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Cattle Genetic Improvement Strategies for Sustainable Development in Tropics: Review

Birhanu TESEMA

Bule Hora University, College of Agricultural Sciences, Department of Animal Science, P. O. Box 144, Bule Hora, Ethiopia
** Corresponding author: B. Tesema e-mail: berhan2m@gmail.com*

REVIEW

Abstract

Inefficient use of genetic variation among and within breeds of different breeds is an obstacle to enhancing the livestock population in underdeveloped countries. The best productive and adaptable animals for each environment must be identified for breeding objectives. Changing numerous aspects of production is required for successful livestock genetic improvement. In developing countries, genetic improvement efforts are unlikely to succeed unless they are supplemented by better diet, herd health, and management. Improvement strategies that are now taken for granted in developed countries are not implemented in most developing countries. The high expense of such procedures is one of the main reasons for their poor adoption rates. As a result, the economic evaluation of improvement programs is critical. Population increase, market development, technological change, and a shifting resource base are all examples. These dynamics that drive a specific livestock production system, as well as the entire subsector, must be anticipated and identified in development strategies. It is vital to understand the direction and speed with which these elements may change, both at the sectoral and farm levels, for future initiatives to respond appropriately. As a result, improving local cattle genetic value and devising genetic improvement methods accordingly is critical for the country's and sector's long-term development. Insufficient research has negative impacts on different breed types in diverse and dynamic livestock production systems assessment in developing countries, which creates significant knowledge gaps about breed-change interventions. Hence, supporting researchers, research institutions and higher education institutions is crucial to the success of policy in reducing the knowledge gap and strengthening the relationships between the livestock owners and government. Moreover, the development of national livestock strategies, effective policies, and the establishment of breeding cooperatives have an impact on the development and implementation of national livestock strategies for sustainable development.

Keywords: Livestock, genetic improvement, strategies, development, likelihood.

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INTRODUCTION

Approximately 300 million heads of cattle are reared in Africa, representing about one-fifth of the world's cattle population (Tadele et al., 2019). In developing countries, different types of livestock production systems from pastoral systems controlled by smallholder farmers to large-scale industrial production systems with a focus on commercials are practiced. On the continent, cattle play important social, economic, and cultural functions. They represent a major source of protein (milk and meat) as well as fertilizer and fuel (manure), and they provide draft power for crop farming (Mwai et al., 2015) and contribute substantially to stallholder farmers' livelihoods. Most of the breeds show low productivity, which may reflect a lack of exploitation of their genetic potential as well as inadequate nutrition, health services, and management (Hanotte et al., 2009). However, conditions are a unique reservoir of genetic resources for the continuous improvement of livestock productivity in Africa and elsewhere (Gamaniel et al., 2019). For instance, different breeding strategies and policies have been implemented to improve cattle productivity in Africa. However, few strategies and policies have been saucerful in Sub-Saharan Africa. As a result, the production of cattle-derived goods such as milk is grossly insufficient to meet growing demand in various countries, necessitating the import of dairy and meat products.

Successful livestock improvement needs changes in several components of production. Breeding can influence reproductive performance and lifetime productivity including the age at first calving, the longevity of animals, and their resistance to diseases, mainly because of the permanent and cumulative changes each year (Cassell, 2009). In underdeveloped nations, a genetic improvement strategy is rarely effective unless it is combined with better management of feed supplies, stockmanship, and herd health, as well as increased nutrition and herd health. Genetic improvement strategies can be optimized to suit the needs of very different production systems and geographic regions. In the case of smallholder breeding systems, simple breed selection or crossbreeding programs aimed at increasing productivity, longevity, or reproduction which can directly support food security and resilience to climate change. In practice, such changes are best accompanied by genetic improvement programs either for pure indigenous breeds by breed substitution or crossbreeding with exotics. Traditional breeding practices are characterized by a lack of genetic progress recording in productivity due to diverse selection criteria, and low selection intensity (small individual flock sizes, communal uncontrolled breeding practices, and negative selection practices) through the sale of best-performing animals (Kosgey and Okeyo, 2007).

Gamborg and Sandøe, (2005) reported that the concept of sustainability in agricultural production has received increased attention. In addition, consumers are interested in products produced sustainably. Increasing the number of animals in already existing herds or the number of livestock herds to meet consumer demands is not considered sustainable (Steinfield, 2006), so the key to boosting production is striving to improve the current herd's efficiency. The welfare of animals could be improved through advancements in genetics, management, and technology without compromising output (Dawkins, 2016). Therefore, animal breeders' discussions should be engaged for sustainability. The degree to which animal breeding and reproduction, as managed by professional organizations, contribute to the preservation and proper treatment of animal genetic resources for future generations is a general definition of sustainable animal breeding (Gamborg and Sande, 2005).

Sustainability in animal breeding and reproduction means the extent to which animal breeding and reproduction, as managed by professional organizations, contribute to the maintenance and good care of animal genetic resources for future generations (Elzabieta, 2021). The breeding business and livestock keepers are the ones that generate the genetics used in the livestock industry, thus these genetics must satisfy their customers' needs and be regarded favorably by society. Hence, designing and implementing effective breeding programs under smallholder livestock farming systems is challenging. However, there has been some evidence of success with community-based breeding programs among smallholders in the tropics, particularly with small ruminants. The potential of genetic improvement to increase livestock productivity is, however, increasingly being recognized by decision-makers, with many developing countries now explicitly including genetic improvement within their national livestock development plans. Generally speaking, a sustainable breeding program must take into account maintaining genetic variance over the long run while achieving sufficient rates of genetic gain in the short term (Bijma et al., 2001). Thus, the objective of this review is to assess cattle genetic improvement strategies and increase productivity for the sustainable development of smallholders in developing countries.

