The Pathway to Genetic Gains in Ethiopian Dairy Cattle: Lessons Learned from African Dairy Genetic Gains Program and Tips to Ensure Sustainability

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Abstract

In recent years, information and communication technology, and genomic tools have respectively enabled crowd-sourced herd performance recording and fastening of genetic gains in dairy cattle. The African dairy cattle genetic gains (ADGG) program is a collaborative effort of International Livestock Research Institute, Livestock Development Institute, and other national and international partners to foster sustainable genetic improvement. The ADGG program has developed and implemented digital herd performance recording tools, national dairy recording platforms, digital extension services, and genomic evaluation pipelines for Tanzania, Kenya, and Ethiopia. The initial program's target was to register 12,000 dairy herds in each country, however in Ethiopia's in 98 districts and 6 regions, more than 74,500 herds and 157,000 animals had been registered by July 2022. The volume and diversity of data being captured by national dairy database is steadily growing. For example, today 440,000 test-day milk yield and 313,000 body weight records have been captured. The above data has been used to undertake the first genomic evaluations, results of which have been publicized in the national Cow and Bull Catalogue for the locally bred but genetically superior bulls and cows. Three of the top ranked bulls have been recruited into the National Artificial Insemination (AI) center for broader use nationally. So far, a total of 67,000 semen straws have been extracted from these bulls and are being used to breed cows and heifers in 14 districts of Ethiopia, thereby not only benefiting many local smallholder dairy farmers, but also significantly saving the country foreign exchange which would otherwise have been used to import bulls and semen from outside the country most of bulls may not be as locally adapted and genetically superior. The great achievement has been realized due to existence of systematic animal identification and consistent performance recording, both of which are crucial for sustained national genetic evaluation, identification, and use of genetically superior and locally adapted dairy breeding stock. Furthermore, identifying roles and responsibilities, and strengthening collaboration among key dairy actors and strong government leadership and support are mandatory to build sustainable breeding program.

Key words: Genetic gains, sustainability, dairy actors

Background

Ethiopia's human population is growing at an estimated rate of 2.57% per year and is predicted to reach 205.4 million by 2050 (https://www.worldometers.info/world-population/ethiopia-population). Nearly 40% of Ethiopia's human population are below 14 years of age and would naturally demand higher amounts of animal source foods. Given the fast-growing human population in Ethiopia, it is imperative that significant increase in agricultural productivity, including livestock, in order to meet the national food and nutritional security needs. Better (i.e. more productive and resilient) genetics is highlighted as the desired goal in the Ethiopian Livestock Master Plan and Livestock Sector Analysis as one of the interventions for increasing livestock productivity (Shapiro *et al.,* 2015; 2017). The Ethiopian dairy sector development is one key area of focus for sustainably providing high-quality animal protein. Selection based on genetic merit enables milk production per animal to be increased whilst reducing the number of unproductive cows (Brito *et al.,* 2021). Innovative application of existing and emerging digital, genomic, and reproductive technologies provides pathways for identification and rapid and steady delivery of locally adapted improved genetics to smallholder dairy farmers.

In the past, dairy cattle genetic improvement research and development programs have been implemented by various actors in Ethiopia (Gebreyohanes *et al*., 2021b). However, demonstrable related best practices, especially in the application of new technologies and knowledge leading to scaled improvement, have been rare. The ADGG program implemented by ILRI, the Ministry of Agriculture (MoA) and Livestock Development Institute (LDI), picked up digital and genomic solutions as complementary technologies to catalyze dairy cattle genetic improvement programs in Africa, initially in Ethiopia and Tanzania. Ongoing efforts need to be scaled up to attract long-term resourcing, investment to realize sustained genetic improvement. Additionally, creation of pooled funding mechanism for genetic gains, through broader range of partners contributions, towards shared goals is the way to go. Moreover, aligning dairy genetic improvement initiatives with the national programs such as Agricultural Growth Program and other national breeding strategies ensure longer-term resourcing and on evidence basis, informs the development and implementation of national breeding policy and strategies by the Ministry of Agriculture. Design that integrates new technologies and innovatively apply the relevant old ones, for the purpose of

optimizing performance of dairy cattle are critical. This paper presents and discusses the key lessons learned in the Ethiopian component of the ADGG program and recommends how sustainable genetic improvement program can be further built and sustained in Ethiopia. It also outlined the roles and responsibilities of public, private actors, and development partners in implementing sustainable genetic improvement program.

