that they are applied within the context of breed conservation as well as development. Recently, development of effective technologies opens new avenues for correctly characterizing the genetic resources, not only within the very diverse domestic breeds, but also in their wild relatives. In conclusion, genetic characterization of indigenous breeds of farm animals by the use of effective techniques and their conservation is only alternate to maintain farm animal bio-diversity.*

**Keywords:** Bio-diversity, Conservation, Farm animal, Genetic resource, Germplasm, In vivo, In vitro

## Introduction

The Indian subcontinent is one of the few countries in the world, which has contributed richly to the international livestock gene pool and improvement of animal production in the world. Keeping livestock is an important risk reduction strategy for vulnerable communities, and livestock are important providers of nutrients and traction for growing crops in smallholder systems (Rosegrant *et al.*, 2009). Also, livestock breeds reflect the cultural and historical identity of the communities that developed them, and have been an integral part of the livelihood and traditions of many societies. Loss of typical breeds, therefore, means a loss of cultural identity for the communities concerned, and the loss of part of the heritage of humanity. Among the domesticated livestock, a various breeds/types of cattle, buffaloes, sheep, goats, pigs, horses, camels, etc. have evolved over time through natural selection and a few human efforts. Great changes in livestock production systems over the last century, which have mainly been connected with agricultural industrialization, mechanization, and globalization, have led to the abandonment of many local animal breeds (FAO, 2007). Advancement in all areas of animal husbandry, including breeding and genetics, reproductive physiology, nutrition, and animal health, can unintentionally contribute to the decline in the number and diversity of breeds and types. Among the genetic approaches, selective breeding and exchange of germplasm among users within and across countries are most commonly used strategies of enhancing livestock production (FAO, 2012). The great concerns are the inflated loss of indigenous breeds impacting the livelihood options for the poor owing to utilization and management of these genetic resources (Tisdell, 2003). Loss of genetic diversity threatens livestock production systems throughout the world. Preserving the capacity to continue to develop modern livestock requires global actions, on national and international levels, to prevent the loss of valuable genetic resources (Belew *et al.*, 2016). The best way of conservation would be the development of a management system which might both maintain genetic variability of existing livestock resources and at the same time permit continuous improvement in productivity and adaptability of that resource (FAO, 1981).

The science of conservation is emerged in the seventies with the goal of preserving ecosystems, species and genes (Wilcox and Soule, 1980). Within this field, conservation genetics deals with the application of genetic concepts and tools to conservation problems. Conservation strategies involve both *in situ* and *ex situ* techniques, the latter being divided between *ex situ-in vivo* and cryoconservation (*ex situ-in vitro*), which is defined as the collection and deep-freezing of semen, ova, embryos, skin, blood, DNA fragments, or tissues in liquid nitrogen for potential future use in breeding or regenerating animals (FAO, 2019). This review therefore, explores the needs, approaches and benefits and limitation of conservation approaches of animal genetic resources with the following heading i.e., 1) Why conserve the genetic diversity of livestock, 2) Approaches for conservation of livestock germplasm, 3) Benefits and limitation of genetic resource conservation techniques, 4) Programmes and policies for genetic conservation of livestock, and 5) Future concern.

### 1. Why Conserve the Genetic Diversity of Livestock

The genetic diversity of livestock populations is dwindling for a multitude of threatening factors that lead to decline/extinction of domestic animal diversity (Belew *et al.*, 2016). This decline increased reliance on animals of a single breed or type for commercial production at the expense of other recognized types. If genetic diversity is further reduced, it may limit future options for improving livestock populations. Furthermore, depleting diversity due to current breeding technologies, worldwide movement of germplasm, proliferation of highly selected industrialized breeds, and commercial stocks founded on a relatively small number of breeding individuals are also responsible to conserve genetic biodiversity. The conservation of livestock is to prevent the loss of the many differentiated populations that, because of geographic or reproductive isolation, have evolved distinct characteristics and now occupy different environmental niches. There are usually multiple types of threat and reasons why farm animal genetic resource (FAnGR) should be conserved, with the ranking of these threats and reasons varying with the countries, agro-ecosystems, farming system, species, breed, etc. Below mentioned key factors identified as causing threats to FAnGR in the developing world-

#### i. Pressure to Adopt Improved Animal Breeds

Cross-breeding and subsequently the replacement of locally adapted breeds by a narrow range of high yielding international trans-boundary breeds is the major concern affecting animal genetic diversity in developing countries (Boettcher *et al.*, 2010; Taberlet *et al.*, 2011).

