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Review

Threats, attempts and opportunities of conserving indigenous animal genetic resources in Ethiopia

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Loss of genetic diversity among animal populations occurs due to genetic introgression, crossbreeding, inbreeding, climate change and its related factors. Therefore, the objective of the study was to quantify threats, previous conservation attempts and opportunities of conserving indigenous animal genetic resources in Ethiopia. The consequences of genetic introgressions include reduced survival and fitness of the first and second generations, accelerated growth rate, decreased predator avoidance behaviors and increased agonistic behaviors. Inbreeding allows rare, harmful recessive alleles to become expressed in the homozygous form, with resulting harmful effects and reduces genetic variability and performances on the offspring. The cause threatening the survival of the adapted indigenous animal breeds in Ethiopia is indiscriminate crossbreeding with exotic germplasm. On the other hand, due to climate changes, indigenous animal breeds are changing their distribution patterns. Animals specially the wild are shifting their ranges, altering their phenology, changes in population dynamics, and some are facing extinction, or have become extinct. Different organizations have made attempts to conserve 3 indigenous cattle breeds and one sheep breed in Ethiopia. Their attempts are failing due to the gaps of information for sustainable utilization and conservation of animal genetic resources. Setting priorities to conserve, develop and utilize the available genetic resources as well as *ex situ* conservation can be taken as an opportunity for the maintenance of nucleus flocks as a repository of the pure breed.

Key words: Climate change, crossbreeding, genetic introgression, inbreeding, Ethiopia.

INTRODUCTION

Conservation of animal resources should ideally be undertaken at global level, because of the existence of non- and trans-boundary breeds. However, national conservation programs better serve specific local interests, such as conservation with the objectives of improving indigenous breeds. There are obviously many reasons why genetic conservation should be considered, e.g. cultural, historic, and scientific interests and on the one hand for more practical and economic considerations.

It is necessary to characterize and conserve animal genetic resources, population size trends and their distributions are components of characterization and should precede any conservation efforts, of valuable breeding stocks. In developed countries, most conservation programs are based with strong collaboration between gene banks and the animal breeding industry. In these countries, few breeds of the major species are covered by conservation programs, and the programs are of variable quality; the focus is typically on *in situ* conservation (FAO, 2007a). Strategies for setting conservation priorities for livestock populations depend on the nature and severity of the threats, the species and available technologies. The argument is conservation for

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sustainable utilization of the resources currently and for posterity (Solomon et al., 2008). If risk strategy were to be adopted for setting conservation priorities for Ethiopian animal genetic resources, then most of the genetic diversity would have been conserved.

Loss of genetic diversity among populations occurs due to high rate of gene flow from other populations (Staines, 1991; Abbott, 1992; Tesfaye, 2004), genetic introgression (McGinnity et al., 2003; Hutchings and Fraser, 2008; Kidd et al., 2009), inbreeding (Keller and Waller, 2002; Fredrickson et al., 2007) and climate change (McCarthy et al., 2001, 2003; Thomas et al., 2006; Boko et al., 2007).

According to the Institute of Biodiversity Conservation, IBC (2004) Farm animals are an integral part of the Ethiopian agricultural fabric. They are sources of food, traction, manure, raw materials, investment, cash, security, foreign exchange earnings, social and cultural identity. The Ethiopian agriculture is based on availability and/or contribution of farm animals and no agricultural practices other than mowing are conducted without the involvement of farm animals. Land cultivation is mainly done by oxen, horses, donkeys or their combinations. Farm animals serve to level the ploughed field, shortly before and after sowing. In some areas, farm animals are involved in weeding, especially maize and sorghum fields. Transportation of the harvested crops to and from threshing sites, threshing itself, transportation to and from the market is conducted by the farm animals. Similarly, transportation of water, firewood, mobile houses, construction materials and other goods is conducted by farm animals and they are the main means of human transport. Therefore, the objective of this review was to quantify the threats, previous conservation attempts and opportunities which exist for conserving indigenous animal genetic resources in Ethiopia.