ADGG program: Lessons learned

The establishment of a centralized and organized national dairy cattle performance recording in Ethiopian history dates to 2012 with the initial support by the Natural Resources Institute (Luke) Finland and subsequent entry of, and merger with the ADGG program in 2016. The ADGG program is addressing the challenges that smallholder dairy system current face by innovatively applying ICT and genomic technologies for data capture, digital extension education and genomic evaluation for selection of top ranked animals. The program's key activities are presented and discussed elsewhere by Gebreyohanes *et al.*, (2021a). The program is being implemented in 65 districts from Southern Nations, Nationalities, and People's (SNNP), Oromia, Amhara, Sidama, and Tigray regions, and Addis Ababa city administration. Through these collaborative activities over the past ten years, above 74,500 dairy farms and 157,000 dairy animals are identified and registered in the national database (Table 1). The distribution of registered animals nationally is mapped in Figure 1, while dairy cows represent more than 75% of all the animals registered on the platform (Figure 2). The national dairy database consists of a variety of phenomics data (i.e., milk yield, calving, artificial insemination (AI), and bodyweight records) and are presented in Table 1.

Table 1: Number of registered farms and animals, and recorded animal events in Ethiopia's National Dairy Cattle Database

	Registered			Animal Event			
Region	**District**	**Farm**	**Animal**	**Milking**	**Calving**	**AI**	**Body Weight**
Addis Ababa	5	601	9445	46697	5986	1902	6513
Amhara	24	25335	45844	94599	22064	54344	93925
Oromia	36	18810	57664	200324	39475	35931	141627
SNNP	16	11588	15426	46216	9715	17332	23883
Sidama	5	4819	7625	25003	6050	7371	21740
Tigray	12	13413	21396	27792	10154	52805	26262
Total	**98**	**74566**	**157400**	**440631**	**93444**	**169685**	**313950**

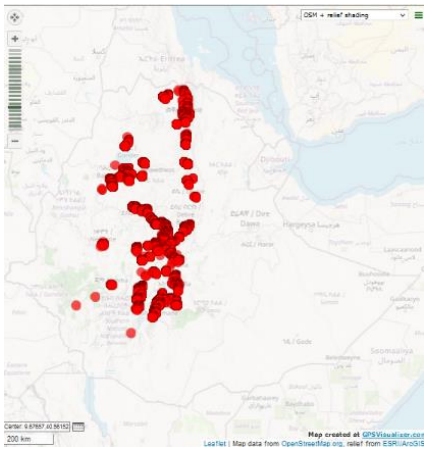

Figure 1: Distribution of ADGG registered farms in Ethiopia.

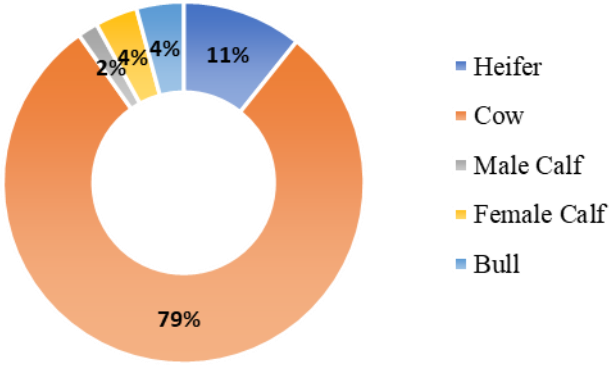

Figure 2: Percentage of dairy cattle by animal type registered in national database.