MATERIALS AND METHODS

Methods

Study design

In this review study selection flow was done based on preferred published original articles and reviews, proceedings, books as well as reporting items for systematic review.

Population

No direct participation of individual participants is need in the current work. However, previously published individual studies were considered as study participants.

Inclusion and exclusion criteria

Inclusion criteria

Studies conducted under this review were: developing tropical countries cattle breeding experiences were assessed and included; developed countries cattle genetic improving experiences; studies reported findings of cattle breeding strategies, production, productivities and challenges.

Exclusion criteria

Unpublished reports, letters, were excluded.

Search strategy and sources

This scoping review was made through deep and thorough questing for the relevant article on the topic from the essential databases. The relevant articles were searched from MEDLINE/PubMed, web of science, universities data base and SCOPUS. Quality assessment for the selection of articles that meet the inclusion criteria was carried out. The main themes of cattle genetic improvement strategies and sustainability were categorized. Accordingly, a total of 732 studies were identified from searching sources. Among these 69 studies met the inclusion criteria.

RESULTS AND DISCUSSIONS

Overview of the Livestock Breeding Program

Livestock genetic improvement programs, beginning with selective breeding using statistical prediction methods, such as estimated breeding values (EBVs), and more recently genomic selection (GS), in combination with assisted reproductive technologies (ART) have enabled more accurate selection and intense utilization of genetically superior parents for the next generation to accelerate rates of genetic gain. Typically, simultaneous improvements in the environment and genotype lead to an increase in production. A set of improvements for boosting livestock productivity includes genetic enhancement. The challenge is how to create sustainable breeding programs for native breeds in tropical environments where resources are scarce, feed quality and availability vary widely depending on the type, region, and season, and there is growing demand for animals that are better able to adapt to the environment's constant change as a result of climate change. In livestock breeding programs, the breeder's equation is used to measure the rate of genetic gain (ΔG) towards the breeding objective of a given production system.

It is computed as

$$\Delta \mathrm{G} = \frac{I \times r \times \delta A}{L}$$

where i is selection intensity (how extensively the most elite animals are used as parents of the next generation);

r is selection accuracy (how well the EBV represents the true breeding value of selection candidates);

σA is genetic diversity (as determined by the population's additive genetic standard deviation);

and L is the generation interval (interval measured as the average age of the parents at the time of progeny's birth) (Lush 1937).

Increasing the elements of the breeder's equation in the numerator and reducing the denominator, or generation interval, are methods to increase rates of genetic gain in a population. It is crucial to remember that a well-structured breeding program with a distinct breeding target and regular collection of pedigree and performance data on the population under selection serve as the cornerstone of genetic improvement. Genomic information can supplement pedigree information and increase the relationship matrix's accuracy.

The scope of any breeding program must be set with the resources available and the stage of development in the region concerned. Payne and Hodges (1997) reviewed in detail the past developments of genetic improvement programs for cattle in the tropics and what could be seen as the major options available for the future in seeking sustainable breeding systems. Therefore, depending on the actual breed, the production technique, and other factors, the design may vary greatly. A strategy that guarantees the conservation of animal genetic resources must be considered while designing a breeding program. Further, the breeding program needs to be integrated and its success is largely determined by the scope of farmers/livestock owners' participation. The following Figure 1 shows the components of a breeding program.

Currently, research in the area of farm animal gene engineering has mostly centered on enhancing the effectiveness of food production as well as animal health and welfare. In developed nations, efforts are also made to lessen the negative effects that animal products have on both human health and the environment (Van Eenennaam, 2019, Niemann et al., 2009). One of the most recent developments in genetic enhancement techniques is genome or gene editing (GnEd). Through the use of this cutting-edge biotechnology, animal breeders can very accurately target the addition, deletion, or substitution of base pairs in the genetic code to affect desired traits. GnEd has potential opportunities for introducing helpful genetic diversity from one breed of cattle to another without the presence of undesirable linkage drag or even advantageous features from different species in cow breeding programs.

High-throughput SNP genotyping has made it possible to create methods for predicting an animal's genetic merit from its DNA (Meuwissen *et al.,* 2001). Genomic estimated breeding values (GEBVs) can be anticipated for each genotyped individual by using only its SNP genotypes and estimated SNP effects in genomic selection (GS). SNP effects are first assessed using genotyped individuals that are phenotyped for the attributes of interest.