## **ii. *Paradigm Shift in Production System***

Livestock production systems have changed in ways (intensification and commercialization) that have had a major impact on the use, exchange and conservation of farm animal genetic diversity and in turn lead to the loss of livestock genetic diversity (FAO, 2007).

## **iii. *Population Pressure, Globalization and the Livestock Revolution***

Population pressure and increasing in income levels are putting pressure on livestock owners in developing countries to increase production by urging to depend only on a limited range of genotypes (FAO, 2009).

## **iv. *Climate Change, Biotechnology and Development Policies***

In the tropics and subtropics, in particular, increasing heat stress is expected to cause daunt challenges in livestock production by retarding production and fertility, increasing mortality rates; elevated water requirements and deterring feed intakes (Philipsson *et al.*, 2011). Advancements in biotechnology are projected to boost the use of superior genotypes across the globe, which may negatively affect conservation of global farm animal genetic diversity (Drucker *et al.*, 2007). Wrongly, planned policies and development programmes often trigger the threats to AnGRs by promoting superior genetic resources particularly if cross-breeding takes place in unsupervised condition (FAO, 2009).

## **v. *Urbanization and Rural Migration***

The rapid urbanization results in high demand for animal origin products like milk, meat, fish, egg, etc.; on other hand, labour demand has been increasing from urban space leading to rise in wage rate in rural sector. Therefore, responsible for rapid reduction in genetic diversity of livestock. Urbanization and rural migration driven reduction in genetic diversity of livestock require policies for sustaining livelihoods in both rural and urban communities.

## **vi. *Changes in Market Preferences***

The products from animal origin utilized in India are rather different to those of other countries because the particular nature of religion, caste and culture of the Indian population. Major livestock products consumed by Indian population are namely milk, eggs and chicken meat therefore these products dominant in Indian market. Consumption of selective animal products is the major cause of reduction in genetic diversity of livestock.

## **vii. *Competition for Natural Resources***

Drastic increase in human population directly compete with livestock biodiversity and responsible for its reduction. More and more agricultural land is utilized for the human food production rather than for the production of feeds and fodders for livestock.

## **viii. *Lack of Valuation of Local Breeds***

Local breeds often suffer from a lack of recognition of the value of their products. Therefore, their products may currently have low quality or be available only in small quantities. Lack of evaluation of local breeds results into the mixing of their germ plasma and loss of their diversity.

## **ix. *Natural Disasters, Epidemic and Endemic Diseases***

Heavily reliant on weather, climate and water for its ability to thrive, agriculture and livestock sector are particularly vulnerable to natural disasters. Disasters, epidemic and endemic diseases can have rapid or slow onset, with serious health, social, and economic consequences. In past few decades these events killed millions of livestock and adversely affected the genetic biodiversity no. of animals.

## **x. *Trade Agreements***

International trade of food and feed greatly influences global food security, resource sustainability and livestock

biodiversity.

Significance of conserving genetic bio-diversity of livestock is as follows:

- a. To prevent genetic erosion of populations that retains value for current use.
- b. To maintain sufficient genetic diversity to meet the needs of current and future utilization.
- c. To provide options for adaptation to changing environmental conditions.
- d. To support sustainable animal production systems for food security.
- e. To provide genetic resources for cross-breeding and development of new genotypes.
- f. To provide options to meet the demands of new markets for livestock products and services.
- g. To preserve cultural and historical values.
- h. To fulfil the rights of an existing genetic resource to continue to exist.