THREATS TO INDIGENOUS ANIMAL GENETIC RESOURCES OF ETHIOPIA

Threads caused by breeding processes

Genetic introgression

In both domestic and wild animals, genetic introgression between invasive organisms with exotic germplasm and local populations would enhance genetic homogenization, leading to the disintegration of the components of genetic diversity generated by divergent adaptation to heterogeneous habitats (Randi, 2008). Introgressive hybridization among local, wild and invasive populations together with habitat degradation and loss of ecological structure as well as unsustainable selective pressures for adaptation to global climate changes, over exploitation and loss of community structure, are major threats to conservation of animal genetic resources (Allendorf et al., 2001; Randi, 2008). Though it is important for farm animals up to some generation, the consequences of genetic introgressions of domestic and exotic germplasm are extensive and includes reduced survival and fitness of the F_1 and F_2 generations, accelerated growth rate, decreased predator avoidance behaviors and increased agonistic behaviors (McGinnity et al., 2003; Wessel et al., 2006; Hutchings and Fraser, 2008). In Ethiopia, genetic introgression has occurred between Simien fox and Ethiopian wolfs, the trepidation of genetic introgression between Walia ibex (Capra walie) and domestic goats (*Capra hircus*) (Kefyalew et al., 2011a) at and near the national parks are becoming some of the problems which threat both wild and domestic indigenous animal genetic resources.

Inbreeding

Loss of genetic diversity and an increase in inbreeding rates are also critical genetic issues to be considered in animal genetic resources (Ballou and Lacy, 1995). Inbreeding and loss of genetic variation are inevitable consequences of small population sizes (Frankham et al., 2002). The extent to which a population becomes inbred or loses genetic diversity over time depends on a number of factors, including immigration, effective population size, generation length, and selection intensity (Jamieson et al., 2006). Small populations face inbreeding, genetic drift (Pronounced effects of random genetic drift that lead to erratic fluctuations in allele frequencies) and high susceptibility to catastrophes, diseases and environmental stochasticity (Frankham et al., 2004; Von et al., 2007; Kefyalew et al., 2011c). Saccheri et al. (1998) and Fredrickson et al. (2007) disclosed that inbreeding reduces fitness and increases the risk of population extinction. Significant impacts of inbreeding depression on extinction risk in populations with carrying capacities of up to two thousand individuals have been noted (O'Grady et al., 2006). Increased inbreeding rates also have a strong and significant effect on overall population growth rate of small and isolated populations and are associated with inbreeding depression (Smith et al., 1998). Moreover, an increased rate of inbreeding also means an increased risk of loss of genetic diversity (Meuwissen, 1991) and a reduced additive genetic variance is expected (Falconer and Mackay, 1996). Small population size animals and the primary factors contributing to extinction are habitat loss, introduced species, overexploitation and pollution. These factors are caused by humans, and related to human population growth (Frankham et al., 2002).

The consequence of the inbreeding process is the reduction in the genetic variability within a population and in performance mainly in traits that are associated with the fitness of an individual (Maiwashe et al., 2006). High inbreeding rates have higher contribution to over all inbreeding of all the populations and hence inbreeding depression (Marshall et al., 2002). Inbreeding allows the rare, harmful recessive alleles to become expressed in the homozygous form, with resulting harmful effects on the offspring such as reduction in fertility, fecundity, offspring size, growth and survival, and physical deformities (Lomker and Simon, 1994). Inbreeding can potentially reduce population growth rates and increase extinction (Newman and Pilson, 1997). In Ethiopia, due to lack of grazing lands, the indigenous animals are kept together and interbreed themselves with harmful effects on the offspring. All these lead the farmers to abandon the local animal genetic resources and shifting to exotic germplasm, which again reduce their performances especially after the third generations.

