RESEARCH PROGRAM ON Livestock

More meat, milk and eggs by and for the poor

# Breeding and related delivery pathways for sheep and goats in Ethiopia: Lessons Learned and Implications for Scaling

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RESEARCH PROGRAM ON Livestock

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# Executive Summary

*Small ruminant production is part of the livestock production system that contributes to food security and livelihoods for the smallholder farmers and pastoralists and one of the main foreign exchange earners for Ethiopia (Gizaw et al., 2013). There were a number of efforts in improving the productivity of the indigenous livestock through various intervention strategies that are mainly based on external inputs in terms of genetic material introduction, forage development and disease control practices that did not respond to the amount of input introduced in the subsistence and resource poor farming situation (Workneh et al., 2003).*

*Genetic improvement efforts targeting smallholder production systems are constrained by small animal numbers per household, single-sire flocks, lack of systematic animal identification, absence of performance and pedigree recording, illiteracy, poor infrastructure and ill-functioning public institutions (Mirkena et al., 2012). Crossbreeding and on-station selective breeding was initiated in 1960 and 1980, respectively and CBBP was initiated in 2010 in Ethiopia. CBBP, a more participatory approach started gaining global interest (Mueller et al., 2015. This approach is inherently sustainable as it supports local-level decision making, focuses on locally adapted indigenous breeds, considers the constraints that smallholder farmers face and empowers farmers' organizations (cooperatives) in low input systems (Mueller et el., 2015). The expansion of CBBP in a number of villages and the persistence of CBBP over 12 years is indicator of the sustainability of the program. The sustainability of the program is emanated from affordability and simplicity of the program that included farmer's participation, capturing indigenous knowledge, market outlets and*

*skill incentives and a continuous capacity building at each stage. Ethiopia recognized community-based breeding programs as the strategy of choice reflected in national livestock master plan.*

*The result of CBBP embraces social cohesion, increase productivity, improvement in farmers' income and genetic conservation through improvement and utilization. CBBP goes beyond genetic and productivity improvements and includes hastening village social affinity and cohesion. The social network plays major role and serve as entry point in sharing of breeding rams and advance CBBP.*

*The increase in litter size, combined with the increased 6-month body weight, has contributed to the increased in income by 20% and farm-level meat consumption has also increased from one sheep per year to three per year slaughter (Haile et al., 2019). CBBP recognizes proper, feasible and robust delivery pathway for improved genetics in the planning process. The delivery pathway focuses on proper distribution of the improved genetics and utilization of reproductive technologies to maximize the utilization of improved sires. It was noted that, under natural mating in a period of 20 years, the genetic progress for six months weight was 3.6 kg and with inclusion of AI the genetic progress can reach up to 4.5 kg during the same period, however, the genetic dissemination due to AI implies the increase in cost.*

*There are good opportunities to advance CBBP and improve the livelihood of resource poor and small holder farmers. The CBBP is run based on local inputs such us indigenous breeds and under farmers setting. The huge number of core population, the number of breeds characterized for genetic improvement and the demand created to buy improved rams is opportunity to advance CBBP. The breeding program and methodology has been tested and adjusted over 12 years, the communication* *channels between stakeholders are working and positive results are already documented that will pave the way to advance CBBP. A simple guideline for setting up community based small ruminant breeding program has been developed for a wider use and circulation and utilization that will create opportunity to scale up CBBP initiatives.*

*There are good lessons accumulated over 12 years of the project. The project has developed a robust tool to set breeding objectives; demonstrated a breeding strategy in a small flock; there is in-built capacity building and monitoring and evaluation; the selection has been shifted from phenotypic ranking to breeding value through farm level performance recording for decision making; delivery pathways are diversified in CBBP. In sum, CBBP is proved to be sustainable and affordable that fits very well under small holder farmers setting that, requires a strong commitment to scale up/ out by engaging various stakeholders.*

**Breeding and related delivery pathways for sheep and goats in Ethiopia: Lessons Learned and Implications for Scaling**

# Background

Small ruminant production is part of the livestock production system that contributes to food security and livelihoods for the smallholder farmers and pastoralists and one of the main foreign exchange earner for Ethiopia (Gizaw et al., 2013). In Ethiopia, sheep and goat populations are estimated at 30.7 and 30.2 million, respectively (Central Statistical Agency, 2017). The diverse production systems, a varied agro-ecologies, huge genetic resources with diversity in the country is a triggering factor for small ruminant production.

The production objectives documented on sheep and goat community-based breeding programs include both tangible (generating income from sale of live animals, capital investment/saving, producing meat, milk, fat tail consumption as a source of high energy food, and manure for soil health and fuel, and producing skin for both sale and household use and intangible (capital accumulation and fulfilling social obligations like dowry and gifts) (Haile et al., 2014; Gizaw et al., 2020).

The top production objective of sheep rearing was cash income generation followed by meat production and capital investment/saving (Gizaw et al., 2013; Gizaw et al., 2020). Similarly, the production objectives in goats in most production system are cash generation, but its average rank was not different from the other objectives.

The production objectives in small ruminant varied among livestock production system (Gizaw et al., 2013; Gizaw et al., 2020;) in that pastoralists tended to give more emphasis for milk and meat consumption and social functions.

The huge small ruminant genetic resources and potential have not yet been fully exploited because of a lack of structured genetic improvement programs. Previous attempt to improve small ruminant productivity based on centralized nucleus and exotic sires were not successful as such approaches did not considered the indigenous knowledge of farmers, resource and risk management (Workneh et al., 2003; Gizaw et al., 2013; Haile et al., 2014). Genetic improvement efforts targeting smallholder production systems were also constrained by small animal numbers per household, single-sire flocks, lack of systematic animal identification, absence of performance and pedigree recording, illiteracy, poor infrastructure and ill-functioning public institutions (Mirkena et al., 2012). In addition, most interventions are project based hardly staying for five years and the farmers participation is minimal and there has been poor transition of NGO-supported genetic improvement projects into ongoing sustainable breeding programs (Haile et al., 2019).

Learning from the previous failures, a more participatory alternative approach called community-based breeding program (CBBP) was started in 2009 in Ethiopia and gaining a national and global interest (*Mueller* et al., 2015; Shapiro et al., 2015). This approach is inherently sustainable as it supports local-level decision making, focuses on locally adapted indigenous breeds, considers the constraints that smallholder farmers face and empowers farmers' organizations (cooperatives) in low input systems.

A lot of evidences showing the success of sheep and goat genetic improvement has been coming out from the on-going CBBPs. This working paper is thus to review the research outputs from small ruminants in CBBP that can serve as empirical evidence for technical and policy decision making and to recommend good practices of CBBPs for scaling up/out in resource poor and small holder management condition.

# Genetic improvement modalities/strategies in livestock production

Animal breeding is tool involving mating of good quality animals to produce highly productive and sustainable animals for enhancement of overall performance in the subsequent generations. Genetic improvement coupled with husbandry management such us feed intervention, disease control and market outlet allows the expression of the genetic potential of an animal or community flock. Genetic improvement in a sustainable manner requires setting breeding goals and objectives (Gizaw et al., 2013; Haile et al., 2019). The traits preferred for selection were chosen based on market demand, farmers preference, the environmental setting and readiness to modify the management options (Haile et al, 2014). The breeding tools are broadly stratified as crossbreeding, selective breeding and community-based breeding programs with unique characteristics and could be planned for a sustainable genetic improvement and changing the lives of the livestock keepers (Table 1).

Table 1. Description of genetic improvements schemes/alternatives tested in Ethiopia

| Breeding schemes | Description | The system was extended mainly | Sources |
|---|---|---|---|
| Centralized Breeding schemes/ Crossbreeding/ | • Breeding program: No definite Breeding program<br>• Species: Cattle, sheep, Goats<br>• Genetic sources: Depends on exotic germplasm<br>• Providers/Technical: Government extension and research system<br>• Users participation: No farmers participation and top–down planning<br>• Genetic conservation: Indigenous genetic resource eroded<br>• Stories build: Since 1960<br>• Delivery Pathway: Poorly designed and not sustainable<br>• Sustainability: Not sustainable and less impactful | • Urban and peri-Urban in dairy<br>• Breeding and multiplication centers/ranches | Ayalew et al., 2003 in goats; Sandros et al., 2000 and Haile et al., 2006 in cattle |
| Centralized breeding schemes/selective breeding | • Breeding program: No definite breeding program<br>• Species: Cattle; sheep, Goats<br>• Genetic sources: Depends on local germplasm<br>• Providers/ Technical /: Government and research system<br>• Users participation: No farmers participation and top – down planning | • Research centers and farmers in the proximity of research cenetrs | Gizaw et al., 2013 in small ruminants |

| | | | |
|---|---|---|---|
| | • Genetic conservation: Indigenous genetics not improved as planned to sustain conservation<br>• Delivery Pathway: Not planned/broken<br>• Stories build: Since 1960<br>• Sustainability: Not sustainable and not-impactful | | |
| Community-based breeding program | • Breeding program: Breeding plan set at early stages<br>• Species: sheep, Goats<br>• Genetic sources: Depends on Local stock<br>• Providers/Technical /: Government extension and research system and farmers<br>• Users participation: Detailed farmers participation and bottom-up approach<br>• Genetic conservation: Indigenous genetic resource improved and conserved<br>• Delivery Pathway: Properly designed<br>• Stories build: Since 2010<br>• Sustainability: Sustainable and impactful | • Organized small holder farmers | Mueller et al., 2015;<br>Haile et al., 2014; 2019; 2020 in small ruminants |
| Traditional breeding Practices | • Breeding program: No definite breeding program<br>• Species in order: All species<br>• Genetic sources: Depends on local stock<br>• Providers/technical /: Farmers<br>• Users participation: Farmers driven<br>• Genetic conservation: Indigenous genetic resource maintained but not improved<br>• Delivery Pathway: Home grown but not systematic<br>• Stories build: Indefinite time<br>• Sustainability: Sustainable and not impactful | • Existing farmers practices stayed over years | Farmers practice since domestication |

The improvement on animal productivity entails changing the livelihood and social cohesion of the small holder and resource poor community. There are a number of genetic improvement strategies in improving the productivity of livestock. The choice of the strategy depends on the technical, policy and resource availability (Gizaw et al., 2013). The genetic improvement strategy extends from the farmers practice to the advanced and molecular assisted genetic improvement with sophisticated statistical tools.

# Farmers indigenous knowledge in genetic improvement

The farmers and pastoralists recognize the importance of selection and practice it with their own selection criteria. There are communalities in the traits that the sheep and goat owners select at the different sites, however, the order of importance of traits varies among communities, for example, body size and color is trait preferred in Bonga and milk yield, lambing interval were preferred in Afar (Haile et al., 2013). Haile et al., (2013) assessed the farmers indigenous knowledge on genetic parameters and reported that, their knowledge on heritability of traits and genetic correlations between traits is more or less concurs with scientific evidence in literature argued that. Indigenous knowledge and existing practices in the communities, developed through years of practical experience, provide an excellent basis for designing sheep breeding programs.