## 2. Approaches for Conservation of Livestock Germplasm

Conservation biology is a relatively new field of research that emerged in the seventies with the goal of preserving ecosystems, species and genes (Wilcox and Soule, 1980). Within this field, conservation genetics deals with the application of genetic concepts and tools to conservation problems. Several approaches for conservation can be applied. Broadly, conservation strategies are categorized into *in situ* and *ex situ* techniques, the latter being divided between *ex situ–in vivo* and cryoconservation (*ex situ–in vitro*), which is defined as the collection and deep-freezing of semen, ova, embryos, skin, blood, DNA fragments, or tissues in liquid nitrogen for potential future use in breeding or regenerating animals (FAO, 2018).

*In vivo* conservation is that the conservation of a breed through the maintenance of live animal populations. It consists of both *in situ* conservation of breeds within their typical production systems and their *ex-situ in vivo* conservation in a controlled environment (FAO, 2013). *In situ* and *ex situ* conservation methods are complementary. The most common form of *ex situ* conservation is *in vitro* cryoconservation of gametes or embryos in a gene bank. Whenever breeds are conserved *in vivo*, whether *in situ* or *ex situ*, they should be managed in ways that maintain their genetic variation in the long term (FAO, 2007). It is well known that a small population size may lead to loss of allelic diversity and an increase in inbreeding (Furlan *et al.*, 2012). *In situ* conservation involving continued use as part of an ongoing livelihood strategy at one end through to conservation in zoos with no connection to ongoing use at the other (Kasso *et al.*, 2013). After having passed a certain threshold of endangerment, populations that are put under *in situ* conservation programmes will have to be managed with specific conservation breeding programmes. *In situ* conservation approaches are to be preferred as a method of conservation where maintenance and management of the FAnGR is the best available livelihood option for the farmers involved. *In situ* conservation ensures that a breed is maintained in a dynamic state and, when including appropriate genetic improvement programmes, can make sure that the breed retains its relevance to changing production, marketing and social environments. *Ex situ in vivo* conservation of FAnGR in the developing world are designed to support current use by farmers or are populations being maintained for research purposes (Kasso *et al.*, 2013). There were a small number of cases of *ex situ in vivo* herds of developing world FAnGR being maintained purely for research purposes.

The techniques that are currently accessible and economically feasible for *in vitro* conservation of AnGR are those for cryoconservation of reproductive cells, embryos and tissues (Buriak *et al.*, 2020). Materials conserved using these techniques may preserve their livability and functional state for decades or even centuries. More recent biotechnologies, including cloning, transgenesis and transfer of somatic material, have great potential for future applications in FAnGR conservation, but at present they are only accessible to a few laboratories. The low reliability and extremely high costs of these technologies are two factors likely to limit their use in FAnGR conservation in the coming years. Detailed regarding cryoconservation of reproductive cells, embryos and tissues is as follows:

### i. Cryoconservation of Semen

Cryoconservation is one of the main strategies to conserve farm animal genetic resources, providing opportunities for genetic improvement and adaptation to changes in production environments and consumer demands (Leroy *et al.*, 2019). Semen from all mammalian livestock species has been successfully frozen in past decades. Where semen is used to reconstruct breeds by backcrossing, some percentage of the genes from the female population used in the backcross will remain in the reconstructed breed (Leroy *et al.*, 2019).

## ii. Cryoconservation of Oocytes

Embryos from some mammalian livestock species can be produced *in vitro* from matured oocytes collected at slaughter or from live females by ovum pick-up. Such oocytes can be frozen for prolonged periods prior to *in vitro* fertilization to produce embryos. Successful cryopreservation of oocytes would also preserve the genetic material from unexpectedly dead animals and facilitate many assisted reproductive technologies (Ledda *et al.*, 2001; Checurea and Seidel, 2007; Pereira and Marques, 2008). Two methods of freezing can be distinguished based on the rapidity of the freezing procedures. Slow freezing procedures are currently feasible in cattle and potentially applicable in sheep and goats, but success rates in obtaining progeny remain extremely low (Prentice and Anzar, 2011). Ultrarapid freezing procedures, also called vitrification, are currently developed experimentally to limit damage to the oocyte resulting from chilling injuries or the toxicity of cryoprotectants (Lee *et al.*, 2009).