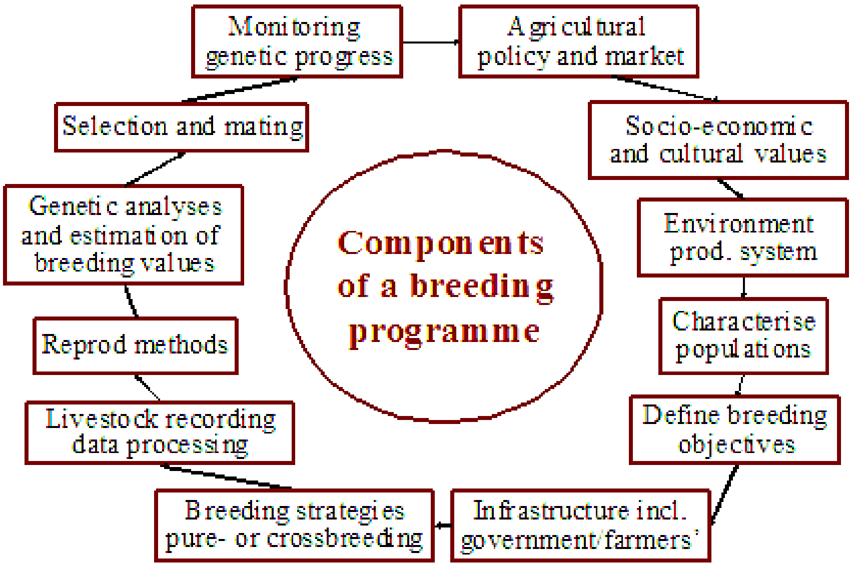

Figure 1. Components of a breeding program (source: Animal genetic resources training)

Treatments and procedures that manipulate reproductive cycles, gametes, or embryos are referred to as assisted reproductive technology (ART). In order to increase selection intensity and speed up the rate of genetic gain, ART techniques such as AI, cryopreservation of sperm or embryos, estrus synchronization, multiple ovulation ET (MOET), ovum-pick up (OPU), and in vitro embryo production (IVP) have been incorporated into cattle breeding schemes. Assisted reproductive technology enables production of live GnEd offspring. Gene editing must reliably edit the germline of breeding stock, so the edits can be passed on to the next generation (Figure 2).

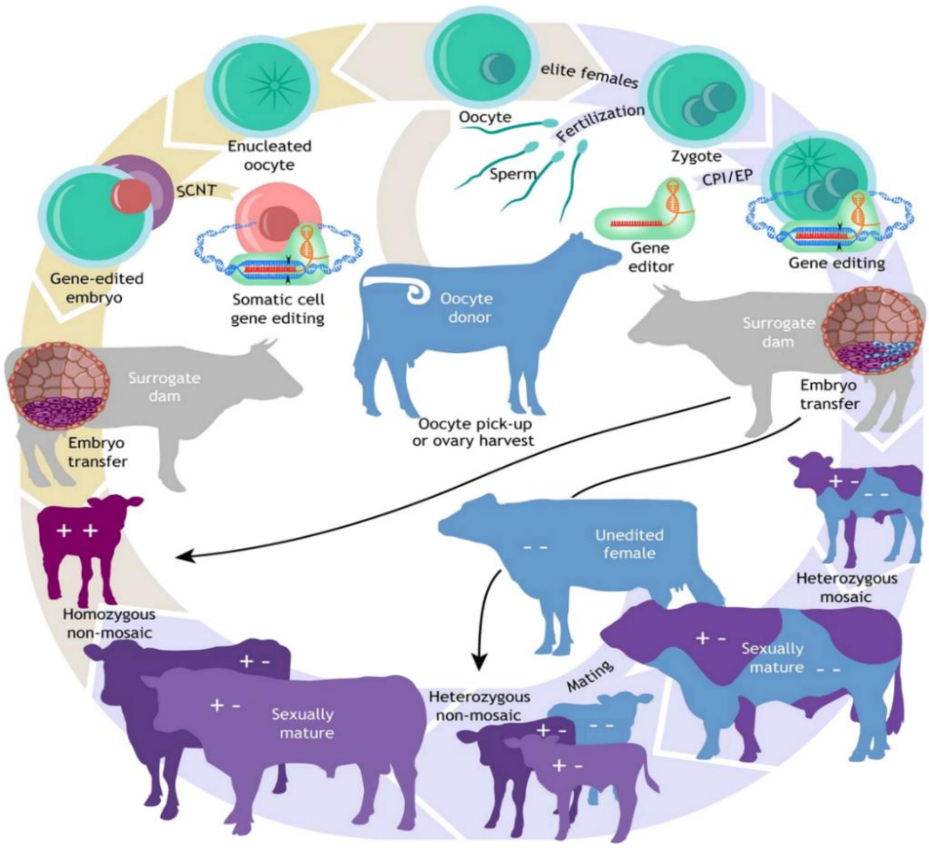

Figure 2. Schematic showing the number of steps required to produce live, homozygous, non-mosaic, GnEd livestock (maroon calf) through either somatic cell nuclear transfer (SCNT) cloning (tan arrows) or zygote microinjection (light purple arrows)

Cattle genetic improvement programs

Breeding programs are systematic and structured processes for changing a population's genetic makeup per quantifiable performance standards. To increase livestock productivity in developing countries, simultaneous actions are typically needed in the areas of animal nutrition, health, and genetics. The interventions often take the form of strengthening the skills of livestock owners and other actors in the value chain, ensuring input accessibility and availability. Providing new technologies or customizing existing ones, encouraging participation from the private and/or public sectors, and advocating for supportive policies. A genetic improvement plan often begins with determining the best livestock breed or cross-breed type for a specific livestock production system. However, a considerable number of livestock breeding programs designed to improve smallholder livestock production have failed in developing countries (Roessler et al., 2008). Among the reasons for the failures limited involvement of farmers who are the final beneficiaries, in both planning and implementation, leading to ineffective breeding programs. Further, the transfer of breeding plans and approaches from developed countries has been unsuccessful.

