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Strategies to balance productivity and genetic diversity for the sustainable use of indigenous livestock breeds: A case study of Ethiopia

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Abstract: Livestock genetic improvement and conservation approaches follow divergent paths to achieve livestock productivity and genetic diversity, respectively. However, designing a win-win solution is mandatory to secure sustainable utilization of indigenous livestock breeds. To recommend a balanced solution, a systematic review was conducted to summarize the advantages and limitations of both approaches in developing countries using Ethiopia as a case study. Within-breed selection, breed substitution and crossbreeding programmes were implemented to achieve livestock genetic improvement while *in situ* and *ex situ* methods were used to maintain the genetic diversity of the indigenous livestock breeds. The genetic improvement approach offers advantages such as increased productivity, climate change mitigation and reduced animal aggression. However, it is also associated with limitations, including genetic erosion, maladaptation, inbreeding, high costs, and longer time requirements. On the other hand, the conservation approach focuses on maintaining genetic diversity, adaptable breeds, unique traits, cultural heritage and market-demanded products. However, maintaining indigenous breeds without genetic improvement is often associated with lower productivity, which hinders food security and income generation for farmers. Therefore, a balanced application of both approaches is recommended to achieve optimal productivity while preserving the genetic diversity of indigenous breeds. To ensure sustainable utilization, it is recommended to identify indigenous livestock breeds through phenotypic, genomic and historical characterization; conduct breed-, sex- and age-specific population censuses; evaluate breeds on station and on farm; delineate conservation areas; implement cryoconservation; and improve husbandry practices.

Keywords: Adaptability, climate change, conservation, genetic erosion, inbreeding

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Introduction

In many developing countries, livestock (cattle, sheep, goats, poultry, camels, horses and donkeys) play a vital role in rural economies (CSA, 2021). Livestock provide meat, milk, eggs and other products essential for human nutrition. Livestock also serve as a source of income, draught power and manure for crop production. Moreover, livestock is deeply intertwined with cultural practices and traditions, making it an integral part of the social fabric (Adane and Girma, 2008; Gizaw, 2009; CSA, 2022). The sector is dominated by indigenous animals that have evolved over centuries and are managed in diverse production environments, including lowlands, highlands, arid and semi-arid areas (EBI, 2016; Assefa and Hailu, 2018).

However, the sustainable use of livestock in most developing countries has been significantly affected by two major challenges: climate change and the poor productivity of indigenous breeds. Climate change is one of the most pressing challenges of our time, with far-reaching impacts on agriculture and food security (El-Bilali *et al*, 2020). Developing countries, which are often more vulnerable to climate variability, face significant risks to their livestock production systems. Climate change exacerbates existing challenges in livestock production, including water scarcity, feed

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shortages and disease outbreaks (Degefu and Milkias, 2024). Rising temperatures and changing precipitation patterns can reduce the availability of pasture and water, leading to decreased productivity and increased mortality rates (Woldeyohannes *et al*, 2023). At the same time, the poor productivity of indigenous breeds poses a significant challenge to the livestock sector in many developing countries, limiting the sector's potential benefits. This issue stems from a combination of low genetic potential and environmental constraints, including inadequate feed, veterinary care and management practices (Gizaw, 2009; Mustefa, 2022).

Therefore, to ensure the sustainable use of livestock, addressing these two major challenges is essential. In this context, two primary strategies have emerged: genetic improvement and the conservation of indigenous breeds. Livestock production and productivity can be enhanced through the implementation of various genetic improvement programmes. Selective breeding, crossbreeding and breed substitution are viable options for improving the genetic potential of indigenous breeds (Philipsson *et al*, 2006). On the other hand, the application of *in situ* and *ex situ* conservation, or a combination of both can help maintain the diversity of indigenous livestock breeds, enabling them to cope with upcoming climate-driven changes. Indigenous livestock breeds are known for their ability to adapt, produce and reproduce under harsh environmental conditions, such as scarce feed and water, extreme temperatures, disease challenges and prolonged drought periods (EBI, 2016; Assefa and Hailu, 2018; Endris *et al*, 2022). In addition to their adaptability, indigenous breeds are valued for their desirable products, such as eggs, meat and milk. The market value of products from indigenous breeds is often higher than those from exotic breeds.

However, enhancing productivity and diversity simultaneously is challenging because the concepts of genetic improvement are often associated with decreasing diversity (EBI, 2016). Moreover, according to Article 2 of the Convention on Biological Diversity (CBD), sustainable use is defined as "the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations" (CBD, 2004).

Therefore, balancing genetic improvement with the conservation of indigenous livestock breeds is crucial. To achieve this, it is necessary to review the principles and on-the-ground impacts of these approaches. Thus, the current study aims to recap the advantages and limitations of both options (conservation and genetic improvement) for the sustainable utilization of indigenous livestock breeds with a focus on cattle, sheep, goats and chicken, using Ethiopia as a case study, and to recommend a win-win solution.

A systematic review was conducted, following five steps as stated in Khan *et al* (2003):

- Step 1: Framing review questions. The review question focused on the advantages and limitations of livestock genetic improvement and conservation programmes related to the sustainable utilization of the livestock production sector.
- Step 2: Identification of relevant work. Relevant published articles as well as unpublished MSc and PhD thesis works addressing the framed review questions were extensively searched.
- Step 3: Quality assessment. Articles published in reputable journals were selected alongside the MSc and PhD thesis works.
- Step 4: Summarization of evidence. Information related to the genetic improvement programmes using within-breed selection, crossbreeding and breed substitution approaches, as well as *in situ* and *ex situ* conservation programmes, was compiled.
- Step 5: Interpretation of findings. The main findings from Step 4 were interpreted by comparing the achievements and limitations of genetic improvement and conservation approaches, as well as examining them against scientific justifications.