Communities practices selection to improve the productivity of the flock and considering animal conformation, coat color and other morphological characters (Haile et al., 2013). The selection practice and breeding management constitutes selling good looking rams to fetch good money, slaughter of good looking animals for ritual purposes and keeping disproportionate male to female ratios that lead into negative selection (Haile et al., 2019). Mediocre lambs remain in the flock for mating and the lack of breeding rams contribute ewes to remain open and there are few lambs born compared to the actual potential (Haile et al., 2014; Gizaw et al,2013). In this regard, (Gizaw et al., 2014) reported that, farmers usually sell off fast-growing rams that are potentially 'best' breeding ram and this resulted in negative selection. Keeping disproportionate male to female ration in a flock has effect on the reproductive efficiency of the community flock, that need a closer look and intervention. It was noted that, mechanisms for retaining fast growing rams was designed to avoid negative selection (Haile et al., 2014). Selection and reproductive management also includes culling of black rams and sharing of rams in a community. The culling of black rams is attributed to poor market demand as black sheep have unaccepted esthetic value in the face of community. Hotels are the one buying black sheep for slaughter because of low market price and corresponding higher weight of black sheep. However, it was reported that, the genetic worth of the black sheep was better than the counter red and white sheep that need to be considered (Gizaw et al., 2014; Getachew et al., 2020). For instance, Menz sheep farmers have less preference for black coat color as such animals have less market value, but unfortunately, black animals are heavier than other animals (Gizaw et al. 2011). The proportion of black coat color increased by (2.1% per year) in station based breeding where color was not considered as selection criteria while declined at 1.03–1.05% per year under on-farm management where farmers select against black (Getachew et al., 2020). The same study showed that, birth and growth traits of black-colored sheep were consistently superior to white-colored sheep and the mean yearling weight and EBV of black rams used in the on-station flock was 24.3 kg and 3.7 kg, respectively, while the values for white-colored sheep were 19.7 kg and 1.6 kg, respectively. The farmers and researchers interest in trait preference in relation to black color is not confirmatory such that researchers are in favor of weight and farmers are in favor of color and weight. Thus, selection against black coat color in the CBBPs seems to have an adverse effect on the genetic progress of growth traits in the Menz sheep. This shows to devise a strategy to develop black sheep lines targeting export markets and local markets that may not have prejudice to black sheep (Gizaw et al., 2020; Getachew et al., 2020). A clear community practice and knowledge in livestock breeding is reflected in mule production from horse and donkey species hybridization in Awi zone, Ethiopia (Box 1).

Box 1, Shows community breeding practices in horse to produce mule which can be translated into other species by integrating scientific principles of breeding with the traditional genetic improvement practices.

***Box 1. Farmers community practice in breeding: the case Mule production in Awi district, Ethiopia***

*Sire sharing is commonly practiced in mule production which is species hybridization between horse and donkey to produce mule. The community members buy a breeding donkey and is kept in a special and isolated grazing land. The donkey is a property of the community and there are community leaders controlling the management of the sire in feeding and breeding. The farmer brings their horse for breeding in that specific area to get the service. The male donkey is sheltered during evening in households in rotation bases in a community. The sire is offered crushed barley and straw in the shelter. The owners of the horse reared their newborn mule for about 5 to 12 months and sold to merchants who collect mules and re-sale to different part of the country. Mule is a hardy animal to hasten transportation in the rural setting. A household owning mule is considered as a respected and wealthier person in the community. This donkey sire utilization and management is a good lesson that could serve as entry point to set up sheep and goat CBBPs in villages.*

In sum, farmers have good deal of experience in livestock and genetic management accumulated over years. The importance of indigenous knowledge in animal breeding has been documented (Haile et al., 2014; Gizaw et al., 2020). (Gizaw et al 2011) studied the congruence between selection based on breeding values and farmers' selection criteria and revealed that, selection criteria based on EBV alone for production traits address farmers' trait preferences only partially. These results, therefore, indicate the need to consider indigenous knowledge of farmers/ pastoralists when designing and implementing improvement strategies in the community.

# Breeding strategies

## Conventional and centralized Breeding

Conventional/centralized breeding is practiced in a form of nucleus breeding scheme that connects core population/small holder farmers and on-station breeding schemes. The selection programs were designed with a hierarchical structure involving two or three tiers or with only a single tier. However, the delivery pathway to disseminate improved genetics is not efficient and lacks sustainability (Gizaw et al., 2020). Conventional breeding scheme is characterized by large scale data recording, provision of the recorded data to a data processing center, estimation of breeding values using complex statistical methods and central decisions about the use of male breeding animals which are important elements of such breeding programs (*Mueller* et al., 2015; Haile et al., 2019). Centralized breeding scheme is run by specialized breeding farms and breeding companies or by the state and implemented by large national breeding programs with high input of livestock production system which produce improved breeding stock readily available for use in commercial farms.

In the centralized nucleus scheme, animals are kept on-station and little consideration has been given to on-farm performances management of animals, fail to consider intangible, socio-economic, and cultural roles that livestock play in each situation and usually leads to setting wrong breeding objectives (Kosgey 2004). Such centralized schemes have failed to sustainably provide the desired genetic improvement to small holders (continuous provision of sufficient number and quality of improved males) and also failed to engage the participation of the end users in the process (Haile et al., 2019). The failure of the conventional breeding in developing world has been reported and this is attributed to dependence on external inputs, top-down decision making, poor infrastructure and capacity, project-based approach with poor exist strategy, a limited skill and poor participation of farmers in planning and implementation (Kosgey et al., 2006; Mirkena et al., 2012; Haile et al., 2019). Hence, such circumstances have triggered to look for alternative and sustainable breeding strategy that may work under small holder farmers reach and affordability.

## Cross breeding for Genetic improvement

Importing improved commercial breeds in the form of live animals, semen, or embryos for crossbreeding purpose is another alternative method for genetic improvement. The small ruminant breeding strategies adopted in Ethiopia over the last few decades largely focused on importing exotic breeds for crossbreeding and since the early 1960s substantial efforts have been made (Tibbo, 2006). These have included importing exotic sheep breeds such as Bleu du Maine, Merino, Rambouillet, Romney, Hampshire, Corriedale, Dorper and Awassi and goats breeds of Saanen, Anglo-Nubian, Toggenburg and Boer. Different governmental institutions (research institutes and universities), non-governmental organizations (example FARM-AFRICA) and projects (examples Chilalo Agricultural Development Unit and Ethiopia Sheep and Goat Productivity Improvement Program) undertook these introductions and supervised the crossbreeding. Crossbreeding has been planned in producing high level exotic crossbred animals and distribution of crossbred rams/bulls from stations/ranches to villages.  Crossbreeding requires both exotic and indigenous stock in a continuous manner that makes the breeding management complicated in the low input system. Disseminated sires are usually crossed with the local and ‘less productive’ breeds to upgrade them. In most cases, this is done without sufficient pretesting of the suitability and adaptability of the exotic breeds in different environments and with no clear strategy concerning what the final genotype would be. Genetic erosion of these local populations and breeds has occurred where indiscriminate crossbreeding with local populations has been practiced (Haile et al., 2018). Sheep and goat crossbreeding programs did not result in the expected improvement in productivity, farmers’ and pastoralists’ livelihoods and the national economy (Haile et al., 2019). The major limitation faced by livestock crossbreeding programs in Ethiopia has been the lack of clear and documented breeding and distribution strategies (Haile et al., 2019; Gizaw et al.2020). Little consideration has been given to the needs of the livestock producers, their perceptions and indigenous practices. Additionally, they had limited or no involvement of farmers in the design and implementation of the breeding programs because of the top-down classic approach, resulting in low commitment of end users (*Mueller* et al., 2015). Furthermore, the breeding programs lacked breeding schemes to sustain crossbreeding at the nucleus centers and at the village level (Gizaw, et al., 2010).

## Biotechnology for breed improvement

With advance of biotechnology marker assisted selection has been introduced to improve genetic gain in developed world. The advancement of reproductive technology such as AI and Embryo Transfer has a contribution to disseminate proven genetic materials and advanced genetic gains in a wider scale.

The success and rate of progress in genetic improvement in various forms is facilitated by the advent of reproductive technology and molecular techniques in the developed world (Haile et al., 2018). There is also an attempt in the developing world to introduce reproductive technologies such us artificial insemination and molecular techniques mainly in dairy cattle crossbreeding programs. The application of genomics and its associated tools is most often done in genetic characterization to understand the genetic profile of an individual, populations and breeds in the developing world. The reproductive technology is not as such successful attributed to irregular supply of the germplasm/ semen, poor motivation of technicians and a limited skill in heat detection and insemination and infrastructure problems such as motor bikes, poor road access, semen quality and facilities (Haile et al., 2019).

There might be also an opportunity to introduce molecular techniques and reproductive technologies in CBBP programs with advancement of infrastructure and flexibility of the technology in small holder livestock management situation for a wider genetic gain and accuracy of selection. The efforts made in the use of a prostaglandin-based protocol composed of 2 injections in 11 days apart, preceded by a careful selection of non-pregnant ewes (BCS > 2) using ultrasonography for cervical fixed-time AI with fresh semen, was a feasible reproductive management option for the dissemination of genetic gain in the framework of CBBPs in Ethiopia (Shambel et al., 2020). The correction of failure stories in reproductive technology can bring remarkable change in reproductive efficiency and improve the delivery path ways and produce more lambs from the proven rams even under small holder management condition. The AI introduced with fresh semen, which is affordable with small subsidies until farmers stand by their own can improve the delivery pathways.

## Community based breeding programs

Failure of the conventional and hierarchical breeding schemes in sheep and goat has led to community-based breeding schemes as viable options in smallholder and resource poor farming community (Sölkner et al. 1998; Kahi et al. 2005; Kosgey and Okeyo 2007; Gizaw and Getachew 2009; Haile et al., 2018). A community-based breeding program refers to village-based breeding activities planned, designed, and implemented by smallholder farmers, individually or cooperatively, to effect genetic improvement in their flocks and conserve indigenous genetic resources (Gizaw et al., 2013; Mueller et al., 2015). The process was facilitated, coordinated, and assisted by development and research experts in governmental and non-governmental organizations (Gizaw et al., 2013). This approach is inherently sustainable as it supports local-level decision making, focuses on locally adapted indigenous breeds, considers the constraints that smallholder farmers face and empowers farmers' organizations (cooperatives) in low input systems (Mueller et al., 2015; Haile et al., 2019). CBBP is participatory in nature, follows bottom –up planning, applicable in resource poor and small holder farmers situation and captures farmers choice, farmers common interest, and experience/knowledge, focuses on locally adapted population, considers proper farmers breeding objectives, infrastructure, participation and ownership (Mueller et al., 2015).

No matter how much effort is put into financial and technological support, the eventual survival of improvement programs depends on whether the farmers understood and agreed with the objective of the projects (Kosgey et al., 2006). However, CBBPs are also challenging to establish and difficult to sustain in time in pastoral areas (Kosgey et al. 2006; Wurzinger et al. 2011; Mueller et al., 2019), that requires to set a unique CBBP model that will work in pastoral areas by considering the seasonal mobility of flocks and social fabrics of the pastoralists (Getachew et al., 2020).

This new approach has been tested with promising results in several places (e.g. with sheep and goats in Ethiopia, dairy goats in Mexico, llamas and alpacas in Bolivia and Peru, sheep in Argentina) (Mueller et al., 2015). There are some success stories of community-based breeding programs. These include. the significant involvement of a women's group in Northern Togo, involvement of farmers in the selection and control of inbreeding in south and Southeast Asia, and use of the indigenous Tzotzil selection criteria in southern Mexico (Perezgrovas 1995; Kosgey et al. 2006; Castro-Gámez et al. 2008). In Ethiopia, the success stories in Bonga zone in Bonga Sheep, Horro zone in Horro sheep in Menz zone in Menz Breed is has been reported (Haile et al., 2020; Mueller et al., 2015; Gutu et al. 2014). Their success is based upon proper consideration of farmers' breeding objectives, available infrastructure, participation, and ownership (Sölkner et al., 1998; Wurzinger et al., 2011; Mueller et al., 2015; Haile et al., 2018).

