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Dairy industry development in Ethiopia: Current status, major challenges and potential interventions for improvement

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Dairy industry development in Ethiopia: Current status, major challenges and potential interventions for improvement

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Acronyms

AABNet	African Animal Breeding Network
ADGG	African Dairy Genetic Gains
AI	Artificial insemination
ALPPIS	Addis Livestock Production and Productivity Improvement Service
AGP	Agricultural Growth Program
ATA	Agricultural Transformation Agency
ATVET	Agricultural Technical Vocational Education and Training
BA	Breeding age
BRIDGE	Building Rural Income through inclusive Dairy Business Growth in Ethiopia
CSA	Central Statistics Agency
EDDP	Ethiopian Dairy Development Project
EDGET	Enhancing Dairy Sector Growth in Ethiopia
EIAR	Ethiopian Institute of Agricultural Research
FEED I, II and III	Feed Enhancement for Ethiopian Development
ICAR	Indian Council of Agricultural Research
ILRI	International Livestock Research Institute
IPMS	Improving Productivity and Market Success of Ethiopian farmers
LFSDP	Livestock and Fishery Sector Development Project
LIVES	Livestock and Irrigation Value chains for Ethiopian Smallholders
LMD	Livestock market development
LUKE	Natural Resources Institute of Finland

MoA	Ministry of Agriculture
NAIC	National Artificial Insemination Center
NAGII	National Animal Genetics Improvement Institute
NARS	National Agricultural Research System
NDRI	National Dairy Research Institute
PAID	Public-Private-Partnership for Artificial Insemination Delivery
RED&FS	Rural Economic Development and Food Security platform
SDGs	Sustainable Development Goals
SNNPR	Southern Nations, Nationalities, and Peoples' Region

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Summary

Dairy production in Ethiopia is subsistence smallholder-based and characterized by low production and productivity. The annual production of livestock and livestock products in the country is too low to meet the current and projected demands of the growing human population. To attain government goals of poverty reduction, food security, nutrition, foreign currency earning, and contribute to the national economy; the current livestock production system must be transformed to a commercial market-oriented one.

To achieve, this the dairy industry transformation process requires periodically identifying critical challenges and opportunities and designing interventions and investment options for the public and private sector.

This study discusses the dairy industry, its constraints, and interventions for its development in Ethiopia. Actors in the dairy value chain and their engagement modalities are also suggested to bring a sustainable integrated dairy development. The study used a value chain approach and identified actors, and their roles, and the horizontal and vertical integration among these actors. The main challenges in the dairy sector are lack of market orientation; insufficient and inefficient input and service delivery; lack or limited private sector investment; weak regulatory institutions; limited technical, technological, and financial capacity; lack of market infrastructure and weak market linkages among actors in the value chain. Reorganizing and strengthening institutions supporting the dairy sector, creating an enabling environment for private sector participation, improving inputs supply (feed, improved breeds, artificial insemination and veterinary inputs), service provision (veterinary, extension, market, regulatory), value addition and market linkages, and strengthening research to develop high yielding tropically adapted dairy breeds, are recommended to drive the commercialization of the dairy sector. Public sector interventions in selected and targeted investments and revising existing and designing new policies, strategies, regulations, and standards supportive to the dairy sector transformation could lay a foundation for private sector investment. At the same time, development partners engaged in dairy development must be aligned with government initiatives for a better and wider impact.

Introduction

Livestock is an integral part of agriculture contributing to the household livelihood and economies of developing countries (Herrero et al. 2013). Livestock production and marketing of its products are essential to the livelihoods of more than one billion people in Africa and Asia (McDermott et al. 2010). Livestock contributes to poverty reduction, nutrition and food security and improved income and job creation, which are the United Nations' Sustainable Development Goals (Smith 2015). Investment in livestock has a potential to create a multiplier effect. A USD1 spent in livestock will generate USD2.9 in primary livestock production and USD5.9 in value added products (AU-IBAR 2015). Dairy production has the highest potential to sustainably contribute to the Sustainable Development Goals (SDGs) due to its extended value chain.

Dairy production in the tropics is predominantly subsistence, characterized by low production and productivity, dependent on local breeds, and managed under extensive grazing and uncontrolled breeding. Milk produced in these systems is dominantly from local breeds, and in Ethiopia, about 95% of milk produced is from local breeds (CSA 2019). The demand for milk and milk products is increasing in developing countries and the drivers of change to the dairy sector are demography, growing economies, underserved markets, conducive policy and enabling environment, globalization, and market opportunities (Shapiro et al. 2017).

Meeting the increasing demand for milk and dairy products cannot be realized without rapidly increasing the number of high producing tropically adapted cows, the number of commercial dairy herds, and the number of cows per herd and productivity per cow. To support the dairy sector, different interventions have been made by the government, development partners, national and international research institutions, and non-governmental organizations. However, in Ethiopia, the sector is yet to fully realize its potential to produce enough milk and dairy products to meet the domestic demand. As a result, the country is forced to import powdered milk and other milk products.

The major constraints on intensification of livestock in general and dairy are unavailability of adaptable high-yielding improved genetics, lack of feed, animal diseases and poor animal health, extension and market services. In Ethiopia, genetic improvement of indigenous breeds through crossbreeding and upgrading, and the accelerated production of crossbred cows from farmers' indigenous breeds through artificial insemination (AI) started more than 40 years ago following the establishment of the National Artificial Insemination Center (NAIC). However, the number of improved breeds in the country is still too small to transform the current subsistence-based smallholder dairy system to market-oriented commercial dairy production and boost milk production to meet current and predicted future domestic demands (CSA, 2019). Ethiopia's dairy value chains has been assessed in the past by Yilma et al. (2011). However, there is need to have periodic assessments of these value chains to provide up-to-date information for informed evidence-based interventions by policymakers. The objective of this paper is to review the status of the dairy improvement programs in Ethiopia, identify the key challenges and potential interventions, and describe how the latter can be effectively implemented.