Digital data capture tools and ICT-based farmer education

The ADGG program customized and deployed offline Open Data Kit (ODK) and another of open access web-based digital tools to capture environmental and relational data among animals, and to continuously record individual animal performance from both smallholder and large-scale farmers (Gebreyohanes *et al.*, 2021a). The tools comprise modules developed to capture information mainly farm and animal registration, test day milk yield, milk quality, Somatic Cell Count (SCC),

fertility, and growth from dairy animals. Most recently, a sensor technology was introduced to measure and predict milk quality and SCC using machine learning algorithms. This initiative has been buoyed by increase in the number of mobile phone subscribers in Ethiopia, which is expected to reach 40% of the population in 2025 (GSMA, 2021), thereby opening up more space and opportunities for use of digital tools and platforms and greater impact in the dairy sector.

The program guides dairy farmers through a digital advisory system (Mrode *et al.*, 2020) implemented in collaboration with iCow (http://www.icow.co.ke) through which a total of 26,500 farmers received educational messages and 5,300 farmers have received cow-calendar based messages. Over time, more than 10,000,000 educational and 165,000 cow calendar-based messages have been disseminated to farmers. Additionally in collaboration with Farm-ink four digital training courses have been developed for dairy farmers in East Africa (https://www.ilri.org/news/dairy-genetics-gains-platform-launches-dairy-e-learning-tool-farmers-across-africa).

Generation of genotype data and genomic evaluation

Hair samples have been collected from 8,500 dairy animals, and then genotyped in two rounds. The genotype data has been used to estimate breed composition, and where possible to generate genetic relationships among animals, and to aid genomic evaluations as well as offering opportunities for other genomic studies. The feedback on breed composition/proportions in the genotyped animal were communicated to farmers to enable them to know their animals' breed compositions and help them adjust overall management to match the animals' genetic makeup. From the national dairy cattle genomic evaluations, a list of top ranked dairy animals was generated and digitally published in the first catalogue ever in Ethiopia, available on CGSpace (https://hdl.handle.net/10568/113069). A mobile based application that enables farmers and breeding technician access the animal catalogues was developed and availed through google play store (https://play.google.com/store/apps/details?id=org.ilri.adggcatalogue&hl=en&gl=US).

Identification of the locally bred and genetically superior bulls and cows was achieved through partnering with thousands of smallholder farmers who provide performance data of their cow and

herd records to national performance recording platform (Picture1 and 2). The genomic estimated breeding value (EBV) of farmers' top ranked bulls were comparable with some imported pure exotic AI bulls in addition to ranks of bulls born through contractual mating of exotic sires on large scale dairy farms (Negussie *et al.*, 2022). Identifying and publicizing top ranked animals is opening doors to dairy farmers to sell breeding bulls and cows at a better price.

Publication of the national bull and cow catalogue and listing of the cow ranks has increased the farmers' bargaining powers, in that the sale prices for their certified top ranked animals have significantly increased. Three locally bred and adapted top ranked bulls owned by farmers were examined and qualified for health and breeding soundness and were promoted to the AI center for national use. Through ADGG, the semen collected from the elite bulls are currently being disseminated to farmers in 14 selected districts since March 2022 to produce future replacement heifers in smallholder farms, thus enable farmers to benefit more widely from the intended genetic gains. Besides, bulls that pass through such genetic evaluation will also be used for breeding replacing the uncontrolled indiscriminate breeding. Most smallholder farmers raise their own replacement heifers and thus, maximizing use of top bulls through private and public AI service delivery is an entry point to improve the smallholder dairy genetics.

So far, a total of 67,727 semen straws have been produced in the last one year from the three locally born and adapted bulls. Currently, the average cost of each straw is about 20 ETB (equivalent to $0.38) at LDI AI center. The total cost of all the semen straws produced so far is about $25,800. In contrast, the average cost of each imported semen straw of Exotic dairy breeds is about $10 and therefore, the total cost will be $677,270 for 67,727 straws. The use of the three bulls has resulted in saving in foreign currency of $644,200 through import substitution.