Crossbreeding

Crossbreeding may increase the overall genetic diversity as it introduces new genes in the population and new genotypes (e.g. synthetic breeds). However, the major threat to the adapted indigenous breeds in Africa is indiscriminate or irrational crossbreeding. Crossbreeding can be considered as "a necessary evil" as it delivers the much desired fast growth in livestock productivity and at the same time threatens the indigenous breeds through breed replacement (Solomon et al., 2008).

Rege and Gibson (2003) suggest that, the use of exotic germplasm, changes in production systems, producer preference because of socio-economic factors, and a range of disasters (drought, famine, disease epidemics, civil strife/war) as the major causes of genetic erosion. Tisdell (2003) suggested major causes for threats of animal populations which are development interventions, specialization (emphasis on a single productive trait), genetic introgression, the development of technology and biotechnology, political instability and natural disasters. For at-risk animal breeds in Africa, (Rege and Gibson, 2003) lists as major cause's replacement by other breeds, crossbreeding with exotic breeds or with other indigenous breeds, conflict, loss of habitat, disease, neglect and lack of sustained breeding programs among the threats. The increased demand for livestock products in many parts of the developing world drives efforts to increase the output of meat, eggs, and milk for the market (Delgado et al., 1999).

Effects of crossbreeding on animal genetic resources in Ethiopia

Indigenous livestock are well adapted to tropical conditions and have high degree of heat tolerance, which are partly resistant to many of the diseases prevailing in Ethiopia and have the ability to survive long periods of feed and water shortage. These attributes have been acquired through natural selection over hundreds of generations. They are all essential for successful animal production (Rege and Lipner, 1992). Indigenous stocks represent a genetic resource which should not only be conserved for future use, but should also be fully exploited for short-term benefits (Rege and Lipner, 1992). Due to the low genetic potential of indigenous cattle, milk-meat production and productivity remain low in Ethiopia (Shiferaw et al., 2003). Improvement of the genetic potential of indigenous cattle was achieved by cross breeding with high producing cattle of temperate origin. Of course, crossbreeding was and still is perceived as "the way forward" to improve productivity of indigenous livestock under smallholder conditions and development policies has largely ignored the adapted farm animal genetic resources (ILRI, 1999). In Ethiopia, crossbred cattle mainly cross of zebu with Holstein-Friesian cattle have been used for milk production for decades (Negussie et al., 1998). However, crossbreeding with exotic breeds clearly is a major factor contributing to the erosion of locally adapted animal genetic resources (Köhler-Rollefson, 2004). Crossbreeding also results inconsistent and rapid loss of genetic diversity by dilution of the autochthonous genetic makeup. Therefore, designing of a crossbreeding program in Ethiopia needs to take into consideration a mechanism that ensures conservation of animal genetic resources (Aynalem et al., 2011).

Major causes threatening diversity of genetic resources in Ethiopia include poorly designed and managed introduction of exotic genetic materials, droughts and consequences of drought associated indiscriminate restocking schemes, political instability and associated civil unrest, and weak development interventions (Nigatu et al., 2004). The effects of the misguided and uncontrolled introduction of exotic genes and that of interbreeding among indigenous breeds might require application of molecular genetics for purposes of precision. In extreme scenarios, however, it could have a drastic effect leading to extinction of a breed within few generations (ESAP, 2004).

Even indigenous genotypes may well be adequate and able to respond sufficiently to reasonable economic improvements in their production system (Workneh et al., 2003), trends of improving indigenous cattle already exist in Africa and the population of pure indigenous cattle breeds is likely to diminish, because of crossbreeding or neglect of local animal genetic resource (Rege, 1992). As a result, some of the animal genetic resources are endangered, and unless urgent concerted efforts are made to characterize and conserve these breeds, they may be lost even before they are described and documented (Zewdu et al., 2008). Loss of genetic diversity increases the risk of the subsistence for the millions of livestock keepers who depend on these resources to secure their livelihoods (Fedlu et al., 2007).
Unique germplasm is threatened by replacement of breeds with more productive or popular stocks, dilution of