The Ethiopian government has accepted CBBP as the strategy of choice for genetic improvement of small ruminants as explicitly indicated in the Ethiopian Livestock Master Plan (Shapiro et al., 2015). There are many on-going sheep CBBPs in Menz, Horro, Bonga, Washera, Doyogena, Gondar Arsi-Bale and Atsbi areas, and goat CBBPS in Konso, Borana, Gondar, and Abergelle areas in more than 100 CBBP villages in Ethiopia. The zonal and district livestock agencies are putting CBBP in their annual plan and indicators are put to evaluate the program implementation. The experience in running CBBP under small holder farmers situation is presented in guideline, where the program can be initiated by government, non-government organizations and farmers cooperatives to improve the livelihood of small holder farmers (Haile et al., 2018). There is a huge interest to scale up/out the CBBP in Ethiopia by involving more stakeholders in a complementary bases and under win-win situation. Ethiopian Universities are brought in a platform to manage CBBP that would serve as learning site for students and as a contribution to the national effort in genetic improvement and changing the livelihood of farmers at university doorsteps. Many universities are committed to include the CBBP in a curriculum as detailed in course description, course outline and modules to disseminate the knowledge to students and ensure their readiness in implementing CBBPs in the work front after graduation.

Understanding guiding principles/concepts, the tested technologies under farmers condition and participatory approaches in CBBP are vital to sustain the initiative and ensure long term profitability of the program. Community based breeding program was initiated as alternative breeding program under small holder farmers management situation (Mueller et al., 2015; Haile et al., 2020). The concept is emanated from farmers knowledge, availability of shared resources, incompatibility of conventional breeding under smallholder's management condition and feasibility of CBBP under small holders' circumstances. The concept and design of CBBP combines genetic theories, farmers participation and indigenous knowledge of farmers in genetic improvement and to achieve increased productivity. Conceptually speaking, CBBP has steps to advance genetic improvements includes consideration of enabling environments; understanding the production system and defining the breeding objective; choice of selection criteria and recording; development of a genetic evaluation and breeding structure and its organization; evaluation of the proposed programme and dissemination of the improved genetics (Muler et al., 2015). CBBP is community driven initiatives that, uses community's own genetic resources to produce males to serve as sires instead of the regular use of produced males that strongly influences the breeding program (Mueller et al., 2015; Haile et al., 2018). CBBPs are thus expected to deliver animals, which fulfil sets of breeding objectives in the production environment under which the communities operate or thrive (Mueller et al., 2019).

A wide range of technologies and mode of delivery pathways are corner stones of expanding CBBP under smallholder management situation. Technology is not only a physical inanity but also the skill and knowledge to utilize the technology in effective manner. The technologies produced and transferred in CBBPs are results of the research institutions and farmers engagements at various levels. Improved sires selected from the community flock are primary technologies extended to improve the genetic worth of the community flock and ultimately improve the livelihood of the community. The sires are selected following conformation and breeding values computed from data generated. Selected sires are then distributed in to breeding groups (Haile et al., 2020). Rams are used communally by forming 'sire-user-groups' and this was based on settlement patterns and the use of communal grazing areas (Haile et al., 2018). There is always a question from farmers side that, selection of an ewe to be the attention in the CBBP. It is true that, selection both from the sire and dam side improves genetic worth of the community flock. However, the breeders are inclined more in sire evaluation because the sires have inherent capacity to produce more impact on flocks' genetic merit (Falconer, (1986) and to produce progenies per year, say they can mate up to 30 ewes per breeding season in natural mating with possibility of expanding transmitting its genetic worth to about 300 to 400 progenies per breeding season (Haile et al., 2018). In addition, females are required for replacement in which tightening the selection intensity is not feasible that may end up with few ewes retaining in a flock and exert an effect on overall flock performance. This intervention also allows the CBBP to supply breeding rams to community outside CBBP project sites and core population that pave the way a wider genetic improvement at population level (Gutu et al., 2015).

As a result, the project team promoted the idea that, the proven ram should not be restricted to serve 30 ewes per mating season using natural mating necessitated to introduce AI and synchronization of estrus. It was also noted that, the demand for improved ram is increasing outside the CBBP project sites. The price of the improved ram is extending up to 5000 Ethiopian Birr as compared to 2000 for a sire outside CBBP project sites (Gutu et al., 2015). This necessitated to introduce AI and estrus synchronization in advancing sheep and goat production in CBBP sites and core population. Complementarity of natural meeting, AI improves the delivery pathway and disseminating the improved genetics. However, the AI and estrus synchronization incurs cost and government incentives such as subsidized prices of AI and estrus synchronization during initial establishment years has encouraged investment and uptake (Haile et al., 2019). In this regard, a simple and field level fresh semen processing and synchronization schemes have been introduced in many CBBP sites and that showed improvement in the use of proven sire effectively with a reasonable technology sophistication (Shambel et. al., 2020). Insemination using fresh semen collected in the field and relying on basic infrastructure is regarded as a promising technology for a wider delivery of improved genetics under low input systems (Haile et al., 2018).

### Complementary interventions

Complementary interventions are inputs and knowledge which are equally important to enhance genetic improvement and farmers' livelihoods. It was reported that, disease prevalence (critical in Horro) and feed shortages (critical in Menz) have compromised the benefits of genetic improvement (Gutu et al., 2015). Complementary interventions in broad include health services, quality of feeds and feeding, market information and services and animal Husbandry/management. CBBP was run in modification of complementary activities concurrent to genetic improvement. Non-genetic factors are outside the control of the gene, that requires strategic intervention. Complementary interventions require inputs/technologies and skills to exploit improved genetics. It has been noted that, the recent assessments of the views of farmers as well as researchers and development practitioners in the highlands of Ethiopia have shown that genetic improvement should receive similar priority to feeding and health issues (Edea 2008; Getachew et al. 2010). Therefore, an integrated approach that considers genetics, nutrition, health, input supply, service delivery and market access are necessary for sustainable and impactful CBBP in the villages. (Gutu et al, 2015). Animal health interventions like strategic parasite control, vaccination and other disease control strategies motivates farmers to be part of CBBP breeding group at initial stages till the understand the outcome of the intervention (Gutu et al., 2015).

Interventions like market incentives and information fuels agricultural productivity including breeding sire marketing.  In CBBP, commodities for market are mainly young rams for slaughter, improved rams for breeding and fattened rams with special feed interventions. The cooperative organizations have role in creating conducive environment and fueling the value addition along the value chain in ram marketing. The integration of various actors/ extension offices, research system and international organization/ with a definite role and accountability has impact in making CBBP effective and profitable (Haile et al., 2019).

Capacity development interventions are also crucial in enhancing the performances of CBBPs. The experience in Bonga showed that, the commitment and integration of various actors contributed the increase in small holder farmers income up to 20% (Gutu et al., 2015). The same study revealed that, the comparison among CBBP participant and non-participant for flock size was different in favor of CBBP participant farmers. The variation in flock size could be attributed to the improvements in reproduction of sheep, better sheep husbandry practices, customized training offered and continuous follow-up from implementers (Gutu et al., 2015). Continuous capacity development for various actors including cooperative leaders has played pivotal role in making CBBP effective (Gutu et al., 2015). Through repeated training and awareness in CBBPs, owners care for their animals and feed and manage them better than in the traditional smallholder system (Gutu et al., 2015). The community members were continuously given training on the CBBP operations and on management/use of their rams/bucks/ flock and husbandry practices and this was done by the researchers from the national system (Haile et al., 2018). The training was also offered to medium and higher-level professions in the areas of breeding and genetics to bridge the skill gap (Haile et al., 2019).

The cooperatives have a role to supply medicaments and seeds for forage development on the top of ram marketing facilitation. The contents of training resources were customized based on the role and educational status of actors. A simple and elaborated resource material and a practical and hand on training makes the training acceptable in the face of farmers. The training content to the development agents and Woreda livestock officers should be customized based on the educational level and experiences. The experiences in CBBP showed that, arranging training, preparation of resource material in terms of content and mode of delivery is based on skill gap (Haile et al., 2018). The extension system has a role to manage the relevance and the content of the resource material. The CBBP success has also emanated by introducing relevant learning materials and mode of communication that fits to different actors such that researchers, extension staff and farmers. The training and its facilitation is participatory and gap based that has facilitated the dissemination of the knowledge and technology to improve the livelihood of small holder farmer (Gutu et al., 2015).

Genetic improvement is long term investment that requires a long-term vision, commitment, and participation. However, it should be noted that short- to perhaps medium-term returns on investment will most likely come from non-genetic gains, such as improvement in feeding, disease control and better reproductive management, (for example, making breeding sires available in the required number to serve all females will result in more lambs) and market linkages (Haile et al., 2019).

The study conducted in three CBBP sites showed a genetic gain per year of 0.21 ± 0.018, 0.18 ± 0.007 and 0.11 ± 0.003 kg/year for Bonga, Horro and Menz, respectively and argued that, the result quite substantial for an on-farm situation (Haile et al., 2020). The genetic gain that are accumulated and gained over years by increasing participating farmers through scaling out and scaling up procedures would increase the productivity of indigenous stock over years of engagement. Farmers' motivation is reflected in their interest in a breeding project, their readiness to organize and adopt innovations, to respect bylaws and take over responsibilities (Haile et al., 2019).

### Role of community participation

The farmers participation starts on the production system analyses and description. The participatory nature of CBBP has contributed to the expansion and sustainability of the initiative. For example, CBBP in Ethiopia was initiated in 2004 and extended in scale of operation in 2009 and expanded in wider till today, that has captured more than 100 CBBP sites and influenced the government to integrate CBBP in the extension and grand agricultural development projects in Ethiopia (Haile et al., 2019). The participation is not only the community at a grass root level but it also participates various actors in the public and private sector by setting clear responsibilities and roles for the success of the CBBP initiatives (Shapiro et al., 2015). The extent of participation is explained in various segments of activities and roles. The participation process extends from the planning, implementation, and evaluation of the initiative to advance future correction and then expansion of good practices in coverage and scale of operation (Mueller et al., 2015).  The participation of the community and public service actors in designing, planning, implementing CBBP has been well documented in a guideline for setting community-based breeding programs in small ruminants (Haile et. al., 2018).  The participatory approach follows PRA techniques (Chambers, 1994).

Characterizing the production systems is a first natural step in designing CBBPs ( Dossa et al. 2009; Scherf & Tixier-Boichard 2009; FAO 2010; Robinson et al. 2014). This exercise comprises various components such as the characterization of production and product use at household level, breed description, livestock population and structure, land use, and the role of livestock at household and community levels and market analyses (Ayalew et al., 2004; Gizaw et al., 2013). Findings from production systems studies and the participatory research with farmers revealed shortages of breeding rams, inbreeding, and negative selections as some of the problems in sheep breeding practice (Gutu et al, 2015). Hence, CBBP is designed to addressing these problems as part of the objectives of the breeding programs. The farmers are also deeply involved in choosing specific breeds and defining breeding objectives. Past studies have shown that, farmers preferences for specific breeds or types of animals (Bebe et al. 2003; Scarpa et al. 2003;) through their participation. These studies made clear that, the reasons for choosing an animal is to choose the local breed, a cross-bred animal or one of an exotic breed to suit the existing situation. Farmers are also deeply involved in trait preference in that specific breed and the traits preferred by the community are considered in defining breeding objectives (Gizaw et al., 2013). The understanding preferred traits of sheep /goat by farmers is helpful in matching genotypes with prevailing socioeconomic conditions and the production environment. The participation of farmers in production system studies, breed choice and trait preference have given a space and the importance of valuing the knowledge of farmers in defining the breeding goal (Mueller et al., 2015).