Every system has a different set of systematic genetic enhancement strategies in Africa. These include breed-substitution with other African breeds or breeds from other tropical countries, as well as breeds from elsewhere; cross-breeding with the highly adapted but lowly productive indigenous breed; breeding with an exotic breed that is poorly adapted but high productive; less frequently, breed improvement (FAO, 2015). Increasingly, simple attention is being paid to the development of working models to ensure the sustainability of these programs, as it has been well demonstrated that the models implemented in developed countries cannot be directly applied. The application of genomics ranges from the determination of the breed composition of animals in the absence of pedigree data for in-situ comparison studies. It is only recently that the use of genomic selection in breed improvement programs is becoming more widespread, frequently removing limitations like the absence of recorded pedigree. Genetic-improvement programs can only be implemented where accurate performance and pedigree recording are possible. Due to the ignorance of local communities, the majority of nationally coordinated performance and pedigree-recording schemes have failed in many developing countries (Darfaui, 2000; Rewe et al., 2002; Kosgey et al., 2005). Genetic-improvement programs will be successful if developed as an integrated livestock production package and not in isolation. Improvement programs are necessary to increase and sustain the productivity of these cattle breeds to meet the demands of the human population. There is a propensity for genetic improvement projects to concentrate on identified, market-driven qualities like milk or meat production in isolation from environmental problems and larger livestock system activities practiced in poor nations (Ouma et al., 2004). Farmers must get involved early in the process of breed improvement, to ensure that their breeding perceptions are taken into account and that they provide the support needed for the program to work (Zumbach and Peters, 2002). In addition, the development of genetic improvement programs for cattle will only be successful when accompanied by a good understanding of the production systems and when simultaneously addressing several constraints - e.g. feeding, health control, and management (Baker and Gray, 2003).

Strategies for cattle genetic improvement

Livestock are a vital source of economic security and an asset for most households in rural communities. They provide meat and milk for home consumption, as well as financial gain from animal and milk sales, manure for fertilizer and fuel, as well as fiber and skins. Any attempt at genetically improving them should be viewed as a means of bettering the welfare of these rural communities and aspirations if it is to be successful (Sölkner et al., 1998). Animal genetic improvement is a systematic process that includes several key steps, including the definition of breeding objectives, the development of selection criteria, genetic evaluations, animal selection, the design of appropriate mating systems, and strategies for genetic superiority dissemination. A breeding strategy combines the elements of a breeding program into a systematic method for genetic improvement to achieve a specific goal. It is a tactic designed to integrate new technologies and to improve old ones, to maximize the performance of existing stock (Charles, 1988). Various breeding strategies and policies must be created and assessed to improve cattle production and boost the role of livestock in sustainable economic growth in developing nations. Some livestock genetic improvement strategies applied in different countries and boost animal productivity are discussed below.

Open herd nucleus for large and small ruminants

The basic idea of Open Nucleus Breeding System (ONBS) using Multiple Ovulation and Embryo Transfer (MOET) is to set an elite herd (or a few elite herds) of males and females and carry out intensive selection and testing within herd/s selecting males and females at an early age using family information. According to Nicoll (1976), a nucleus breeding scheme is based on the principle that in each herd there is a small number of genetically very superior animals which if brought together will form a nucleus whose average genetic merit is far greater than that in any of the contributing herds. Open nucleus breeding schemes (ONBS), which also allow inflow of high potential breeding animals from other herds, have been proposed as ideal for genetic improvement in situations with moderate levels of management (Smith, 1988). Indigenous breeds are the foundation for cattle production and they are resistant to diseases and drought, can walk long distances and survive on poor pastures, and show good fertility (Ahozonlin et al., 2019). Farmers exploit these adaptive traits to use the animals for pulling/towing work and for producing milk and meat (Rege et al., 1999). In underdeveloped countries, livestock production is typically characterized by small herd sizes, unrestricted mating, and a lack of pedigree and performance documentation. The implementation of successful genetic enhancement projects is constrained by these factors. To overcome these problems, designing different strategies is needed. For example, nucleus breeding schemes have been suggested, in which genetic improvement is centrally organized in a population maintained in research institutes or government farms. In an open nucleus breeding scheme, the sire breeding nucleus is open to some gene flow, usually through highly selected females, from the general population or base. By allowing greater selection pressure along the dams of sire's path- way, this can lead to an increased rate of genetic gain (James, 1978). Phillips (2001) reported that the most important decision in establishing a nucleus breeding operation is to determine its size. There are several tradeoffs. With increasing nucleus size, greater selection pressure can be applied to potential breeding stock resulting in more rapid genetic gains. Applying ONBS for many generations of selection could accelerate the rate of genetic gain of milk production in buffalo and increase the average milk yield by 15% in G1 to 26% in G4. Hopkins (1978) emphasized that using more efficient selection strategi es and short generation lengths in the nucleus would increase rates of gain. A more straightforward process for creating and distributing breeding stock with known value is provided by the open nucleus breeding plan. The establishment of an open nucleus breeding system to maximize genetic improvement, reduce the inbreeding rate and reduce the total cost of recording in smallholder systems, improve milk production, and increase the rate of genetic gain. Open nucleus breeding allows animals to flow between the nucleus and the local population in both directions, while the closed scheme allows animals to flow only from the nucleus into the population. Nucleus programs can allow accurate recording of the performance in developing countries where such recording does not normally occur on farms (Guangul, 2014). The annual genetic progress in MOET – ONBS was 4-6 % higher as compared to classical progeny testing schemes and this response was reduced to 1- 2% when the nucleus was closed. It allows more rapid improvement with limited resources & data recording, which is practically most suitable for developing countries (Kush Shrivastava et al., 2018). However, for nucleus programs to operate successfully, they need proper infrastructure and technical support (Kosgey et al., 2006). Many such programs in developing countries have failed for a lack of sustainable support and involvement in the community (Sölkner et al., 1998; Sölkner et al., 2008; Wurzinger et al., 2011).