Genetic improvement

Livestock genetic improvement refers to the enhancement of the genotype of live animal breeding populations to increase their productivity, efficiency and resilience (Mueller and Van Eenennaam, 2022; Tesfa *et al*, 2024). The primary goals of livestock genetic improvement activities in most developing countries are to increase meat, milk and egg production, as well as improve feed efficiency. This can be achieved through selective breeding, crossbreeding, breed substitution and the use of advanced biotechnologies such as genomic selection and gene editing (Belew *et al*, 2016; Haile *et al*, 2020; Woldeyohannes *et al*, 2023).

Within-breed improvement involves selecting superior animals from the same population to serve as parents for the next generation while culling low-performing animals from the flock (Haile *et al*, 2020). Crossbreeding improves the genotype of indigenous animals by crossing them with high-performing exotic breeds. Breed substitution, on the other hand, involves replacing low-performing indigenous animals with high-performing exotic breeds (Vaccaro and Steane, 1990; Solomon *et al*, 2014).

Ethiopia has successfully implemented genetic improvement programmes of cattle (Beneberu *et al*, 2021), sheep (Getachew *et al*, 2020), goats (Solomon *et al*, 2014), and chicken (Yigzaw *et al*, 2024). Alongside within-breed selective breeding initiatives, numerous crossbreeding and breed substitution programmes have been implemented, introducing several exotic cattle, chicken and small ruminant breeds (Table 1).

Table 1. Exotic livestock breeds that were introduced into Ethiopia in the past decades

Livestock species/breeds	Introduction year	References
Cattle		
Angus	1950s	Tucho *et al* (2021)
Brahman	1950s	Chebo and Alemayehu (2012)
Brown Swiss	1947	Hunde (2018)
Hereford	1950s	Tucho *et al* (2021)
Holstein-Friesian	1950s	Albero (1983)
Jersey	1987	Beneberu *et al* (2021)
Simmental	1950s	Mwenya (1992)
Sheep		
Awassi	1980	Getachew *et al* (2020)
Corriedale	1967	Getachew *et al* (2016)
Dorper	2007	Habtegiorgis *et al* (2025)
Hampshire	1967	Sheriff and Alemayehu (2018)
Merino	1944	Getachew *et al* (2016)
Rambouillet	1967	Tibbo *et al* (2006)
Romney	1967	Sheriff and Alemayehu (2018)
Goats		
Anglo-Nubian	1970s	Workneh (2000)
Boer	2007	Mustefa *et al* (2019b)
Saanen	1940s	Awgichew *et al* (1989)
Toggenburg	1975	Girma *et al* (2000)
Chicken		
Arbor Acre	2000s	Alemneh and Getabalew (2019)
Australorp	1953	Gage and Suntebo (2023)
Bovans Brown	1950s	Melkamu *et al* (2017)
Brown Leghorn	1950s	Chebo *et al* (2022)
Cobb-500	2000s	Sidrak *et al* (2021)
Dominant Brown D102	2000s	Guteta (2021)
Dominant Sussex	2000s	Yigzaw *et al* (2024)
Fayoumi	1996	Geleta *et al* (2013)
Hubbard Classic	2015	Fekadu *et al* (2022)
Hubbard JV	2015	Tolasa (2021)
ISA Brown	1950s	EBI (2016)
Koekoek	1950s	Abadi *et al* (2020)
Lohman Brown	1950s	Kidie *et al* (2024)
Lohmann Silver	2022	Fekadu *et al* (2022)
New Hampshire	1953	Gage and Suntebo (2023)
Novo Brown	1950s	Yigzaw *et al* (2024)
Rhode Island Red (RIR)	1953	Hussen and Anja (2017)
SassoT44	2014	Chebo *et al* (2022)
Sussex	1950s	Chebo *et al* (2022)
White Leghorn	1953	Chebo *et al* (2022)

Advantages of livestock genetic improvement programmes

Increased Productivity

The primary significance of genetic improvement methods lies in enhancing productivity (Mueller and Van Eenennaam, 2022). The objectives of genetic improvement programmes can differ with focuses on aspects like growth, production and reproductive performance. Some of the reported results for each species are presented below.

Cattle

Most of the cattle genetic improvement programmes carried out in Ethiopia so far were aimed at increasing milk yield (Getahun *et al*, 2020). The lactation milk yield results of both the indigenous and crossbred cows are presented in Table 2. Notable differences were observed between the indigenous and crossbred cows where the latter performed more than threefold in most cases. The Holstein Friesian crosses were observed to produce better milk yield than the Jersey crosses. Furthermore, the on-farm results were lower than the on-station reports. This might be due to the suboptimal management practices of the farmers as well as limited adaptability of the crossbred animals to the local environment.