The Ethiopian dairy sector

In Ethiopia, dairy production is generally a subsistence smallholder-based industry with relatively few small and medium commercial dairy farms. In 2019, close to 6.7 million dairy cows produced an estimated 3.6 billion litres of milk nationally, with most of it (over 95%) from local breeds (CSA 2019). Ethiopia's per capita milk consumption ranged from 32.8 to 36.5 litres per head/year for the period 2003 to 2012 (Yilma et al. 2017), which is lower than the 110 litres per head/year in neighbouring Kenya (Corne et al. 2016).

Ethiopia's five-year (2015 to 2019) average total cattle population was 59.2 million animals (range 56.7 to 61.5 million), comprising 55.3% and 44.7% females and males, respectively, and growing at an annual growth rate of 1.2% (Table 1). Despite the large number of indigenous breed milking cows in the country, their milk production and productivity remain low. The annual cow milk production for the period 2015 to 2019 ranged from 3.06 to 3.30 billion litres (average 3.13 billion litres) (Table 1) mainly attributed to low genetic potential of the indigenous breeds, limited availability of feed, high disease prevalence and poor animal health services, low level of husbandry, and limited extension and research support. The annual increase in milk production is lower than the annual human population increase, hence the country is forced to increasingly import powdered and UHT milk and other dairy products.

The number of breeding male cattle is small compared to that of heifers and cows, with an average male to female ratio of 19.51 (Table 2). The large population of breeding female cattle provides an opportunity to make genetic improvement through their use as dams for production of crossbred heifers to support intensified dairying in the country. However, considering the small number of breeding male animals, their poor distribution across the different production systems and the inefficient breeding strategy in place, continued use of such few males for breeding could lead to inbreeding or inadequacy of breeding bulls. Indigenous bulls graze with the rest of the herd in communal grazing areas, which are often overgrazed, hence without preferential supplementation, such bulls have low fertility and libido resulting in low cow and heifer fertility. The few crossbred bulls in the country are mostly managed indoor for breeding purposes. Most dairy farms do not keep breeding bulls because of the associated high feeding and management costs; male calves are culled at an early age.

Table 1. Cattle population, proportion of female herd, milking cows, and annual milk production in Ethiopia

Year	Cattle population (million)			Female out of total cattle population (%)	Number of dairy cows (million)	Dairy cows out of female population (%)	Annual milk yield (billion litres)
	Total	Male	Female				
2014/15	56.71	25.26	31.44	55.45	6.50	20.66	3.07
2015/16	57.83	25.81	32.02	55.38	6.74	21.05	3.06
2016/17	59.49	26.48	33.01	55.49	7.16	21.68	3.10
2017/18	60.39	27.37	33.02	54.68	6.66	20.17	3.10
2018/19	61.51	27.27	34.24	55.67	7.09	20.71	3.30
Average	59.19	26.44	32.75	55.33	6.83	20.85	3.13

Source: CSA 2015, 2016, 2017, 2018 and 2019.

Table 2. Proportion of male and female cattle of breeding age group from the total cattle population (millions) in Ethiopia

	Cattle population, millions			Cattle in breeding age (BA) group (million)		Proportion of cattle in BA group		
Year	Total	Male	Female	Male	Female	Male BA out of all males (%)	Female BA out of all females (%)	Male BA to female BA ratio
2014/15	56.71	25.26	31.44	0.57	12.52	2.24	39.83	22.16
2015/16	57.83	25.81	32.02	0.74	12.84	2.85	40.11	17.46
2016/17	59.49	26.48	33.01	0.78	12.82	2.95	38.84	16.42
2017/18	60.39	27.37	33.02	0.57	13.17	2.09	39.89	23.08
2018/19	61.51	27.27	34.24	0.74	13.60	2.71	39.72	18.44
Average	59.19	26.44	32.75	0.68	12.99	2.56	39.67	19.51

Source: CSA 2015, 2016, 2017, 2018 and 2019.

Draft oxen constitute 55% of the male cattle population and 24.7% of the total cattle population (Table 3). In the mixed crop-livestock production system, the local breeds provide replacement male calves for draft power and heifers for milk production. This is substantiated by the high number of draft oxen reported across all years by the Ethiopia Central Statistics Agency (CSA). Male cattle are commonly castrated for traction at the age of three to four years (ILCA 1981). The stronger and the more vigorous bulls with good body conformation are usually selected for traction purpose, hence are the ones castrated, leaving the inferior bulls to breed, and thus genetically impacting negatively on growth and milk yield.

Table 3. Draft oxen and breeding male population (in million) and proportion of draft oxen

Year	Total cattle population (million)	Total male population (million)	Number of draft oxen (million)	Proportion of draft oxen (%)	Oxen out of male population (%)	Male breeding animals (million)
2014/15	56.71	25.26	14.15	24.95	56.00	0.57
2015/16	57.83	25.81	14.30	24.72	55.39	0.74
2016/17	59.49	26.48	14.65	24.62	55.31	0.78
2017/18	60.39	27.37	15.38	25.47	56.20	0.57
2018/19	61.51	27.27	14.65	23.82	53.74	0.74
Average	59.19	26.44	14.62	24.72	55.33	0.68

