# Leapfrogging Towards a Sustainable Dairy Breeding Program in Tanzania

*G. Msuta[2], E. Lyatuu[1], K. Neema[1], D. Komwihangilo[2], Gebreyohanes, G.[1], J. Ojango[1], S. Kahumbu[3], E. Chinyere[1], R. Mrode[1], and Okeyo A. Mwai[1]*

[1] *International Livestock Research Institute, Nairobi P.O. Box 30709*
[2] *Tanzania Livestock Research Institute (TALIRI), P.O. Box 834, Tanzania*
[3] *Green Dreams Tech, Nairobi,*

## Abstract

*Tanzania smallholder dairy is constrained by lack of access to high yielding and locally adapted genetics. To improved dairy genetics Artificial insemination (AI) is the best tool to use. However, uptake of AI services is variable across the country. Information on individual animals born through AI and their performance levels within the different environments are lacking, hence difficult to evaluate the performance of the progeny born from AI bulls and to select best genetics. To develop a successful breeding program, regular animal performance recording is necessary that will provide reliable records for genetic evaluation and ranking of animals based on the performance in different traits of choice to be used as parents of future replacement in the herd. The African Asian Dairy Genetic Gains (AADGG) program in partnership with the International Livestock Research Institute (ILRI) and Tanzania Livestock Research Institute (TALIRI) initiated a national dairy performance recording, evaluation, and breeding program in 2016. This paper reports on the journey so far in building a breeding program at the national level and suggests a way forward for its sustainability. The program started with revamping the existing national animal identification system. This involved initiating farmer, herd, and individual animal registration, establishing a national digital database that enabled recording and genotyping of cows and bulls owned by farmers. From 2016 to 2023, 33,769 farms with 79,269 animals have been registered, and total of 260,827 test-day milk yields and 44,853 body weight records have been captured. About 7,458 animals have been genotyped and used to generate genomic breeding values. Results from the genomic evaluations were used to develop a selection index that improves the rate of milk production but keeps the body weight constant. Semen from the top bulls is being produced and promoted through AI to benefit thousands of dairy farmers. From the analysis of the production trends, an improvement of approximately 54% (from an average of 6.7 litres to 10.34) of milk yield/cow/day, from 2016 to-date is reported. Therefore, the Tanzanian dairy industry can benefit from sustained breeding program that continuously identifies and delivers improved adapted and productive dairy genetics.*

***Key words:*** *Dairy, breeding program, database, animal identification, genetic gains, Tanzania*

## Introduction

Livestock production in smallholder farming systems contributes significantly to household livelihoods. The contributions of cattle raised in these systems include milk (and its products), manure for fertilizer, job creation and overall household nutrition, which are critical for food security at household and national levels. However, current levels of production measured by the economically important traits such as milk yield, growth rate, fertility, age at first calving, calving interval and survival are low compared to similar herds in the region as well as better managed medium and large-scale farms in Tanzania.

The challenges facing smallholder dairy systems in Tanzania include little or no systematic and sustainable breeding programs, limited access to the dairy genetics or breed types/choices that best suit the different production systems, inadequate access to various services and inputs, and inadequate access to information or farmer education and training services. The problems are aggravated by low coverage of animal identification and registration systems, limited field data recording and data capture tools, and low technical institutional capacity at national level to use these to give feedbacks as well as targeted and timely advisory services. The National Artificial Insemination Center (NAIC) has been supplying processed semen for both crossbreeding and pure breeding aimed at improving the genetic potential for productivity of the local dairy cattle populations. However, apart from distribution of semen and training of technicians to provide Artificial Insemination (AI) services at national level, there is no system by NAIC for reporting of the services done and registering of calves born from the AI to allow for subsequent monitoring, evaluation and improvement of the AI service. Strucken *et al*. (2017) reported that there is an average exotic breed proportion of 0.78 (±0.18) in crossbred animals raised on small holder farmers in Tanzania, which is relatively high for the smallholder farmers to management-wise match, given the local production environments. Such mismatches result in underperformance of the dairy animals and increase the risk of animal loss, especially given the relatively high costs of production (feeding and health care). Developing and implementing a sustainable breeding program which continuously identifies superior bulls from within Tanzania and promotes their wider use, thus progressively enabling genetic gains in the wider population is needed. This however requires unique animal identification and continuous pedigree and performance recording, and genotyping of a proportion of the total herd and use of these information to evaluate the national herds and use the results to select bull-dams and future breeding bulls routinely genetically. These sets of activities require investments in data recording and management, appropriate infrastructures, personnel, and time at different levels of the dairy value chain. The International Livestock Research Institute (ILRI) in collaboration with the Tanzania Livestock Research Institute (TALIRI) began implementing the African Dairy Genetic Gains (ADGG) (https://africadgg.wordpress.com) program in 2016 to address challenges of the smallholder farming systems. Through the program, ICT tools have been developed to capture, monitor, and provide feedback on performance records from herds kept by smallholder dairy farms. The ADGG program also provides education extension messages and evaluates data collated across the different farming systems for benchmarking.