The enumerators are selected by community members to run the recording and grass root follow up of the CBBP in villages (Haile et al., 2018). A breeding ram selection committee composed of about 3–5 members elected by the community are involved in the selection. If, for example, 15 rams/bucks were to be selected from 100 candidates, 20 would be preselected based on their breeding values, and the committee ranks the selected rams/ bucks culling the last five (Haile et al., 2019). The committee checks on the conformation, coat color, presence or absence of horns, horn type, tail type and other criteria in decision making. The number of rams/bucks to be selected depends on the number of ewes/does available for mating with a male to female allocation ratio of 1 ram/buck to 30 ewes/does while accounting for the replacement rate required (Haile et al., 2018).

Farmers are the primary owners of CBBP initiatives. The facilitators representing different institutions have also a role in making CBBP effective and productive. Haile et al., (2019) reported that, roles and responsibilities of the different institutions engaged in genetic improvement of small ruminants were not clearly set, and this created an overlapping effort on the same tasks among National Agricultural Research Systems, Institute of Biodiversity, Ministry of Agriculture, CGIAR, and NGO's. The lessons from the past failure have triggered to engage the stakeholders to hasten CBBP in the project sites (Haile et al., 2019). It is believed that, beyond the genetic improvement a program, the same initiative has contribution real stakeholder participation and that could be a lesson to run rural development projects in various sectors (Haile et al., 2019). The facilitators of the program include extension staff in CBBP site, district level livestock experts, zonal livestock experts, research institutes in national agricultural research system and NGOs like ICARDA. A committed team composing different institutions set to monitor the planning, implementation, and success of the program (Haile et al., 2018). The success in CBBP can be viewed as a collaborative role among the team from the farmers and facilitating institutions side that could be transferred to other rural development projects as a lesson. The participatory approach follows PRA techniques (Chambers, 1998) that engage communities and facilitating institutions.

To ascertain the need and interest for a CBBP in specific communities, farmer workshops was run where intervention priorities are discussed and formal ex-ante impact assessments can be performed (Mueller et al., 2015). Thus, a CBBP should ideally be community driven right from its inception or must be at least backed by a strong motivation of a group of farmers and facilitating institutions. Completely self-sustained CBBPs seem to be difficult to realize in short run and there is a need to build the capacity of farmers, farmers organizations and local extension staff to run the program in a sustainable manner through participatory approach. Hence, CBBPs aim at collaborative action of many farmers, with the support of local research and extension units (Mueller et. al., 2015).

## Sustainability of community-based breeding programs

Concerns about sustainability in agricultural systems center on the need to develop technologies and practices that do not have adverse effects on environmental goods and services, are accessible to and effective for farmers, and lead to improvements in food productivity (Pretty 2018). Maintain the sustainability of CBBP is an issue that requires a concerted effort and commitment. It was reported that, CBBPs are challenging to establish and difficult to sustain in time (Kosgey et al. 2006; Wurzinger et al. 2011) as it needs a careful planning, implementation and monitoring to exploit the benefits. To ensure sustainability, the choice of CBBP sites should be given a priority and follow set criteria to initiate the program (Haile et al., 2018). The choice of site was given using criteria such as farmers' motivation, livelihood perspective of smallholders, genetic value of target population, prospective markets for regional products, logistic feasibility as well as political will and support (Mueller et al., 2015). The dividends of genetic improvement are tapped when the initiative is sustainable. Sustainability in CBBP is also a function of the meeting breeding objectives of individuals, communities for which they were established; ensure self-sufficiency (technically, economically and socially) and registered environmentally friendly (locally and globally) (Haile et al., 2019). Over years several approaches were devised to advance genetic improvement in the developing world. The centralized breeding program which is replicated from the developed world had little success and sustainability due lacking infrastructure and technical capacities in developing countries. The expansion of CBBP is indicator of the sustainability of the program. The sustainability from an alternative approach comes simplicity of the program that included from participation of the end user, market outlets and incentives and a continuous capacity building at each stage.

# Contribution of community-based breeding program for environment and diversity

Community-based breeding programs (CBBP) can be described as a system of genetic resources and ecosystem management in which the livestock keepers are responsible for the decisions on identification, priority setting and the implementation of activities in conservation and sustainable use of the livestock (Rege, 2003; Tesfahun et al., 2008). Community-based breeding programs usually work with locally adapted animals, and therefore, the issue of environmental sustainability is embodied in the programs (Haile et al., 2015; Haile et al., 2019). Focusing on indigenous breeds in CBBP implementation is to exploit the inherent adaptability and better coping ability to climate change than exotic breeds, because they are already adapted to harsh conditions (Haile et al., 20011). CBBPs could also therefore contribute to averting the perceived negative effects of livestock on the environment, because small ruminants typically eat low-quality grazed forages and crop residues (Tibbo, 2006). Consequently, CBBPs provide a sustainable option for conservation of local animal genetic resources (AnGRs) by utilizing and improving them, as there are often no affordable long-term alternatives (Mueller et al., 2015).

## Institutions in community-based breeding programs

The implementation of CBBP is targeting to institutionalization of the initiative for sustainability and long-term impact to small holder farmers. This is emanated from the past failures in genetic improvement that small ruminant genetic resource in Ethiopia has not been institutionalized (Haile et al., 2019). However, institutionalization of the CBBP in a sensible and practical way for sustainability of the CBBP and to attain potential genetic gain in the long run. CBBP run by ICARDA, ILRI and national research system is in a pilot stage and the collaborative institutions are working on institutionalizing the program for a wider coverage and sustainability (Gutu et al., 2015). The nationalization takes at formal and informal institutions level such as formation of mating group and cooperatives and supporting governmental institutions. Informal organizations led by farmers in villages were crucial in implementing CBBP. The resources shared in a form of communal grazing areas and mating groups that were arranged to share rams were entry points to advance community based breeding programs. Traditionally a good-looking sire owned by individual farmers are shared guided by customary and formal and informal by-laws. The owner of the sires allows the villagers to use the ram for breeding. However, the sires are not selected by the community and the owner of the ram is the one who retains the ram for breeding. There is little effort to use such informal institutions to transfer technologies and farm skills in Ethiopia. Hence, institutionalization of CBBP by using informal organizations of farmers should be strengthened to scale up and scale out CBBPs. The informal institutions are specific and unique to a certain tribe or linguistic group, that may require to understand the inherent characteristics of the informal organization and use them as entry point to advance CBBP for sustainability and peacefulness (Haile et al., 2019). Formal institutions such as extension, research centers and cooperative promotion institutions are relevant to advance the CBBPs. Hence, all relevant stakeholders and institutions were included right from the initiation of the breeding program to ensure the sustainability. It was suggested that CBBPs should become a part of the researchers' daily practice, engagement with a community, collaborate with institutions in the extension wing and included CBBP activity in the annual and strategic plan of extension and research programs to ensure sustainability (Wurzinger et al.2020). Community based breeding program main actors, roles and benefits received by actors for sustainability is presented in Table 2.

Table 2. Community based breeding program main actors, roles and benefits received by actors for sustainability

| CBBP actors | Main roles | Benefits |
|---|---|---|
| Farmers | • Provide information for characterization study<br>• Trait preference and breeding objectives setting<br>• Role on cooperative formation<br>• Ram selection<br>• Management of breeding animals | • Income Improved<br>• Social status improved<br>• Genetic resources conserved |
| Research Centers | • Technician backing in a form of training<br>• Data analyses and sire ranking and selection<br>• Enhance scaling up/out of CBBP<br>• Scaling up/out of CBBP | • Data sources for analyses<br>• Discharge responsibility<br>• Capacity development |
| Extension staff | • Technical backing in implementing CBBPs<br>• Complimentary intervention technical backing<br>• Scaling up/out of CBBPs | • Technical support<br>• Capacity building |
| Cooperatives | • Credit contract<br>• Market access<br>• Sire purchase and sale | • Increase in scale<br>• Discharge responsibility |

| | | |
|---|---|---|
| | | • Capacity development |
| Other Government offices e.g. Cooperative authorities; Micro finance | • Market channel<br>• Create new jobs e.g. in improved sire sale<br>• Ensure Credit access | • Discharge responsibility<br>• Income from loan from micro-finance institutes |
| Community Based Organizations (CBO) | • Mating groups setting<br>• Sire sharing set<br>• Communal grazing land sharing and management | • Convert CBO in development<br>• Social cohesion |
| Input providers and animals buyers | • Supply inputs such us medicaments, forage seeds; vaccines<br>• Procure sires for breeding and culled animals for slaughter | • Market opportunity<br>• Income improved |
| Enumerators | • Data recording and transmission to research centres<br>• Make a follow up the CBBP | • Employment opportunity<br>• Capacity Development |

Transforming subsistence sheep and goat production to become market-oriented businesses is crucial by introducing innovative approaches such us breeders' cooperatives (Gutu et al., 2015). Ethiopian sheep breeding programs suggests that sustainability largely depends on effective and well-functioning breeder cooperatives (Gutu et al., 2015). The cooperative institution provides audit, transfer skills in financial management and licensing of breeder cooperatives free of charge. However, the sustainability of the cooperatives should be ensured through empowerment of breeder cooperatives through continuous capacity building, access to credit, access to market and technical back stopping in data entry and analyses (Gutu et a., 2015; Haile et al., 2018). The access to market and credit fuels the profit margin of cooperatives and fuels the development initiatives. However, in the short run the breeder cooperatives are not expected to run breeding programs without technical support from research and extension (Gutu et al.,2015).

Therefore, government and private sector support in linking breeders' cooperatives to input supply, breeding animal multiplication and dissemination as well as markets is needed. Some breeder cooperatives such as in Bonga have been serving as a source of finance, facilitating ram sale for breeding and slaughter, ram selection, skill transfer and contributing to financing the community-based organizations such as construction of meeting halls, buying bond for the great renaissance Nile dam and supporting schools (Gutu et al., 2015). The breeder cooperatives empower farmers to make decisions at various stages of CBBP activities, that have impact to sustain the genetic improvement endeavor at smallholder farmers management situation. The experience in CBBP breeder cooperatives showed that, the initiative is run in a collaborative and cost sharing bases. The public intuitions and NGO are providing technical back stopping, offer ear tags and medicaments, provision of breeding sires to start the program and continuous supervision (Gutu et al. 2015). As cooperatives get matured, the financial contribution in a form of sire purchase, medicament purchase, seeds for forage development and cooperative offices and animal collection yard construction for breeding were covered by the breeder cooperatives through the revolving fund approach (Haile et al., 2019). However, the continuous skill development, technical support, enumerators recruitment, data entry and analyses remained the activity of the national extension and research centers to ensure sustainability (Haile et al., 2019).

To hasten the complimentary activities and benefit from genetic improvement, the private sector, including farmer cooperatives, veterinary drug suppliers, feed processors and traders should be linked with breeder cooperatives, that could play role in provision of inputs and services to support breeding programs (Haile et al., 2019). Primary role of the government is to create enabling environment to advance economic and social development of the citizens. Government commitment and support is essential for sustainability of CBBP (Haile et al., 2011). The political will and support expressed by government is prerequisite for assuring that, CBBP will be sustainable for longer than the duration of an externally funded projects (Mueller et al. 2015). There is strong commitment from Ethiopian government side to changing the scale of genetic improvement approach from centralized breed improvement to CBBP that has been emanated from the long-time investment of centralized breed improvement approach and corresponding poor return from centralized breed improvement investment (Haile et al., 2020; Gizaw et al., 2020). The involvement of the government can take different forms to advance CBBP and genetic improvement. Harmonization of CBBP with governmental development priorities and plans is important as these create enabling legal frameworks, for example subsidies, access to affordable credits and technical backstopping (Mueller et al., 2015; Haile et al., 2019). The Ethiopian Government has accepted CBBP as the strategy of choice for genetic improvement of small ruminants as explicitly indicated in the Ethiopian Livestock Master Plan (Shapiro et al., 2015). Government incentives such as accessing credits, providing land at subsidized prices and withholding tax during initial establishment years has encouraged investment and uptake of CBBPs which should be able to become long term and self-sustaining (Haile et al., 2019).