Source: CSA 2015, 2016, 2017, 2018 and 2019

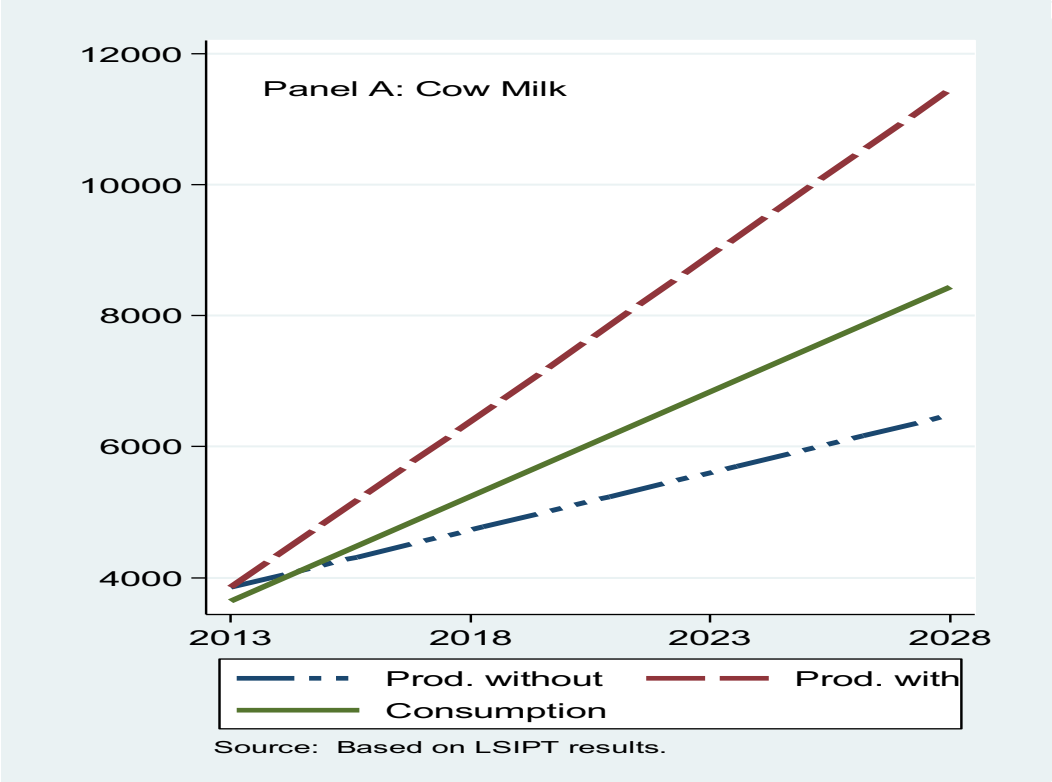
Dairy production in the country can be categorized into mixed crop-livestock, pastoral, specialized urban, and peri-urban production systems. The pastoral system depends on indigenous breeds, which are managed under extensive rangeland grazing, and cattle are the main source of pastoral households' milk, cash, asset accumulation and savings. The pastoral areas are the main source of beef for the domestic and export markets. Farmers predominantly keep indigenous breeds that are generally resilient but are of lower production and productivity quality compared with exotic specialized beef breeds. There is high and significant between and within-breed variations in milk yield. The within-breed variation both in milk yield is high (ranging between 1 and 1,800 kg), while lactation length varies between 3 and 300 days for Boran cows kept under research centre (Yohannes et al. 2002). Under smallholder management conditions, most of the animals depend on grazing communal lands and crop residues for feed. According to the Food and Agriculture Organization of the United Nations (FAO), the total estimated annual potential biomass available in Ethiopia for animal feeding was 144.48 million tons out of which grazing biomass and crop residues contributed 57.09 and 52.7 million tons, respectively (FAO 2018). However, with the expansion of commercial smallholder dairy production, and the extension support, farmers started keeping one or two crossbred cows and planting improved forages to supplement their milking animals.

In the smallholder specialized urban and peri-urban dairy production system, which is mainly practiced in and around cities and towns, farmers keep both crossbred and exotic breeds of cows for producing milk for sale. These systems mainly depend on purchased forages, grass hay, crop residues and compound feeds for livestock feed. Dairy farmers in this system have better access to various dairy farm inputs and services (AI, veterinary, extension) from both public and private input and service providers.

Milk is sold either directly to processors or to cooperatives. Except in a few areas where dairy producers are organized into milk marketing cooperatives, milk marketing is predominantly through informal/unorganized channels where raw milk is sold primarily on contractual basis and butter in nearby open markets (Yilma et al. 2017). Unavailability of support services such as cooling facilities, logistics (transportation, electricity, water, etc.) to collect milk from producers and market fluid milk to processors is believed to have favoured the informal market where milk is sold to neighbours or processed to butter and cheese locally. However, ready access to the fluid milk market has encouraged farmers to intensify production compared to farmers who operate in remote areas.

The Ethiopian livestock sector analysis (Shapiro et al. 2015) identified a huge gap between annual projected milk production and demand for the years 2013 to 2028 (Figure 1). Moreover, the analysis suggested that public and private interventions in the feed supply, genetics and animal health inputs and services would be required to move milk production from a deficit of 23% of the demand to a surplus of 20% of the demand by year 2028. The increase in milk demand is driven by population growth, increase income and urbanization. According to FAO (2017) Ethiopian's human population is anticipated to grow from about 99 million in 2015 to almost 190 million people in 2050 with the share of urban population almost doubling to nearly 40% over the same period. At the same time, gross domestic product (GDP) per capita is expected to grow from less than USD700 in 2015 to over USD5,500 in 2050 (FAO 2017). These changes will have an implication on government policies, investments, and development priorities.

Figure 1. Projections of production with and without intervention and consumption balances for cow milk (million litres).



Source: Shapiro et al. 2017

The dairy sector has the potential for creating jobs. In developing countries such as Ethiopia, where job creation for the youth is a priority government agenda, a vibrant dairy value chain has the potential to generate gainful job opportunities. As indicated by Filippo et al. (2017), dairy-related activities at farm level are estimated to generate 77 direct full-time jobs per 1,000 litres of milk produced. This means that, to tap the potential for job creation, the government must put in place enabling policy and infrastructural environments for all actors in the dairy value chain to invest in expansion of existing dairy businesses and in new ones.