In developing countries, with limited or no pedigree data, use of genomic information offers a huge opportunity for prediction of the genetic merit of animals (Hayes *et al*., 2013; Raphael *et al*., 2020). The ADGG program utilizes genomic technologies to genotype animals, and subsequently uses both phenotypic and genotypic information to develop more robust breeding objectives and realistic selection indices that are then used to select top ranking bulls and cows as "seed" animals for dairy production under local smallholder farming systems. This paper presents lessons learnt from the ADGG project activities in Tanzania, its prospects in catalysing enhanced productivity, and recommends what needs to be undertaken to sustain such activities at country level.

## The African Dairy Genetic Gains Program

The African Dairy Genetic Gains (ADGG) program https://portal.adgg.ilri.org/ is a farmer and country-focused International Livestock Research Institute (ILRI) led project, funded by the Bill and Melinda Gates Foundation (BMGF), which has started in Tanzania and Ethiopia since 2016 and in 2022 scaled to Kenya and Uganda with plans for implementation in Rwanda and Nepal. ADGG was initiated with a vision of enabling African smallholder dairy farmers to continuously access more productive dairy genetics, access breeding services alongside education and extension services and thus making such dairying systems to be more productive, profitable and competitive. The goal is to enable working breeding systems based on public-private partnerships with a clear route to long-term sustainability beyond the funded phase of the program. The objectives of the program are to (A) establish performance recording and sampling systems; B) Use the information and samples collected to develop systems to select crossbred bulls and cows of superior genetic merit for artificial insemination (AI) and natural mating; C) Pilot farmer-feedback systems that assist farmers to improve their productivity and D) Establish public-private, non-government organizations, and producer partnerships necessary for future funding and scaling of the ADGG activities.

### ADGG key leapfrogging strategies as interventions and achievements towards a sustainable Dairy breeding program in Tanzania

#### *Standardization of animal identification system*

Animal identification and registration play an important role in animal and animal product traceability, animal movement control for disease management, genetic improvement, ownership verification, planning, and enabling access to loans from financial institutions (Gebreyohanes *et al*., 2022). A sustainable breeding program cannot be successfully implemented without an operational, harmonized national animal identification and registration system. Realizing the importance of a national animal identification system, the Government of Tanzania, enacted the livestock identification, registration, and traceability Act No. 12 of 2010. The Act provide for the establishment of the National Livestock Identification, Registration and Traceability System (TANLITs) for purposes of controlling animal diseases and livestock theft, enhancing food safety assurance, regulating livestock movement, improving livestock products and production of animal genetic resources and to promote access to markets. ADGG supported the Government in piloting the national identification using the national 15 characters standard animal

identification (ID) system (Figure 1) with the three letters (TZA) showing the country code and the eight-digit numbers animal ID with the last four digits written in bigger fonts to improve visibility from a distance following ICAR (2014) and ICPALD (2014) standards. Besides, the Government of Tanzania through Ministry of Livestock and Fisheries recently reviewed the Animal Identification standards and adapted them for the country. The adapted identification system replaced the prefix TZA with country code (255), followed by two digits that represent the region code then three digits that represent the Local Government Authority (LGA) codes. The last 7 digits with a bigger font are a unique number for identification of individual animals. Additional features added to the Animal ID is a scannable barcode that encodes more detailed information of the animal identified.