The commitment of regional governments in advancing CBBP is essential to genetic improvement and dissemination of the proven genetics. In this regard there is a variation among regions and projects sites in implementing CBBP. The follow up and commitment of the local and regional government in Bonga is exemplary which can be expressed in different forms. In Bonga, the regional government has started organizing cooperatives and started scaling-up the CBBP (Gutu et al., 2015). The Bonga sheep cooperatives have supplied breeding rams to different areas of the region as well as other parts of the country. The scaling-up effort in Bonga aiming to reach the wider region is being undertaken by Bonga research center. Haile et al. (2019), summarized national level, benefits from CBBP that include, among others, (a) Job creation for different value chain actors in the society, including women and youth; (b) Increase in productivity and income of the communities ultimately contributing to food security and livelihood improvement at national level; (c) Increased productivity and offtake rates leading to reduced prices of animal source food, hence an opportunity for consumption of animal protein that would reduce malnutrition and stunted growth; and (d) Support the national economy through export of live animals and meat. These benefits have encouraged government to invest in CBBP. It has been noted that, CBBP is widely implemented in small holder farmers situation. There is a need to put incentives by governments to encourage the private sector to advance CBBPs that could result in sustainable and yet rewarding benefit to all actors in the small ruminant value chain. The lead engagement of the government is putting enabling policies, access to credits, marketing and technical backing, gender and youth involvement and coordination of activities among the different regional states and the federal government to avoid duplication of efforts and wise use of genetic resources to ensure sustainability of the initiatives and benefits from the dividends of CBBP (Haile et al., 2019). In the short run, the cooperatives are not able to run the breeding program without technical support by hiring their own experts. Therefore, continuous technical support of the government to the cooperatives is crucial for sustainability of the program by considering the skill needed to run a breeding program. However, the frequency of visit and support may reduce as compared to the initial stage of implementing CBBP that will give more chance to hasten the scaling up process and reach more villages and ensure equitable benefit of the technology to the community. The expansion in coverage (villages and countries), the continuation of the initiative since 2008 to date, species diversification in coverage (sheep and goat in Ethiopia, Illama in Peru, Cattle in Burki Nafaso, Goats in Malawi, and Uganda and Mexico), the increase in total flock size and the increase in income up to 20% of sheep keepers is a good indicator for sustainability of community-based breeding programs. For example, in Ethiopia, the initiative started in 8 communities in 4 sites in 2008, increased in 2013 to 15 communities, in 2016 the number increased to more than 30 communities (One community can cover up to 100 farmers and more than 700 animals now. Through livestock and fisheries sector development, the plan is to cover 100's of villages in 4 regional states which is a good indicator of sustainability of the program and that paves the way for scaling up/out the technology (Haile et. al., 2019).

**Community-based program fits for low-input system**

Low input livestock production system is characterized by a system that depends on adaptive local stock, keep different livestock species, bases livestock improvement on internal inputs, the flock size is small (up to 13 heads in sheep in the highland), productivity per head is believed to be poor but responds well to good management, the community shares resources such as grazing land, water points and rams/bucks (Azage et al., 2013). Livestock management is traditional and heavily depend on the indigenous knowledge than borrowed ‘’modern ‘’livestock management practices from outside (Jahnke, 1982). The objective of keeping livestock is subsistence, for multiple purposes/cash, meat, milk, social benefits, manure for soil health, no insurance for loss of animals in various forms (Gizaw et al., 2013). The fear of inbreeding and poor genetic variability in small flock is perceived as unsuccessful for genetic improvement act in the face of conventional breeders in low input system (Haile et al., 2014). Breed improvement in small flock population which is the case in small holder farmers circumstance is not well perceived to respond for genetic improvement by conventional breeders working on centralized breeding schemes. As a choice, centralized breeding programs in a form of selective breeding and/or crossbreeding has been replicated from high input system and operated in low input system with little success (Gizaw et al., 2013; Haile et al., 2019). The distinction between conventional and community-based breeding programs is presented in Table 3, to understand the system for livestock production intervention.

Table 3. Typical characteristics of conventional and community-based livestock breeding programs

| Characteristics | Conventional Breeding Methods | Community-Based Breeding Programs |
|---|---|---|
| Geographical limit | Regional – inter-regional | Communities |
| Market orientation | Commercial Subsistence | Commercial |
| Agent of programs | Breeding company breeder organization | Farmer – breeder |
| Breeding objective | Defined by company – breeder organization | Defined by breeder – farmer |
| Breeding structure | Large scale, Pyramid | Small scale, one or two tiers |
| Genetic resources | International | Local |
| Infrastructure | Available | Limited |
| Management | Intensive – high input | Extensive – low input |

| | | |
|---|---|---|
| Risk taker | Company- farmer organization | Farmer |
| Decision on share of benefits | Variable | Farmer |

Source: Mueller *et al.,* 2015

Community based breeding program is operated and believed to be suitable in low input system. Community-based breeding (CBBP) is a farmer-participatory approach having common interest to conserve and improve their genetic resources under low-input production system (Mueller et al., 2015; Bhuiyan, et al., 2017). The results of CBBP in low input system and highland of Ethiopia is appealing (Haile et al., 2019; Mueller et al., 2020). They focus on indigenous stock and consider farmers' needs, views, decisions and active participation, from inception through to implementation, and therefore provide a participatory and bottom up approach. Community-based breeding programs cover a range of situations (e.g. Sölkner et al., 1998; Haile et al., 2018) but typically target low input systems and farmers within limited geographical boundaries having a common interest to work together to preserve and improve their genetic resources (Mueller et al., 2015). Community-based breeding programs are mostly managed by farmers themselves and stakeholders such as research, development agencies and governmental institutions are providing support and facilitation. Their success is based upon proper consideration of farmers' breeding objectives, infrastructure, participation, and ownership (Mueller et al., 2015; Haile et al., 2020; Wurzinger et al., 2011).

In low input small holder production systems, flock sizes are essentially small, and this makes the design of breeding programs difficult and there is a danger of inbreeding (Mirkena et al., 2016). Pooling farmers flock to make the flock size larger has contributed to ensuring genetic variability, reduce the risk of inbreeding and provides opportunity to assignee breeding sires proportionate to the breeding dam number that improves reproductive efficiency of the flock and ultimately improve genetic improvement in the flock (Mueller et al., 2020). Hence, selection is undertaken at community flock level, with the selected best sires shared among the community members thereafter. Designing of CBBPs is much more comprehensive than simply applying genetic theories to achieve increased productivity that makes the program suitable to low input system. Its implementation combines infrastructure, capacity development of national partners, community development, indigenous knowledge, and the opportunity to improve farmer livelihoods by creating integrated processes for productive breeding of adapted animals and the markets for their products. Indigenous knowledge of the community is considered at each phase of the CBBP activity. For example, the community decides how breeding sires are managed, how breeding objectives are set and how rams are shared and used in the program and in such communities the tradition of ram sharing is already existing (Haile et al., 2014). CBBP is robust, simple and flexible that contributed to implement in low input system. Haile et al. (2018) asserted that CBBP technology is easy to implement in local communities; requires little funding compared to centralized nucleus schemes. The technology develops confidence in local communities as it is based on existing management and breeding practices. The failure of earlier centralized schemes makes CBBP simple and fit to small holder management condition under low input system. CBBP uses a simple, flexible, follows cost effective performance recording, enumerators for data recording are recruited by the community to run breeding programs. Hence, CBBP is fit in low input livestock production system and has proved to be sustainable, attributed to participation of the farmer, long standing capacity building, institutionalization of the program and coordinated efforts of the stakeholders (details of sustainability is presented in section 4 of this paper). CBBP is run in cost sharing approach such that the farmers are managing the flock and the government and NGO are mainly involved in technical backstopping and initial finical support to buy rams and vaccinations and ear tagging of the flock (Haile et al., 2018). CBBP is run in farmers flock that combines improvement and utilization and the cost incurred is mainly covered by farmers such has feeding and overall management of the flock, that cuts the cost which would have been expensive when the selection was in centralized flock, which is expensive and not sustainable leading to interruption of the program. As a result, CBBPs have been successfully implemented in small ruminants using indigenous genetic resources of smallholders in countries of Latin America with sheep, goat and llama (Mueller et al., 2002; Wurzinger et al., 2013), with sheep and goat in Africa (Ojango et al., 2010; Haile et al., 2014) and with goat and pigs in Asia in low input system (Mueller et al., 2015).

The results of CBBP in low input system and highland of Ethiopia is appealing and promising (Haile et al., 2018; Mueller et al., 2020). However, the coverage as well as the little attempt in introducing CBBPs in pastoral areas where preferred breeds for export by slaughterhouses and live animal exporters are available (Getachew et al., 2020). The flock mobility, high flock size per household, very high temperature, frequent droughts and poor infrastructure in the pastoral system so far limits designing and implementation of community based breeding programs in pastoral areas (Getachew et al., 2020). This entails the fact that, CBBP approach in lowland and arid areas need to be piacular and hence, tailoring these programs to fit the pastoral system by considering its context need to be investigated (Getachew et al., 2020). The extension system working in highland may not also work in the pastoral areas, that may need a context specific extension system fit for arid areas. Mobile and strong extension system needs to be in place to facilitate input supply, health service, animal identification and pedigree recording, data collection and linking with market following their route. Establishment of an electronic data collection system supported by information technology is required to implement data collection (Getachew et al., 2020). Hence, the realization of CBBP in pastoral areas requires a CBBP model that fits the system, long term commitment and well-integrated activities among stakeholders working in pastoral areas.

# Results from CBBPs in Ethiopia:

## Social cohesion and economic benefit

From both technical and socio-economic evaluations, it became clear that the pilot CBBPs are technically feasible, socially acceptable, and financially rewarding (Mueller et al., 2015). Results of CBBP is not only improvement in genetics and productivity, it embraces also social, economic and livelihood changes. The wording ‘community-based’ is preferred to ‘village based’ for these programs because it implies deep social links and avoids restricting these programs to a simple demographic unit (Mueller et al., 2015). Hence, CBBP goes beyond genetic and productivity improvements and includes village social affinity and cohesion. Villages have social ties stayed over years, functioning in community resource sharing, funerals, local credits access and celebrating festivities in common. The social network plays major role in sharing of breeding rams and this needs to be given special emphasis in organizing of ram use groups. Community-based breeding programs usually involve communal ram sharing through different arrangements including ram groups and ram groups are arranged based on settlement pattern and the use of communal grazing areas (Haile et al., 2013). The settlement patterns have traditional Community based organizations (CBO) organized for social commitment which could be turned to accommodate breed improvement. In Afar, ram is considered as property of a given clan. Hence, CBBPs are built on existing social ties and indigenous knowledge within the respective communities that have created the opportunity to hasten the social cohesion and community livelihood improvement (Haile et al., 2014).

The social cohesion aspect can also be hastening in a form of income from sire sale for breeding and sale for slaughter that served to build infrastructure for social, economic and cooperatives service delivery. The breeding cooperatives in Bonga are engaged in many social activities and the income from sale of sheep has been contributed in meeting the needs of children for schooling such as buying of stationeries, school fees and school uniforms. CBBP work with both women and men headed households, although the number is in favor of men headed households. However, family member including women are involved in CBBP decision making and the benefits are usually shared among the family members although this needs detailed study (Haile *et al*., 2014). The project focused on sheep/goat breed improvement and gendered approach is limited that, women are rarely represented in the membership or leadership of the cooperatives (Gutu et al., 2015). The involvement of women in cooperative leadership and participation in decision making needs further strengthening in CBBP sites (Gutu et al., 2015). Villages in their neighborhood are celebrating religious festivals and weeding by slaughtering lambs for consumption that hastens the social interaction and communication. CBBPs participating villages slaughter 3 lambs per year as compared to non-participant farmers who slaughter 1 lamb per year (Gutu *et al*., 2015). The increase in frequency of contact during festivities of the community members accompanied by slaughters has in turn increased the social cohesion and interaction. The social and economic benefits incentivized the community members to promote CBBP in more villages.