## iii. Cryoconservation of Embryo

Embryos of mammals can be successfully frozen, thawed and then transferred into recipient females to produce progeny however; widespread use of embryo cryoconservation is limited to cattle, sheep and goats (Youngs, 2011). Embryo collection in pigs requires the sacrifice of the female, and the procedure remains experimental in equine species. A number of factors including the method of embryo collection, and stage of maturation, greatly affect the probability of obtaining live progeny (Alasmari *et al.*, 2016). A variety of protocols to freeze and thaw embryos from livestock have been proposed. In slow freezing, equilibration of cryoprotectants and solutes between the medium surrounding the embryo and its intracellular compartments occurs slowly, thus limiting the risks of membrane rupture due to intracellular ice formation (Jang *et al.*, 2017). Fast freezing or vitrification techniques involve ultra-rapid cooling and freezing of embryos in a very small amount of suspending medium in which cryoprotectant and other solutes are generally at high concentrations (He *et al.*, 2008).

## iv. Cryoconservation of Somatic Cells and Somatic Cell Cloning

Somatic cells cloning technology has been shown to work for most mammals. The current state of the technology is costly, with extremely low success rates. If reconstitution of live animals from somatic cells is developed to the point where it becomes both reliable and cheap, preservation of somatic cells would become an attractive option for cryoconservation of AnGR (Tian *et al.*, 2003). Major advantage of this technique would be that it would be possible to choose exactly which animals to conserve, and later to reconstitute a population of clones of these animals (National Academy of Sciences, 2002). Unlike cryopreserved embryos, the cytoplasmic DNA is not preserved in animals derived from somatic cells. Also, collection of somatic cells is, however, far simpler than collection of embryos, and it would be feasible to collect samples extensively from field populations.

## 3. Benefits and Limitation of Genetic Resource Conservation Techniques

The methods used for conserving livestock genetic resources have different advantages and disadvantages.

### In-situ Techniques

#### Advantages

- a. Allows the breed to continue to develop in the context of changes in production conditions and offers greater opportunities for research.
- b. Facilitates breed evolution and adaptation to the environment and gives insight into breed characteristics.
- c. Helps in maintaining the indigenous knowledge of livestock keepers.
- d. Creates possibilities for sustainable utilization in rural areas.
- e. Allows the breed to maintain its cultural role and its contribution to nature management.
- f. Method can be financially self-sustainable.

#### Disadvantages

- a. Exposes the breed to risks associated with disease outbreaks.
- b. Does not protect alleles from genetic drift when the population is small (alleles with a low frequency in the

population can easily disappear because of low numbers of breeding animals).

### **Ex situ In-vivo**

#### **Advantages**

- a. Offers insurance against changes in production conditions and offers opportunities for research.
- b. Allows for strict control of selection and mating decisions.
- c. Offers an opportunity to regenerate a breed quickly from the limited number of females without applying a cross-breeding strategy.

#### **Disadvantages**

- a. Inhibits breed evolution and adaptation to the contemporary production environment.
- b. Contributes only minimally to objectives related to the sustainable utilization of rural areas.
- c. Does not safeguard the breed against disasters and diseases.
- d. Does not protect alleles from genetic drift.
- e. Can be costly in the long term, especially if the breed's productivity is low.
- f. The advantages of cryoconservation (FAO, 2012) are as follows:
- g. Safeguards the flexibility of the genetic system.
- h. Protects the genetic information of a breed against catastrophic events such as disasters and disease outbreaks.
- i. Protects alleles from genetic drift (founder animals that are no longer in the recent generations of the pedigrees of living animals can be re-used for breeding).
- j. Requires relatively little cost for the maintenance of stored germplasm.
- k. The disadvantages of cryoconservation are as follows:
- l. Inhibits breed evolution and adaptation to the environment.
- m. Does not contribute to objectives related to sustainable utilization of rural areas
- n. Implementation requires particular technical skills and the costs of establishing a cryoconservation programme can be high.