The government, development partners, national and international research institutions, and non-governmental organizations have been implementing initiatives such as the Building Rural Income through inclusive Dairy Business

Growth in Ethiopia (BRIDGE) project, the Enhancing Dairy Sector Growth in Ethiopia (EDGET, https://snv.org/project/BRIDGE), project, the United States Agency for International Development (USAID) Livestock Market Development project, the Land O'Lakes PAID project, and the African Dairy Genetic Gains (ADGG, https://www.ilri.org/research/projects/african-dairy-genetic-gains, and https://portal.adgg.ilri.org) project to support dairy sector development in Ethiopia. The Ethiopian government has more recently invested in: (i) capacity development through introduction of exotic breeds to enhance bull semen production capacity, (ii) establishment of supporting institutions, (iii) establishment of new and strengthening existing AI centres, (iv) training of AI technicians, and (v) development and promotion of policies that support private sector participation and investment in this sector. On the other hand, private sector players have invested and continue to invest in commercial dairy farms, milk processing plants, feed processing, and supply of dairy inputs and services. In some areas, cooperatives are beginning to play a key role in milk aggregation, processing and input supply to members. Besides, improved extension and veterinary services are being provided by public institutions and by projects in close collaboration with the public service providers.

In Ethiopia, the use of AI aimed at improving indigenous breeds through crossbreeding started 40 years ago. However, to date, the number of improved breeds (crossbred and exotic cows) is reported to be only 2.34% of the total national cattle population (CSA 2018; CSA 2019). This number is far too low to bring about the expected growth and transformation of the dairy sector.

The transformation of smallholder subsistence dairying into market-oriented commercial dairy production requires engagement of smallholder farmers in commercial dairy farming and private investment in input supply, service delivery and milk value addition to overcome fluctuations in raw milk demand and supply due to seasonal consumption of animal products in the country. Marketing of dairy products faces challenges during the long periods of fasting by the Coptic Orthodox Church followers especially in areas where there is no value addition that can ensure longer shelf life for these products, which would, for example, enable them to be transported to other part of the country. Lack of facilities for preserving dairy products during the fasting period, which in some cases is 55-days long, is an additional constraint. Among other measures, farmers cope with these market problems by stopping or lessening the use of feed supplements to reduce the amount of milk their cows produce.

Different developing countries have pursued different business models to transform their dairy sector. For instance, the Anand Pattern cooperative dairy model has been used in India, the dairy park model in China, and the contract farming model in other Asian countries. Similarly, cooperatives have played a significant role in linking dairy farmers with processors in Kenya. Uganda succeeded to start exporting milk because of the cluster approach that they pursued, in addition to its smallholder farmer dairying system. Ethiopia could adopt a similar approach to transform its dairy sector. Developing a country-specific dairy strategy that transforms the sector requires critical assessment of the opportunities and challenges and possible interventions.

The Ethiopian dairy value chain

A sustainable food value chain is defined as the full range of farms and firms and their successive coordinated value-adding activities that produce raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use. They operate in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources (FAO 2014).

The dairy value chain includes production and supply of inputs and services, milk production, aggregation, processing, marketing, and consumption (Gebremedhin et al. 2012). It involves different actors in input supply and services (veterinary, extension, market and financial). The dairy value chain could be mapped based on core processes in the value chain, the main actors involved in the process and their functions, flow of product and volume of product flow, etc. (Gebremedhin et al. 2012). The success of dairy development depends on how well the value chain is supported or enabled and how well the challenges at each node of the value chain are sustainably resolved.

Development efforts have so far not addressed the whole value chain, and this could be the reason why transformation of the dairy sector has not occurred in Ethiopia. Interventions by different actors in the dairy value chain target a specific part of the value chain. Thus, it is important to critically assess the whole dairy value chain, identify the challenges, and exploit the opportunities by adopting objective and viable solutions, and focusing on roles and responsibilities of different actors in the value chain and modalities of engagement of different actors based on their comparative advantages.

In the mixed crop-livestock production system, dairying is mainly smallholder based, dependent on local breeds, and on informal market channels for raw milk and butter. The formal market is limited to urban and peri-urban dairy production systems. Depending on the distance to market, milk produced is either consumed locally or sold as butter. This is mainly due to the low daily milk production, lack of access to market, and an underdeveloped milk market infrastructure. Dairy producers are not organized into cooperatives for marketing their milk or for accessing inputs, which had led to slow uptake of improved technologies (e.g. feed, genetics), AI and veterinary services. However, in areas where development interventions have addressed the value chain, dairy farmers tend to benefit as individuals or as a cooperative from the vertical and horizontal integration of dairy farmers with input suppliers and markets. This is substantiated by the report of McDermott et al. (2010), which notes that as production and marketing systems evolve, support to smallholder farmers to provide efficient input service, link to output market and risk mitigation measures will be important if they are to provide higher value products.

Three case studies have been presented to demonstrate the impact of linking a cooperative with a processor (Box 1), the effect of market linkage for milk on input demand (Box 2) and changes on herd management (Box 3). The case studies are from SNV-EDGET project district field visit in 2017.

Box 1: Case study one: Success story of Hiwot Dairy Cooperative in Dangla, Amhara, Ethiopia

Hiwot Dairy Cooperative has been involved in milk collection from its members in a milk collection centre established in Dangla (left photo). The performance of the cooperative was poor until an SNV-EDGET project linked the cooperative to a processor in Bahir Dar known as Ever Green. The monthly milk collection of the cooperative was 2,754 litres and sales of ETB38,249 in January 2017 (middle). However, after the cooperative was linked with the processor, the monthly milk collection increased drastically and after nine months (September 2017) monthly milk collected increased to 35,643 litres and sales to ETB405,976. The lesson from the growth in this cooperative is that farmers needed extension support and were provided with improved breeds and training, but these interventions alone were not enough to offer sufficient benefit for farmers from their dairying. This case study shows that interventions to transform dairy should follow a complete value chain approach. (Photos: Gebregziabher Gebreyohanes).Pi

Photo 1

Photo 2

Photo 3

Box 2: Case study two: Input demand and utilization by smallholder farmers

Farmers around Dangla, Awi Zone, Amhara region were reluctant to grow forages and buy crossbred heifers before they were organized in the Hiwot Dairy Cooperative and linked to a processor. The cooperative collects milk from members and supplies it to the processor, which has motivated farmers to use inputs (improved genetics, feed, health services) and devote their land for forage production. For example, a woman household head and farmer with three children started dairying with one crossbred cow provided by the Amhara regional government. After she realized the benefit from sales of the milk to the Hiwot Dairy Cooperative located in Dangla, she started to expand her dairy farm, devoted her land for planting Rhodes grass and bought additional crossbred cows to increase production and productivity due to the financial empowerment from the existing herd. (Photos: Gebregziabher Gebreyohanes).

