Veterinary Integrative Sciences 2024; 22(1): 231 - 250 DOI; 10.12982/VIS.2024.018

Vet Integr Sci

Veterinary Integrative Sciences

ISSN; 2629-9968 (online)

Website; www.vet.cmu.ac.th/cmvj

Review article

Genetic improvement approaches of indigenous cattle breeds for adaptation, conservation and sustainable utilization to changing climate in Ethiopia

Tariku Woldeyohannes[1,*], Simret Betsha[2] and Aberra Melesse[2]

[1]*Department of Animal Sciences, College of Agriculture, food and climate sciences, Injibara University, Injibara, P,O.BOX: 40, Ethiopia.*
[2]*School of Animal and Range Sciences, College of Agriculture, Hawassa University, Hawassa, P.O.BOX: 05, Ethiopia*

Abstract

This paper attempts to review the cattle genetic improvement approaches for sustainable utilization, adaptation, and conservation in the face of changing climatic conditions. Livestock production is affected by climate change, which poses a greater threat to populations that rely on them for their overall food security. Climate change negatively affects cattle production directly through its impact on animal physiology, behavior, and health and indirectly through its effect on feed and water availability, quality and quantity of pasture, forage crops, and rangeland due to increased temperature droughts. Improvement of cattle genetic resources that are efficient and well adapted to extreme temperatures, low-quality diets, and disease challenges is critical to effectively cope with climate change. Designing suitable breeding strategies will facilitate improving the performance of cattle breeds and enhance their tolerance to the dynamics of climate change. Replacement of local cattle breeds with exotic ones and unplanned crossbreeding with them without enough consideration of environmental conditions are among the major factors contributing to the loss of locally adapted breeds that possess certain adaptive traits. Maintenance of indigenous cattle's genetic diversity, which underpins resistance to environmental stresses is a viable strategy to mitigate the possible effects of future climatic challenges. In contrast to the traditional selection, genomic selection increases the accuracy of selection with the largest genetic gain, for the low heritability traits such as adaptability and longevity. In conclusion, any breeding strategies should be relevant in terms of breed suitability, performance, and adaptability in the given production environment to sustain cattle production.

Keywords: Adaptation, Climate change, Conservation, Genetic improvement, Indigenous cattle

*Corresponding author: Tariku Woldeyohannes, Department of Animal Sciences, College of Agriculture, food and climate sciences, Injibara University, Injibara, P.O.BOX: 40, Ethiopia. Email: tarikuw52@gmail.com.

Article history; *received manuscript: 8 May 2023,*
revised manuscript: 30 May 2023,
accepted manuscript: 9 June 2023,
published online: 5 September 2023
Academic editor: *Korakot Nganvongpanit*

INTRODUCTION

Livestock contributes considerably to global food security in general and to that of developing nations in particular. Livestock production contributes 40% of global agricultural gross domestic product (GDP) and supports the livelihoods of at least 1.3 billion people worldwide (FAO, 2018). They make tremendous contributions to global food security by providing 18% of global kilocalorie consumption and 34% of global protein consumption. Moreover, livestock provides essential micro-nutrients, such as vitamin B12, iron, and calcium (FAO, 2018). Livestock further plays a significant role to marginal lands, where they serve as a unique source of energy, proteins, and micronutrients (Ruo, 2018). Ethiopia is believed to have the largest livestock population in Africa, with nearly 65.35 million cattle, 39.89 million sheep, 50.50 million goats, 2.11 million horses, 8.98 million donkeys, 0.38 million mules, about 7.70 million camels, and 48.96 poultry population in the country (CSA, 2020). The direct contribution of livestock to the nation's economic growth is accounting for 39% of the country's agricultural GDP and 17% of its overall GDP (Shapiro et al., 2017).

Ethiopia is the 12th most populous country in the world, accounting for 1.47% of the global population (Diriba, 2020). As a result of fast population growth, urbanization, rising economies, and changes in dietary patterns associated with increased demand for high-quality nutritious food from animal products, addressing the issue of food security remains a challenge (Hoffmann, 2010; Calicioglu et al., 2019). To feed the ever-increasing demand for milk, milk products, and beef of the human population, genetic improvement of the indigenous cattle has been proposed as one of the options in Ethiopia.

Ethiopia is endowed with a variety of indigenous cattle genetic resources with millions of people depending on them. Despite their importance, cattle genetic diversity in Ethiopia is under threat due to information gaps on sustainable utilization and genetic improvement programs (FAO, 2007; Chebo and Alemayehu, 2012; Tesfa et al., 2017), and little attention is given to conserve the diversity of the indigenous cattle breeds (Alemayehu, 2013; Tiruneh and Tegene, 2018). Cattle genetic improvement programs have not yet adequately considered traits that are responsible for adaptation and mitigation of current global climate change (Hoffmann, 2010; Kantanen et al., 2015).

In addition to the shrinkage of grazing lands, scarcity of feed and water, inbreeding, climate change (Negash, 2018; Tiruneh and Tegene, 2018), and increased focus to rely on few high-output exotic breeds is the main factor compromising productivity and the genetic integrity of indigenous cattle genetic resources in Ethiopia (FAO, 2007; Alemayehu, 2013). Livestock production is also affected by climate change while it also contributes to climate change due to its competition for land and water (Rojas-Downing et al., 2017; Escarcha et al., 2018). This complex phenomenon poses a greater threat to the rural farming communities that are dependent on livestock production for their overall food security (Nardone et al., 2010; Gashaw et al., 2014; Gezie, 2019). It impacts the ecosystems and natural resources on which the livestock sector depends and is considered as one of the most important challenges to sustainable development (Field et al., 2014; Rojas-Downing et al., 2017). Climate change leads to reductions in cattle genetic diversity and productivity by depressing animals' adaptive response mechanisms to heat stress, and diseases causing agents (Nimbkar et al., 2008; Bett et al., 2017). Climate change is already hampering and expected to be severe and lasting in many developing countries such as Ethiopia, necessitating a much broader view of the risk management approach (Gashaw et al., 2014; Escarcha et al., 2018; Henry et al., 2018).

Ethiopia is one of the most vulnerable countries to climate change-induced disasters such as drought, floods, and epidemics, that endangers farmers and pastoralists who depend on climate-sensitive livelihoods and livestock production (Belay et al., 2014; Gashaw et al., 2014). These necessitates the introduction of adaptive measures like altering breeding and management strategies (Zhang et al., 2017). On the other hand, changes in production technology and farming systems could affect the productivity of the farm animals (Thornton, 2010). Sustainable intensification, adaptation to current and future production environments, and competition for natural resources are key issues to be considered for the sustainable global animal protein production (Hoving et al., 2014). Improvement of cattle genetic resources that are efficient and well adapted to extreme environmental temperatures, low-quality feeds, and disease challenges is crucial to effectively deal with climate challenges (Hoving et al., 2014; Rojas-Downing et al., 2017). This paper presents an overview of the impact of current cattle genetic improvement approaches on adaptation, and diversity conservation in response to climate change in Ethiopia.

DIRECT AND INDIRECT IMPACTS OF CLIMATE CHANGE ON CATTLE PERFORMANCE

Climate change has a direct influence on livestock due to rising temperature variation in photoperiod as well as precipitation, and indirectly due to the detrimental impacts on feed, increasing susceptibility to disease, as well as water and land use (Lipper et al., 2014; Angel et al., 2018; Escarcha et al., 2018). Some of them are briefly reviewed in the following sections.