#### **4. Programmes and Policies for Conservation of FAnGR**

The most effective way of protecting biodiversity is possible by making regulations in Constitution and international conventions. Various new indigenous breeds of farm animals are registered by different institutions of India. Among them, few recently registered breeds of domestic animals are mentioned in Table 1.

**Table 1:** Newly registered breeds of farm animals (NBAGR, 2020)

S. No.	Breed	Home tract	Accession no.
<b>Newly registered cattle breeds</b>			
1	Poda Thurpu	Telangana	INDIA_CATTLE_3600_PODATHURPU_03044
2	Nari	Rajasthan and Gujarat	INDIA_CATTLE_1704_NARI_03045
3	Dagri	Gujarat	INDIA_CATTLE_0400_DAGRI_03046
4	Thutho	Nagaland	INDIA_CATTLE_1400_THUTHO_03047
5	Shweta Kapila	Goa	INDIA_CATTLE_3500_SHWETAKAPILA_03048
6	Himachali Pahari	Himachal Pradesh	INDIA_CATTLE_0600_HIMACHALIPAHARI_03049
7	Purnea	Bihar	INDIA_CATTLE_0300_PURNEA_03050
<b>Newly registered buffalo breeds</b>			
8	Gojri	Punjab and Himachal Pradesh	INDIA_BUFFALO_1606_GOJRI_01017
<b>Newly registered sheep breeds</b>			
9	Kajali	Punjab	INDIA_SHEEP_1600_KAJALI_14044
<b>Newly registered pig breeds</b>			
10	Mali	Tripura	INDIA_PIG_1900_MALI_09009
11	Purnea	Bihar and Jharkhand	INDIA_PIG_0325_PURNEA_09010

Various programmes with different activities being carried out in India for conservation of FAnGR are as follows. Among them, most of the projects are either functional or completed by NBAGR, Karnal, India.

### ***i. National Agricultural Technology Programmes (NATP) at NBAGR, Karnal***

Under these programmes, animal genetic resource biodiversity, genetic characterization and conservation of important sheep and goat breeds of arid zone and integrated national agricultural resources information system related activities are performed.

### ***ii. ICAR's SRC project at NBAGR, Karnal***

In this programme, characterization and establishment of genetic relationships among various breeds of sheep using microsatellite markers were performed.

### ***iii. Network project on animal genetic resources at NBAGR, Karnal***

The project aims at genetic characterization and conservation of indigenous breeds of livestock and poultry. The project has been in operation since 8<sup>th</sup> plan involving various agencies such as SAUs, State AH Departments with the coordinating unit at NBAGR. Two core laboratories stationed at TNUVAS, Chennai and GAU, Anand were identified to carry out the genetic characterization/distancing work based on microsatellite markers for the southern and western zones, respectively while, NBAGR was identified to cater the needs of the northern zone.

### ***iv. Network project in sheep improvement at CSWRI, Avikanagar***

There are five farm based cooperating units and two fields based cooperating units of project in addition to project coordination cell situated at CSWRI, Avikanagar. The breeding policy for Network project in sheep improvement is selective breeding in indigenous breeds.

## **5. Future Concern**

The efficient conservation programmes should use available monetary or non-monetary resources in such a way that the conservation objective is maximized. The questions to be answered while conserving FAnGR are: 1) For which breeds within the species under consideration should conservation programmes be implemented 2) What share of the total conservation budget should be allocated to each of the chosen breeds and 3) Which conservation programmes should be implemented for any chosen breed. The first step toward an efficient conservation strategy for domestic livestock is the proper characterization of the conservation value of the different breeds and of the wild relatives. This step relies on genetic technologies, and we can be optimistic at that level according to the current revolution in these approaches. However, the implementation of the subsequent steps is more puzzling, as conservation strategies for farm animal genetic resources must integrate economical, sociological, and political parameters.