Small ruminants

Thus far, most of the small ruminant genetic improvement programmes carried out in Ethiopia have targeted growth traits (Tesema *et al*, 2020). Body weight results from birth to yearling age of both the indigenous and crossbreds are presented in Table 3. Differences were observed between the indigenous and crossbreds in most cases. Most of the crossbreds had better growth performances than the indigenous breeds except for Afar sheep and Central Highland Goat crosses where the indigenous performed better than the crosses. This might be due to the lower adaptability of the crossbreds which were managed on station with intensive and semi-intensive management systems. On the other hand, community-based breeding programmes (CBBP) were observed to bring outstanding results in Bonga sheep while their effect was small in Menz sheep and Abergelle goats.

Chicken

Chicken genetic improvement programmes primarily aimed to improve egg production, while growth and reproduction traits were also given due consideration (Dana *et al*, 2010; Esatu, 2015; Chebo *et al*, 2022). According to Alemneh and Getabalew (2019), the overall egg production of the Ethiopian indigenous chicken breeds was reported to be 30–60 per hen per year. Compared to this value, notable productivity gain were obtained through the implementation of genetic improvement programmes under intensive and extensive management systems (Table 4). Extremely lower egg production was also observed for Sasso (133) and Bovans Brown (124), which might be due to adaptation problems under certain production conditions (Assefa *et al*, 2019; Litigebew *et al*, 2021).

Similarly, notable successes have also been documented using the within-breed selection approach where a 21% egg number increment at 24 weeks was reported for the indigenous Horro chicken selective breeding programme (Esatu, 2015). Moreover, improved Horro chicken showed a 124% egg increment by week 45 (Wondmeneh *et al*, 2016), and were also reported to produce 150 eggs/hen/year, which is significantly higher than the egg production per year of the unimproved Horro chicken (Moges *et al*, 2010).

Climate change mitigation

Climate change, driven by rising temperatures, is among the factors limiting the sustainable use of animals and their products. The emission of greenhouse gases, including methane, carbon dioxide, nitrous oxide and halocarbons, is regarded as the primary driver of temperature increases. While livestock production is often seen as a victim of climate change, it is also identified as a major contributor to the process (Cassandro, 2020). Therefore, minimizing the contribution of livestock production to climate change is imperative. Genetic improvement is recognized as an important tool for mitigating climate change by reducing greenhouse gas emissions (Cassandro, 2020; Stranden *et al*, 2022). The intensification approach to genetic improvement, which reduces the total number of animals while improving their efficiency, has been reported to decrease emissions (Cassandro, 2020). According to Jardine *et al* (2012), reducing the number of animals could result in an estimated 8% drop in greenhouse gas emissions. Alongside decreasing animal numbers, increasing feed efficiency has been shown to significantly reduce greenhouse gas emissions in dairy production (Edwards-Jones *et al*, 2009; Bell *et al*, 2011). Hence, genetic improvement in addition to extensive pasture-based farming systems is regarded as a cost-effective approach to climate change mitigation (Cassandro, 2020; Stranden *et al*, 2022; Marchegiani *et al*, 2025).

Reducing aggressiveness

Animal temperament, or docility, is an important trait in cattle production, influencing not only human safety but also animal welfare and productivity (Norris *et al*, 2014). According to Norris *et al* (2014), poor animal temperament is associated with reduced performance, carcass quality and animal health. Thus, temperament affects the sustainable use of a given breed, with docile animals often preferred over aggressive ones (Dickson *et al*, 1969). Most indigenous breeds are reported to be more aggressive than exotic breeds. Therefore, crossing indigenous breeds with or replacing them with exotic breeds may reduce their aggressive temperament. One widely introduced cattle breed in most developing countries is the Holstein Friesian. According to Dickson *et al* (1969), Holstein Friesians, known for their high

Table 2. Lactation milk yield (kg) of representative indigenous and crossbred cows in Ethiopia. HF, Holstein-Friesian; JE, Jersey.

Breeds/Genotypes	Lactation milk yield	Breed type	Management	References
Arsi (AR)	809	Indigenous	On station	Niraj *et al* (2014)
50% HF x 50% AR	2,247	Crossbreds	On station	Million *et al* (2004)
75% HF x 25% AR	2,497	Crossbreds	On station	Million *et al* (2004)
50% JE x 50% AR	1,741	Crossbreds	On station	Niraj *et al* (2014)
Begait (BE)	672	Indigenous	On station	Tadesse and Dessie (2003)
50% HF x 50% BE	2,312	Crossbreds	On station	Tadesse and Dessie (2003)
75% HF x 25% BE	2,373	Crossbreds	On station	Tadesse and Dessie (2003)
50% HF x 50% BE	1,488	Crossbreds	On farm	Bekele *et al* (2011)
50% JE x 50% BE	970	Crossbreds	On farm	Bekele *et al* (2011)
Borana (BO)	771	Indigenous	On station	Demeke *et al* (2000)
50% HF x 50% BO	2,203	Crossbreds	On station	Getahun *et al* (2020)
75% HF x 25% BO	2,959	Crossbreds	On station	Getahun *et al* (2020)
50% JE x 50% BO	1,684	Crossbreds	On station	Gebregziabher *et al* (2014)
75% JE x 25% BO	1,832	Crossbreds	On station	Gebregziabher *et al* (2013)
Horro (HO)	559	Indigenous	On station	Gizaw *et al* (2011)
50% HF x 50% HO	1,836	Crossbreds	On station	Gebregziabher *et al* (2013)
75% HF x 25% HO	2,184	Crossbreds	On station	Gebregziabher *et al* (2013)
50% JE x 50% HO	1,621	Crossbreds	On station	Gebregziabher *et al* (2013)
75% JE x 25% HO	1,724	Crossbreds	On station	Gebregziabher *et al* (2013)

Table 3. Growth performance of some indigenous and crossbred small ruminants in Ethiopia. BHS, Black Head Somali; TU, Tumelie; DO, Dorper; AW, Awassi; CHG, Central Highland Goats; WG, Woyto Guji; BW, birth weight; WW, weaning weight; SMW, six months' weight; YW, yearling weight; IN, indigenous; CR, crossbred; OS, on station; OF, on farm; CBBP, community-based breeding programme.