Feed resources

Livestock production depends on the availability to feed and water that animals need to survive, produce and reproduce. Climate change will negatively influence the quality and quantity of feed for cattle in a given production environment, which may result from the deterioration of the productivity, decline in quality, and quantity of pastures and forage crops, and rangeland as a consequence of increased temperature and droughts (Rust and Rust, 2013; Rojas-Downing et al., 2017; Escarcha et al., 2018). Higher temperatures as a result of climate change leads to the lignification of animal feed resources and decreases their digestibility. In Ethiopia, about 87% of the overall animal feed is attributed to green fodder from grazing land and crop residues from crop land, which make up about 59 and 28%, respectively which are highly climate-sensitive (Yalew et al., 2018). Climate change particularly affects the rangelands that have been turned into bare termite mounts and land that has been covered by unpalatable, poisonous plant species as a result of bush encroachment (Tiruneh and Tegene, 2018). Similarly, the direct effects of climate change on feed supplies, rangeland carrying capacity, and grazing management may have a major impact on livestock production, and their sustainability under the milieu of climate change (Kefyalew and Addis, 2016; Getu et al., 2019).

Water availability

Water and land resources are critical inputs in cattle production systems, especially in the production of feed crops. Agriculture uses 70% of freshwater resources globally, making it the world's largest consumer (Rojas-Downing et al., 2017). The livestock sector alone consumes 8% of the world's water use and their water requirement increases with increased ambient temperature. The major issues in animal production affected by climate change are water scarcity and its depletion, which are reported to seriously affect the livestock productivity (Escarcha et al., 2018). Climate change would affect water resources by decreasing river run-off, and energy production, as well as increasing floods and droughts (Gezie, 2019). According to Tiruneh and Tegene (2018), decreasing water levels in rivers and a low level of water accumulation in community ponds have been observed in Ethiopia in the recent years. Most pastoral regions in Ethiopia such as Loka Abaya and Boran pastoralists, have faced critical water shortages, frequent erratic and reduced amounts of rainfall, temperature rises, and prolonged and frequent periods of drought as a result of climate change (Berhanu and Beyene, 2015).

Production performances

Climate change causes a wide range of detrimental impacts on the performance of cattle, including reduced growth rate, impaired animal health, lower milk yield as well as meat production, and deteriorated reproductive efficiency (Angel et al., 2018). In tropical and subtropical environments, Holstein-Jersey dairy cattle breeds milk production might be 40 to 60% lower than in temperate conditions (Henry et al., 2018), raising serious concerns regarding the resilience of the dairy industry to future global warming. Collectively, these effects are expected to influence cattle production and productivity. Some researchers have speculated that climate change could result in reduction of livestock productivity maybe by 50% in the 2050s as compared to that of without climate change scenarios (Tiruneh and Tegene, 2018). Heat stress due to climate change is the most significant pressing factor that could affect cattle productivity (Sejian et al., 2015). Heat stress directly impairs the performance of dairy cattle by suppressing the feed intake, which could result in reduced daily weight gain, feed conversion efficiency, milk yield, and milk component (Rust and Rust, 2013; Das et al., 2016; Angel et al., 2018; Escarcha et al., 2018), this causes significant economic losses to dairy cattle producers (Sejian et al., 2018). Lamesegn (2019) has reported that milk yield has declined by 0.2kg per increasing temperature-humidity index. Lactating cows are especially sensitive to heat stress due to their high metabolic activity associated with increased milk output.

Reproduction

Many studies have reported that the ambient temperature associated with climate change will alter the physiology of livestock, by reducing male and female fertility thereby increasing reproductive problems through alterations in the heat balance (Pilling and Hoffmann, 2011; Kebede, 2016). Variability in temperatures and heat stress results in reproductive inefficiency of cattle such as decreased fertility, increased age at first calving, conception rate, and longevity (Kebede, 2016; Rojas-Downing et al., 2017; Sejian et al., 2015; Idrissou et al., 2020). The conception rate of dairy cows could be dropped by 20-27% in summer. Moreover, heat-stressed cows often have poor expression of estrous due to impairment of ovarian functioning and embryonic development (Sejian et al., 2015; Das et al., 2016). Heat stress compromises oocyte development by changing progesterone secretion (Sejian et al., 2018; Lamesegn, 2019). An increase in uterine temperature of 0.5°C above average has caused decrease in conception rates by 6.9 to 12.8% (Polsky et al., 2017; Lamesegn, 2019). In general, high-producing breeds from temperate regions, which make up most of the market's production today, are not well adapted to heat stress situations (Pilling and Hoffmann, 2011; Renaudeau et al., 2012). As a result, selection for improved meat, and/or milk traits without considering adaptation to extreme environmental conditions may increase animals' susceptibility to elevated temperatures (Bayssa et al., 2020). Therefore, selection and breed improvement strategies should not only exploit the production potentials of animals but also their adaptability capacity so as to limit the productivity losses and other health effects on animals.

Health and wellbeing

Climatic impacts livestock health mainly through variations in temperature and humidity (Escarcha et al., 2018; Idrissou et al., 2020). Climatic changes may have an indirect impact on animal health by increasing the incidence and distribution of climate-sensitive infectious diseases, increasing survival and development rates of pathogens in the production environment, range, and abundance of vector-borne diseases and parasites, and spreading foodborne diseases during extreme weather events (Rust and Rust, 2013; Hoving et al., 2014; Rojas-Downing et al., 2017; Escarcha et al., 2018), which could lead to high rates of heat stress-induced morbidity and mortality (Pilling and Hoffmann, 2011). The pattern and occurrence of heat livestock infectious diseases especially vector-borne are significantly affected by climate changes. In addition, climate change can have impacts on the spread of certain diseases that are associated with water, which could be worsened by flooding. Zhang et al. (2017) reported that those diseases related factors which could be affected by climate change include, the molecular biology of pathogens, vectors, zoological factors, farming practices, and the establishment of a new micro-environment. For instance, variations in seasonal rainfall distribution and specific weather conditions could cause the outbreak of certain diseases such as anthrax, bluetongue virus, facial eczema, rift valley fever, and tse tse flies which causes trypanosomiasis in ruminants (Tesema et al., 2018).

Genetic diversity

The pattern of genetic diversity of cattle plays an important role in adapting to different production systems. However, this diversity could be threatened by climatic change effects (Pilling and Hoffmann, 2011). Climate change will accelerate the loss of genetic and cultural diversity in farm animals in general and in cattle in particular (Nefzaoui and Salem, 2011). It has been speculated that climate change has the potential to extinct 15% to 37% of all species in the world (Rojas-Downing et al., 2017). Some of the consequences of climate changes on animal genetic diversity could be associated with the death of a significant number of animals as a result of disease epidemics, loss of natural habitats and grazing areas due to recurrent drought, replacement of indigenous cattle with more drought tolerant farm animals such as camel and goat, and shifting livestock production towards to more suitable crop production system (Pilling and Hoffmann, 2011; Melesse et al., 2022). Droughts in Ethiopia in the 1980s and 1990s has resulted in 49% of herd losses under communal land use, while drought of the 1990s caused, 57% of the cattle mortality under ranch management (Tiruneh and Tegene, 2018). Moreover, bush encroachment and population pressure led to the diminishing availability of good pasture are among various reasons for the loss of genetic diversity (Tiruneh and Tegene, 2018; Tesema et al., 2018; and Naod et al., 2020).