Community-based breeding

Indigenous breeds' productivity and profitability are increased through community-based breeding without compromising their hardiness and genetic integrity or requiring costly treatments. The approach is participatory, relatively cheap, and implemented directly by farmers, unlike the often-unsuccessful conventional breeding programs involving nucleus schemes and/or importation of exotic breeds for crossbreeding Haile et al, (2020). Indeed, several studies recommend community-based breeding programs for traditional, low-input smallholder farming systems (Haile et al., 2011; Haile et al., 2018; Sölkner et al., 2008). Community-based breeding programs focusing on local genotypes are being advocated as the strategy of choice for the genetic improvement of small ruminants (Haile et al., 2011; Kosgey & Okeyo, 2007). In contrast to a conventional top-down strategy, a community-based approach involves farmers in all steps of implementation to take into account indigenous knowledge of breeding practices and objectives. Typically, these programs feature a single tier, with no distinction between breeding and production units because all farmers involved are both breeders and producers (Gizaw et al., 2018). Farmers were heavily involved in the community-based initiative in Burkina Faso that featured Baoulé and Baoulé x Zebu at various levels of implementation. This plan made use of the village herd's potential to produce a lot of breeding prospects and enable rigorous selection. Breeding programs for Menz, Horro, Bonga, Washera, Doyogena, and Atsbi sheep, as well as Konso, Arsi, and native goats, are now being conducted in Ethiopia. These programs are primarily financed by the government or by short-term development projects. Based on the success of the community-based strategy the Ethiopian government has designed three strategies for Menz, Bonga, and Horro sheep breeds (Mueller et al., 2015). Strategy 1: Outscaling to more CBBPs considering current production environments Strategy 2: Upscaling more males produced per CBBP. Strategy 3: Upscaling more intense use of males.

Village scheme breeding

The genetic improvement of several breeding programs aims to qualities of local livestock species in the tropics, village breeding programs have been proposed. For instance, a village breeding program has been implemented to improve pure Lobi cattle and their crosses (Lobi × Zebu) for meat production and trypanotolerance in the southwest of Burkina Faso (Ouédraogo et al., 2021). The Tharparkar cow breed has been preserved in India because of a village breeding scheme (FAO, 2013). The Tharparkar bulls used in this breeding operation were chosen, and each bull was handed to a family in the hamlet who promised to care for it in exchange for money made from other farmers using the bull to naturally mate their cows. The breeding effort has revealed a rise in the number of pure Tharparkar cows. In addition, a village-based breeding program was suggested for improving the beef production of indigenous cattle in the Mangwe district of Zimbabwe (Bidi et al., 2015). In India, the Key Village Scheme' was the first systematic attempt in India to improve the quality of cattle initiated during the First Five Year Plan. The program was invigorated with the introduction of the Intensive Cattle Development Projects (ICDPs) in 1965. Intensive Cattle Development Projects were designed to provide cattle owners with a package of improved practices and envisaged intensive coverage of 1 lakh cows and buffaloes of breedable age for achieving a marked impact on milk production. The breeding plan should emphasize the existing system rather than transforming the existing system into capital and labor-intensive, biological, and environmentally sensitive. A successful animal breeding system in developed regions of the world is a high-technology operation involving sophisticated methods of measuring and evaluating animals. It demands a high input of capital, skilled men power, and a high level of organization and it supports commercial large-scale production. Moreover, the cooperative breeding village plays a role in genetic improvement in body weights could be feasible if appropriate breeding designs are adopted to overcome the constraints to implement effective village breeding programs, including small individual flock sizes and uncontrolled mating of Menz sheep under smallholder (Solomon et al., 2013). In comparison to selection among the tiny flocks of individual farmers, a higher selection intensity and selection differential were made possible by the cooperative design.

In developing and underdeveloped countries, breeding activities should be aimed at supporting small and subsistence farmers in the absence of these inputs. They should be able to develop cost-resource-saving methods of production under the prevailing conditions and provide the basic needs to the family and stay on the land. One such program is the village-breeding program. Village breeding programs are carried out by rural communities under the most likely unchangeable environment such as:-Poor feed resources with a large seasonal variation; high disease prevalence; low level of organization and data recording is difficult, and the flow of information between levels of hierarchical set up is not functioning.

The target groups are usually the livestock users (animals are left on their own for feed, water, and reproduction) and the livestock keepers (one considers only the basic needs such as fodder and water). The method of improving animal productivity through breeding is to make good bulls of native breeds of their locality available and cross-breeding with exotic breeds. The village bull breeding scenario assumed cooperation between farms in the same village, meaning that all farms in one village used the same bull to mate with their cows.