Community based breeding program has economic benefits, which incentivized the programs and contributed to the sustainability of CBBP initiatives. The economic benefit has made sheep/goat farming once a side line activity for these farmers, which is now the main business and the linchpin of their livelihoods (Haile et al., 2020). The economic benefit is emanated from the sale of sires for breeding with in the cooperative and outside the cooperative and selling of lambs for slaughter through fattening. The study conducted by Gutu (*et al*., 2015), compared CBBP participant and non-participant farmers in terms of income, family food supply, social cohesion and flock size. The same study reported that, the participant farmers slaughter 3 lambs per year as compared to non-participant farmers who slaughter 1 lamb per year and pparticipants of the CBBP earned Ethiopian Birr 3,100 per household, per year, on average, while non-participants earned 2,486 (Gutu et al., 2015). This could be attributed to the improved production and productivity of the flock kept by members of the CBBP, resulting in more sheep for sale. The income from sale of lambs by participant farmers is 1.1. times better than lambs from non-participant farmers, indicating that sheep keepers are giving great value for improved genetics which could be a job opportunity that may lead to a new specialized job creating model in the traditional sector. The improved rams from CBBP participating villages were 2.5 times higher than rams from non-participating villages sold for slaughter. Hence, improved and a breeding ram was sold for around Birr 5,000, while a rams sold for slaughter of the same size fetched Birr 2,000 (Gutu et al., 2015). This clearly indicated that, the new job opportunity and business model has created which could be specialized and engage unemployed youth group and females in such a business (Haile et al., 2019).

The running of CBBP in resource deprived areas, known for crop failure and dependent for grain donation has changed to self-reliance by introducing CBBP (Haile et al., 2019). The participating households in Menz CBBP site have graduated from the government-run safety net and emergency relief programs. CBBP participating farmers are now use income from the sale of sheep to meet their subsistence needs (Haile et al., 2020). The income in a form of seed money from the project or members contribution is a means to capital accumulation of the cooperatives that served as a revolving fund to procure improved rams and retain in the community flock (Haile et al., 2014; Gutu et al., 2015). Return to investment in replicating CBBPs resulted in 5.1 USD per 1 USD invested (Mueller et al., 2019).

Increasing the dissemination of rams produced in a CBBP during the last 20 years generated an income from a flock (6,000 ewes belonging to 600 households in six villages) of about a quarter of a million USD (Haile et al., 2019). Increasing the number of rams through AI can further increase genetic progress and economic income (Mueller et al., 2019). Recent analyses of the genetic progress and economic benefit of sheep CBBPs out and up-scaling strategies in Ethiopia indicated that genetic progress and economic impact due to selection for weaning weight have created favorable strategies to replicating CBBPs and increasing the number of rams reaching core population (Mueller et al., 2019). In conclusion, the CBBPs were technically feasible to implement, economically rewarding as reflected in increased income and meat consumption and resulted in substantial genetic gain in biological traits (Haile et al., 2019; Mueller et al., 2019).

## Performance improvement

The increase in litter size, combined with the increased 6-month body weight, has contributed to the increased in income by 20% and farm-level meat consumption has also increased from one sheep per year to three per year slaughter (Haile et al., 2019). CBBP which is an emerging and alternative genetic improvement approach has an immense contribution in the increase in productivity and genetic improvement as depicted on some preferred traits by small holder farmers. For example, in three breeds, Bonga, Horro and Menz sites, six months weight (SWT), the major selection trait in CBBPs, increased over the years (Figure 1). Sheep in CBBPs have shown improved performance, such as lamb growth rate, lambing interval, reduced mortality and attract higher market prices compared to sheep/goats from non-CBBP farmers (Gutu at al., 2015). In Bonga, the average increase was 0.21 ± 0.018 kg/year, followed by 0.18 ± 0.007 and 0.11 ± 0.003 kg/year in Horro and Menz, respectively. This is quite substantial result for an on-farm situation. The increases were more pronounced in the larger Horro and Bonga breeds compared to the smaller Menz sheep (Haile et al., 2020). Based on current breeding practices, the genetic progress in SWT modelled for an average Menz CBBP resulted in 0.11 kg/year, accumulating 2.4 kg in 20 years from the initial live weight of 13.3 kg (Mueller et al., 2019).

This rate of genetic improvement measured in the CBBP is also progressively achieved by the base population which regularly receives rams from the CBBP nucleus flock. The annual discounted benefit of the whole system (CBBP + base population) increased over years up to about 15 years, then it became rather flat. The accumulated discounted benefit came to USD54,290 and overall, for each dollar invested in establishing one new average CBBP, more than USD 5.1 was obtained with the assumptions made and parameters used in the reference model (Mueller et al., 2019). The genetic trends for age at first lambing, lambing interval and litter size over the years were all significant, implying that the breeding program implemented with the communities has resulted in measurable genetic gains for the reproductive traits (Tera et al., 2021). The genetic trend for prolificacy and six months weight over the years in both Bonga and Horro flocks was positive and significant as depicted in Figure 2 (Haile et al., 2010). The genetic trend for birth weight did not increase and birth weight was not deliberately chosen as trait under selection to curtail dystocia that may arise because of higher birth weight. The genetic gain and the increase in productivity under local stock and resource poor community landscape paves the way to scale-up and scale-out CBBP in small ruminants with careful planning, implementation and monitoring.

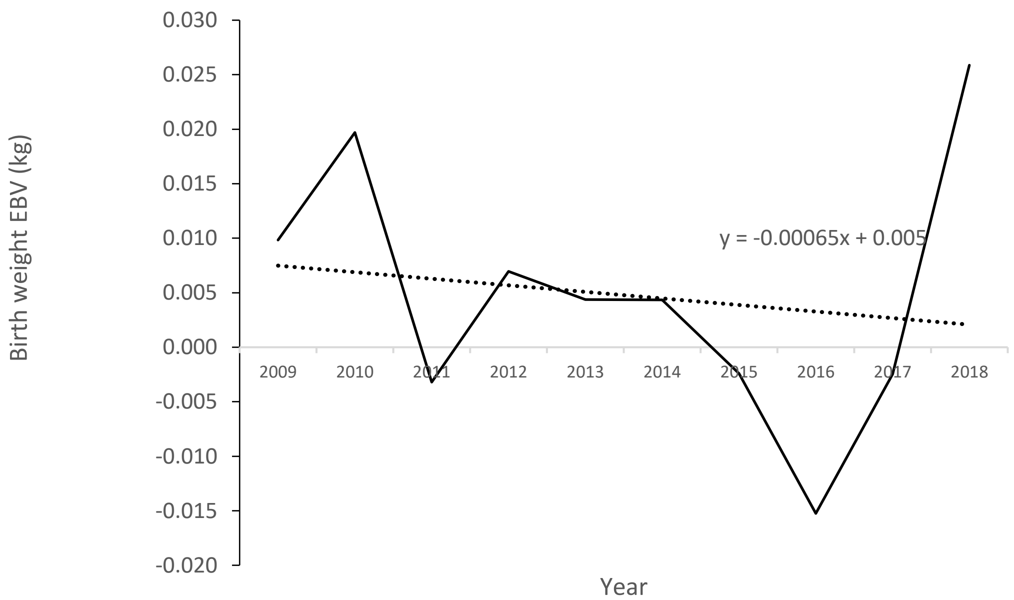


Fig 1. Genetic trend for Birth weight in Bonga sheep over years

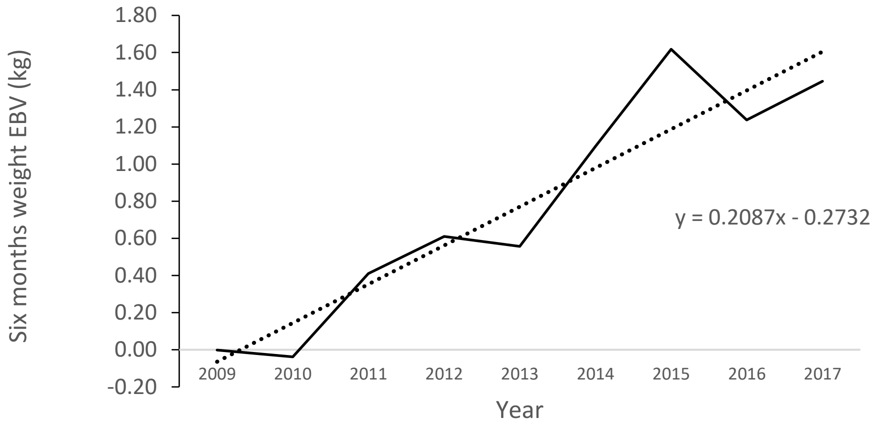


Fig 1. Genetic trend for six months weight in Bonga sheep over years

The estimated inbreeding coefficients obtained in CBBP sites was (< 1%) which is by far less than critical limit (6.25%) as recommended by Li et al. (2011). However, the inbreeding coefficient needs to be monitored continuously to prevent significant decrease in growth performance. (Haile et al., 2020). The estimated inbreeding coefficients reduction is a result of controlled mating, ram rotation and increase in flock size by bringing households who owned small flock sizes together (Haile et al., 2020). In the same study, it was also practiced that rams with the lowest relationship with ewes in the flock were used for mating. Rams that remained for two years in a flock were either sold as breeding animals to communities far from the CBBP sites or sold for slaughter to decrease the rate of inbreeding in the population. The breeder cooperatives have a contribution in retaining improved and good-looking rams through buying proven rams from the revolving fund schemes and they buy best rams and used for breeding (Gutu et al., 2015). As a result, “Best of stock” growing breeding lambs/kids, that were previously sold and slaughtered (“negative selection”), are now retained as the breeding stock (Haile et al., 2019). High demand for breeding rams from neighboring communities, other government programs and NGOs in all sites, provides the foundation for specific business models around production of breeding sires and semen for artificial insemination. In sum the dividends of CBBP include, genetic improvement by ensuring genetic gain, increasing productivity, reproductive management in a form of reverting inbreeding and keeping proper ram to ewe ratio.

# Delivery pathways for dissemination of improved genetics from CBBPs: Technological and institutional pathways

Genetic improvement is targeted to produce improved sire. Breeding sires have the capacity to breed with more ewes and the use of AI enhances the use of proved sires more efficiently in the breeding program. The ewes are needed for replacement and exerting selection pressure will end up reducing the number of ewes in a flock and ultimately reduce flock productivity. Hence, the delivery pathway focuses on proper distribution of the improved genetics and utilization of reproductive technologies to maximize the utilization of improved sires.

Improved sires should have as much progenies as possible to bring genetic and productivity increase at a large scale and bring feasible impact at a community level which can be witnessed by the community. Therefore, a proper, feasible and robust delivery pathway for improved genetics is necessary that should be part of the planning process. One of the constraints in centralized breeding programs is the loose in delivery system for improved genetics that failed to reach the wider community and inefficient genotype multiplication and distribution (Gizaw et al., 2013; Haile et al., 2010). The success of delivery pathways that meets the demand for proven sire requires a technology and associated functioning institutions (Mueller et al., 2015). Providing improved rams to the core or target sheep populations, which are those in the main production tract of the breeds is not manageable unless we diversify delivery pathways (Haile et al., 2019). The current supply of young rams from the Menz, Bonga and Horro CBBPs are 7%, 29% and 4%, respectively of the total needed (Mueller et al., 2018). The challenge of any population wide breeding program is to increase improved ram proportions or otherwise consider a lesser ambitious program with smaller targeted core population sizes (Mueller et al., 2018).