Species Breed/Genotype	BW	WW	SMW	YW	Breed type	Management	References
Sheep							
Afar (AF)	2.7	11.5	-	26.6	IN	OS	Yibrah (2008)
50% DO x 50% AF	2.6	9.5	13.2	25.0	CR	OS	Abebe *et al* (2016)
BHS	2.5	11.3	-	23.1	IN	OS	Yibrah (2008)
50% DO x 50% BHS	3.0	15.1	-	-	CR	OS	Teklebrhan *et al* (2014)
Menz (ME)	2.1	9.1	-	17.3	IN	OS	Markos (2006)
50% DO x 50% ME	2.8	12.3	17.3	31.3	CR	OS	Abebe *et al* (2016)
Menz	2.6	9.0	13.3	19.9	IN	CBBP	Abebe *et al* (2020)
Tumele (TU)	2.4	8.5	11.9	22.4	IN	OS	Lakew *et al* (2014b)
50% DO x 50% TU	3.2	15.0	20.4	31.4	CR	OS	Lakew *et al* (2014b)
Wollo (WO)	1.9	10.8	15.7	21.6	IN	OF	Amare *et al* (2018)
50% AW x 50% WO	2.4	13.8	22.7	30.4	CR	OF	Amare *et al* (2018)
Bonga	-	-	16.7	-	IN	OF	MoA (2018)
Bonga	3.9	16.3	27.8	-	IN	CBBP	Arega *et al* (2024)
Goats							
Abergelle (AB)	2.2	6.9	9.5	14.2	IN	OF	Hagos *et al* (2018)
50% BO x 50% AB	2.9	15.3	19.6	27.9	CR	OS	Belay *et al* (2014)
Abergelle (AB)	2.0	7.2	10.1	15.9	IN	CBBP	Gobeze *et al* (2017)
CHG	2.0	9.0	13.8	20.6	IN	OF	Deribe and Taye (2013)
50% BO x 50% CHG	2.6	8.8	11.2	16.7	CR	OS	Mustefa *et al* (2019b)
WG	2.0	9.0	11.5	-	IN	OF	Zergaw *et al* (2016)
50% BO x 50% WG	2.8	11.6	16.2	29.2	CR	OS	Dea *et al* (2019)

Table 4. Egg production per hen per yearof exotic chicken breeds in Ethiopia under intensive and extensive production management.

Intensive management system		
Breed	**Eggs**	**References**
Bovans Brown	292	Melkamu *et al* (2017)
Lohman Brown	275	Kidie *et al* (2024)
Faoumi	160	Geleta *et al* (2013)

Extensive management system		
Breed	**Eggs**	**References**
Bovans Brown	218	Melkamu *et al* (2017)
Koekoek	176	Abadi *et al* (2020)
Sasso	133	Assefa *et al* (2019)
Bovans Brown	124	Litigebew *et al* (2021)

milk yield and good temperament, have been selected for docility over generations. Moreover, within-breed selection for more docile animals may reduce the aggressiveness of indigenous breeds; however, this type of selection is not commonly practised in developing countries, including Ethiopia. The Sheko cattle breed of Ethiopia, known for its trypano-tolerant ability, is also noted for its aggressiveness (Desta *et al*, 2011; Aleme and Mengistu, 2023). For this reason, farmers often choose to cross it with other relatively docile cattle breeds (Desta *et al*, 2011; Aleme and Mengistu, 2023). Therefore, reducing aggressiveness is another advantage of genetic improvement approaches.

Limitations of livestock genetic improvement programmes

Genetic erosion

The concept of genetic improvement in indigenous livestock breeds is often associated with a reduction in within- and among-breed genetic variation. Both the less destructive within-breed selection approach and the more destructive indiscriminate crossbreeding and breed substitution approaches contribute to decreasing genetic diversity in indigenous breeds (Belew *et al*, 2016; Woldeyohannes *et al*, 2023). Even though its effect is less severe than other methods, continued within-breed selection can lead to genetic erosion due to random genetic drift. This occurs when a few genes responsible for economically important traits are favoured, while a large proportion of genes responsible for survival and adaptation traits are lost. The more severe options, such as crossbreeding and breed substitution, are even more destructive, with their contribution to genetic erosion observable within a short period (Rahman *et al*, 2013). Genetic erosion, caused by genetic drift, reduces adaptive genetic variation, limiting evolutionary responses (Köhler-Rollefson and Mundy, 2010). Therefore, genetic erosion negatively affects the long-term sustainable utilization of indigenous livestock breeds. Thus, genetic improvement approaches contribute negatively to the future sustainable use of indigenous livestock breeds due to their role in the erosion of adaptive genotypes (Rahman *et al*, 2013).