Bull loan scheme breeding

In regions where artificial insemination (AI) services are few and unreliable, purebred dairy-type bulls are given to qualified farmers for natural mating with purebred dairy-type buffaloes, crossbreds, and native carabaos. In the Philippines' dairy cattle breeding program, this service is an integral part of the genetic improvement program aimed at producing animals with improved productivity for milk and meat, without disregard to draft power. For one or two seasons or years a selected bull will be lent to the farmer who owns around 30 to 40 breed cows. The owner should be advised to castrate all but one or two breed males of his herd as a standby.

After one or two years or seasons of breeding, the stud bull should be returned to the multiplication center for distribution to other farmers. The rotational use of village bulls within village groups assumed cooperation among villages within the same administrative unit. The sires are provided from a different subpopulation than the dams (Windig and Kaal, 2008). According to Elhady et al. (2022), rotational mating achieved lower genetic gain than the village bull breeding scenario. This could be attributed to the low number of selection cycles for bulls in the simulated rotational breeding scenario because, on average, bulls were rotated 4 to 6 years before the selection of young bulls was carried out to replace the old ones. In contrast to both the village and farm bull breeding scenarios, this suggested a longer generation interval for bulls in the rotational breeding scenario. A higher genetic variation can be maintained as a result of the rotating usage of village bulls within village groupings. By balancing the genetic contributions of the breed's subpopulations, rotational mating may generally be used to promote the genetic diversity within a breed (Windig and Kaal, 2008; Mucha and Komen, 2016; Elhady et al., 2022). The Butana region does not have a usual practice of rotating the usage of village bulls among villages within groups, which increases organizational complexity. As a result, the willingness of farmers to accept such a breeding program needs to be examined (Elhady et al., 2022).

Community bull scheme breeding

Males used for improvement can often be shared among a few herds of a village. Such a cooperative community bull could lead to the formation of new strains suitable to that area. Cooperation among farmers is required. A group of cattle keepers are the joint owners and are responsible for the maintenance of the bull. The stud mating can be practiced (bring the cows for mating) or herd mating can be practiced. After one or two seasons or years, the bull should be returned to the multiplication center. The implementation of such breeding strategies requires the involvement of farmers who are willing to genetically improve their cattle and to take an active part in the development and implementation of any policy, from the planning through the execution stage. A village bull breeding program for Butana cattle may be more easily designed and implemented if farmers are ready to create associations and share information (Omer et al., 2020). Furthermore, some Butana cattle farmers currently rely on bulls from their neighbors, thus a village bull breeding program may only minimal change the farmers' current breeding practices (Musa et al., 2006; Omer et al., 2020). However, the creation of village-run AI programs employing frozen or fresh semen (Rege et al., 2011; van Arendonk, 2011) should be viewed as a complement to or alternative to natural bull mating, though, for better utilization of a bull within village herds, when possible.

Bull service scheme breeding

The bull is given on a loan to a farmer possessing few cows in a small herd and interested in having a selected bull for improvement of his herd. He is free to charge other farmers for providing the service of bull. The charges may be in kind or in cash, which will provide some income for the maintenance of the bull and may even add some income to the family while improving his herd.

After one or two years or seasons, he should return the bull to the center. Lower genetic gains achieved with the farm bull breeding scenario in the current study compared to the village bull breeding scenario showed that individual farmer attempts to advance genetic diversity are difficult due to limited herd sizes (Elhady et al., 2022). Additionally, inbreeding and the ongoing selection of farm bulls within a farm herd are most likely to blame for the considerable loss in genetic variation under the farm bull breeding situation (Gorjanc et al., 2015). The regulation of inbreeding, genetic improvement, and the efficient use and exploitation of breed-specific traits all depend on genetic variance (Makina et al., 2014; Cervantes et al., 2016; Ouédraogo et al., 2021). Generally speaking, a sustainable breeding program must take into account maintaining genetic variance over the long run while achieving sufficient rates of genetic gain in the near term (Bijma et al., 2001). Generally speaking, a sustainable breeding program must take into account maintaining genetic variance over the long run while achieving sufficient rates of genetic gain in the near term (Bijma et al., 2001).

Bull owner scheme breeding

A farmer, who can afford to purchase a bull to improve his herd and/or to enhance his social status, can purchase the breeding bulls from the multiplication center at a subsidized price.

The price fixed should discourage the farmer from sending the bull to slaughter or sell to unscrupulous traders. The bulls supplied to the community should be of greater genetic potential than any bull of that locality. Breed/type should exist or preferred type/breed, which suits the ecological and social components of the target group. Breeding bull owners are selecting breeding bulls without any additional advice from breeding specialists. They depended on information about the performance of potential bull dams and growth performance and appraisal of young bulls. The knowledge about the dam of the breeding sire and her milk yield indicates that herd owners are well aware of their stock. Gambia has also reported selecting bulls born to high-yielding cows (Jaitner et al. 2003; Steglich, 2006).

It is better to select farmers with a reputation, of a younger age, and willing to learn better husbandry practices. All the bulls supplied should be permanently branded.

A breeding program is costly and may not be sustainable as it serves only poor farmers. The government should provide technical assistance. A traditional and well-established community organization is a suitable candidate to handle a sustainable and site-specific breeding program. This will allow a permanent evaluation of the improvement process. Bull owner Scheme breeding is different from farm bull breeding where in the farm bull breeding scenario, it was assumed that each farm used its breeding bull to improve the milk yield. If the phenotype and genotype of the breeding bulls supplied are really good, the demand will be more than the production capacity of multiplication centers. Hence great care should be taken to select the beneficiaries on merit so that it will not become a political issue.