Figure 1: Plastic ear tag and animal identification number used by ADGG (left) and National system (right)

***Establishment of data platform and data capture system***

ADGG has supported the establishment of a national dairy performance recording center (DPRC) that hosts the data platform on the Electronic Government Agency server (eGA) to collate data coming from smallholder farmers through digital tools. The open data kit (ODK) has been used to collect data. The project is working to develop & implement online and offline digital data capture system to collect animal performance data from the field and link it to the DPRC and digital extension. For instance, medium and large dairy farmers are supported to use their mobile phone to collect data and send such information directly to the DPRC and to as well manage such information by themselves. To enable data collection, capacity has been created at TALIRI by procuring motorbike, computers, tablets, lactoscan, weight measuring tape, and training local staff on data collection, data analysis and genomic evaluation. Local staff selected at Local Government Authority (LGAs) were trained on how to collect hair samples for genotyping and milk sample to instantly determine milk quality traits using lactoscan. The data platform is designed in a way to integrate data from different sources, with data validation, management and extraction tool, and data analytics to make genomic evaluation and provide feedback to farmers (Figure 2). The data platform (Figure 2) is robust and provides different feedback summaries and services to various actors in the dairy value chain.

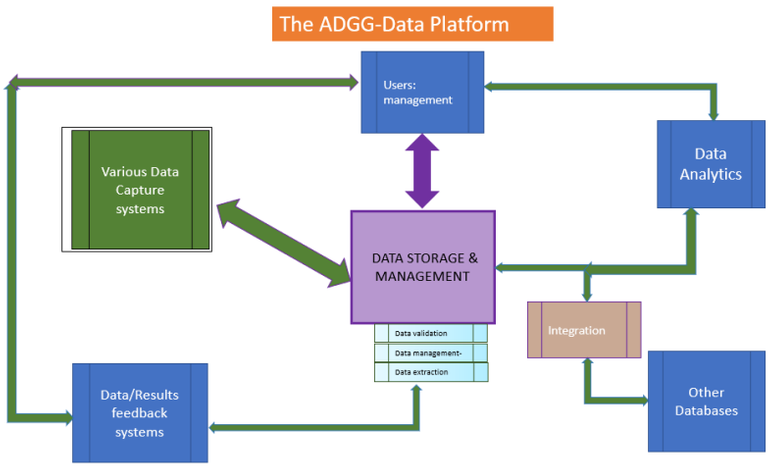


Figure 2: The schematic structure of ADGG data platform

The platform's country landing page (Figure 3) provides on real time a summary of data collected and the map reflecting data collection points. Depending on the requirements and access levels provided, managers and policy makers can obtain more detailed information from the platform that would routinely inform their decisions. For example, in Tanzania summaries are available for the different categories of animals (Mature cows, heifers, calves and bulls), breeds within each region, and number of AI services recorded in each month, the latter being available only for AI service providers who are registered on the data platform. Data collected from each household is accompanied with georeferenced information that could be used to pull out related global weather and environmental data that are then used to predict resilience and productivity attributes.

### *Phenotypic data collection*

To sustainably support national dairy cattle performance recording, genetic evaluation, and certification, ADGG in partnership with TALIRI initiated a digital Tanzania Dairy Cattle Performance Recording Center to register herds and animals and capture and process phenotypic, pedigree and genomic information on all the registered herds and animals in the Country. The data is used to annually predict genomic breeding values (GEBVs), and to rank bulls and cows, with the top two ranked young bulls being recruited to the National Artificial Insemination Center for semen collection and wider distribution through AI. The rest of the top ranked bulls are certified and then recommended for natural service to replace uncertified village bulls. Besides, top ranked cows could be used as bull dams. Initial data collection focused on test day milk yield, calf and cow weights, the latter using weigh bands (Figure 4). Currently, milk quality traits (milk fat, protein, and lactose), birth and calving dates and economic; climatic variables and disease incidences at animal levels are being collected, thus enabling age at first calving, calving intervals to be derived. All these traits together with key udder traits would then be used to develop robust selection index and national certification systems.