## **Conclusion**

Traditions and cultural values are important driving forces for conservation. The erosion of genetic resources has been clearly documented for farm animals and within few decades, we might lose most of the highly valuable farm animal genetic resources that humanity has gradually selected. Urgent conservation measures must be taken to avoid such an irremediable loss. Various approaches have been tried for conservation of FAnGR. *In vitro* methods provide an important back-up strategy when *in vivo* conservation cannot be established or cannot conserve the necessary population size. It may also be the only option in the case of emergencies such as disease outbreaks or wars. Recent advances in instrumentation and biotechnology results into the development of the next generation DNA sequencing technology, it will be possible to resequence whole genomes and to properly assess the genetic diversity and the conservation value of the different breeds, avoiding the ascertainment bias due to the use of microsatellites or single nucleotide polymorphisms. The development of genomic tools will allow optimizing the breeding strategies for ensuring the improvement of performance together with the preservation of genetic diversity.

## **Conflict of Interests**

There is no conflict of interest.

## Publisher Disclaimer

IJLR remains neutral concerning jurisdictional claims in published institutional affiliation.

## References

1. Alasmari, N. M., Son, W. Y. & Dahan, M. H. (2016). The effect on pregnancy and multiples of transferring 1-3 embryos in women at least 40 years old. *Journal of Assisted Reproduction and Genetics*, 33(9), 1195-1202.
2. Belew, A. K., Tesfaye, K. & Belay, G. (2016). The State of Conservation of Animal Genetic Resources in Developing Countries: A Review. *International Journal of Pharma Medicine and Biological Sciences*, 5(1), 58-66.
3. Boettcher, P. J., Boichard, M. T., Toro, M. A., Simianer, H., Eding, H., Gandini, G., et al. (2010). Objectives, criteria and methods for using molecular genetic data in priority setting for conservation of animal genetic resources. *Animal Genetics*, 41, 64-77.
4. Buriak, I., Fleck, R. A., Goltsev, A., Shevchenko, N., Petrushko, M., Yurchuk, T., et al. (2020). Translation of cryobiological techniques to socially economically deprived populations-Part 1: Cryogenic Preservation Strategies. *Journal of Medical Devices*, 14(1), 010801.
5. Checura, C. M. & Seidel, G. E. Jr. (2007). Effect of macromolecules in solutions for vitrification of mature bovine oocytes. *Theriogenology*, 67(5), 919-930.
6. Cognie, Y., Baril, G., Poulin, N. & Mermillod, P. (2003). Current status of embryo technologies in sheep and goat. *Theriogenology*, 59(1), 171-188.
7. Drucker, A. G., Hiemstra, S. J., Louwaars, N., Oldenbroek, J. K., Tvedt, M. W., Hoffmann, I., et al. (2007). Back to the future: How scenarios of future globalization, biotechnology, disease and climate change can inform present animal genetic resources policy development. *Animal Genetic Resources Information*, 2(41), 75-89.
8. FAO. (1981). Animal genetic resources - Conservation and management. *Proceedings of the FAO/UNEP technical consultation*, Food and Agriculture Organization of the United Nations, Rome.
9. FAO. (2007). The State of the World's Animal Genetic Resources for Food and Agriculture [Rischkowsky, B., Pilling, D., (eds.)]. Food and Agriculture Organization of the United Nations, Rome.
10. FAO. (2009). The use and exchange of animal genetic resources for food and agriculture. Food and Agriculture Organization of the United Nations, Rome, Background study paper no. 43.
11. FAO. (2012). Cryoconservation of animal genetic resources. Food and Agriculture Organization of the United Nations, Animal Production and Health Guidelines No. 12. Rome.
12. FAO. (2013). *In vivo* conservation of animal genetic resources. Food and Agriculture Organization of the United Nations, Rome, Animal production and health guidelines no. 14.
13. FAO. (2019). Status and Trends of Animal Genetic Resources-2018; Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture. Food and Agriculture Organization of the United Nations, Rome, Accessed on 30 August, 2020).
14. Furlan, E., Stoklosa, J., Griffiths, J., Gust, N., Ellis, R., Huggins, R. M. & Weeks A. R. (2012). Small population size and extremely low levels of genetic diversity in island populations of the platypus, *Ornithorhynchus anatinus*. *Ecology and Evolution*, 2(4), 844-857.
15. He, X., Park, E. Y., Fowler, A., Yarmush, M. L. & Toner, M. (2008). Vitrification by ultra-fast cooling at a low concentration of cryoprotectants in a quartz micro-capillary: a study using murine embryonic stem cells. *Cryobiology*, 56(3), 223-232.
16. Jang, T. H., Park, S. C., Yang, J. H, et al. (2017). Cryopreservation and its clinical applications. *Integrative Medicine Research*, 6(1), 12-18.
17. Kasso, M. & Balakrishnan, M. (2013). *Ex Situ* conservation of biodiversity with particular emphasis to Ethiopia. *International Scholarly Research Notices*, <https://doi.org/10.1155/2013/985037>.
18. Ledda, S., Leoni, G., Bogliolo, L. & Naitana, S. (2001). Oocyte cryopreservation and ovarian tissue banking. *Theriogenology*, 55(6), 1359-1371.
19. Lee, H.J., Elmoazzen, H., Wright, D., et al. (2010). Ultra-rapid vitrification of mouse oocytes in low cryoprotectant concentrations. *Reproductive BioMedicine*, 20(2), 201-208.
20. Leroy, G., Boettcher, P., Besbes, B., Danchin-Burge, C., Baumung, R. & Hiemstra, S. J. (2019). Cryoconservation of animal genetic resources in Europe and two African countries: A Gap Analysis. *Diversity*, 11(12), 240.