Reproduction should be optimized through adequate reproductive technology, feeding management and health care. Rams produced in CBBP are technologies that requires certification through certification development protocols. The certified rams should have a premium price to encourage the production of proven rams and reach out the core population. The certified rams should not be only restricted to natural meeting but also need to introduce AI to disseminate the desirable genes in the population and hasten the scaling up and scaling out efforts (Mueller et al., 2019), noted three strategies to increase the availability of improved rams: Increase the number of new CBBPs, increase the supply of improved rams per CBBP and increase efficient use of improved rams. Three strategies are further elaborated and the requirements of each strategy is presented us follows;

- Increasing the number of new CBBPs requires additional project staff for recording and extension work, additional identification and weighing supplies, larger coordination and supervision efforts.
- Increasing the number of rams supplied per CBBP requires participating farmers to enhance reproduction, recording and maintaining a higher proportion of male progeny till final selection.
- Increasing the use of improved rams through higher dissemination or through extending their use in time. Higher dissemination is possible through artificial insemination (AI). Increasing the age of ram disposal also leads to higher dissemination, although at the cost of an increased generation interval.

Artificial Insemination (AI) is universally represented as the most common technology that serves as an effective delivery path way of the improved sires and a vehicle to out and upscale the proven technology, proven ram. In this this regard, and with reference to the context of CBBPs in Ethiopia, Mueller et al. (2019) have identified AI, complementarity to natural mating, as one strategy to increase genetic progress and dissemination of proven sire in more intense way in community flock. Artificial insemination (AI) allows the use of fewer males and/or increase in the number of females served with improved males. Including feasible AI programs in current CBBPs helps to increase the rate of genetic improvement in existing CBBP sites or increase the dissemination of improved rams in base populations resulted in higher incomes but also in much higher costs. However, AI implementation and operation costs could be covered externally with a subsidy to small scale farmers (Mueller et al., 2019). As a result, with 50% of AI implementation and operation with a subsidy, return on investment for existing CBBP would increase from USD 2.3 to USD 3.4 and for a base population the increase is from USD 0.9 to USD 1.7 (Mueller et al., 2019). At the general flock level, AI allows extensive dissemination of superior genetics by cutting costs involved in AI programs so that only outstanding rams should be considered for AI, particularly if used at the CBBP level (Mueller et al., 2019).

Genetic superiority is guaranteed through proper recording and genetic analyses with appropriate tools, that may require quick and robust breeding value estimations techniques at a field level. In the same study, it was noted that, under natural mating in a period of 20 years, the genetic progress for six months weight is 3.6 kg and with inclusion of AI the genetic progress can reach up to 4.5 kg during the same period, however, the genetic dissemination due to AI implies very high increase in cost. AI using frozen semen in cattle is highly subsidized by the extension system in cattle in Ethiopia which can benefit also in small holder farmers keeping small ruminants till cooperatives are able to cover costs by increasing their income by selling proven rams in a premium price to the base population.

The development of technically and financially feasible field solution AI and affordable synchronization protocols may be an important step towards improving the delivery system of improved rams in disseminating proven rams by reducing costs (Mueller et al., 2019; Rekik et al., 2016). As part of the dissemination strategy of proven sires, ICARDA and local research centers have established seven low cost field AI labs in Ethiopia and the results of the technology in terms of cost and technical soundness needs to be evaluated for further scaling up/ out at a community flock level.

The capacity of the AI technician is also important in hastening the delivery path way of the proven genetics. Successful development of the capacity for mass synchronization and AI in small ruminants could have a large impact on the ability to disseminate and upscale the benefits from existing CBBPs (Haile et al., 2019; Haile et al., 2018). A continuous capacity building of technicians and incentivizing technicians based on successful delivery of lambs/ inseminating technician rather than number of inseminations/technicians may increase the benefits of the technology and delivery pathway. Incentive mechanisms introduced for AI technicians in cattle has yielded tangible results in terms of number of calves born per insemination across different technicians in Ethiopia which can be borrowed to small ruminants (Melesse et al., 2020).

Institutions are the main drivers of improved genetics delivery pathways in existing and new CBBPs in small ruminants. The institutions are categorized farmers driven initials or community-based organization (CBO), government managed organizations and NGOs. CBO are community driven organizations stayed over years with a community and which are set following settlements pattern and targeting to deliver social commitments such has social support which have been turned into to accommodate breed improvement programs in their local stock. Proven rams obtained from CBBP initiatives are used communally by forming 'ram-user-groups' and this was based on settlement patterns and the sharing of communal grazing areas (Haile et al., 2019). The use of existing CBO which were established to handle funerals and traditional festivities as a delivery pathway for proven rams is an innovation that hastens technology adoption.

Continuous technical and institutional support to cooperatives from national research system, NGO and extension service is crucial to ensure their sustainability and enhance delivery pathways (Haile et al., 2019). The coordination, alignment of interests, role sharing of institutions and regular monitoring and improvement are key in the proper functioning of CBBP (Wurzinger et al., 2020). Enabling policies, legal and institutional frameworks, and funding are seen as critical prerequisites to ensure the continuity of breeding programs and enhancing of delivery pathways (Haile et al., 2019; Lobo et al., 2019). Based on the report, Leroy et al. (2017) concluded that development interventions should promote coordination among livestock keepers by creating and empowering cooperatives, associations, or community-based institutions. Kaumbata et al. (2020) described the difficulties of CBBP scaling and concluded that it needs to be part of a breeding program's initial planning stages and delivery pathways should be planned at initial stages of CBBP activities. Coordinated action and alignment of interests are imperative to promote CBBPs from the innovation systems perspective. From the outset of community-based breeding programs, the understanding of the stakeholder network and institutional environment needs to be a primary focus as well as the facilitation of institutional learning and creation of ownership (Wurzinger et al., 2021). Delivery pathways in a form of technology and institutions are vital in disseminating best genetics that needs a critical analyses at each stage and sharpen the efficiency and effectiveness of CBBP through continuous monitoring and evaluation.

# Scaling opportunities and readiness of various actors in advancing CBBP

The dividends of the operation of CBBPs are recorded through production of the best genetics and corresponding dissemination of the best genetic material. There are three core production regions to disseminate the best genetic material such us initiating new CBBPs, adjusting the operation of existing CBBPs and improving or developing breeding links between CBBPs and general or core flocks (Mueller et al., 2018). Current CBBPs are primarily designed for improved rams to serve in own community. However, some additional young rams are produced and sold externally in Bonga Region and its number is however substantially less than the number required for serving the whole target sheep populations of each breed (Haile et al., 2018; Gutu et al.,2015). The scope of dissemination depends on the number of proven rams, associated technologies and coordination of operating institutions/sectors. The increasing the ram service period also increases the scale of operation; however, this increases the generation interval and genetic gain per year in the population (Haile et al., 2018). It has been reported that, from both technical and socio-economic evaluations, it became clear that the pilot CBBPs are technically feasible and financially rewarding, therefore it is important to solicit appropriate opportunities and models for up/out-scaling of CBBPs in relevant sheep production regions (Mueller et al., 2018). There are good opportunities to advance CBBP and improve the livelihood of resource poor and small holder farmers. The CBBP is majorly running the program based on local inputs such us indigenous breeds and under farmers production setting. The pilot CBBPs are based on local sheep named after their respective regions of origin and captures community indigenous knowledge that created a fertile ground for scaling up/out of CBBP (Haile et al., 2019; Mueller *et al*., 2015).

The huge number of core population, the number of breeds characterized for genetic improvement and the demand created to buy improved rams is opportunity to advance CBBP. There are more than 12 breeds of sheep and more than 13 breeds of goat in Ethiopia which could be an opportunity to run CBBP for genetic improvement (Gizaw et al., 2013; ILRI, 2014). The demand created for breeding sire can be considered as a good opportunity to scale-up CBBP sites for small ruminants (Gutu et al., 2015). A key marketing tool for CBBPs is to offer officially certified rams and farmers may be prepared to pay more for certified rams.

An attractive return on investment in up scaling CBBPs should motivate policymakers and development agencies to invest in the establishment of new CBBPs and create enabling distribution environment of more CBBP sires to general flocks and then policymakers may consider this rural employment opportunity as an additional motivation to invest in CBBPs (Haile *et al*., 2019).

There is a great opportunity to scale up/out CBBP in Ethiopia attributed to long standing experience in CBBP since 2010. The successful operation of several pilot CBBPs in both, sheep and goat breeds for more than 12 years in different regions. The breeding program and methodology has been tested and adjusted, the communication channels between stakeholders are working and positive results are already documented. A Guideline for setting up community based small ruminant breeding program has been developed for a wider use and circulation that can serve research centers, non-governmental organizations (NGOs), farmers' associations and livestock development projects and government extension officials (Haile et al., 2018). Thus, a positive working environment is already in place to scale out/up CBBP program.

## Lessons from CBBP and delivery Pathways

Community based breeding program in Ethiopia was introduced in 2009 by the International Center for Agricultural Research in the Dry Areas (ICARDA) in partnership with the International Livestock Research Institute (ILRI), University of Natural Resources and Life Sciences in Austria (BOKU), and the Ethiopian National Agricultural Research System. In Ethiopia, the implementation of community-based breeding programs (CBBPs) started with four communities representing different breeds and productions systems by now the program is part of the livestock master plan of Ethiopia (Haile et al., 2019). Over the last 12 years of implementation a number of lessons have been drawn and based on the lessons new innovations have been introduced and the lessons are also documented in manuals and scientific articles

(Haile et al., 2018). The notable lessons can be divided into technical, Institutional and Community engagement lessons.

## Technical lessons

***Robust tool development to set breeding objectives****:* Farmers have breeding objectives and identifying breeding objectives with appropriate tools is important to catch the interest of farmers and ensure high rate of adoption to the initiatives. There are many tools which can help define breeding objectives of communities, including structured surveys, choice card experiments, group and individual rankings bio-economic analyses or combinations of different approaches (Duguma et al., 2011). However, given the complexity, resource need and the ultimate output generated, own flock rankings offer the best option. This is very easy and allows the full participation of owners in choosing their best and worst animals from their flocks (Mirkena, 2010; Getachw et al., 2020).

***A breeding strategy in a small flock:*** The centralized breeding programs are arguing that genetic improvement through selective breeding in small flock and low input system is unthinkable. However, CBBP has disproved the notion and showed genetic improvement in a small flock and resource poor farmers context. The program persuades farmers and captures farmers indigenous knowledge and pool individual farmers flock to create large flock for genetic improvement based on shared communal grazing areas and water points. The flock size reaches up to 1780 and the breeding ewes reach up to 850 that would be sufficient to ensure genetic variability and improvement. The pooling of small flock has also reversed negative selection, fear of inbreeding is tackled and the best rams/bucks are now retained in the community flock for breeding instead of being sold for slaughter. The fear of genetic erosion in small ruminant is curtailed and genetic improvement through improvement and utilization is practiced which is a lesson that could be scaled up/out through critical analyses of the production system and past experiences in pilot programs. Selection is taking place in two steps such that, researchers are selecting rams based on breeding values and farmers are consulted to make decisions on rams selection and the combination of researchers and farmers knowledge is addressed to recommends rams for breeding in appropriate delivery pathways.