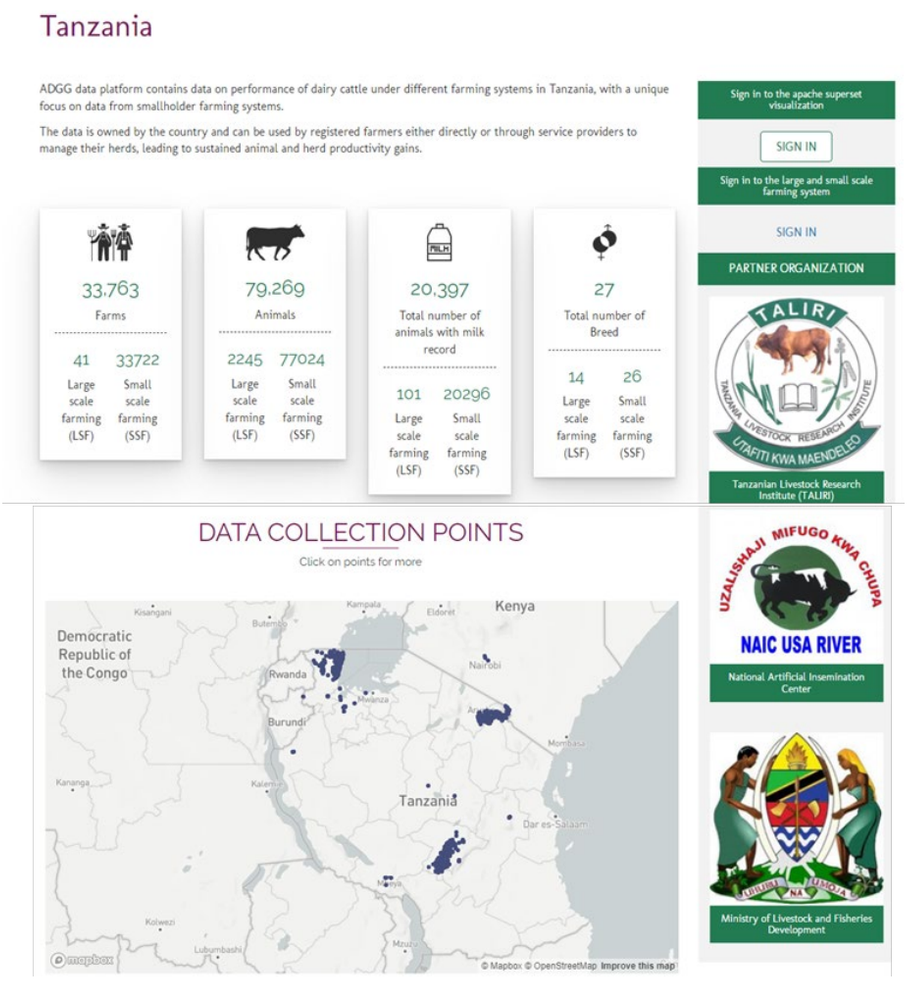


Figure 3. ADGG platform landing page for Tanzania (December 2022)

Test day milk production trends from 2016 to 2021 have shown a tremendous improvement of approximately 54% from an average of 6.7 litres to 10.34) of milk yield/cow/day (Figure 4). This suggests that farmers have realized a productivity gains as they continue using more productive and locally adapted dairy genetics.