Maladaptation

Maladaptation is a significant limitation of genetic improvement approaches using exotic livestock breeds. Crossbreeding and breed replacement are not always effective potentially due to the poor adaptation of exotic breeds to local environments (Köhler-Rollefson and Mundy, 2010). Morbidity and mortality rates of crossbred livestock breeds in different locations of Ethiopia are presented in Table 5. Accordingly, a significantly higher mortality rate was observed for the crossbreds of Boer goats with Central Highland and Woyto Guji goats indicating their suboptimal adaptability to local conditions. Similarly, higher morbidity and mortality rates were also observed for the crossbreds of Holstein Friesian cattle. Moreover, the lower egg production per hen per year presented in Table 4 for Sasso (133) and Bovans Brown (124) might be due to their maladaptation to the local environment (Assefa *et al*, 2019; Litigebew *et al*, 2021). Exotic breeds, developed and selected for specific environmental conditions, often perform poorly when introduced to new environments due to adaptation problems (Köhler-Rollefson and Mundy, 2010).

Inbreeding

Genetic improvement is associated with the selection and use of a few high-performing sires as parents for the next generation (Mueller and Van Eenennaam, 2022). The use of elite sires, increased selection pressure and reproductive technologies like artificial insemination (AI) increase the likelihood of offspring being half-siblings, leading to inbreeding in successive generations (De-Roos *et al*, 2011). One of the negative effects of inbreeding is inbreeding depression, where the increased likelihood of offspring inheriting two copies of harmful recessive genes leads to reduced fertility, vigour and overall fitness (Tongsiri *et al*, 2019; Lozada-Soto *et al*, 2021). Reduced genetic diversity is another negative effect of inbreeding. Inbreeding decreases genetic diversity within a population, making it more vulnerable to diseases, parasites and environmental changes. These factors decrease productivity and increase mortality rates, making livestock production less sustainable (Tongsiri *et al*, 2019; Lozada-Soto *et al*, 2021). Moreover, ethical concerns arise from inbreeding, as it can lead to increased suffering and reduced welfare for animals due to genetic defects and health problems (Frankham, 2005; Skotarczak *et al*, 2020). On the other hand, selecting traits that enhance animal welfare, such as reduced aggression, can lead to more humane and sustainable use of animal populations.

Cost and time

Implementing genetic improvement programmes can be expensive, requiring investments in infrastructure,

Table 5. Morbidity and mortality rates of crossbred livestock breeds in different locations of Ethiopia. Exotic breeds (HF, Holstein-Friesian cattle; DO, Dorper sheep; BO, Boer goats; Bovans Brown; Sasso); Indigenous breeds (GHC, Gojjam Highland Cattle; AM, Ambo cattle; GO, Gofa cattle; TU, Tumelie sheep; WL, Wolaita sheep; AD, Adilo sheep; CHG, Central Highland Goats); OS, on station; OF, on farm.

Breed/Genotype	Morbidity (%)	Mortality (%)	Management	Location	References
Cattle					
50% HF x 50% GHC	56.5	28.1	OF	Bahir Dar zuria	Ferede *et al* (2014)
50% HF x 50% GHC	65.0	37.0	OF	Gozamen	Ferede *et al* (2014)
50% HF x 50% AM	62	22.0	OF	Ada'a Liben	Wudu *et al* (2008)
50% HF x 50% GO	66.7	20.0	OF	Wolaita soddo	Assefa and Ashenafi (2016)
50% HF x 50% GHC	47.3	17.9	OF	Bahir Dar	Yeshwas (2015)
Sheep					
50% DO x 50 TU	-	7.0	OS	Tumelie	Lakew *et al* (2014a)
50% DO x 50 WL	-	28.4	OF	Mente Dubo	Habtegiorgis *et al* (2025)
50% DO x 50 AD	-	9.8	OS	Boloso	Gemiyo *et al* (2017)
Goats					
50% BO x 50 CHG	-	56.1	OS	Ataye	Mustefa *et al* (2019a)
75% BO x 25 CHG	-	64.0	OS	Ataye	Mustefa *et al* (2019a)
50% BO x 50 WG	-	48.0	OS	Jinka	Molla (2016)
50% BO x 50 WG	-	41.0	OS	Konso	Dea *et al* (2019)
Chicken					
Bovans Brown	-	3.2	OS	Mekelle	Melkamu *et al* (2017)
Bovans Brown	-	20.3	OF	Mekelle	Melkamu *et al* (2017)
Sasso	16.1	12.7	OS	Sidama	Hailegebreal *et al* (2022)

technology and skilled personnel (Wojtkowski, 2008; Biscarini *et al*, 2015). Moreover, genetically improved animals often require better management because the genetic modifications that enhance certain productivity traits can also create new vulnerabilities or amplify existing issues, making them more susceptible to environmental stressors and requiring more precise care to maintain their optimal health and productivity (Wojtkowski, 2008; Biscarini *et al*, 2015). However, smallholder farmers in developing countries often have limited access to the technology and resources needed to implement effective genetic improvement programmes. Therefore, the high cost of genetic improvement programmes can be a significant barrier for smallholder farmers in developing countries. In addition to higher costs, genetic improvement approaches also require considerable time. Genetic improvement is a long-term process, often taking many generations to achieve significant results. This can be a challenge for farmers who need immediate solutions to improve their livelihoods (Biscarini *et al*, 2015).

Conservation

Conservation of farm animal genetic resources refers to various human interventions aimed at maintaining the diversity of farm animal genetic resources, without genetic change as far as possible, to contribute to current and future food and agricultural needs (Henson, 1992). Conservation of indigenous breeds not only preserves their genotypes but also allows farmers and breeders to select and develop new breeds that can adapt and produce under changing environmental conditions, making this approach critically important for sustainable utilization (Gicquel *et al*, 2020).