breeds through crossbreeding programs, and decreased diversity within highly selected breeds or lines that have a small number of breeding individuals (FAO, 2007). The application of artificial insemination (AI) in indigenous cattle using semen from exotic cattle breeds is, for instance, resulting in unforeseen substitution of indigenous genes by exotic genes (ESAP, 2004; IBC, 2004). The application of these technologies for germplasm propagation and dissemination may contribute to the erosion of diversity. Besides, exotic sheep breeds, such as Awassi, Hampshire, Blue-de-main, Merino, Romney, Corriedale, and Dorper were introduced to Ethiopia for their wool and mutton production. Crossbreeding of the Menz breed with the 5 exotic breeds, namely Awassi, Hampshire, Bleu-de-Main, Romney and Dorper are being used for development and research activities (Solomon, 2008). However, the mating of indigenous sheep and cattle exotic genetic resources was indiscriminate. According to FAO (1999), about 30% of the world's farm animal breeds are subjected to the risk of extinction due to this.

Threads caused by climate change

Challenges such as climate change underline the importance of retaining a diverse portfolio of livestock breeds (FAO, 2007b). Livestock production both contributes to and is affected by climate change (Hoffmann, 2010). There are evidences that livestock and environmental trade-offs are currently substantial and that these will increase significantly in the future as a result of the increased demand for livestock products from the growing population (Herrero et al., 2009a). Some of the most important impacts are those associated with land use change for feed production both for ruminants and monogastrics, which have significant simultaneous impacts on a range of environmental dimensions (land use, emission of gases , water cycles, nutrient balances, biodiversity) (FAO, 2007b; Herrero et al., 2009a). Moreover, livestock mitigation measures could include technical and management options to reduce emissions from livestock as well as the integration of livestock into broader environmental service approaches (Thornton et al., 2007).

Adapting to global climate change is likely to present a serious challenge to many livestock producers over the coming decades. The pastoral systems of the world’s dry lands are among the most vulnerable, with climate change taking place against the background of natural environments that are already experiencing resource degradation. In general, climate change is likely to present significant problems for production systems where resource endowments are poorest and where the ability of livestock keepers to respond and adapt is most limited (FAO, 2007b).

Climate change is adding to the considerable development challenges (Thornton et al., 2007) and this will require more efficient animal production systems, careful husbandry of natural resources and measures to reduce waste and environmental pollution (FAO, 2010). Climate change impacts such as rising temperatures and declining rainfall in combination with other stresses could result in the shifting of ecological zones, loss of flora and fauna and an overall reduction in ecological productivity (Thomas et al., 2006; Boko et al., 2007). There is compelling evidence that in response to on-going changes in regional climates, species are already shifting their ranges (Walther et al., 2005; Lavergne et al., 2006; Thomas et al., 2006), altering their phenology (White et al., 2003), changes in population dynamics (Balmford et al., 2003; Forsman and Monkkonen, 2003), fluctuation in population growth rates (Lande et al., 2003; Grosbois et al., 2008) and alters ecosystem functioning (Doran et al., 2002; Hays et al., 2005) and that some species are facing extinction, or have become extinct (Foden et al., 2007).

In addition to the physiological effects of higher temperatures on individual animals, the consequences of climate change are likely to include increased risk that geographically restricted rare animal breed populations will be badly affected by disturbances (Hoffmann, 2010). The IPCC, (2007a) predicted that by 2100 the increase in global average surface temperature may be between 1.8 and 4.0℃. With global average temperature increases of only 1.5 to 2.5℃, approximately 20 to 30% of plant and animal species are expected to be at risk of extinction (FAO, 2007).

Climate change in Ethiopia

Both instrumental and proxy records have shown that, there is significant variations in the spatial and temporal patterns of climate in Ethiopia. According to NMA (2006), the country experienced 10 wet years and 11 dry years over 55 years analyzed, demonstrating the strong inter-annual variability. Between 1951 and 2006, annual minimum temperature in Ethiopia increased by about 0.37℃ every decade. The climate change profile for Ethiopia also shows that the mean annual temperature increased by 1.3℃ between 1960 and 2006, at an average rate of 0.28℃ per decade (McSweeney et al., 2008).