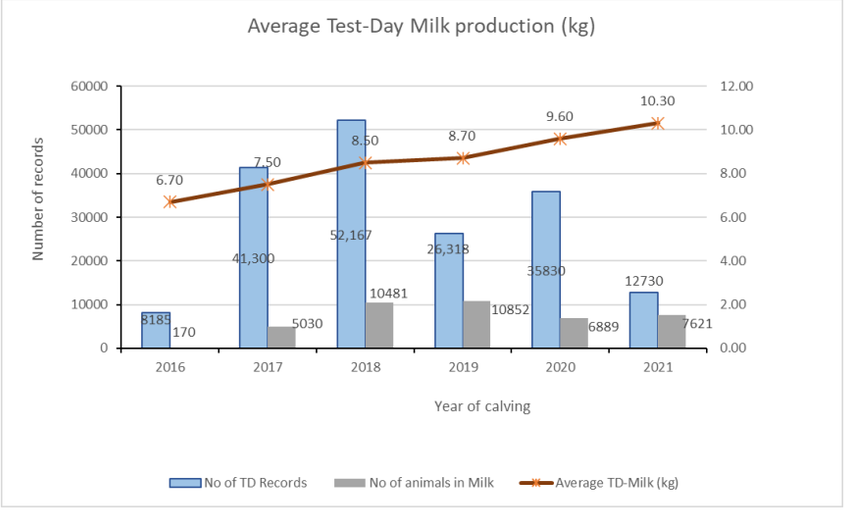


Figure 4. Trends in data collection and average milk yield

### *Genotyping of animals and genomic evaluation*

Adoption of genomic evaluation in developed countries has led to faster genetic gains and is one of the emerging innovations that ADGG has introduced and is promoting to enhance genetic

gains in developing countries where phenotypic data recording is a major constraint for the traditional progeny testing approaches (Hayes *et al*., 2013; Marshall *et al*., 2019). The ADGG project has developed country specific genotyping strategy that guides as to which animals should be sampled and genotyped annually and information used together with the existing pedigree and phenotypic data to generate breeding values and to nationally rank the animals https://portal.adgg.ilri.org/sites/default/files/ADGG-Tanzania-Top-Animals-January-2021-Evaluaiton.pdf. To-date, hair samples from 7,458 animals with phenotypic data and pedigree information have been collected and genotyped for Tanzania in two rounds of sampling.

The genotypic information and phenotype data collected have been and will be used to estimate genomic estimated breeding value using single step GBLUP (Mrode *et al*., 2020). So far genomic evaluation of dairy animals was done twice in Tanzania with the third evaluation being done in the year of 2023. In 2019, Tanzania ADGG project organized an exemplary Animal Parade that demonstrated the top ranked bulls and cows which were selected following the 2019 genomic evaluation (Mrode, et al 2019, Komwihangilo *et al*., 2021; Lyatuu *et al*., 2021; Figure 5). Bulls and cows were ranked based on estimated genomic breeding value and top ranked bulls were bought by Honarable Luhaga Joelson Mpina, Member of Parliament and Minister for Livestock and Fisheries and brought to NAIC for semen production.

**Figure 5.** ILRI Director General, Dr. Jimmy Smith (left) and Minister for Livestock and Fisheries Hon. Luhaga Joelson Mpina (2nd to left) present the award for best bull at a special bull and cow show at the Nane Nane exhibition grounds in Dodoma, Tanzania, June 2019. Photo credit by ILRI

Genotyping of the farmers' dairy animals has also made farmers to understand the different breed proportion of their crossbred cows, thus enabling them to decide on which animal to breed to which bull and which animals to retain or buy-in for future breeding thus better matching the genetics to the type of management (feeding, health care, breeding, etc) at farm levels. Knowledge of the breed proportion of cows within herds also help extension agents to deliver better informed and more targeted extension messages, support and advise to the smallholder farmers for enhanced productivity and profitability.

Continued registration, pedigree and performance recording of newly born calves and performance recording of their relatives, coupled with strategic genotyping will continue to build the national reference population, eventually providing sufficient phenotype data, pedigree information and genotype data to allow for continuous and more robust genomic evaluation and

selection of young bulls and bull dams. The calves and heifers born from the top ranked bulls and cows, would then be promoted as replacements of older and uncertified cows. This way, Tanzania as country would have in place a solid system for internally identifying and promoting the use of genetically superior (i.e. more productive and locally adapted) dairy genetics, thus saving foreign exchange use to import semen and/or bulls that are bred in other countries and which may mostly likely be as suitable to the local production conditions in Tanzania.