Animals can be conserved using *in situ* and *ex situ* conservation methods. *In situ* conservation maintains live animal breeding populations in their production environments (Henson, 1992). Under this approach, the animals continue to contribute to the food and agriculture of their breeding areas. On the other hand, *ex situ* conservation maintains genetic resources outside their production systems. There are two ways of conserving genetic resources using the *ex situ* approach: *ex situ in vivo* and *ex situ in vitro*. *Ex situ in vivo* involves maintaining live animal breeding populations outside their production environments, while *ex situ in vitro* involves the cryopreservation of semen, oocytes, embryos, cells and/or tissues in genebanks (FAO, 2012a).

In recent decades, several *in situ* and *ex situ* conservation programmes have been implemented in Ethiopia (Table 6). The primary objective and progress of the *in situ* conservation programmes have been to create exotic-free breeding tracts for the mentioned breeds. Similarly, the *ex situ in vivo* approach conserves live animal populations at ranches or research centres to produce pure parental lines for genetic improvement programmes, but has been applied to two indigenous cattle breeds so far: the Sheko and Fogera cattle breeds (Tibbo *et al*, 2004). Moreover, the *ex situ in vitro* conservation programmes aim to preserve the semen of the cattle breeds for future restoration purposes, but has been applied to five indigenous cattle breeds so far: the Sheko, Fogera, Borana, Begait, and Irob cattle breeds out of the country's registered 28 cattle breeds (Assefa *et al*, 2021). The success of these programmes has been directly linked to the restoration of dwindling population sizes. Restoration of endangered breeds requires more budget and time than other conservation programmes, which are typically carried out through successive awareness-raising campaigns. Below are some of the advantages of conservation approaches for the sustainable utilization of indigenous livestock genetic resources.

Advantages of conservation

Genetic diversity

One of the main advantages of conservation programmes is the maintenance of genetic diversity (Köhler-Rollefson and Mundy, 2010; Gicquel *et al*, 2020). Maintaining genetic diversity is crucial because once genes are lost, they cannot be replaced except through cumulative selection or mutation (Smith, 1984). Maintaining within- and among-breed variability supports current and future research and development activities. It also enhances the effectiveness of within-breed selection-based genetic improvement programmes. Genetic improvement is more attainable in highly variable populations than in populations with low variability. Highly variable populations provide opportunities for the development of specialized breeds. The creation of synthetic breeds for specific purposes through crossbreeding requires the conservation of pure parent stocks. Maintaining the variability of indigenous breeds is also essential for their ability to adapt, produce and reproduce under future environmental changes (Silva *et al*, 2019; Gicquel *et al*, 2020). Moreover, ensuring a diverse genetic pool helps secure a more reliable and resilient food supply, which is particularly important in the face of climate change and other unpredictable challenges that can impact food production (Köhler-Rollefson and Mundy, 2010). According to Smith (1984), the conservation of indigenous breeds provides alternative breeding stock for future changes in market demands, husbandry practices and climate-driven environmental changes. Therefore, the conservation of indigenous breeds maintains genetic diversity, which in turn supports the sustainability of livestock production.

Adaptability

Adaptation to local environments can be defined in various ways, including disease resistance and tolerance to harsh conditions. Many indigenous breeds have natural resistance to local diseases and parasites (Köhler-Rollefson and Mundy, 2010). For example, the Sheko cattle breed is known for its trypano-tolerance (Desta *et al*, 2011; Aleme and Mengistu, 2023). Such genetic resilience is invaluable in most developing countries, where access to veterinary care and modern disease control methods is limited. On the other hand, indigenous breeds are often well-suited to challenging environments, such as arid and mountainous regions. They can thrive on limited resources and withstand harsh weather conditions, making them valuable assets for food security in marginal areas. The overall adaptability of indigenous breeds is due to their long-term evolution in specific local environments. In addition, in the face of future climate change, indigenous breeds often offer several advantages over exotic breeds (Silva *et al*, 2019). Thus, the conservation of indigenous breeds makes them more efficient and sustainable under current local climatic and management conditions, as well as future climate change (Köhler-Rollefson and Mundy, 2010; Gicquel *et al*, 2020).

Unique traits

The conservation of indigenous breeds is significantly associated with maintaining their unique traits. For example, the conservation of Sheko cattle in southwest Ethiopia is directly linked to preserving their trypanotolerant ability (Desta *et al*, 2011; Aleme and Mengistu, 2023). Similarly, other special traits of indigenous breeds have been reported, such as the screw horns of Racka sheep in Hungary (Bodo, 1994) and the seaweed-eating sheep (Balasse *et al*, 2019). Moreover, indigenous breeds are known to produce items with special qualities, such as coloured wool, super-fine fibre, and tasty products like milk, meat and eggs (Köhler-Rollefson and Mundy, 2010). Therefore, for local communities that have adapted to these traits, the sustainable approach is to conserve them rather than crossbreed or replace them with high-yielding exotic breeds.