The temperature increase has been most rapid from July to September (0.32℃ per decade). It is reported that the average number of hot days per year has increased by 73 days (an additional 20% of days) and the number of hot nights has increased by 137 days (an additional 37.5% of nights) between 1960 and 2006. IPCC"s mid-range emission scenario show that compared to the 1961 to 1990 average mean annual temperature across Ethiopia will increase by between 0.9 and 1.1℃ by the year 2030 and from 1.7 to 2.1℃ by the year 2050. The temperature across the country could rise by between 0.5 and 3.6°C by 2080, whereas precipitation is expected to show some increase (NMA, 2006). Unlike the temperature trends, it is very difficult to detect long-term rainfall trends in Ethiopia, due to the high inter-annual and inter-decadal variability. According to NMA (2006), between 1951 and 2006, no statistically significant trend in mean annual rainfall was observed in any season. As compared to the 1961 to 1990, annual precipitation showed a change of between 0.6 and 4.9% and 1.1 to 18.2% for 2030 and 2050, respectively (NMA, 2006). The percentage change in seasonal rainfall is expected to be up to about 12% over most parts of the country (ICPAC, 2007).

Climate change projections suggest also that, further selection for breeds with effective thermoregulatory control may be needed (Hoffmann, 2010). Animal breeding indices should include traits associated with thermal tolerance, low quality feed and disease resistance, and give more consideration of genotype-by-environment interactions to identify animals most adapted to specific conditions (Hoffmann, 2010). The conservation of existing animal genetic resources and diversity as a global insurance measured against unanticipated change (Thornton et al., 2007).

NMSA (2001) has also stressed that, mean temperature and precipitation in Ethiopia have been changing over time. Over the past 60 years, some of the years have been characterized by dry rainfall conditions resulting in drought and famine where as the others are characterized by wet conditions. Droughts in Ethiopia can shrink household farm production by up to 90% of a normal year output (World Bank, 2003).

All these have effects on animal genetic resources directly on heat stress (Thornton et al., 2009), emergence, spread, and distribution of livestock diseases ((Baylis and Githeko, 2006), feed and water availability (Thornton and Gerber, 2010) and genetic mechanisms which influence fitness and adaptation (Hoffmann, 2010).

PREVIOUS ATTEMPTS TO CONSERVE ANIMAL GENETIC RESOURCES IN ETHIOPIA

Conservation of local breeds of farm animal genetic resources should be a part of animal management and the communities should be informed by pertinent parties for the distribution, structures, and trends, productive and adaptive performances of populations of the existing breeds. Although much information is lacking, conservation of farm Animal Genetic Resources (AnGR) in the Ethiopian perspective should be viewed from the rational utilization and protection of existing genotypes from genetic erosion (IBC, 2004). Unfortunately, except for limited activities that are meant to maintain pure stocks of 3 cattle breeds and 1 sheep breed, no conservation activities of farm AnGR have so far been practiced in the country. To date, Borana cattle bred at Did Tuyura Ranch, Horro cattle breed at Horro Ranch, Fogera cattle breed at Metekel Ranch and Andassa Agricultural Research Centre, and Menz sheep bred at Amed Guya Research Centre (IBC, 2004) are the only conservation attempts made in Ethiopia.

Conservation measures for threatened breeds have already been established in some countries (FAO, 2007a) and are a priority of the global plan of action for animal genetic resources (FAO, 2007b). In Ethiopia, institutions involved in *in situ* conservation of biodiversity include the IBC, the Ethiopian Agricultural Research Organization (EARO), Regional Agricultural departments, Higher Learning Institutions, etc. However, the impact of their work on conservation of biological resources in practical terms is very limited (FDRE, 2005). Loss of animals as a result of droughts and floods, or disease epidemics related to climate change may thus increase (FAO, 2008). If breeds are geographically isolated (endemic) as is the case for some local and rare breeds, there is a risk of their being lost in localized disasters. Therefore, identifying the status of the livestock genetic resources and designing conservation strategies based on the priorities is crucial.