### *ICT based extension education and feedback.*

Extension and education services help to improve efficiency, and profitability of the farming. These services to small holder farmers are provided by Government, private sector (input suppliers), non-governmental organizations (NGO's) or projects. However, given the fragmented nature of smallholder farming systems, it is not possible for extension agents to physically reach every farmer, therefore extension service is increasingly being constrained by limited of budgetary allocations, access to the farms and logistics. ICT technology is providing huge and innovative opportunity for delivering extension services (Nuer, 2018; Mwantimwa, 2019). ADGG has introduced mobile phone-based extension education for farmers registered in the platform which could complement existing limited physical extension service. The extension text messages are crafted based on farmers need identified by the extension officers called Performance Recording Agents (PRAs) and on cow calendar. More importantly, because the PRAs and extension agents are linked to the ADGG platform and receive summaries of the respective performance of the registered cows and herds, by using such information, they are more targeted and effective in their extension service delivery.

The platform has also developed electronic training modules that provide valuable information on breeding management and animal health practices in dairy herds (https://portal.adgg.ilri.org/related-links; ADGG Dairy Tool).

The ADGG project partnered with green Dreams Tech (iCOW) based in Nairobi to provide the short messaging service (SMS) and feedback to the smallholder farmers. Since the start of the project more than 24 million extension messages have been delivered to registered farmers in project countries out of which 13.5 million are from Tanzania. Such extension tools if widely adopted by farmers could complement existing extension service as indicated in a study by Marwa et al. (2020) where the use of ICT-based extension services is shown to increase annual milk production per cow hence increases household income by 13%, 29%, and 22%, respectively. In addition, the use of ICT based extension services was highly appreciated during the COVID-19 era where physical movements of the extension officers were maximally limited but farmers continued to be reached virtually via digital extension through their mobile phones by direct receipt of an educative SMS, herd or animal performance feedback that required immediate farmers' action as well as through a USSD menu where they were able to ask any question and get instant answers.

### *Promotion and Delivery of genetic gains to small holder farmers*

The success of any breeding program depends on how widely the selected young bulls are used to breed future cows. This can be achieved through both AI and natural mating. Semen have been produced from the top ranked and certified bulls that were selected in 2019 and 2021 evaluations by NAIC and TALIRI. NAIC has processed and supplied 600 straws of semen for AI. The 2nd tier of ranked and certified bulls have also been used for natural mating, replacing the uncertified village bulls within the smallholder dairy communities where AI service are currently unavailable. Such production of semen will improve the availability of locally adapted dairy animals and play role in import substitution. However, the 600 doses are far too low to make significant impact. NAIC needs to produce thousands and thousands more semen doses, and promote their wider use, given that the top bulls are much better suited to Tanzanian conditions than imported foreign seeds. In any case, the top ranked bulls ranked better than some of the foreign born and imported bulls, regardless of their genetic composition.

### *Animal certification*

Identification, registration and certification of bulls, cows, and heifer's benefits smallholder farmers in many ways. Officially identified and genetically certified dairy animals are proven and fetch higher prices. Such animals are also recognized by financial/lending institutions and are valued higher when used as collaterals for credit purposes. Even under normal purchases particularly where certified animals are sold for breeding, herd replacement or establishment of new dairy farms tend to fetch higher prices. Certification can also facilitate exchange of genetic material between countries. ADGG introduced animal certification system for bulls, cows and heifers registered in the platform and with phenotypic records in Ethiopia (Gebreyohanes *et al*., 2021; Figure 6). Wider use of certified crossbred bulls to crossbred cows has the potential of protecting unplanned crossbreeding and erosion of indigenous cattle genetics both within and across the African countries. Provision of certificates to farmers increase trust and motivates them to continuously provide and send accurate data to the national dairy cattle platform. Thus, similar experience will be adopted for Tanzania. Apparently, Tanzania is developing the National certification system that will eventually be used widely.