Picture 1: Example of top ranked cow (ET000008265) of Tsige dairy farm, Debre Libanos, Oromia region (photo credit: ILRI/Apollo Habtamu)

Picture 2: Examples of top ranked bull (ET000009717) of Mola Erekeyehun farm, Adama, Oromia region, Ethiopia (photo credit: ILRI/Apollo Habtamu)

Capacity building

The project has been strengthening the local infrastructure and human resource capacity to sustain ADGG vision beyond the project life. Infrastructural capacity has been created at LDI and 65 districts to build sustainable dairy cattle performance recording center in the country (Gebreyohanes *et al.*, 2021a). Short term trainings are provided to performance recording agents and AI technicians to use the ADGG platform on data capturing and feedback provision to farmers. Further, four series of advanced genomic evaluation trainings have been delivered to 15 researchers and graduate students to ensure the continuity of the national routine genetic evaluation program. Additionally, the program avails analytical software, data, and technical support to 5 PhD graduate fellow from three Ethiopia's agricultural universities, namely Addis Ababa, Haremaya and Hawassa universities.

Dairy farmers testimonies - Highlights of what the farmers' views on ADGG program

In the ADGG registered regions, willing dairy producers are participating in the national dairy animal identification system and keep and share performance records of their dairy animals. The platform has provided huge opportunities for dairy farmers to interact and exchange knowledge with scientists, industry experts and each other. The following are a few quotations on what farmers are saying about ADGG:

a) Adugna Kassa Bahir Dar Zuria, Amhara region:

Adugna said I read and implement the SMS message. "I improved the housing structure, allocated 0.25 hectare of land for improved forage. I managed to cultivate Elephant grass to feed lactating cow and calf. Milk production is increased, and calf mortality is reduced" he claimed.

b) Taye Negussie, Wondo Genet, SNNP:

Taye said many times different government and projects applied permanent marker labeled ear tag (temporary) for synchronization and other activities. Currently, all bodies refer the same number after my dairy animals tagged with the national nine digits printed ear tag. "I feel identifying animals' nationally is a sign of civilization. Additionally, I am always keen to read and implement the SMS real time messages. For instance, I received message to check the pregnancy status of "ET000787673" cow and immediately I called technicians for checkup and the cow is confirmed positive."

c) Adelegn Ashagre Bahir Dar Zuria, Amhara region:

He said identifying animals by national ear tag number is helpful to get AI service and keep performance record by their identification number. Pedigree information and performance of animals were not recorded in my farm. However, after joined ADGG program I realized that record keeping is important to refer each animal's information for management decision in my farm. Additionally, monthly visit by performance recording agents hired by the project and advise on feeding and overall dairy husbandry practices helped to improve conventional practices.

d) Warsamo Lebeso, Wondogent, Sidama region:

"Recording the performance of the cow on the cow card helps to compare their production of milk across lactation and with other lactating cows. Besides, I continue to learn a lot from digital message received in my mobile phone and the message is short that is incredibly good to read and understand quickly" Warsamo said.

e) Mastewal Mesganaw GGK farm manager, Ada'a district, Oromia region:

Mastewal stated that the farm has no animal identification system prior to joined the national performance recording system. With a larger herd size, we can't recognize the dam and sire of calves. Keeping history of animals are helping to identify productive animals and decided which animal to be culled from the herds.

f) Mola Erkyehun, Adama, Oromia region:

He stated "I am happy that my bull "ET000009717" won the competition. I see one of the fruits of dairy farming in one decade journey and proud to be part of the national performance recoding scheme and serving the community by sharing the best genetic of my selected bull"

Roles and responsibilities of actors in building and implementing a sustainable national dairy cattle genetic improvement program

A sustainable breeding program for livestock should include defining the production system and the breeding goal, strengthening, and unifying the national recording system, undertaking appropriate animal evaluation, and building well organized structures for the dissemination of improved genetics. It is important to note that there is no one size fits all breeding goal for the different economic, social and production system and countries. In Ethiopia, the first proof of genetic evaluation was published in 2019. This was later updated in the first genomic evaluation in 2021 through collaboration of ADGG and other national and international partners. Test day milk yield was the only trait included in the initial breeding goal for selecting best animals, because that was what the available data could support. As more data becomes available, the Ethiopian national genetic evaluation will increasingly incorporate and include other traits such as, reproduction, milk quality, body weight as a proxy for maintenance requirements, welfare, and resilient traits in the breeding goal and appropriate selection indices will be developed to appropriately assign the economic weights for these traits. The national dairy genetic improvement program can be improved through new ways of recording (time saving and less expensive technology) and analyzing combined traits, biotechnology, and reproductive tools. Further an increased knowledge of genes and their regulation may improve the genetic selection strategies and have a large impact on genetic evaluation programs.