Box 3: Case study three: Shift from free grazing to controlled cattle management

Free grazing has been a challenge in grazing land management and livestock productivity and health in many parts of Ethiopia. Extension information to farmers on the benefits of controlled grazing for livestock production, productivity and health has been poorly adopted by farmers. However, promotion of crossbreeds and linking farmers with sustainable markets for milk has led to increased adoption of crossbred animals and indoor livestock management. The pictures below show a farmer who adopted controlled grazing, built a barn with a cemented floor and established forage farming to feed his animals. His reason for doing this was the high value of the crossbred cows and reduced risk of animal losses. Besides, the farmer also increased his income from milk sale whose production increased because the crossbred cows produced more when managed indoors. Thus, under the mixed crop-livestock system, dairy value chain development could contribute to a shift in herd management system and greater use of technologies, inputs and services, and proper use of natural resources. (Photos: Gebregziabher Gebreyohanes).

In the pastoral production system, pastoralists have no access to milk markets due to poor infrastructure (i.e. lack of facilities to collect, chill and process milk). This has made milk marketing difficult in pastoral areas. Postharvest milk and dairy product losses in the country is estimated at 20 to 35%, due mainly to spillage and spoilage (Getachew et al. 2012). In the Ethiopian Somali region, pastoralists bring camel milk to a central place where trucks collect the milk to supply to a processing plant in Jijiga. Such a system, although good, does not bulk the collected milk, rather it is sent to the processor in individual cans. The experience could be improved and scaled up by supporting pastoralists to establish mobile or fixed milk collection centres equipped with solar powered refrigerators or chillers, supplying them with facilities for testing milk quality and bulking, providing training and linking them with processors. Such interventions could also enable pastoralists to sell cow milk in addition to camel milk.

Strengths, weaknesses, opportunities, and threats in the dairy value chain

Detailed analysis of the dairy val strengths, weaknesses, opportunities, and threats are presented in Table 4.

Table 4. Strength, weakness, opportunities, and threats analysis of the Ethiopian dairy value chain

Strengths	Weakness
Widely acknowledged economic and social benefits of dairy	Development and extension approach are fragmented and scattered
Presence of ongoing projects and good experiences and lessons for scaling up	Interventions lack continuity
Presence of private sector investment in dairy processing, feed processing and input supply	Poor access to input and services (feed, AI, veterinary, extension) at region and district levels
Presence of government extension structure from federal to village level, AI technicians, veterinarians	Low disease surveillance, prevention and control
The presence of capacity for semen, vaccines, and liquid nitrogen production	High cost of production
Growing number of cooperatives engaged in milk collection and processing, and input supply	Low milk quality and high milk losses
Established national dairy performance recording database , data capture tools, use of ICT technology for data capture and feedback, capacity for genomic evaluation	Weak regulatory capacity
	Cooperatives are financially weak to invest in milk collection centres, equipment, transport, etc.
	Lack of quality-based milk pricing
	Extended value chain actors
	Low overall value addition and uneven distribution of processors
Opportunities	**Threats**
Supportive policy (nutrition, job creation, food security, import substitution, establishment of industry parks)	Poor quality control
Increased demand for milk and milk products	Poor infrastructure for marketing milk
Continued government investment to support the sector	Lack of regulation
Growing private sector interest in investing in dairying, value addition and compound feed processing	Lack of tailored training and extension
Presence of different stakeholders and projects supporting the dairy sector	Seasonality in market
Presence of international and national research institutions, non-governmental organizations	Animal diseases
The existence of diverse indigenous breeds to be used for crossing with exotic breeds	Low number of improved breeds
	Low investment by private sector
	Low quality feed and risk of aflatoxin
	High reproductive wastage
	Postharvest milk loss
	Milk importation and lack of protection of local producers from market competitiveness

Challenges and key interventions to improve the dairy value chain in Ethiopia

The major challenges and potential interventions aimed at contributing to the improvement and transformation of the national dairy sector are briefly discussed in sections 5.1 to 5.9 below.

Lack of market orientation in the dairy sector

The dairy sector in the country is based on subsistence production with low market orientation. Milk produced is consumed at the household level mainly due to low production and lack of market access, poorly organized marketing systems and an underdeveloped milk market infrastructure. A large proportion of the national cattle population is kept by smallholder farmers. In the mixed crop-livestock production system, cattle are kept for the purpose of producing draft oxen to support crop production. These animals are used only for an average of 45 days, and maximum of 70 days in a year (Gryseels and Anderson 1983), yet they are fed and managed daily for the rest of the year. Farmers prioritize feeding draft oxen followed by milking cows. The resources used on such oxen could be released to support more commercial beef and dairy production if they were to be replaced by small, mechanized alternatives. In areas where market access for fluid milk is lacking, milk is sold as butter, which is an option for coping with the market challenge but is economically unprofitable compared to selling fluid milk because a large amount of milk (16 to 18 litres) is churned to produce a kilo of butter.