CATTLE BREEDING FOR IMPROVED ADAPTATION TO CHANGING ENVIRONMENTS

After the initial assessment, the patient was hospitalized. Initially, urine outputAdaptation refers to an action that people's and society's adjustment in response to actual or expected climate effects, in a way that minimizes harm and optimizes the positive impacts of climate change or makes use of beneficial opportunities (Akinnagbe and Irohibe, 2015; Nadod et al., 2020). Adapting to climate change would increase the resilience of the system, assuming that future climate will push species to the limits of their tolerance range (Henry et al., 2018). Genetic adaptation can enhances productivity, efficiency, and genetic diversity, allowing more opportunities to match breeds to changing climates (Hoving et al., 2014). Adaptation measures include but not limited to the modification of production and management systems, breeding practices, structural and policy improvements along with science and technology developments (Rojas-Downing et al., 2017). Reducing exposure to the risk of damage, improving the capacity to cope with unavoidable damages, and taking advantage of new opportunities are the three goals of adaptation (Akinnagbe and Irohibe, 2015). Different communities are attempting to deal with climate-change related impacts through the improvement of livestock resilience by adopting appropriate technologies, applying traditional knowledge and related skills, and diversifying livelihoods. Apart from this, identifying those phenotypes and genes relevant to adaptation phenotype is one way to get a better understanding of adaptive capacity. This could be achieved by characterizing livestock species using FAO recommended phenotypic traits and genetic marker panels (FAO, 2012; Melesse et al., 2022). The application of the latter technology would enable researchers to identify selection footprints in the animal genome.

Genetic improvement of cattle may involve the choice of an appropriate genotype and/or breeds suitable to a given production environment, the selection of the appropriate pure breeding or crossbreeding approach, and the application of genetic enhancement strategies within the breed (Nimbkar et al., 2008). The choice of suitable cattle breeds and breeding systems in developed nations has been a significant contributor to improvements in livestock productivity. In developing countries, improvement of cattle genetic resources that are efficient and well adapted to extreme temperatures, low-quality diets, and greater disease challenges is necessary to address the challenges of adapting to climate change and increasing productivity (Pilling and Hoffmann, 2011; Hoving et al., 2014).

Changes in breeding strategies can help animals increase their tolerance to changing climates and improve their reproduction and production capacities (Rojas-Downing et al., 2017). The ability of cattle to adapt to environmental challenges is a valuable characteristic of a breed, which has been increasingly important in running cost-effective animal production. This is especially important as the climate becomes warmer, conditions for diseases occurrences turn out to be more favorable and feed resources become scarce leading to cost rises (Hoffmann, 2010; Kantanen et al., 2015). Adaptive characteristics to climate change encompass a wide range of physiological, behavioral, and morphological features (Melesse et al., 2011a; Melesse et al., 2011b; Melesse, 2016; Bayssa et al., 2020). Climate change adaptation strategies address not only livestock tolerance to heat, but also disease resistance, water scarcity tolerance, and the ability to cope with poor quality feed. These are valuable characteristics of a breed and have importance when mitigating and adapting to environmental changes (Hoffmann, 2010; Melesse et al., 2011a; Kantanen et al., 2015).

Many local breeds in tropical regions that have evolved over centuries in diverse, stressful tropical climates have been selected for unique adaptive traits that enable them to be productive in harsh environments (Melesse et al., 2022). Indigenous cattle breeds are better adapted to high temperatures, high solar radiation, and dry conditions than exotic cattle breeds due to their physical and morphological characteristics, which allow them to successfully regulate their body temperature. These locally adapted cattle breeds possess genes that code for specific traits desired by the major breed owners (Kantanen et al., 2015; Tesfa et al., 2017). Moreover, they have a greater capacity to grow and reproduce during unfavorable seasonal conditions with poor nutrition and higher disease and parasite prevalence than high-performance breeds (Renaudeau et al., 2012; Tesfa et al., 2017; Henry et al., 2018). They can also be expected to cope with the effects of climate change more comfortably than their exotic counterparts. Currently, the dominant pattern of gene flow does not focus on the improvement of locally adapted breeds, but on the high-output breeds that need highly controlled production environments. Since exotic cattle breeds are not well adapted to the tropical production environments, they require controlled and intensive feeding and management practices if they are thought to stay healthy and productive.

In many developing countries like Ethiopia, are usually characterized by a lack of appropriate technology suitable for livestock genetic improvement programs that might help to speed up the process of adaptation to a changing climate at a global level. Although crossbreeding of high-producing cattle breeds with indigenous cattle over many years has led to increased productivity (Henry et al., 2018), many of them are still less adaptive to heat stress and susceptible to environmental challenges (Eisler et al., 2014; Leroy et al., 2016; Gaughan et al., 2019). According to many studies, the commercial and widespread breeds may show failings in some traits, such as insufficient resistance to diseases or tolerance to other environmental stress due to climatic changes (Nardone et al., 2006; Hoffmann, 2010). If climate change becomes faster than the process of the natural selection, the risk to survival and adaptation to it, and the vulnerability of the commercial cattle breed to climate change would be inevitably high. In this context, it might be necessary to identify suitable genetic improvement strategies such as breeding livestock for adaptability rather than focusing on high productivity. Such measures may include conducting characterization studies to identify the local animal genetic resources that have the potential to be adapted to local climate conditions and feed sources (Melesse et al., 2022). Moreover, improving the genetic potentials of the local breeds through cross-breeding with heat and disease-tolerant breeds might be another option to explore (Melesse et al., 2011a; Melesse et al., 2011b). According to Aby and Meuwissen (2014), an efficient approach is the introgression of locally adaptive genes into commercial breeds through efficient breeding strategies that may be needed to bring better adapted to rapidly changing environmental conditions. When attempting to establish a cattle improvement program for a challenging environment, the selection of the stocks that are likely to be the most adaptable to local conditions is also critical. In addition, any animal genetic improvement programs thought to mitigate the effect of a changing climate, should be augmented with improved feeding, housing, and disease control.

Adaptive traits of crossbred cattle usually deteriorate overtime in comparison to local breeds (Leroy et al., 2016). High levels of upgrading cattle have generally resulted in animals with less resistance to diseases and less resilient to environmental stress due to loss of genes responsible for better fitness and survival (Philipsson et al., 2011). Successful genetic improvement strategies require proper planning of pure breeding, crossbreeding, or the development of synthetic breeds (Hoving et al., 2014). The choice among these strategies is dependent on many factors such as availability of skilled manpower, infrastructures, sufficient number of exotic genetic materials, and high operating costs. According to Hoving et al. (2014), well-designed breeding programs are needed to develop breeds with higher production while maintaining climate-adaptive qualities. When designing breeding strategies, breeders must ensure the development of appropriate livestock breeds considering future climatic conditions, which possess thermo-tolerance, drought tolerance, and the ability to survive in limited pastures (Sejian et al., 2018). Breeding programs should also be seen in the context of long-term development strategies, somehow flexible and responsive to variable scenarios of climatic conditions for future needs of the programs.

In order to mitigate the negative effects of climate change and maximize any benefits, the best adaptation options must further combine technological, behavioral, management, and policy options. Apart from this, any genetic improvement programs should consider environmental conditions, future climatic changes, and livelihood security (Nimbkar et al., 2008). Therefore, breeding strategies given to farming communities should be accurate and relevant to the production system and consider traits such as performance, adaptability, and suitability of breeds as much as possible.

BREEDING AND CONSERVATION OF CATTLE GENETIC DIVERSITY

Genetic diversity of domesticated animals is vital to the livestock sector. The diversity of farm animal species is the result of a long history of human practice; thus closely related to the diversity of production systems and socio-cultural values (Hoffmann, 2010). The genetic diversity of animal genetic resources (AnGRs) ensures the long-term viability of a breed or population as well as genetic improvement and adaptation to the changing environmental conditions (FAO, 2007; Boettcher et al., 2015). Conservation of genetic diversity of cattle population is not only important to meet present requirements of the society, but also important for meeting future challenges (Hoffmann, 2010), supporting sustainable cattle production for food security, maintaining genetic variability for further use, and conserving heritages (Hiemstra et al., 2006). Increasing productivity and efficiency will be fundamental, but maintenance of genetic diversity will also be importance (Boettcher et al., 2015). Having broad genetic diversity would allow opportunities for genetic improvement by selection and mating strategies to maximize genetic response in the long run (Chebo and Alemayehu, 2012), and adaptation to the changing environmental conditions, including not only those associated with climate but also changes in the market, management, and diseases challenges (Boettcher et al., 2010), as well as to develop new and improved breeds and to match breeds to a changing climate (Hoffmann, 2013). In conservation, maintenance of both within and across-breed genetic diversity is the primary aim (Biscarini et al., 2015). The maintenance of cattle genetic diversity underlying resistance to harsh environmental conditions provides a valuable resource for fighting the effects of possible future climatic challenges.