Cultural heritage

Indigenous breeds are deeply woven into the fabric of many cultures, playing significant roles in various aspects of life, from sustenance and livelihoods to social customs, traditions and religious practices (Smith, 1984; Köhler-Rollefson and Mundy, 2010; Marsoner *et al*, 2018). Indigenous breeds are often associated with specific cultural identities and traditions. They may be used in ceremonial events, festivals and traditional practices, symbolizing heritage and cultural continuity. Similarly, in many cultures, indigenous breeds are used as sacrificial offerings in religious ceremonies, symbolizing devotion and gratitude (Marsoner *et al*, 2018; Silva *et al*, 2019). Therefore, the conservation of indigenous breeds helps preserve cultural identity and history, which in turn supports the sustainable use of these breeds.

Market demand

In most developing countries, consumers highly prefer products from indigenous livestock breeds over those from exotic breeds (Sharif and Farooq, 2004; Silva *et al*, 2019). Several traditional beliefs and scientific reasons

Table 6. Ethiopian indigenous livestock breeds under conservation.

Livestock breeds	Conservation type	References
Cattle		
Sheko	*In situ* & *ex situ in vivo*	Aleme and Mengistu (2023)
	Ex situ in vitro	Assefa *et al* (2021)
Fogera	*In situ* & *ex situ in vivo*	Tesfa *et al* (2024)
	Ex situ in vitro	Assefa *et al* (2021)
Borana	*In situ*	Tessema *et al* (2022)
	Ex situ in vitro	Assefa *et al* (2021)
Begait	*Ex situ in vivo*	Mekuriaw and Kebede (2015)
	Ex situ in vitro	Assefa *et al* (2021)
Begaria	*In situ*	Aseged *et al* (2023)
Raya	*In situ*	Assefa *et al* (2021)
Irob	*Ex situ in vitro*	Assefa *et al* (2021)
Sheep		
Washera	*In situ*	Amane *et al* (2010)
Menz	*In situ* & *ex situ in vivo*	Gizaw *et al* (2013)
Bonga	*In situ* & *ex situ in vivo*	Mustefa (2023)
Wollo	*In situ*	Assefa *et al* (2021)
Horro	*In situ* & *ex situ in vivo*	Molla (2020)
Gedeo	*In situ*	Assefa *et al* (2021)
Goats		
Highland	*In situ*	Assefa *et al* (2021)
Arsi-Bale	*In situ*	Assefa *et al* (2021)
Chicken		
Horro	*In situ*	Taye (2024)
Metekel	*In situ*	Assefa *et al* (2021)
Jarso	*In situ*	Assefa *et al* (2021)
Kundudo	*Ex situ in vivo*	Sufiyan (2022)

can explain this preference. In Sri Lanka, for example, it is traditionally believed that milk from indigenous cows has medicinal and therapeutic properties due to its low likelihood of causing milk allergies in humans (Rajapakshe *et al*, 2015). According to Silva *et al* (2019), milk from indigenous cows is preferred in the Southern Province of Sri Lanka due to its high-fat content, which produces a firm curd structure and good flavour. Scientifically, meat from indigenous chickens has been reported to have better physicochemical and sensory parameters than meat from commercial broilers (Rajapaksha *et al*, 2014). Senarathne *et al* (2016) reported high mineral and fat contents in eggs from indigenous chickens. Physical and chemical analyses by Lordelo *et al* (2020) indicated higher quality in eggs from indigenous chicken breeds in Portugal compared to commercial breeds in many characteristics. Therefore, due to consumer preferences, eggs, meat and milk from indigenous breeds have become highly priced products in most developing countries (Silva *et al*, 2019). Thus, maintaining indigenous breeds helps ensure the availability of these preferred products in the market which also improves the income of farmers.

Limitations of conservation

Maintaining indigenous livestock breeds is significant for securing the sustainable utilization of these genetic resources; however, it comes with its own set of challenges. Below some of the limitations are presented.

Lower productivity

Compared to modern, high-yielding exotic breeds, indigenous cattle breeds often have lower milk yields, slower growth rates and lower feed conversion efficiency. For example, the average milk yield of Ethiopian indigenous cattle breeds (1.32–2.19 litres/cow/day) (Ayalew *et al*, 2018) and the average egg production of most indigenous chicken breeds (45–75 eggs/hen/year (Tolasa, 2021) and 30–60 eggs/hen/year (Alemneh and Getabalew, 2019)) are significantly lower than those of their exotic counterparts. Similarly, the slower growth rates of indigenous livestock breeds mean it takes longer for them to reach market weight, leading to increased feeding costs and delayed returns on investment for farmers. Moreover, the lower feed conversion efficiency of indigenous breeds means they require more feed to produce the same amount of meat or milk compared to modern breeds under uniform management and controlled environment. This increases production costs and reduces profitability. These factors can result in lower profits for farmers, making indigenous breeds less attractive to those who need to maximize their outputs to remain profitable. Thus, solely maintaining indigenous breeds can affect sustainable food security and income generation goals, which can further influence their sustainable use.

Discussion

In Ethiopia, livestock genetic improvement programmes have been implemented through within-breed selection, crossbreeding and breed-substitution programmes. The within-breed selection programmes were mainly implemented in small ruminants and chicken through community-based breeding programmes (CBBPs) and on-station selection programmes. Similarly, several exotic breeds of cattle, sheep, goats and chicken were also imported to conduct crossbreeding and breed-substitution programmes. Accordingly, notable achievements were reported in cattle milk yield, chicken egg production and growth performances of small ruminants. Alongside increasing livestock productivity, livestock genetic improvement programmes were also reported to minimize the aggression of indigenous livestock breeds. These programmes were also reported to contribute to climate change mitigation. However, despite these achievements, livestock genetic improvement programmes were reported to have some limitations. These include the facilitation of genetic erosion and inbreeding, maladaptation of the exotic and crossbred to the local production environment, the need for a long implementation time, and high costs for both importing and managing the high-producing exotic breeds. Similarly, conservation programmes were also reported to have advantages and limitations regarding sustainable utilization of the livestock production sector. The advantages of conservation programmes include the preservation of genetic diversity of indigenous adaptable breeds, the maintenance of unique traits and cultural heritage, and the availability of products from indigenous breeds that meet market demands. However, maintaining indigenous breeds without genetic improvement is often associated with keeping low-productivity animals, which hinders food security and income generation for farmers. Therefore, designing a balanced approach is recommended to achieve optimal productivity while preserving the genetic diversity of indigenous breeds.