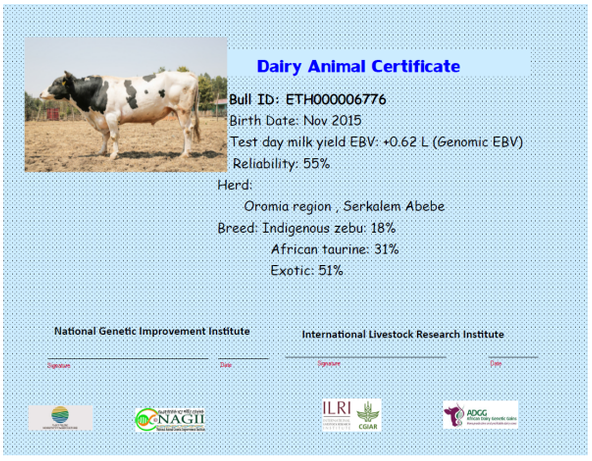


Figure 6. An Example of a dairy animal certificate developed after the first-round of genetic evaluation in Ethiopia.

***Local capacity building and partnerships***

Breeding program is a long-term initiative that requires commitment, dedication, and joint investment by Government, breed societies or the private sector. Establishing a sustainable breeding program must be country led, owned, and supported. ADGG has been working with local partner institution and through partners to catalyse multi-actor participation thus ensuring sustainability of country-based breeding programs beyond the project period. The critical success factors include building and strengthening of the local capacity to lead and undertake the breeding program. ILRI and its Advanced Research Institute Partner roles is to create or strengthen local capacities in terms of skills, logistics and other resources to continuously collect data and analytical capacity of local staff. ADGG has also come up with business models that are multi-actor focused and therefore would sustainably support continued data collection and genetic evaluation and delivery. These models are being tested and adapted to fit local institutional situations.

**Opportunities and challenges for scaling up and sustainability.**

***Opportunities:***

The ADGG project has created the following opportunities:

1. Many innovative ways for packaging/deploying digital farmer extension tools: Several digital platforms already exist in the country and elsewhere that can be used for quick crowd-sourcing of phenotypic data and genomic data that could be used to improve the selection index; links and crow-sourcing disease surveillance, livestock input and price data which can be used to manage livestock disease and better inform input, animal breeding and health service provision and regulations.
2. Links to global genomic resources: Having the ADGG platform and data capture system in the country and sustainable breeding program will help to partnerships with global genetic companies (Genus, URUS) and national institutions to generate robust evaluation results, thus making locally based NAICs & AI centers to better compete with the global counterparts (Bull suitability indices) and Initial steps for inter-country genetics evaluation platforms and eventually to Interbull.
3. Providing opportunities for training future experts through use of locally generated data and the national capacity enhanced (technically, infrastructure and data capture tools) for sustainability.
4. Deep dives to historical (semen bank) and existing genetic resources (crossbred populations) as sources of additional genetic variations. The genomic technology could help to incorporate semen stored in semen banks on the genomic evaluation using genomic relationships to make use of potential genes for the improvement of future generation of breeding animals.
5. Easily scalable and tweakable to support other livestock species: the present platform created in the country could be used with slight modification to capture

data from other species of livestock. Thus, similar genetic evaluation can be done to select top ranked males and females.

6. Inclusion of links to traits that are difficult to measure traits in selected herds: Disease tolerance traits, milk compositions, methane emissions-new enviro-cow project.
7. Development of innovative multiplication and delivery mechanisms: Mass delivery through synchronization and emerging embryo transfer technologies
8. Bull and bull-dam certification system enable access to credits by youths and women.
9. Uniform animal identification system in use and supports: Development and deployment of harmonized national/multi-national animal identification and traceability system catalysed for genetic improvement, control animal diseases and track animal movement and enable traceability of animal and products.
10. Undertake rapid surveys from representative sample of farmers and tracking performance of breeding service providers.
11. Opportunities for cross/multiple country genomic evaluations
12. Possibility of quicker development of tropically adapted & productive synthetics dairy genetics from pooling of crossbred populations from different countries and /or from multiple edits of naturally occurring mutations.
13. Solid evidence generated and used to inform national and regional policy formulations/decisions.