Insufficient and inefficient input and service delivery

The most important services in the dairy sector development are artificial insemination (AI), animal health (veterinary), extension and regulatory services. The major inputs for the above services are improved genetics (semen from proven bulls, heifers), liquid nitrogen, improved feed, vaccines, veterinary drugs and other equipment. The challenges faced in the delivery of these services relate to inefficiency, inadequacy and low quality of services and products. Besides, there is limited participation of the private sector and lack of national capacity to produce some of the inputs.

Improved genetics, AI inputs and services

The cost of importing purebred dairy breeds is high, hence the most practical entry point to commercial dairying in the country is through use of crossbred cows. The demand for crossbred cows is increasing with the growth of the dairy sector and increasing demand for milk. There is no multiplication centre to supply improved breeds in the country. The main sources of crossbred heifers are from the AI services provided mainly by the public, and a few private, technicians. However, AI services are not available everywhere and where available, semen from bulls that have not been appropriately selected are offered. Also, charges for AI delivery are high, yet low conception rates are achieved (McDermott et al. 2010). The number of crossbred heifers and cows reported by the CSA annually are much lower

than the anticipated number given the efforts and resources deployed by government, private sector and development partners. This is principally attributed to an inadequate monitoring and evaluation system. Current genetic improvement is through crossbreeding, however, semen distribution and AI service have had no feedback systems to monitor progress and genetic trends across the years. There is no follow-up after the AI service, to determine which of the inseminated cows conceive and no follow-ups are made 18–22 days post-insemination so that cows that failed to conceive can be re-inseminated in good time. Even for those that conceived, follow-up until calving and calf management thereafter is rarely done this might have contributed to the high young stock mortality in the country.

Public AI service providers dominate in the urban and peri-urban areas and in the mixed crop-livestock systems. There are a few private AI service providers in cities and secondary towns. AI technicians are trained, equipped with insemination materials and deployed to provide the service to smallholder farmers. Access to AI service is limited due to the low number of inseminators, limited technical skills, lack of adequate supply of semen, liquid nitrogen and logistics (e.g. motorcycles for transporting semen). The National Animal Genetic Improvement Institute (NAGII) annually trains about 100 public AI technicians recruited from the regions. There is no regular training arrangement for private AI technician unless requested for by specific projects. This is a small number compared with the number of cattle-keeping households and the number of services required to produce the targeted number of crossbred and improved dairy animals necessary to increase production as per the livestock master plan and government's five years (2015 to 2020) plan and beyond. Furthermore, the Public-Private-Partnership for Artificial Insemination Delivery (PAID) project has been providing refresher and full-fledged training to public, private and community AI technicians since 2016. PAID has also trained female inseminators and in this regard broken the 'taboo' for females to inseminate. The ADGG project-supported data recording platform has been redesigned to use local language (Amharic) to make it more user friendly and enable easier recording and effectively monitoring of the technicians' performance and to appropriately award good performers and reprimand or retrain poor performing technicians. However, for the system to deliver the desired results both private and public AI technicians need to be registered on the platform, where they can be objectively tracked, and their performance routinely monitored.

Current logistics facilities (e.g. motorcycles for transport) are inadequate to enable the technicians to reach all their potential clients in good time. Inadequate transport has limited AI service to just the more accessible farms in the urban and peri-urban areas, only. Farmers in the rural areas who need and request for the service are not getting it on time and farmers are forced to use the available bulls in the herd irrespective of it breed, breed composition, exotic blood level and pedigree. Absence of breeding records at household and national levels creates makes it difficult to monitor and control exotic breed proportions of crossbred cows in smallholder systems. This has resulted in high exotic dairy breed proportion in crossbreeds averaging 0.78±0.2 (Strucken et al. 2017).

Oestrus synchronization-supported AI services and programs have been implemented to improve the efficiency in the AI service delivery, especially when targeting the indigenous breeds and in cases where oestrus detection is difficult. However, the low number of qualified AI technicians has made it expensive to deliver AI service conventionally.

The oestrus synchronization has been done following single injection with the Prostaglandin (PGF2α) protocol. The protocol requires skill to palpate corpus luteum to check whether the cow is cycling or not. Although there are variations from place to place and from technician to technician, during the initial application, the protocol enabled more cows to come into heat and improved conception rate to about 62% in the Southern Nations, Nationalities, and Peoples' Region (SNNPR) (Paterson 2012). However, as the experience scaled up to cover wider areas by increasing the number of technicians, the performance declined (Paterson 2012) due to problems associated with the inadequate skill of technicians to accurately detect the presence of corpus luteum, the tight logistical needs, and other external factors. To address the inefficiencies observed, an alternative protocol such as double injection with Prostaglandin was compared with single injection. However, the results showed no significant improvement in pregnancy and recommended a single injection coupled with skill improvement and rapid progesterone test before synchronization because of its cost effectiveness, fewer visits to farms and because the process is less laborious (Tadesse 2015). The double injection protocol has not been tested on farm.

Success in AI service delivery could be realized by strengthening and improving the public service delivery system and engaging more private technicians and cooperatives to provide the service. Improving semen quality and delivery and ensuring uninterrupted supply of liquid nitrogen are other measures for ensuring efficient AI delivery. AI as a stand-alone business may not be sustainable and is expensive for individual technicians due to high initial capital required to procure the necessary inputs (motorcycle, liquid nitrogen containers and other insemination materials) especially when the number of cows for insemination per day is low (<50). In addition, the subsidized public AI service can disrupt the growth and competitiveness of private AI service provision. Access to credit is also limited to only those who can provide collaterals. Most AI technicians often do not qualify thus, preventing them from entering the AI service provision business.

Investment to improve AI service will have a long-term impact on increasing the number of crossbred heifers available to small- and medium-scale dairy farmers to enhance production and productivity. The AI service would stimulate the vibrancy of the dairy value chain and would subsequently create jobs for the youth and women. Thus, government support is required through long-term in kind, or low interest rate, cash or credit arrangements for youth and women and full cost recovery for the public service to have competitive private sector-driven AI service. The private sector should also be supported to invest in private semen production and delivery. In addition, in order to improve the profitability of service delivery to smallholder farmers by private enterprises, a one-stop shops of bundled service (vet services/inputs, AI, feed, etc.) approach must be promoted as a profitable and efficient service delivery system.