The way forward

Although genetic improvement and conservation approaches are inherently opposite and cannot be applied simultaneously to the same livestock population, it is essential to find a win-win solution for the sustainable utilization of indigenous livestock genetic resources to optimize outcomes in the livestock production sector. To achieve this, some recommendations are proposed below.

Identification of indigenous breeds

Characterization of indigenous cattle breeds is a foundational step prior to any breeding programme (FAO, 2012b). Several variables need to be considered at this stage, including the assessment of morphometric and morphological traits, identification of their production environments (origin/breeding tract and distribution areas), identification of unique traits, cultural values, adaptability to harsh environments (e.g. extreme weather conditions and climate change), adaptability to limited resources (e.g. feed, water and veterinary care), and assessment of indigenous knowledge associated with these breeds (FAO, 2012b). Alongside phenotypic and environmental variables, assessing within-breed genetic diversity is necessary to identify a breed. Similarly, assessing the degree of genetic relationship with other indigenous breeds (population structure) is required to determine the number of breeds in the country. Therefore, phenotypic, genomic and historic characterization is recommended.

Breed-level population size census

After identification, conducting a breed-level population size census is essential to assess the endangered status of each breed. Therefore, data on the number of animals by breed, sex and age are required to determine whether conservation or genetic improvement programmes should be implemented. Conservation programmes can be recommended for breeds with small populations to help maintain their genotype. Based on their current population size, appropriate conservation methods can be selected. *In situ* and *ex situ* conservation methods can be applied to critically endangered breeds. An indigenous breed with a large population size and a wide distribution area may be considered for a controlled crossbreeding programme to enhance targeted traits.

Breed evaluation

The assessment of on-station and on-farm phenotypic performances – such as growth, production, reproduction and survival traits – is necessary to understand the potential of each breed. A genomic evaluation of a breed for specific traits is also essential to assess its genetic potential. This evaluation is crucial for selecting a breed, trait, method and location for genetic improvement. Furthermore, within-breed selection-based genetic improvement programmes are recommended for populations with high genetic diversity. In contrast, populations with low genetic diversity may require a controlled crossbreeding programme. Before implementing any livestock breeding programme, evaluating the complementarity of each parent breed is essential. Therefore, breed evaluation is mandatory.

Breed and area delineation for breeding programmes

The results of characterization, breed-level census and breed evaluation activities need to be used to identify suitable breeding programmes for each livestock breed and production environment. Accordingly, breeds and areas can be delineated either for conservation or genetic improvement programmes. Based on this, a conservation programme can be applied to the economically important and endangered livestock breeds. It is also advisable not to implement crossbreeding and breed-substitution programmes in the origin and breeding tract of the indigenous livestock breeds. Within-breed selection approaches can be considered in these areas to bring the desired genetic improvement. Areas out of the indigenous livestock breed origin can be considered for either crossbreeding or breed-substitution programmes based on the complementarity of these livestock breeds with exotic ones. Additionally, exotic livestock breeds can be recommended in commercial farms with intensive management systems and controlled environments.

In situ and *ex situ* conservation

In situ and *ex situ* conservation options can be applied simultaneously or separately for economically important endangered indigenous breeds according to the situation (FAO, 2012a). *In situ* conservation, the maintenance of livestock breeds in their natural production environment, can be carried out for livestock breeds with relatively higher population sizes. Establishing a community and designing an incentive-based approach can be considered during the *in situ* conservation programmes. Similarly, *ex situ* conservation can be applied to livestock breeds with alarming population size or as a complementary method to *in situ* conservation. *In vivo* and/or *in vitro* can be considered simultaneously or separately to the livestock breeds with dwindling population size. *Ex situ in vitro*/cryoconservation is an advanced method of preserving genetic material at extremely low temperatures, typically using liquid nitrogen (-196°C). This technique is widely used in the conservation of livestock breeds, wildlife, plant species and in human medicine (e.g. preserving sperm, eggs and embryos). For indigenous livestock breeds, cryoconservation is a powerful tool to protect genetic diversity and ensure the survival of rare or endangered breeds. The implementation of these methods is expensive and needs a more skilled workforce than the *in situ* method FAO (2012a).

Husbandry practices

Alongside genetic improvement, improving husbandry practices enhances livestock productivity and diversity by optimizing animal health, nutrition, breeding selection and environmental management (Dristan, 2025). These improvements lead to increased yields of meat, milk and eggs, and the development of better genetic traits, while also promoting a broader range of livestock breeds suited to various ecological conditions and market demands (Dristan, 2025). Therefore, improving husbandry practices is essential to ensure the sustainable use of indigenous livestock genetic resources.

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Conflicts of interest

The author declares that there are no conflicts of interest.

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