***Challenges***

***Institutionalization of dairy breeding program***: Sustainability of a breeding program requires leadership, ownership, commitment, and support by the Government. The breeding program must be institutionalized within the relevant government institution and supported with resources (organizational structure, logistics, human resource, and finance) to ensure the continuity of the interventions. In addition, the institutionalizing and main-streaming of the key breeding program components needs to be undertaken through strong and well-structured public-private partnerships.

***National animal identification and registration system***: The Government of Tanzania has a national animal identification, registration system put in place. Such initiative must be supported with appropriate tools to collect data that could be used for different purposes. Data collection tools must be periodically reviewed to integrate new and growing demands for data.

***Supporting private sector actors to record and track performance of their services***: Private sector could play a pivotal role in designing and implementing a successful breed improvement programs and delivery of improved genetics. The role played by private sector is limited. Government must support and encourage private sector to engage in long term business

investment. Loan, land, property right and protection, etc. creates confidence to invest in breeding business in sustainable manner.

***Continuous capacity building***: Establishing a sustainable long-term breeding program requires continuous human and infrastructural capacity building. Domestic universities should play lead role by designing or adjusting existing curriculum to supply skilled, well versed, and capable professional in the field of animal breeding. Besides, linking graduate thesis and dissertations with ongoing activities will boost the data collection, analysis and facilitate execution of different trials or research within a specified period.

***Farmers' continuous education***: Breeding programs are long term processes, thus might not be attractive for farmers to engage and participate in since the fruits of the whole process of data collection, genotyping and genetic evaluation are harvested after many years. Creation of awareness to, and participation of farmers in good animal husbandry practices that relates to the ongoing breeding programs should be improved through continuous education.

**Integrating genetics with improved feeding, health care and management**: The current trend shows lack of integration of improved genetics with the feeding and herd health. Sustainable breeding program should be matched with improved feeding, health care, and access to quality inputs and services and market linkages to fully extract improved genetics and genetic gains. Interventions by different projects and government institutions should target in addressing the whole value chain.

**Breed societies:** Unlike advanced countries, in developing countries breed societies either do not exist or are few with limited involvement in a specific breed improvement. To enable the formation and engagement of breed societies enabling policies must be put in place.

## Conclusions and recommendations

From the above review, the following conclusions and recommendations can be made:

### *Conclusions*

In conclusion, we list the following:

- The breeding program has demonstrated tangible outputs that should be sustained to deliver adaptable high yielding genetics to smallholder farmers in Tanzania.
- The breeding program considered milk production traits only. However, considering the present and future market demands in Tanzania, additional traits must be included in the selection index. Thus, the data capture tools must enable to collect more data on different economically important production and resilience traits.
- The current data collection system involves performance recording agents. This is not a sustainable way of data collection. Farmers must be aware of the importance of data and

incentivised to participate in collecting and sharing their data. Thus, the data collection tools must be farmers friendly and easily operable.

- The initiative taken by the Government to identify animals using a unique identification system, is a one step ahead to design a sustainable breeding program, initiate a traceability system, and disease control. This must be sustained at country level through continuous monitoring of its implementation and availability and supply of necessary inputs.
- Top ranked bulls and bull-dams must be aggressively promoted and widely used through AI service and natural mating. Progenies of these bulls must be compared with progenies from imported bulls under same or similar production environment so that farmers will have more choice of bulls suitable for the production environment.

***Recommendations***

From the experience and lessons gained during implementing the project, the following recommendations can be forwarded:

- Strengthen existing animal identification and data collection system in the country. The data collection could be made using different business models. The tools used must integrate data on genetics, feed, animal health, and resilience traits.
- Promote wide use of bulls selected annually for AI and natural mating.
- Strengthen local capacity to implement and lead national breeding program.
- Demonstrate the opportunities that the data platform can provide to different actors in the dairy value chain so that they see value for their business and financially support for its sustainability.
- Different initiatives that support the dairy sector exist in the country. These must be coordinated for a harmonized support and exploit complementarity. Thus, a government led partnership platform is recommended to map who is doing what and where and monitor progress for better impact.

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