Inefficiency in public AI service delivery could be improved by introducing a result-based (number of AI services delivered and number of confirmed pregnancy) incentive system. The ADGG platform already has a transparent and effective performance monitoring/assessment system with these features. There is also a need for continuous professional skill assessment and capacity development programs that attaches newly AI trained technicians to experienced and high-performing technicians, who will not only mentor them on the technical skills, but also on the ethical and business skills of AI service delivery. Experience from the PAID program showed that performance-based incentive schemes improved AI technicians' efficiency from an average of 24 AI administered/month/AI technician during the pre-PAID program period to an average of 43 AIs administered/AI technician/month currently. For success, AI technicians on job retention mechanism must be attached to older and more skilled and experienced counterparts to benefit from the latter. Some farmers have been trained to provide the AI service under the program showing that farmers can also be trained and deployed to complement the AI service in their communities to improve adoption and efficiency of AI services. In areas where the dairy cooperatives are strong, AI and input services can be provided by hired technicians.

At the same time, the semen and liquid nitrogen supply needs to be improved and made sustainable. Inputs necessary for dairy genetic improvement through AI service delivery are either produced in the country or imported from abroad. Semen is produced in five semen processing laboratories (Kaliti, Nekemte, Hawassa, Bahir Dar and Mekelle) from imported pure exotic bulls and domestically bred crossbred bulls. These laboratories are constrained by lack of proven (i.e. appropriately evaluated and selected) bulls and sustainable supply of laboratory reagents such as diluents and semen packaging materials thus forcing the laboratories to produce semen way below their capacity. There are few private companies such as the Addis Livestock Production and Productivity Improvement Service (ALPPIS) that import semen for own use or for sale. However, most of the imported genetics may be for animals that the average Ethiopian dairy smallholder farmer is unable to profitably keep. Also, the quality of semen delivered to districts for insemination deteriorates at different stages from production centre to the AI service point due to handling challenges, resulting in wastage and inefficiency in the AI service delivery. Comparing the doses of semen produced in the laboratories and dispatched to the regions with the reported number of calves born shows huge loss of semen either due to poor storage or inefficient service providers. For instance, an administrative report from NAGII revealed that for five years (2016 to 2020) average semen produced and dispatched, and calves born was 899,087 doses, 758,504 doses and 360,925, respectively.

Inputs such as semen extenders are not available in the country and are not accessible due to shortages of foreign currency. Thus, to ensure a continuous supply of reagents to the five laboratories a reliable supply of foreign currency and an organized

central supply system are necessary. Semen processing locally is a key substitute to importing semen, thus, local production capacity must be strengthened to produce the amount of semen doses required nationally for insemination.

The current supply of liquid nitrogen is irregular resulting in interruptions of AI service delivery. There are about 24 liquid nitrogen manufacturing plants in the country, but most rely on old equipment, lack spare parts and have limited skilled technicians to operate and maintain them; they operate inefficiently and below capacity. To build local capacity to maintain the liquid nitrogen machines, short-term training was provided to those working in NAGII and the regions. However, the challenge of liquid nitrogen production has persisted and at any given time less than half of these plants are functional.

As observed elsewhere in this paper, the number of improved dairy heifers and cows is too low to meet national demand. Apart from the low and inefficient AI service delivery, the small number of improved dairy breeds is attributed to lack of a nationwide animal identification, registration and recording system, ineffective monitoring of the AI services in farms, and lack of proper calf management to improve the survival and growth of the calves bred via AI. Alongside these, weak extension and customized farmer support systems, has resulted in low numbers of crossbred heifers available in the country.

Male calves, especially crossbred ones, are slaughtered at an early age, while some are castrated and used for draft power. The insufficient nationwide recording and genetic evaluation schemes mean that genetically superior males are not identified at calfhood, which would reduce genetic wastages costs and ensure young bulls sired by elite AI bulls are not slaughtered or castrated. These bulls would be used for both AI and natural service, thus contributing the much-needed overall genetic gains. The ADGG program has started genomic evaluation of crossbred dairy bulls and cows using phenotypic data and genomic information, and the first selection was made using genomic estimated breeding (gEBV) value. Such technologies will, in the future, enable early evaluation of calves and young bulls before they are culled for veal. The heterotic advantage for growth, hence meat production is also not fully exploited due to early slaughter of the calves.

The involvement of the private sector in input supply is limited to the importing of semen, AI equipment and laboratory supplies. For liquid nitrogen production, opportunities exist that can be exploited by the private sector if they invested in liquid nitrogen production as a by-product, given that the gas manufacturing plants can produce different types of gasses for different purposes. For instance, a liquid nitrogen machine can produce oxygen for hospitals and carbon dioxide for the beverage industry, liquid nitrogen for AI service, and the rare gases for special industrial uses. Thus, the public-private partnership modality could be exploited to incentivize private sector investment in the business. This will reduce costs for government and improve input and service delivery. The private sector role in heifer production and delivery and in linking improved heifer demand and supply is an area that has not been exploited. Heifers could be produced by the private sector using different models such as by establishing ranches, or through contract arrangement with farmers who own local breeds.

Veterinary inputs and services delivery

The livestock sector in general is characterized by high adult and young stock mortality. This is mainly linked to limited access to and inefficient veterinary service due to low numbers of animal health centres, animal health laboratories, poor animal disease surveillance, prevention and control capacity, poor facilities, limited manpower in existing animal health centres and mobility of pastoralist livestock-keepers in search of feed and water. The insufficient number of frontline veterinary personnel coupled with inadequate operational resources are further compounded by lack of an organized input delivery system, and logistics, all of which have led to an under-resourced and underperforming national dairy sector.