Globally, livestock genetic diversity is rapidly declining as specialization in animal breeding, and the harmonizing effects of globalization advance (Hoffmann, 2013). In the history of animal production, a very sizable number of animal breeds including cattle breeds have been developed and disappeared globally (Tisdell, 2003). Reports have been noted that in recent centuries there has been an exaggerated increase in the degree of extinction of livestock breeds relative to the rate of formation of new breeds (FAO, 2015; Belew et al., 2016). The cause for the loss of cattle genetic diversity and the lowering of both productivity and population in Ethiopia are due to the increasing pattern of global reliance on a very limited number of modern commercialized livestock breeds suited for the high input-output needs of industrial agriculture and genetic admixture (Gizaw et al., 2013b; Mwai et al., 2015; Belew et al., 2016; Tesfa et al., 2017), and breeding schemes because of agricultural policies that encourage quick solutions to ensure food security or fulfill the rising demand for food (FAO, 2015; Okeyo, 2015). The loss of genetic diversity in domestic species has significant economic, ecological, and scientific implications, as well as social considerations.

LOSS OF GENETIC DIVERSITY BY BREED REPLACEMENT

Breed substitution occurs when improved breeds are directly replaced by other improved breeds or indigenous breeds upgraded to exotic breeds that are considered economically superior, or when synthetic breeds are created by crossbreeding which eventually replaces existing breeds ((ESAP), 2003; Tisdell, 2003). It is often argued that with the use of improved breeds, drastic advances in cattle production can be achieved. Even in areas where the exotic genotypes are ill-adapted, the introduction of exotic genetic material remains seen as a solution to the low productivity of local cattle breeds (Hiemstra et al., 2006; Leroy et al., 2016). According to Belew et al. (2016), the main cause of genetic diversity loss in developing countries is due to the fact that the farmers have a strong pressure to switch to commercialized cattle breeds and breeding schemes. Breed replacement without long-term breeding strategies has contributed to serious genetic erosion, including extinction of a number of locally adapted breeds (Alemayehu, 2013; Belew et al., 2016). No one emphasized the merits of locally adapted animals to environmental conditions. However, often, complete replacement of local breeds by specialized, high productive breeds is not a sustainable strategy in the long run. Alemayehu (2013) also indicated that gene introgression together with an unsustainable selective pressure for adaptation to global climate change are the major challenges to the conservation of AnGRs. There are several well-documented cases of unrealistic livestock development projects based on importations of commercial breeds, these approaches lead to wrong breeding objectives and neglect the potential of indigenous livestock breeds (Hiemstra et al., 2006). However, newly introduced breeds and crossbreds need to be appropriate for the environment and fit within a production system that may be characterized by limited resources and climate changes. The use of misguided and uncontrolled introduction of exotic genes might have a drastic effect on cattle genetic diversity and may lead to the disappearance of indigenous cattle breeds within a few centuries (Chebo and Alemayehu, 2012).

Although exotic breeds are considered as more productive, they lack adaptation to the environmental stress, disease, and parasite resistance traits found in native breeds (Hoving et al., 2014). Selection of highly productive breeds mainly focused on production characteristics and this underestimates functional and adaptive characteristics (Ilatsia et al., 2012). According to Hoving et al. (2014), quick replacement of locally adapted breeds by indiscriminate crossbreeding should be avoided due to the loss of adaptive traits and lower economic benefits.

In contrast to exotic breeds, indigenous livestock breeds in Ethiopia are the hardiest breeds, well suited to the local climate and capable of coping and producing in harsh conditions due to physiological and genetic adaptations (Rojas-Downing et al., 2017; Bayssa et al., 2020). It is clear that breeds that evolved in diverse, stressful, tropical environments possess a unique adaptive traits (Gizaw et al., 2013b). Although they have less production potential than specialized breeds, their level of production is relatively stable during testing conditions where high-producing animals fail (Hoving et al., 2014; Sejian et al., 2018). On the contrary, the productivity evaluation of indigenous cattle breeds in Ethiopia demonstrates that they can outperform crossbreeds under improved conditions (Ayalew et al., 2003). Indigenous cattle breeds maintain their reproductive potential during periods of extreme heat stress, water scarcity, and reduced pasture availability due to their smaller body size, whereas the larger exotic cattle may experience reproductive impairments due to their higher energy requirements (Sejian et al., 2018). Hence, better adoption approaches of the multipurpose functions of indigenous cattle breeds by mapping suitability to the socio-cultural demand must be oriented (FAO, 2007; Philipsson et al., 2011). In this regard, Mekuriaw and Kebede (2015) suggested that realistic ways of improving local genetic resources should be selected and implemented in light of available tools, present and future environmental limitations, and socio-cultural demands.

Maintenance of genetic diversity, which supports resistance to environmental stresses, is a valuable weapon for mitigating the possible effects of future climatic challenges (FAO, 2007). From the long-term point of view, a concentration on environmentally sensitive breeds may pose a serious problem for the viability of cattle production (Tisdell, 2003). Hence moving to a few breeds would eliminate a considerable amount of variation in the breeds, in addition to jeopardizing readily available gene combinations in other remaining gene resources. According to Okeyo et al. (2010), several countries in the developed world have placed their local livestock populations at risk by exotic breed introduction and/or cross-breeding. Bringing cattle breeds that are more adapted to the changed conditions is one option for adapting the production system to the effects of climate change. Thus, for any development agency contemplating introducing a breed to a new area, it is essential to adequately consider the adaptation of breed to the new environment and climate change, properly consult livestock keepers, and thorough assessment of the breed's suitability for use in the current and projected future production environment is critical.

CROSSBREEDING TO THE LOSS OF CATTLE GENETIC DIVERSITY

Indeed, the introduction of exotic breeds and cross-breeding with improved breeds would bring rapid genetic improvement than the time-consuming and wasteful selective breeding of native breeds (Thornton, 2010). Crossbreeding has been successful when it was accompanied by a rigorous selection program involving livestock owners as well as substantial public sector involvement (Nimbkar et al., 2008). Through crossbreeding strategies between local and exotic breeds, the productivity gap between both categories of breeds can be reduced in a short time by combining the high productivity of the former with adaptive attributes of the latter (Chebo and Alemayehu, 2012; Hoving et al., 2014). The success of crossbreeding has been limited due to the co-introduction of other undesirable genetic characteristics of zebu cattle, particularly those associated with low productivity (Mateescu et al., 2020).

Crossbreeding may increase the overall genetic diversity by introducing new genes and genotypes (e.g. synthetic breeds) in the population (Alemayehu, 2013). Cross-breeding can be considered as a necessary evil because it provides the much desired rapid increase in productivity of livestock and at the same time threatens indigenous breeds by replacing them (Alemayehu, 2013; Gizaw et al., 2013b). According to Chebo and Alemayehu (2012) and Alemayehu (2013), the major cause of genetic erosion of locally adapted cattle breeds is indiscriminate crossbreeding or repeated use of imported germplasm. Unplanned crossbreeding with exotic cattle breeds without enough consideration of their environments is also a major factor contributing to the loss of locally adapted cattle breeds through replacement and loss of certain adaptive traits (Philipsson et al., 2011; Alemayehu, 2013; Mwai et al., 2015). This may result in an inconsistent and rapid loss of genetic diversity by dilution of native-born genetic makeup (Chebo and Alemayehu, 2012).