Constraints and lessons learnt

In Ethiopia, information for sustainable utilization and conservation of the farm animal genetic resources are very limited and, if available, are full of gaps (IBC, 2004). It would no doubt be of interest to future generations of animal breeding specialists, as well as to interested laymen, if it were possible to maintain representative samples of some of the once important animal breeds especially in *ex situ* conservation, which are now on the verge of disappearing (FAO, 1990). Practical and economic needs ought to be the most important reason for conservation in future; one could perhaps argue that, farmers with economically competitive breeds or genetic types should take care of their own preservation.

Numerous attempts made to introduce 'improved' breeds with poor success in terms of achieving genetic potential. Fertility and longevity of introduced breeds so poor that continual importation of exotic breeds necessary. Rare breeds often crossed with 'improved' breeds due to small population, dilution of breed characteristics and creation of gene pool from which it is then difficult to identify and utilize favorable local breeds genetic characteristics are also the main threats to animal genetic resources in Ethiopia. Unfortunately, the situation is more complex. The economic and environmental conditions are changing and genetic types which are superior under one set of conditions may be inferior under a different set of conditions. As the changes are gradual and different breeds or types are not generally compared under exactly the same conditions, the individual breeder or leader of a breeding program has usually no interest in, or possibility of, conserving for future use animals which, at any given time, considers slightly inferior to those selected for breeding (Rendel, 1975). However, sustainable use of genetic resources should effectively deal with semen and embryos preservation as part of the ongoing utilization and improvement programs.

OPPORTUNITIES

In situ conservation of livestock breeds is primarily the active breeding of animal populations and their continued use as part of an ongoing livelihood strategy (Solomon et al., 2008). Village-based breed improvement programs must be a complementary to *in situ* livestock conservation objectives with the concept conservation through sustainable utilization. In such a context, it can be viewed as part and parcel of a comprehensive conservation plan, and not as a separate genetic improvement activity, that entails significant additional costs. In the mean time, there are more feasible conservation methods at hand under the current circumstances including *in vivo* conservation. *In vivo* conservation includes *in situ* and *ex situ* methods. *Ex situ in vivo* conservation is the maintenance of pure-bred nucleus flocks in an organized government farms or research farms which can form a repository of the pure breed. A conservation-based breeding program should be based on broader breeding objectives that incorporate the needs and perceptions of the community and maintenance of the genetic diversity such as adaptation traits. Involvement of the farmers in the design and implementation of the breeding program in line with the principles of *in situ* conservation of genetic resources is one of the options which must be considered.

CONCLUSION

From the review, it was possible to see that, genetic introgression, crossbreeding, inbreeding and climate changes and related factors are the threats for animal genetic resources in Ethiopia. The genetic introgression between wild and the domestic, interbreeding among closely related animals, reduction in effective population size and lack of grazing lands all lead to reduction in fertility, fecundity, offspring size, growth and survival, and physical deformities. All these pilot the farmers to abandon the local animal genetic resources and shifting to exotic germplasm. Subsequently, replacing local breeds by range of high-yielding breeds is widespread. Nonetheless, due to the existing climate change effects and gene segregation especially after third generation, high yielding animals could not be used sustainably. Adapting to present climate change and related factors is a serious challenge to many animal producers. Admixture of genes of indigenous animal population with exotic germplasm of conspecifics and increasing temperature will trigger loses of animal genetic resources in Ethiopia. Therefore, to conserve and use sustainably animal genetic resources, controlled and monitored cross-breeding with appropriate records, habitat management of the wild and domestic animals, interbreeding among related but not closely related breeds and tackling climate change related factors are some of the most important ones.

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