Currently, the Ethiopian dairy sector development strategy is dependent on imported genetics and is aimed at the quick increase in animal productivity through continuous upgrading towards pure exotic commercial dairy breeds. However, sustainable genetic improvement requires continuous availability and use of more productive and adapted breeding stock. Therefore, systematic animal

identification and regular performance recording is crucial to reduce unnecessary large imports of genetic material (mainly Holstein Friesian and Jersey) from other countries that have low, or no weighting on tropical adaptation in their breeding objective. It is worth noting that the proportion off identified animals participating in routine performance recording compared to the total cattle population is currently low (only few voluntary dairy producers are part of the national program). Therefore, increased collaborative efforts by the key actors i.e. MoA, dairy producers, farmer associations/cooperatives, service and input providers, AI centers, development organizations, and National Agricultural Research and Education System (NARES) to promote dairy cattle genetic improvement is needed.

Government institutions

In developing countries, government institutions play major roles in establishing, supporting, implementation and often leading genetic improvement programs and dissemination of genetic progress (Martyniuk *et al.,* 2021). In Ethiopia, most dairy cattle genetic improvement activities are overseen by government institutions. Dairy breeding extension services, research, and adoption of technologies are handled under government organizations. Therefore, the public institutions such as MoA, LDI, regional livestock offices, and NARES are key actors in designing and implementing sustainable genetic improvement programs. For instance, LDI is managing the printing and distribution of national dairy animal identification system and implementing on the establishment and scaling up of national dairy cattle performance recording scheme across the country. Besides, five AI centers located in four regional livestock agencies and LDI are the only responsible body for recruiting and procuring bulls (in country and abroad), producing, and distributing semen and liquid nitrogen. The MoA also imports and regulates import of semen, largely from Europe and America.

A national breeding strategy will only be successful if there is a vibrant farmer-based breed organization or association that share roles and responsibilities. It is important that the organization be equipped with the resources necessary to carry out its responsibilities and tasks. The structure of the MoA at region, zone and district level should provide educational and technical assistance to cooperatives to strengthen the economic position of dairy farmers.

The NARES' role in supporting breed organization and operation of cooperatives, thus enabling them to effectively participate at the national genetic improvement program levels is critical. Establishment of National Dairy Development Board (NDDB) to offer overall support to dairy producers is urgently needed to the country. The NDDB would be an autonomous body established by government. The NDDB will be responsible for establishing, strengthening, resourcing, and technically supporting by providing policy design and implementation of the dairy sector. Through all these functions, farmer owned organization would increase the national milk production for self-sufficiency and export market. The board will also contribute to the national genetic improvement program by empowering farmer cooperatives and re-channeling some of the related tax incomes back to directly finance breed improvement and related research.

Additionally, government can play a vital role by facilitating access to credit and other financial services such as credit guarantees to dairy producers, cooperatives, and private sectors and provide a supportive policy environment for private-sector participation. The government should link financial services such as credits, collateral agreements, and any other service to the national database referring on the availability of data of dairy animals and farms.

Private-public partnerships required to ensure that government plays an appropriate role, and that the private sectors enjoy a level playing field and conducive environment for doing profitable business in dairy cattle breeding input and service provision. For instance, telecom company can attract dairy farmers by lowering the costs to access digital farm extension services and sending data to the national database. The government should gradually swoop roles with the private sector by supporting cooperative/private entities to take over roles that are currently solely being played by the public sector. In addition, the government should avoid duplication of efforts by assigning different regulatory authorities to clear operational boundaries along the dairy value chain actors. Finally, integrated interventions in the areas of feed, and health besides genetics are mandatory to improve productivity of dairy animals.