Several ranches in Ethiopia, for example, Abernosa ranch which has been involved in the crossing of Boran cows with Holstein Friesian cattle, Gobe ranch which has been involved in the crossbreeding of Arsi with Holstein

Fresian breeds and also with different grades of exotic cattle such as Jersey and Simmentals to produce F1 heifers for the distribution to the farmers and to increase the production of milk (ESAP, 2003). These ranches have been distributed over thousands of heifers for use as dairy animals to cooperatives and private farmers over the last 30 years. In both cases, a vast range of exotic blood groups and genotypes are prevalent due to subsequent uncontrolled breeding at the level of the community herd, which harms the genetic diversity of the existing breeds through replacement and loss of some important adaptive traits.

Crossbreeding has often been performed indiscriminately in the past, resulting in the extinction of the local breeds that underpin the crossbreeding schemes, due to a lack of understanding by the authorities, companies, and/or farmers concerned that certain pure breeds must be maintained to sustain the system (Chebo and Alemayehu, 2012). Therefore, any breeding strategies offered to the farming communities should be as accurate and relevant as possible in terms of breed suitability, performance, and adaptability in the production environment climatic stress as possible. However, adaptation traits are more difficult to record and to study, have lower heritability, higher levels of non-additive genetic variation and phenotypic variance, and are more susceptible to genotype-by-environment interaction (Hoffmann, 2013). The sustainability of crossbreeding strategy requires careful planning and long-term organization (Leroy et al., 2016). Designing a breeding program needs to take into account a mechanism for conservation of indigenous cattle genetic resources (Chebo and Alemayehu, 2012). Moreover, the use of advanced modern biotechnology tools aids to solve the challenges of climate change and is applied to enhance genetic progress through increasing genetic variation. In contrast to the classical selection, genomic selection increases the accuracy of selection with the largest genetic gain for low heritability traits and reducing inbreeding (Strandén et al., 2019). The genomic selection can be effective in the introgression of favorable alleles of a lowly heritable trait from a donor to a target population (Strandén et al., 2019). Combination of crossbreeding and selection (including genomic selection) may allow the exploitation of both types of populations (Aby and Meuwissen, 2014; Leroy et al., 2016). It is also possible to produce genetically engineered animals that are healthier and have superior disease resistance ability to endemic diseases through the application of transgenic technology to the desired immune system (Tesema et al., 2018; Tesfahun, 2018). Strategies use genomic-based analysis breeding principles, which can accelerate the process of cattle breeding with higher and more productive as well as adapted to the changing environments as a result of climate change, taking epigenetic influence into account (Scholtz et al., 2013).

SELECTIVE BREEDING OF CATTLE TO MITIGATE CHALLENGES OF CLIMATE CHANGE

In many developing countries, the existing animal genetic improvement method has mainly relied on selective breeding by scoring animals based on their phenotypes to determine their breeding value (Singh et al., 2014). These conventional methods of selective breeding were mainly for higher productivity, which has limitations in terms of environmental adaptation such as climate change (Henry et al., 2018). Although selective breeding has significantly improved cattle breeds, several challenges remain such as low genetic progress in some important traits such as feed conversion efficiency, fertility, and adaptation to warmer climatic conditions (Hayes et al., 2013). Selection of cattle for increased output while ignoring traits correlated to traits of conservation interest such as adaptability, genetic diversity, can reduce breed distinctiveness and between-breed variation (Biscarini et al., 2015). As a result, the animals' flexible adaptable capacity to change and diverge in production has been replaced by inflexible, static, and location-specific behavior (Idel et al., 2013). The traits to be considered in mitigating the impacts of cattle production and adaptation to climate change are typically complex and polygenic (Strandén et al. 2022). Selection of cattle for breeding should consider traits associated with heat-tolerance, fertility, feed conversion efficiency, relative adaptability to low-quality feed, and disease resistance and give more consideration to the genotype by environment interaction in addition to high productivity (Alemayehu, 2013; Sejian et al., 2012; Kefyalew and Addis, 2016; Strandén et al., 2022), to address climate change. Breeding for climate change adaptation or mitigation will not necessarily be different from prevailing programs. Therefore, the use of selective breeding together with the optimized crossbreeding enables to attain sustainable breeding maintaining genetic diversity and genetic gain (Li et al., 2022). Recently, emerged modern biotechnological tools have shown vital potential for genetic improvement of beneficial traits and climate change adaptation and mitigation by improving intake, digestibility, and nutritive value of low-quality forage, as well as improving animals' health (Tesema et al., 2018). To balance the mechanism of breeding and optimize the animal breeding program, the use of molecular genetics techniques in combination with conventional animal breeding tools is necessary (Singh et al., 2014; Salisu et al., 2018).

Biotechnology for adaptive crossbreeding plays an important role to adopt and elucidate the problems resulted from climate changes through increasing disease resistance through genomic selection and genetic engineering (Zhang et al., 2017; Tesema et al., 2018; Tesfahun, 2018). Moreover, the use of advanced modern biotechnology tools aids to solve the challenges of climate change and is applied to enhance genetic progress through increasing genetic variation. In contrast to classical selection, genomic selection increases the accuracy of selection with the largest genetic gain for low heritability traits and reduces inbreeding (Strandén et al., 2019). The genomic selection can be effective in the introgression of favorable alleles of a lowly heritable trait from a donor to a target population (Strandén et al., 2019). Combination of crossbreeding and selection (including genomic selection) may allow the exploitation of both types of populations (Aby and Meuwissen, 2014; Leroy et al., 2016). Through repeated crossbreeding and backcrossing animals carrying the favorable disease resistance alleles and a more productive breed the animals, it is possible to combine the ability of disease resistance from indigenous cattle breeds and productivity from exotic breeds (Tesema et al., 2018; Strandén et al., 2019). Backcrossing is introgression of desirable gene from the donor breed to the recipient through multiple backcrosses, followed by one or more generations of intercrossing, to generate an individuals carrying one copy of the donor gene (FAO, 2007). It is also possible to produce genetically engineered animals that are healthier and have superior disease resistance ability to endemic diseases through the application of transgenic technology to the desired immune system (Tesema et al., 2018; Tesfahun, 2018). Strategies use genomic-based analysis breeding principles, which can accelerate the process of cattle breeding with higher and more productive as well as adapted to the changing environments as a result of climate change, taking epigenetic influence into account (Scholtz et al., 2013).

GENETIC IMPROVEMENT FOR SUSTAINABILITY OF LIVESTOCK PRODUCTION

Sustainable use is described as the use of biological diversity components in a way and at a scale that does not result in long-term biodiversity loss, thereby maintaining its capacity to meet the needs of present and future generations (Nimbkar et al., 2008). Sustainability is a multifaceted notion that jointly considers ecological, socio-cultural, and economic parts of the system (Hoffmann, 2010), or an intervention for long-lasting prosperity that meet the needs of the current requirements without compromising the ability of the future. Sustainable use and genetic improvement of AnGRs are proposed as the best strategy for agriculture, food production, adaptation to possible future changes, and maintaining their diversity (Nimbkar et al., 2008; Boettcher et al., 2010). Any sustainable breeding program requires continued development and improvement of the breed to ensure its future competitiveness (Philipsson et al., 2011). Identification of effective breeding objectives and implementation of long-term breeding programs are necessary to achieve sustainable cattle genetic improvement which support livelihoods and minimize the long-term risk for the survival of cattle populations (Nimbkar et al., 2008).