21. National Academy of Sciences. (2002). Scientific and Medical Aspects of Human Reproductive Cloning. Washington (DC), USA. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK223960>.
22. NBAGR. (2020). <http://www.nbagr.res.in/registeredbreed.html> accessed on 30 August, 2020.
23. Pereira, R. M. & Marques, C. C. (2008). Animal oocyte and embryo cryopreservation. *Cell and Tissue Banking*, 9(4), 267–277.
24. Philipsson, J., Rege, J. E. O., Zonabend, E. & Okeyo, A. M. (2011). Sustainable breeding programmes for tropical farming systems, in Animal Genetics Training Resource [Ojango, J. M., Malmfors, B., Okeyo, A. M. (eds.)]. International Livestock Research Institute, Nairobi, Kenya, and Swedish University of Agricultural Sciences, Uppsala, Sweden.
25. Prentice, J. R. & Anzar, M. (2010). Cryopreservation of Mammalian oocyte for conservation of animal genetics. *Veterinary Medicine International*, doi:10.4061/2011/146405.
26. Rosegrant M. W., *et al.* (2009). Looking into the future for agriculture and AKST (Agricultural Knowledge Science and Technology). In Agriculture at a crossroads [McIntyre B. D., Herren, H. R., Wakhungu, J., Watson, R. T., (eds.)], Washington, DC, USA. pp. 307–376.
27. Taberlet, P., Pansu, J. & Pompanon, F. (2011). Conservation genetics of cattle, sheep, and goats. *Comptes Rendus Biologies*, 334: 247-254.
28. Tian, X. C., Kubota, C., Enright, B. & Yang X. (2003). Cloning animals by somatic cell nuclear transfer--biological factors. *Reproductive Biology and Endocrinology*, doi:10.1186/1477-7827-1-98.
29. Tisdell, C. (2003). Socioeconomic causes of loss of animal genetic diversity: Analysis and assessment. *Ecological Economics*, 45, 365-376.
30. Wilcox, B. A. & Soule, M. E. (1980). Conservation biology: an evolutionary-ecological perspective, Sinauer Associates, Sunderland, Massachusetts, USA.
31. Youngs, C. R. (2011). Cryopreservation of preimplantation embryos of cattle, sheep, and goats. *Journal of Visualized Experiments*, (54), 2764.

\*\*\*\*\*