Ranch development

Ranch development aimed to genetically enhance Boran cattle under ranch management conditions. The objectives of the multiplication center were redefined as conserve and improve Boran cattle through selection and controlled breeding; provide foundation and replacement heifers to the Abernossa crossbreeding unit and other interested organizations; produce and distribute Boran × Friesian in-calf heifers to farmers to improve dairy production; and demonstrate the importance of improved livestock management and modern ranching systems under tropical conditions. The first of these ranches to be developed in Ethiopia was the Adami Tulu ranch. At the ranch, selection-managed breeding, and superior management have improved the Boran breed. The ranch operated for the Boran breeding unit undertook a selection and improvement operation on pure Boran cattle while the crossbreeding unit run a crossbreeding operation using improved Boran cows inseminated with frozen semen from Friesian bulls. The superior Borana bulls were utilized in the Borana breeding unit's natural mating process.

Artificial Insemination (AI)

Artificial Insemination (AI) is also another body involved in breeding activities. AI emphasizes increasing milk and meat production in the areas of the growing urban population. However, its programs have steadily spread to several lowland areas as well as the country's highlands. To execute this program the center maintains bulls of 50% and 75% of Friesian and Jersey, crossed with indigenous. The center also keeps pure exotic breeds grading up to 75% exotic blood might be economical. Such a condition was attributed by Baltenweck et al. (2004) to inadequate availability/access, high service costs, and technological failures that resulted in numerous repeats. Additionally, it shows a significant drop in usage, as previous research found that central Uganda had a greater use rate of AI (15%) (Staal and Kaguongo, 2003).

Collecting information for breeding decisions

Numerous attempts have been made to enhance tropical livestock, mostly through crossbreeding of tropical cattle with temperate breeds. Even though it should be acknowledged that enhanced cattle have been produced or introduced effectively in favorable tropical regions, such as some highland locations, coastal climates, and somewhat intense peri-urban production systems, many attempts have failed. The major problems for failures in different reports reveals some common problems, whereas success stories may tell possible ways forward (Philipsson et al., 2006).

The breeding programmes have been too complicated in terms of logistics, technology and requirements of resources without considering the infrastructure available [CS 1.3 by Mpofu].

- Indiscriminate crossbreeding of indigenous breeds with exotic breeds without enough consideration of environmental conditions for production. Lack of plans on how to maintain a suitable level of 'upgrading' or on how to maintain the pure breeds for future use in crossbreeding contribute to non-sustainability. High levels of upgrading have generally led to animals with less resistance to diseases and impaired ability to withstand environmental stress [CS 1.31 by Philipsson].
- Lack of analysis of the different socio-economic and cultural roles that livestock play in each situation, usually leading to wrong breeding objectives and neglect of the potentials of various indigenous breeds of livestock. Examples of these problems are illustrated in several case studies linked to this module [CS 1.12 by Chagunda].
- Lack of comprehensive approaches to design simple, yet effective breeding strategies in low-input environments.
- Lack of awareness of what genetic improvement schemes may achieve in both the short and long terms with different methods and species.

Breeding initiatives seek to improve a population's genetic makeup. A breeding aim is the description of the features that need to be enhanced, together with the importance placed on each trait. It guides how we should enhance the population's genetic makeup. A breeding program has certain breeding goals in mind to produce the next generation of animals. The idea of sustainability in agricultural production has received increased attention and consumers are interested in products produced sustainably. The degree to which animal breeding and reproduction, as managed by professional organizations, contribute to the preservation and proper treatment of animal genetic resources for future generations is a general definition of sustainable animal breeding (Gamborg and Sande, 2005). Product quality, genetic variety, efficiency, environment, and animal health and well-being are the characteristics of sustainable animal breeding (Code-EFABAR, 2004). The success of a breeding program depends on how we perform the components of a breeding program like technical and operational considerations. Knowing the breeding goal, Relevant traits of animal information should be collected to take breeding decisions and help to establish the value of an animal concerning the breeding goal. Figure 3 shows the breeding program cycle.

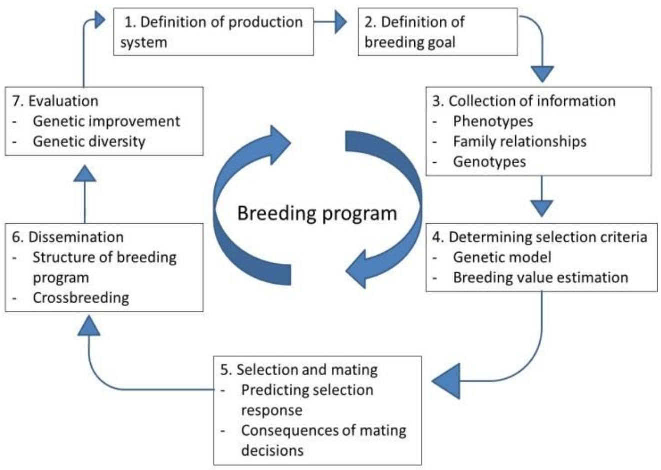

Figure 3. Breeding program cycle (source from textbook of animal breeding and genetics)