Any breeding program is dependent on environmental conditions, the production systems, and the culture in which the animals are bred. As a result, in order to sustain cattle production in an environment challenged by climate change, the animals must have the ability to survive and produce under harsh conditions (Pilling and Hoffmann, 2011). To be sustainable, the breeding program must be adaptable, market-driven, socially appropriate, and consider animals' multi-purpose use, climate change, and the long-term benefits to farmers (Philipsson et al., 2011). The degree to which the environment can be freed from constraints such as diseases, parasites, diet, and climate is minimal. This provides a convincing case for using the best locally adapted, modified genotypes following environmental changes where possible and economical, as well as considering the advancement of suitable breeding programs (Philipsson et al., 2011). Sustainable use of cattle genetic resources depends on the continued use of between and within breed genetic diversity (Hoffmann, 2010).

Sustaining livestock production in the changing climate scenario requires a paradigm shift in the use of existing technologies (Sejian et al., 2018). To maintain the long-term horizon of cattle breeding, the definition of breeding objectives includes determining the relative importance of the different traits of the breed in the context of a given production environment (Philipsson et al., 2011). Breeding objectives must be defined at the national, regional, or local level rather than by outsiders to genuinely reflect the real needs of the area (Philipsson et al., 2011). Participation of farmers is essential that farmers influence the establishment of the breeding objectives and support the direction of change (Philipsson et al., 2011; Sejian et al., 2018) and validate the existing technologies with modifications for specific locations, keeping in mind the requirement of an ultimate target group of farmers (Philipsson et al., 2011). Participation of farmers allows the application of feed and water conservation technologies that are simple to integrate indigenous expertise in advance of climate change-related problems and challenges. Significant livestock research efforts are further needed to identify livestock genetic resources conservation measures through the development of national databases on existing genetic resources and to broaden adaptation for the future to develop resilient and more productive animals (Hoving et al., 2014; Rojas-Downing et al., 2017). Moreover, emphasis must be given to conducting research targeting the impact of multiple environmental stresses simultaneously is required rather than concentrating only on heat stress (Escarcha et al., 2018).

CONCLUSIONS AND RECOMMENDATIONS

Cattle genetic improvement is necessary for the development of livestock sector, to address the challenges of climate change adaption, and to produce animals that are efficient and well adapted to extreme temperatures, low-quality diets, and greater disease challenges. When attempting to establish a cattle genetic improvement program, the selection of stocks that likely to be the most adaptable to local conditions, and considering the future climatic pressures, while ensuring the capacity for increased productivity is vital. Cattle genetic improvements are important for increased productivity of breeds, whereas conservation and, their sustainable use are also essential to secure important locally adapted indigenous breeds. The major causes for the erosion of genetic diversity are unplanned extensive use of exotic germplasm and replacing locally adapted cattle breed due to an increased pattern of reliance on a very limited number of modern commercialized cattle breeds suited for high input-output breeds. The maintenance of cattle genetic diversity underlying resistance to harsh environmental conditions provides an important resource for combating the effects of possible future climatic challenges. Therefore, any breeding strategies should be relevant in terms of breed suitability, performance, and adaptability in the production environment and climatic stress. Genetic improvement methods of cattle currently used in Ethiopia are focused on selective crossbreeding of high-input-output commercialized and indigenous breeds based on their phenotypes, particularly for higher productivity, without considering adaptation of environmental stress such as climate change. Genomic selection of animals in combination with conversional methods considering traits associated with heat-tolerance, fertility, feed conversion efficiency, adaptability to low-quality feed, and disease resistance in addition to high productivity is necessary.

REFERENCES

Aby, B.A., and Meuwissen, T., 2014. Selection strategies utilizing genetic resources to adapt livestock to climate change. In Proceedings of the 10th world congress of genetics applied to livestock production, Vancouver, Canada, 17–22 August 2014.

Akinnagbe, O., Irohibe, I., 2015. Agricultural adaptation strategies to climate change impacts in Africa: a review. Bangladesh. J. Agril. Res. 39(3), 407–418.

Alemayehu, K., 2013. Threats, attempts and opportunities of conserving indigenous animal genetic resources in Ethiopia. Afri. J. Agri. Res. 8(23), 2806–2813.

Angel, S.P., Amitha, J.P., Rashamol, V.P., Vandana, G.D., Savitha, S.T., 2018. Climate change and cattle production: impact and adaptation. J. Vet. Med. Res. 5(4), 1134.

Ayalew, W., Rischkowsky, B., King, J.M., Bruns, E., 2003. Crossbreds did not generate more net benefits than indigenous goats in Ethiopian smallholdings. Agri. Systems. 76(3), 1137–1156.

Bayssa, M., Yigrem, S., Betsa, S., Tolera, A., 2020. Production, reproduction and adaptation characteristics of boran cattle breed under changing climate: a systematic review and meta-analysis. BioRxiv. 2020, 423410.

Belay, K., Beyene, F., Manig, W., Temesgen G., Aleme, M.H., 2014. Climate change and livestock production. Adv. Life Sci. Tech. 22(4), 39–43.

Belew, A.K., Tesfaye, K., Belay, G., 2016. The state of conservation of animal genetic resources in developing countries: a review. Int. J. Phar. Med. Bio. Sci. 5(1), 58–66.

Berhanu, W., Beyene, F., 2015. Climate variability and household adaptation strategies in southern Ethiopia. Sustainability. 7(6), 6353–6375.

Bett, B., Kiunga, P., Gachohi, J., Sindato, C., Mbotha, D., Robinson, T., Lindahl, J., Grace, D., 2017. Effects of climate change on the occurrence and distribution of livestock diseases. Preventive. Vet. Med. 137, 119–129.

Biscarini, F., Nicolazzi, E., Alessandra, S., Boettcher, P., Gandini, G., 2015. Challenges and opportunities in genetic improvement of local livestock breeds. Front. Genet. 5, 1–16.

Boettcher, P.J., Tixier-Boichard, M., Toro, M.A., Simianer, H., Eding, H., Gandini, G., Joost, S., Garcia, D., Colli, L., Ajmone-Marsan, P., 2010. Objectives, criteria and methods for using molecular genetic data in priority setting for conservation of animal genetic resources. Anim. Genet. 41(1), 64–77.

Boettcher, P.J., Hoffmann, I., Baumung, R., Drucker, A.G., McManus, C., Berg, P., Stella, A., Nilsen, L.B., Moran, D., Naves, M., Thompson, M.C., 2015. Genetic resources and genomics for adaptation of livestock to climate change. Front. Genet. 5, 461.

Calicioglu, O., Flammini, A., Bracco, S., Bellù, L., Sims, R., 2019. The future challenges of food and agriculture: An integrated analysis of trends and solutions. Sustainability. 11(1), 222.

Chebo, C., Alemayehu, K., 2012. Trends of cattle genetic improvement programs in Ethiopia: challenges and opportunities. Livest. Rese. Rural Dev. 24(7), 1-17.

CSA, 2020. Ethiopia (Federal democratic Republic of Ethiopia). In Handbook of Federal Countries, 2020, II(March). CSA, [Switzerland], pp. 136–148.

Das, R., Sailo, L., Verma, N., Bharti, P., Saikia, J., Imtiwati, Kumar, R., 2016. Impact of heat stress on health and performance of dairy animals: a review. Vet. Worl. 9(3), 260–268.

Diriba, G., 2020. Agricultural and rural transformation in Ethiopia: obstacles, triggers and reform considerations. Available online: https://africaportal.org/wp-content/uploads/2023/05/ Agricultural_and_rural_transformation_in_Ethiopia-1.pdf

ESAP, 2003. Farm animal biodiversity in Ethiopia. In Proceedings of the 11th annual conference of the Ethiopian Society of Animal Production (ESAP) held in Addis Ababa, Ethiopia, 28-30 August 2003, pp. 441.