The role of private sector actors

In Ethiopia the contribution of private sector to dairy cattle genetic improvement is quite limited. Few private sector actors are participating in the genetic improvement, and even then, on very limited capacity. Most of the private actors are involved in importation and to small extent delivery of exotic bull semen, the later through AI. Some of these actors also import pregnant heifers, while very few locally breed and sell heifer and breeding bulls.

Despite the different roles that farmer cooperatives could play, currently most of their support focuses on fluid milk collection and transportation to private milk processors and only few cooperatives have their own processing facilities. Sustainable national genetic improvement program can be strengthened by the cooperatives ability to collect data, provide inputs and services. To ably do this, the cooperatives capacity will need to be built and /or strengthened. For instance, AI services and semen production could be undertaken by private companies under a public-private partnership model. Private investors need to open their eyes and seize the opportunities that exist or emerge to invest in input and service provision in dairy sector, breed improvement activities included. It is through increased private sector participation that sustained improvement in the national milk productivity and substitute importation of milk powder would be achieved.

Cooperatives have been identified as key institutions in national plans to foster rural economic development (Chagwiza *et al.*, 2016). Chagwiza *et al.*, (2016) recommended that cooperatives can be regarded as suitable business institutions to foster improved livelihoods, food security and rural economic development in Ethiopia. Besides, cooperatives can serve as vehicles for the dissemination of breeding technologies, access to a range of inputs and market services, thus significantly benefiting their members. Besides, cooperatives can be entry points for farmers to receive government subsidies, donor funds and direct research and development services and information. For instance, dairy cooperatives can assist their members to identify animals and participate in the national performance recording platform. Therefore, dairy cooperatives can have spinoff effects that benefit implementing structured genetic improvement program in the country. Farmers tend to trust their own associations/cooperatives and they can serve as a vehicle for the

genetic improvement program. There are international cooperatives has higher share for the genetic improvement of nations and global dairy cattle genetics. Therefore, farmer cooperatives need to aspire to deliver improved genetics for local and export market and provide high tech breeding services. Properly functioning cooperatives could be essential in the initial recruitment and maintaining the participation of dairy farmers in national genetic improvement program. Public sectors and other development partners involved in dairy sector need to therefore support establishment and strengthening of such farmers institutions.

Role of development partners

Local and international development partners have continued to support governments and stakeholder organizations in promoting relevant dairy technologies, improved stakeholder involvement, and encouraged and facilitated sharing of best practices in dairy genetic improvement. Development and research-based organizations have directly and indirectly contributed to national genetic improvement programs for decades in the history of the Ethiopian dairy sector. Food and Agriculture Organization, ILRI, Precision Development, SNV, Land O'Lakes Venture 37, Project Mercy, Send a Cow, GIZ, and other funded projects led by local and international research and academic institutions are played roles to the dairy sector. Besides, international development partners can play a vital role in scaling up and out the best practices by supporting national and regional governmental and public institutions to better conduct their roles in promoting the growth of dairy industries. Therefore, development partners should supplement public and private-sector efforts and align their activities with the national dairy development strategies.

Conclusions and recommendations

A sustainable breeding program cannot be realized without full engagement of all dairy actors in the value chain. The roles of each have been indicated in this paper. Government should be bringing all actors into a common platform to harmonize their work and play a complementary role. From this paper, the following conclusion and recommendations can be forwarded:

- Adopting and integrating digital tools and genomic technology boost the genetic gains.
- Harmonized or unified cattle identification and registration system is a foundation to strengthen the national database center.
- Identifying top ranked locally bred bulls through routine national genetic/genomic evaluation for both AI and natural mating will increase genetic gains, reduce use of uncertified local bulls, and reduce costs of importing semen/bulls for AI.
- To build sustainable genetic improvement, synergy and complementarity among dairy actors is crucial.
- Clearly identifying and defining roles and responsibilities of the different actors and creating an enabling environment to achieve sustained genetic gains will improve the livelihood of many smallholder farmers.
- Ownership is crucial for future sustainability. Therefore, beyond projects, the public and private sectors operating in the country must take the ownership and play a leading role in synergy with the government to ensure the sustainability of the results achieved.

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