Challenges of Implementing the Strategies

The development of the cattle sector frequently receives broad-based guidance from government programs. Effective policy has been and will remain crucial in efforts to achieve sustainable development on a global scale, especially in the cattle industry. Policies and strategies should encourage farmers and breeders to pursue opportunities to enhance livestock production in the most sustainable, viable way, maximizing positive economic and social outcomes while preventing or mitigating adverse impacts (Elzbiata, 2021). In developed countries, the public sector played a major role in establishing and implementing national livestock development strategies, especially regarding animal breeding and reproduction. Depending on the countries and species of livestock, several levels of state-established institutions were in charge of providing breeding services, such as performance recording, evaluation of breeding value, and selection (Elzbiata, 2021). State-run breeding stations are crucial to breeding improvement programs and the dissemination of genetic improvement. The state continues to play a crucial role in establishing breeding services and providing breeding stock. However, in many developing countries the poor policy highly limited the involvement of researchers and other stockholders in the sustainable development of the sector. The design of any efficient breeding program relies on research results which include analysis of breed characterization data, estimation of genetic parameters specific to the actual breed and environment, development of appropriate methods for estimation of breeding values and for selection, analysis of results from different reproduction technologies, and practical experiences. The lack of cooperative breeding companies, institutions, and ineffective involvement of research centers and higher institutions due to the lack of support of governmental and non-governmental organizations.

The other main challenge faced by many dairy operators in the tropic is selecting suitable dairy cattle to breed adjusted to tropical conditions. In the tropics, traits including heat tolerance, seasonal adaptability, feed shortage, tolerance to tick infestation and metabolic disorders, and more, are desirable (Hernández-Castellano et al., 2019). These traits are commonly observed in indigenous dairy breeds in tropical regions, which incidentally have poor milk yield (Berman, 2011). Through effective breeding practices and genetic selection, crossbreeding with temperate breeds may enhance the performance of native dairy breeds. Traits preferred by consumers, which may impact market access, have driven developed livestock industries to account for aspects of production systems beyond those that can be defined economically. Similar to this, breeding goals for agricultural systems where pricing and cost data are not easily accessible must be specified as developing nations develop genetic enhancement initiatives (Kosgey, 2006). The fact that animal value frequently includes intangible factors like prestige, money, insurance, or as a way of performing cultural and ceremonial roles presents another difficulty in defining breeding objectives in developing nations (Kosgey et al., 2004). The best index of lactational yield and length should be used to determine selection criteria. In the tropics, the important traits selected besides meat and milk production, emphasis has to be put on the adaptability of the animal to the environment and the management practices. Very few systems exist for the supply of either improved indigenous cattle breeds, or for artificial insemination (AI) to provide cross-bred cattle that will be needed to sustain dairy systems in often challenging climatic and disease environments. Existing AI services aren't offered everywhere, and when they are, they typically supply semen from bulls that weren't carefully chosen, come with expensive delivery fees, and have low conception rates. Genetic improvement and systems to develop, deliver and sustain that improvement are central to dairy development efforts in these regions (McDermott et al., 2020).

Animal breeders and scientists should include societal viewpoints when developing breeding objectives because communication is crucial when addressing sustainability (Gamborg and Sande, 2005). The lack of information about tropical breeds is a challenge for sustainable production, there are only limited scientific publications in which tropical breeding programs are analyzed retrospect (Acharya and Lush, 1968). Further, breeding strategies applied in temperate countries cannot be transferred directly to tropical conditions without modification because the breeding objectives for cattle in the tropic are not often not identical to those in temperate and there is limited experience in selecting for these objectives. Moreover, the infrastructure required for data recording and processing is often not available as well as the reliability of the recorded data, the technical aspects of the record-keeping, and difficulties to process the data. In addition, misunderstanding of the production system and lack of feedback to the practical breeder are other problems in the tropics.

CONCLUSIONS

The inefficient exploitation of genetic variation across and within breeds of different breeds is a major impediment to increasing livestock populations in developing countries. For breeding purposes, the most productive and adaptable animals for each environment must be identified. For successful livestock genetic improvement, various components of production must be changed. Efforts to improve genetics in underdeveloped nations are unlikely to work unless they are accompanied by improvements in food, herd health, and management. The study looked at cattle breeding programs in developing countries, focusing on cases involving native breeds that were adopted in the last four decades with the primary goals of boosting meat and milk production and disease resistance. The breeding scheme, selection process, stakeholders, outcomes, constraints, and lessons gained were all examined in the context of context, breeding aims, and implementation. In all cases, the key problem was defining clear and attainable breeding objectives, which is common in large-scale production systems. Additionally, crossbreeding makes use of the native breeds' capacity to adapt to local feed and surroundings while preserving their genetic diversity and traits. Varied strategies were used with various levels of farmer involvement, including the open nucleus, community-based breeding, village scheme breeding, bull loan, bull service, ranch development, and so on. Our analysis reveals that in developing countries, successful, long-term cattle breeding strategies necessitate robust, ongoing assistance from local governments and other stakeholders. In exchange, such breeding efforts contribute significantly to the long-term development of country economies and lifestyles through strengthening genetic resources. Insufficient research has negative impacts on different breed types in diverse and dynamic livestock production systems assessment in developing countries, which creates significant knowledge gaps about breed-change interventions. Hence, supporting researchers, research institutions and higher education institutions is crucial to the success of policy in reducing the knowledge gap and strengthening the relationships between the livestock owners and government. Moreover, the development of national livestock strategies, and effective policies, establishing breeding cooperatives, have an impact on the development and implementation of national livestock strategies for sustainable development.

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Conflicts of Interest

The contact author has declared that there is any competing interests.

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