Eisler, M.C., Lee, M.R.F., Tarlton, J.F., Martin, G.B., 2014. Steps to sustainable livestock. Nature. 507(7490), 32–34.

Escarcha, J.F., Lassa, J.A., Zander, K.K., 2018. Livestock under climate change: a systematic review of impacts and adaptation. Climate. 6(3), 1–17.

FAO, 2007. State of art in the management of animal genetic resource. Method for conservation. In The State of the World's Animal Genetic Resources for Food and Agriculture. FAO, Rome, pp. 443–475.

FAO, 2012. Phenotypic characterization of animal genetic resources. In FAO animal production and health guidelines. Available online: https://azerbaijan.un.org/sites/default/files/2021-04/FAO%20Phenotypic%20characterization-ENG.pdf.

FAO, 2015. The second report on the state of the world's animal genetic resources for food and agriculture. Available online: https://www.fao.org/3/i4787e/i4787e.pdf.

FAO, 2018. Animal production. Available online: https://www.fao.org/animal-production/en/ Field, C.B., Barros, V.R., Mastrandrea, M.D., Mach, K.J., Abdrabo, M.K., Adger, N., Anokhin, Y.A., Anisimov, O.A., Arent, D.J., Barnett, J., 2014. Summary for policymakers. In Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, pp. 1-32.

Gashaw, T., Asresie, A., Haylom, M., 2014. Climate change and livestock production in Ethiopia. Adv. Life Sci. Tech. 22, 39–42.

Gaughan, J.B., Sejian, V., Mader, T.L., Dunshea, F.R., 2019. Adaptation strategies: ruminants. Anim. Front. 9(1), 47–53.

Getu, A., 2014. The effects of climate change on livestock production, current situation and future consideration. Afri. J. Anim. Prod. husb. 1(3), 29-34.

Gezie, M., 2019. Farmer's response to climate change and variability in Ethiopia: a review. Cogent. Food. agric. 5(1), 1613770.

Gizaw, S., Abegaz, S., Rischkowsky, B., Haile, A., Mwai, A., Dessie, T., 2013. Review of sheep research and development projects in Ethiopia. International Livestock Research Institute, Kenya.

Gizaw S., Getachew, T., Edea, Z., Mirkena, T., Duguma, G., Tibbo, M., Rischkowsky, B., Mwai, O., Dessie, T., Wurzinger, M., Solkner, J., Haile, A., 2013. Characterization of indigenous breeding strategies of the sheep farming communities of Ethiopia. International Center for Agricultural Research in the Dry Areas, Syria.

Hayes, B.J., Lewin, H.A., Goddard, M.E., 2013. The future of livestock breeding: Genomic selection for efficiency, reduced emissions intensity, and adaptation. Tren. Genet. 29(4), 206–214.

Henry, B.K., Eckard, R.J., Beauchemin, K.A., 2018. Review: adaptation of ruminant livestock production systems to climate changes. Anim. 12(s2), S445–S456.

Hiemstra, S.J., Drucker, A.G., Tvedt, M.W., Louwaars, N., Oldenbroek, J.K., Awgichew, K., Kebede, S.A., Bhat, P.N., 2006. Exchange, use and conservation of Animal Genetic Resources Centre for Genetic Resources. Available online: https://edepot.wur.nl/27689.

Hoffmann, I., 2010. Climate change and the characterization, breeding and conservation of animal genetic resources. Anim. Genet. 41(s1), 32-46.

Hoffmann, I., 2013. Adaptation to climate change–exploring the potential of locally adapted breeds. Animal. 7(s2), 346-362.

Hoving, I.E., Stienezen, M.W.J., Hiemstra, S.J., van Dooren, H.J.C., de Buisonjé, F.E., 2014. Adaptation of livestock systems to climate change: functions of grassland, breeding, health and housing. Livest. Res. Rep. 793, 60.

Idel, A., Fehlenberg, V., Reichert, T., and UNCTAD, 2013. Livestock production and food security in a context of climate change and environmental and health challenges. Available online: https://unctad.org/system/files/official-document/ditcted2012d3_ch2_en.pdf.

Idrissou, Y., Assani, A.S., Baco, M.N., Yabi, A.J., Alkoiret Traoré, I., 2020. Adaptation strategies of cattle farmers in the dry and sub-humid tropical zones of Benin in the context of climate change. Heliyon. 6(7), e04373.

Ilatsia, E.D., Roessler, R., Kahi, A.K., Piepho, H.P., Zárate, V., 2012. Production objectives and breeding goals of Sahiwal cattle keepers in Kenya and implications for a breeding programme. Trop. Anim. Health. Prod. 44(3), 519–530.

Kantanen, J., Løvendahl, P., Strandberg, E., Eythorsdottir, E., Li, M.H., Kettunen-Praebel, A., Berg, P., Meuwissen, T., 2015. Utilization of farm animal genetic resources in a changing agroecological environment in the Nordic countries. Front. Genet. 5, 1–9.

Kebede, D., 2016. Impact of climate change on livestock productive and reproductive performance. Livest. Res. Rural. Dev. 28(12), 12.

Kefyalew, A., Addis, G., 2016. Impacts of climate variability on livestock population dynamics and breed distribution patterns in selected districts of Western Amhara, Ethiopia. Anim. Genet. Reso. 59, 113–121.

Lamesegn, D., 2019. Review on effects of climate change on livestock production in Ethiopia. Online J. Anim. Feed. Res. 8(6), 185–189.

Leroy, G., Baumung, R., Boettcher, P., Scherf, B., Hoffmann, I., 2016. Review: Sustainability of crossbreeding in developing countries; definitely not like crossing a meadow. Animal. 10(2), 262-273.

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., Hottle, R., Jackson, L., Jarvis, A., Kossam, F., Mann, W., McCarthy, N., Meybeck, A., Neufeldt, H., Remington, T., Sen, P.T., Sessa, R., Shula, R., Tibu, A., Torquebiau, E.F., 2014. Climate-smart agriculture for food security. Nat. Clim. Change. 4(12), 1068-1072.

Li, Y., Kaur, S., Pembleton, L.W., Valipour-Kahrood, H., Rosewarne, G.M., Daetwyler, H.D., 2022. Strategies of preserving genetic diversity while maximizing genetic response from implementing genomic selection in pulse breeding programs. Theor. Appl. Genet. 135(6), 1813-1828.

Mateescu, R.G., Sarlo-Davila, K.M., Dikmen, S., Rodriguez, E., Oltenacu, P.A., 2020. The effect of Brahman genes on body temperature plasticity of heifers on pasture under heat stress. J. Anim. Sci. 98(5) 1-9.

Mekuriaw, G., Kebede, A., 2015. A review on indigenous cattle genetic resourses in Ethiopia: adaptation, status and survival. Online J. Anim. Feed. Res. 5(5), 125–137.

Melesse., A., Steffen., M., Von Lengerken, G., 2011a. Effect of long-term heat stress on some performance traits and plasma enzyme activities in Naked-neck chickens and their F1 crosses with commercial layer breeds. Livest. Sci. 141(2–3), 227–231.

Melesse., A., Steffen., M., Von Lengerken, G., 2011b. Effects of genetic group x ambient temperature interactions on performance and physiological responses of naked-neck chickens and their F1 crosses with lohmann white and new hampshire laying hens. J. Anim. Feed. Sci. 20(4), 599–612.

Melesse, A., 2016. Effect of flushing with energy and protein source diets on the reproductive performances of meat goats with high and low body condition scores. Available online: https://globaljournals.org/GJSFR_Volume16/1-Effect-of-Flushing-with-Energy.pdf.