***Continuous capacity building and Monitoring and evaluation:*** It has been noted that, capacity development of the different actors, mainly farmers is extremely important for success of CBBPs. CBBP put capacity development and monitoring and evaluation as a major activity to ensure sustainability and continuous learning. Genetic improvement alone did not yield much improvement in productivity. Farmers were exposed to customized training topics such as basic animal husbandry, including health care, proper feeding, and selection practices.

Cooperative leaders were trained on leadership, financial management and bookkeeping. Tailored trainings were organized for different actors in CBBP. Local researchers were trained on implementation of CBBPs; focusing on data collection, management and analysis, animal ranking and sire use and mating plans; reproductive management and application of reproductive biotechnologies; flock health monitoring and health certification of the improved sires. It was noted again that, breeding programs need long-term commitment and support from different actors. Technical support from research and extension partners mainly in data management, analysis and feedback of estimated breeding values were crucial to ensure genetic improvement. Hence, gap based and customized training with proper certification was crucial in implementing CBBP that ensured the empowerment of farmers in individual and group bases.

***Performance recording for decision making:*** Centralized breeding programs believed that, record keeping, and genetic improvement is not possible under small holder farmers context. However, CBBP has demonstrated that, performance and pedigree data recording is feasible in CBBPs and small holder farmers context. A trained enumerators recruited from the villages in consultation of the community are able to handle the recording and transmission of data to research centers for data analyses. Enumerators are very crucial for data collection and day to day follow-up of the breeding programs. Public support is crucial for breeding programs. Governments should invest and hire enumerators over a longer period until the community becomes economically viable to absorb their costs. It was also learnt that record keeping to be simple and sustainable; agree on few/key economically important traits, especially at the start and align recording to routine practices (weaning, vaccination, sales etc).

Farmers were also aware of the importance of recording for genetic and productivity improvement to ensure their commitment and interest.

***Early planning on delivery pathways in CBBP initiatives:*** The mismatch between genetic improvement and delivery pathways in centralized breeding program has triggered CBBP to integrate a robust delivery pathway on the top of genetic improvement in the planning process. The mating groups is a grass root level institution that shared improved rams to end users and the breeding management is run by the villagers and rams are arranged based on settlement pattern and village grown community-based organizations. The mating group has contribution to multiply the best genetics developed from CBBP initiatives. Community based organizations are organized to serve as supporting organs in a form of credits and funerals. CBBP has used the existing CBO to distribute and enhance multiplication of improved genetics. The breeding cooperatives were established to enhance the delivery pathway, facilitating marketing of improved rams for core population and to sell rams for slaughter. The breeding cooperatives have bylaws and offered practical skills in managing cooperatives and accounting activities for transparency. The delivery pathway has also introduced field level Artificial Insemination of fresh semen to enhance the distribution of best genetics and improve genetic improvement and productivity in community flock.

***Affordable and sustainable:*** CBBP is affordable and sustainable attributed to the cost reduction using internal inputs and lesser use of external inputs. The participation of community members and leadership of the community leaders in managing CBBP has reduced the cost and ensured the sustainability of the CBBP initiatives. The research institutes and extension staff are providing a backup and the decision is made by the community that has contribution in sustaining the program through empowering the community. Coordination and role sharing of participating institutions and continuous monitoring and evaluation has contributed the sustainability of the program. A fresh semen is in use for Artificial Insemination rather than frozen semen which has a role for reduction of cost and enhancing affordability of CBBP in small holder farmers context.

## Institutional

In initiating CBBP in villages, farmers driven and government led institutions were active and functional to run CBBP which have contributed to sustainability, functionality and institutionalization of the program. Breeders cooperative have clear by-laws and formal organizational structure for success of CBBPs. The committees are responsible for effective functioning of the breeding cooperatives and roles and responsibilities are shared among the committees. Breeder cooperatives are legally registered and governed by their by-laws and members abide by their rules. We noted that, legally registered cooperatives had better management and financial resources, better selection and management of breeding rams. Coordination of government led, and farmers driven institutions were crucial in implementing CBBP in villages. The day to day follow-up of CBBP including data collection is done by enumerators monitored by the community and extension and research staff. The research team follows the activities on the ground including compilation of data collected by enumerators and estimation of breeding values and assist in selection decision. The research team also liaises with the CGIAR staff on technical and financial matters. The close interaction of government and farmers driven institutions helps develop trust among the partners for similar interventions. The injection of revolving funds from projects at initial stages, helped the cooperatives to purchase young sires that can be used for breeding. The revolving fund continued through the contribution of cooperatives and project support in offering fund pulled out to ensure the sustainability of the program.

## Community engagement

Communities have seen some benefits from CBBPs for their engagement in terms of increase income, social cohesion and created new employment opportunities in selling improved rams to core population. Within-breed selection schemes have resulted in genetic improvement, improved productivity and profitability. It was noted that, short- to perhaps medium-term returns on investment was recorded from non-genetic gains, such as improvement in feeding, disease control and better reproductive management. Genetic improvement is a long-term investment that should be complemented with market linkage, feed intervention, reproductive management and disease control. Therefore, genetic improvement effort should be part of an overall livestock development agenda across the whole value chain by engaging the community in all stages of CBBP implementations. Community engagement in CBBP is demonstrated in ram management.

The communities have developed different systems of sharing rams and management of the potential candidate rams. For example, in Bonga, following the purchase of potential candidate rams, the cooperative leaders decide who keeps the ram depending on the number required in the mating group, individual experience in managing rams. The farmer manages the communal rams for the period the ram is in service, and thereafter when the ram is sold the profit realized from its sale (i.e. the difference between the cost when the young ram was bought and when sold) is shared between the farmers and the cooperative.

# Future directions and recommendations

Community based breeding program was initiated in Ethiopia since 2010 and lessons were drawn in terms of technical, organizational and coronation to advance the initiatives. However, the program should be dynamic and able to cope up with contemporary issues and foresee future challenges and prospects. The future direction can be enlisted as follows to advance CBBP in the future.

***Expand the lessons for CBBP in different agro-ecologies:*** Community based breeding program is expanded in highland and midlands in small ruminants and there is a gap in expanding the CBBP in pastoral areas, where local breeds are reared by pastoralists and small ruminants are highly preferred for export, slaughterhouses and live animal exporters. Therefore, CBBP should devise a system that considers flock mobility, high temperature, frequent droughts and poor infrastructure in the pastoral system to implement community-based breeding programs. Mapping of pastoralist and herd movement pattern is crucial to implement CBBP. This includes movement period, distance they travel and way of movement (is the group members sharing breeding animal in permanent place move together or not). Mobile and strong extension system fit to pastoral areas needs to be in place to facilitate input supply, health service, animal identification and pedigree recording, data collection and linking with market following their route. Establishment of an electronic data collection system supported by information technology is important to implement data collection, analyses, sire selection and dissemination of improved genetics.

***Expand the lessons for CBBP in different breeding programs :*** Crossbreeding was mainly initiated in small ruminants and dairy cattle to increase productivity in Ethiopia. The program was not successful due to poor delivery pathways in ram distribution in sheep and Poor Bull/AI services for dairying. The blood level of community Herd/ flock is not traceable unless we use molecular. The genetic admixture in Menz sheep and wollo sheep is exemplary between indigenous and exotic breeds that needs a unique community based breeding model leadings to synthetic breed formation through extending selective breeding of the mixed population. Communities possessing flocks with admixture blood level can be identified through molecular techniques and CBBP model should be planned to produce a branded synthetic breed ready for export and local markets. The target population will be in Wollo sheep and Menz sheep where extensive crossbreeding is implemented through the research and extension system.

***Extending CBBP in cattle, chicken and camel:*** CBBPs are more frequent in small ruminants than with cattle, camel and chickens. The experience in CBBP implementation in small ruminants can be extended to other species. The demand for meat and milk is not met by improving small ruminants alone. There is a need to extend good experience of CBBP in small ruminants to cattle, camel and chicken. A CBBP model should be developed that fits to cattle, chicken and camel and contribute in filling demand for animal production.

***Engaging Universities to scale up CBBP and exploit dividends of CBBP:*** The involvement of Universities in extending CBBP is dismal, given the availability of critical mass, budget, and community engagement activity. We need to encourage Universities to establish CBBP sites in the university doorstep that will serve as learning site, source of longitude data to run post graduate program, genetic improvement of local stock, contribute to increasing farmers income and make community services impactful and ensure the sustainability of CBBP. We also recommend integrating CBBP in course description, course outlines and modules and handouts that makes the curriculum relevant and improve quality of education. The lesson from this exercise will expand in other curricula and develop a culture of integrating local data and emerging scientific evidences in the curriculum and ensure the dynamic nature of the curriculum.

***Robust and simple data recording, analyses and farm level decision in ram selection is needed:*** Genetic improvement requires data recording. Date recording should be simple and fit under small holder farmers situation. The data recording in CBBP was simple and the analyses was also in the capacity researchers in the proximity of CBBP villages. However, there is a need to make data recording simple by introducing mobile application, simple and field level analyses to ascertain the genetic worth of the sire and recommend for multiplication.

***Foster Gender participation:*** Community based breeding program work with both women and men headed households. The benefits from CBBP are usually shared among the family members. However, the involvement of women as active membership and leadership in cooperative organization is dismal. Hence, there is a need to integrate gender approach in CBBP villages to benefit rural women and ensure equity and sustainability of the CBBP initiatives.

***Diversification of Delivery pathways:*** Community based breeding program can be more effective through strengthening of delivery pathways by producing certified rams witnessed by the community, expanding AI and synchronization of estrus with affordable price, provision of subsidies and efficiency. The capacity and incentives AI technicians and coordination of partnering institutions is crucial. Therefore, there is a need to give more emphasis to delivery pathways in terms of technological efficiency, policy support, institutional support, affordability, and sustainability. ***Engaging the private sector to advance CBBP beyond small holders:*** CBBP was run under small holder farmers' situation. The engagement need to be supported by specialization that stretches from selling breeding / proven ram to fattening of the rams not selected for breeding. Privates sector enjoyment and commercialization of small ruminants could be possible through organizing unemployed youth group, breeder cooperatives/ Unions and commercial farms with extensive land and capital by providing need based capacity building on CBBP value chains and entrepreneurship and ensure the access to credit and market linkage. Ensuring the synergy and linkage between small holder farmers, youth group, breeder cooperatives and commercial farmers is crucial to expand CBBP practices.

## Conclusion

Small ruminant breeding program development is underway through CBBP in Ethiopia, Since 2010. The program captures farmers indigenous knowledge, participatory in nature, decision is bottom-up, the program is sustainable and runs in a coordinated manner by NGOs, government and farmers driven institutions. The long-term commitment, farmers' participation, formation of farmers' organization and supporting services from the research institutes, government livestock development office and cooperatives are essential for the sustainability of breeding programs. Community-based breeding program are technically feasible to implement, economically rewarding, socially acceptable as reflected in increased income and meat consumption and resulted in substantial genetic gain in biological traits and economic indicators. The premium price offered to improved rams is an indication that, farmers are aware of best genetics that could be a new employment opportunity to engage unemployed segment of the society. The program is in a pilot stage that requires a wider coverage in different species, varied agro-ecologies and business models. Community-based breeding programs are an attractive and alternative option to achieve genetic improvement of small ruminants in low-input systems. Investment by the public and private sectors in small ruminant breeding programs so far has been minimal, and therefore, this is an area that needs investment attention. It is recommended that the government to invest in CBBPs as opposed to the often-unsuccessful centralized nucleus schemes involving cross- breeding with exotic reeds. Incentives by governments for private sector investment in CBBPs could result in sustainable and yet rewarding benefit to all actors in the small ruminant value chain. The expansion of the CBBP from a pilot stage to wider stage through scaling out/up and devising appropriate delivery pathways is recommended to benefit from the initiatives.

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