Melesse, A., Yemane, G., Tade, B., Dea, D., Kayamo, K., Abera, G., Mekasha, Y., Betsha, S., Taye, M., 2022. Morphological characterization of indigenous goat population in Ethiopia using canonical discriminant analysis. Small. Rumi. Res. 206, 106591.

Mwai, O., Hanotte, O., Kwon, Y.J., Cho, S., 2015. African indigenous cattle: Unique genetic resources in a rapidly changing world. Asian-Australas. J. Anim. Sci. 28(7), 911–921.

Naod, E., Addisu Legesse, S., Tegegne, F., 2020. Livestock diversification prospects for climate change adaptation in Dangila district, Ethiopia. Trop. Anim. Health Prod. 52(3), 1435-1446.

Nardone, A., Ronchi, B., Lacetera, N., Bernabucci, U., 2006. Climatic effects on productive traits in livestock. Vet. Res. Commun. 30(Suppl. 1), 75–81.

Nardone, A., Ronchi, B., Lacetera, N., Ranieri, M.S., Bernabucci, U., 2010. Effects of climate changes on animal production and sustainability of livestock systems. Livest. Sci. 130(1–3), 57–69.

Nefzaoui, A., Salem, H.B., 2011. Coping with climate change and risk management strategies for sustainable rangeland-based systems in WANA region. Ann. Arid. Zone. 50(1), 1–10.

Negash, D., 2018. Review on compound animal feed processing in Ethiopia: Condition, Challenges and Opportunities. MOJ. Food. Process. Technol. 6(1), 60-64.

Nimbkar, C., Gibson, J., Okeyo, M., Boettcher, P., Soelkner, J., 2008. Sustainable use and genetic improvement. Anim. Genet. Resour. Inf. 42, 49–65.

Okeyo, A.M., Persley, G.J., Kemp, S.J., 2010. Livestock and biodiversity: the case of cattle in Africa. Available online: https://ageconsearch.umn.edu/record/125244

Philipsson, J., Rege, J.E.O., Zonabend König, E., Okeyo Mwai, A., 2011. Sustainable breeding programmes for tropical low-and medium input farming systems. Available online: http://erepository.uonbi.ac.ke/handle/11295/44897

Pilling, D., Hoffmann, I., 2011. Climate change and animal genetic resources for food and agriculture: state of knowledge, risks and opportunities. Available online: https://www.researchgate.net/publication/267981978_Climate_change_and_animal_genetic_resources_for_food_and_agriculture_State_of_knowledge_risks_and_opportunities#fullTextFileContent
Polsky, L.B., Madureira, A.M.L., Filho, E.L.D., Soriano, S., Sica, A.F., Vasconcelos, J.L.M., Cerri, R.L.A., 2017. Association between ambient temperature and humidity, vaginal temperature, and automatic activity monitoring on induced estrus in lactating cows. J. Dairy. Sci. 100(10), 8590–8601.
Renaudeau, D., Collin, A., Yahav, S., De Basilio, V., Gourdine, J.L., Collier, R.J., 2012. Adaptation to hot climate and strategies to alleviate heat stress in livestock production. Anim. 6(5), 707–728.
Rojas-Downing, M.M., Nejadhashemi, A.P., Harrigan, T., Woznicki, S.A., 2017. Climate change and livestock: impacts, adaptation, and mitigation. Clim. Risk. Manag. 16, 145–163.
Ruo, G., 2018. Climate change adaptation practices by ruminant livestock producer of in Hintalo Wajerat District Tigray Regional State, Northern Ethiopia. Biomed. J. Sci. Technol. Res. 11(5), 8809–8828.
Rust, J.M., Rust, T., 2013. Climate change and livestock production: a review with emphasis on Africa. S. Afr. J. Anim. Sci. 43(3), 255-267.
Salisu, I.B., Olawale, A.S., Jabbar, B., Koloko, B.L., Abdurrahaman, S.L., Amin, A.B., Ali, Q., 2018. Molecular markers and their potentials in animal breeding and genetics. Niger. J. animal. sci. 20(3), 29–48.
Scholtz, M.M., Maiwashe, A., Neser, F.W.C., Theunissen, A., Olivier, W.J., Mokolobate, M.C., Hendriks, J., 2013. Livestock breeding for sustainability to mitigate global warming, with the emphasis on developing countries. S. Afri. J. Anim. Sci. 43(3), 269-281.
Sejian, V., Bhatta, R., Gaughan, J.B., Dunshea, F.R., Lacetera, N., 2018. Review: adaptation of animals to heat stress. Anim. 12(s2), S431–S444.
Sejian, V., Gaughan, J., Baumgard, L., Prasad, C., 2015. Climate change impact on livestock: Adaptation and mitigation. Springer, New Delhi.
Sejian, V., Naqvi, S.M.K., Ezeji, T., Lakritz, J., Lal, R., 2012. Environmental stress and amelioration in livestock production. Springer, New Delhi.
Shapiro, B.I., Gebru, G., Desta, S., Negassa, A., Nigussie, K., Aboset, G., Mechale, H., 2017. Ethiopia livestock sector analysis: a 15year livestock sector strategy. Available online: https://cgspace.cgiar.org/handle/10568/92057
Singh, U., Deb, R., Alyethodi, R.R., Alex, R., Kumar, S., Chakraborty, S., Dhama, K., Sharma, A., 2014. Molecular markers and their applications in cattle genetic research: a review. Biomark. Genom. Med. 6(2), 49-58.
Strandén, I., Kantanen, J., Russo, I.R.M., Orozco-terWengel, P., Bruford, M.W., 2019. Genomic selection strategies for breeding adaptation and production in dairy cattle under climate change. Heredity. 123(3), 307–317.
Strandén, I., Kantanen, J., Lidauer, M.H., Mehtiö, T., Negussie, E., 2022. Animal board invited review: Genomic-based improvement of cattle in response to climate change. animal. 16(12), 100673.
Tesema, Z., Taye, M., Ayichew, D., 2018. Biotechnological advances for climate change adaptation and mitigation in the case of goat production–a review. J. Appl. Adv. Res. 3(5), 148-155.
Tesfa, A., Kumar, D., Abegaz, S., Mekuriaw, G., 2017. Conservation and improvement strategy for fogera cattle: a lesson for Ethiopia ingenious cattle breed resource. Adv. Agri. 2017, 2149452.
Tesfahun, W., 2018. Climate change mitigation and adaptation through biotechnology approaches: a review. Curr. Inv. Agri. Curr. Res. 3(1), 299–305.
Thornton, P.K., 2010. Livestock production: recent trends, future prospects. Philos. Trans. R. Soc. B: Biol. Sci. 365(1554), 2853-2867.
Tiruneh, S., Tegene, F., 2018. Impacts of climate change on livestock production and productivity and different adaptation strategies in Ethiopia. J. Applied. Adv. Rese. 3(3), 52.
Tisdell, C., 2003. Socioeconomic causes of loss of animal genetic diversity: analysis and assessment. Ecol. Econ. 45(3), 365–376.

Yalew, A.W., Hirte, G., Lotze-Campen, H., Tscharaktschiew, S., 2018. Climate change, agriculture, and economic development in Ethiopia. Sustainability. 10(10), 3464.

Zhang, Y.W., McCarl, B.A., Jones, J.P.H., 2017. An overview of mitigation and adaptation needs and strategies for the livestock sector. Climate. 5(4), 1–15.

How to cite this article;

Tariku Woldeyohannes, Simret Betsha and Aberra Melesse. Genetic improvement approaches of indigenous cattle breeds for adaptation, conservation and sustainable utilization to changing climate in Ethiopia. Veterinary Integrative Sciences. 2024; 22(1): 231 - 250