Ethiopia has more than 15 universities, each of which produces hundreds of graduate veterinarians each year. Agricultural Technical Vocational Education and Training (ATVET) centres also produce vet-assistants graduates annually, but the students and faculties in these institutions are not engaged in the veterinary service business during the training as a

part of the community service mandate of the universities. To engage new veterinarians as private service providers individually or groups, universities need to certify them for competence and arrange short courses that give them the necessary practical and business skills before they are deployed to the field. Rationalization of veterinary services for public, private, and public-private investment will encourage participation of more service providers and input suppliers in the sector. Public veterinarians should be encouraged to provide service as side-line businesses so that they contribute to the overall animal disease control efforts and improve job retention in the livestock sector.

In the commercial urban and peri-urban dairying, private and public veterinarians provide AI and animal health services. However, dairy farmers prefer the private service providers mainly because they are readily available for farm visits, and they provide better services compared with their public counterparts. Although, the price charged by private service providers is usually higher than what is charged for the same services by the public technicians, whose services are subsidized, research shows that farmers are willing to pay these higher prices because private services yield better results. Full cost recovery and total withdrawal of government service providers from some of the animal health services have been suggested in the draft veterinary service rationalization roadmap of the Ministry of Agriculture as ways of improving service delivery, but approval of such roadmaps and supportive legislation have been delayed.

Several infectious and non-infectious cattle diseases of economic importance are prevalent in Ethiopia. The government policy on animal disease management mainly revolves around a prevention-based disease control strategy. For effective disease control, improving availability of vaccines for the most communicable animal diseases, regular vaccination and strengthening domestic vaccine production capacity are needed.

Dairy farms with crossbred or pure exotic dairy breeds are more sensitive to transmissible diseases compared with those with indigenous and locally adapted tropical breeds. Zoonotic diseases such as brucellosis and tuberculosis affect many animals and dairy product quality, safety and profitability, besides increasing human health risks. As dairy intensification continues, the risk of zoonotic diseases spread is likely to increase. To manage these threats, the disease prevention system in Ethiopia will need to adopt biosecurity for effective herd-health management and other measures. Herd certification for some of the most important zoonotic diseases and regular check-ups of dairy farms will be critical in helping farmers to produce safe and high-quality milk. To reduce adult and young stock mortality, which is a cause of significant losses in the livestock sector in general and dairy farms in particular, the animal health extension service should enhance the feeding, health care and management of calves.

Feed and forages supply chain

The main feed-related challenges in the country are feed and forage inadequacy, inaccessibility, unaffordability and low quality. Feed is the major cost driver in dairy production, often accounting for about 70% of the cost of production (Seyoum et al. 2018). Feed is a bottleneck for the dairy sector and manifests itself in i) inadequacy, either in absolute or relative, usually seasonal terms; and ii) poor quality and unaffordability (too high feed prices, especially for concentrates). The total amount of feed produced in most smallholder farms is far less than the needs of animals kept, and this cascades to the national level. In fact, research projects that based on current feed production systems, at no time in the future will the amount of feed produced meet the requirements of the ever-increasing Ethiopia's livestock population. The best strategy for matching feed produced with livestock number, and which would yield immediate results, is to reduce the number of unproductive local cows and increase the number of numerically fewer but more productive crossbreeds. Presently, the private sector does not consider commercial feed production as a viable business, neither is the land policy enabling access to land for feed production, as is the case for commercial crop production and industrialization.

The main feed base for smallholder rural dairy farms is grazing, crop residues and a limited number of cultivated forages and legumes mostly for the market-oriented farmers. Farmers who own crossbred cows and who have access to lucrative milk markets allocate some of their land for forage production. With the steady growth of the urban and peri-urban dairy sector, buoyed by an expanding milk market and higher prices, farmers are being encouraged to allocate part of their farmland to improved feed (fodder crops, forages, and legumes) production for own use and for sale. Large-scale commercial production of forages to support dairying is, however, limited due to low participation of the private sector

in commercial forage production, weak seed multiplication systems and feed packing technologies (i.e. for ensiling, baling etc). Feeds are bulky in nature, so to reduce the bulkiness, local availability of feed processing machines is required and energy to run them needs to be affordable. The size of land holdings owned and/or accessible by dairy farmers especially in urban and peri-urban dairying, is small and cannot enable production of sufficient forages. Efficient commercial forage production would stabilize fluctuations in feed supply and price, and output prices. Least-cost production of feed in agriculturally high-potential areas, if supported by adequate transport facilities and market linkages, could transform the livestock sector in Ethiopia.

Commercial forage production requires a sustainable source of seed from the public or private seed multipliers. Forage seeds/germplasm that are available in the gene banks need to be multiplied into high-quality seeds and then delivered or made readily accessible to the smallholder farmers and commercial large-scale producers.

The number of private investors and cooperatives who are involved in compound feed production has increased thanks to government support and greater access to private financing support in this area. However, the feed distribution channels need to be improved to reduce the number of actors in the feed chain, which will make feed more readily accessible and affordable to smallholder farmers.

The amount of crop residues produced in the country is proportional to that of crop production, but its quality varies greatly, depending on the crop species, variety and the way it is managed. There is a trend of an increase in crop production, which has also increased the volume of available crop residues. However, technologies that would improve the nutritive values (palatability, intake and digestibility) of such products are not commonly used by farmers and local processors because of lack of machinery such as choppers, which are often expensive to acquire. Poor treatment of crop residues with urea-molasses or microorganisms render such technical interventions ineffective.

To fully express their genetic potential and bring maximum benefit to farmers, improved livestock breeds need to be fed adequately using good-quality feeds. Besides, most economically important breed traits (e.g. age at first calving, calving interval and milk yield) are influence by the feed and feeding system, and health management. Therefore, farmers' education should focus on feed and feeding as one of the components during the scale up of improved dairy technologies. The International Livestock Research Institute (ILRI), the Ministry of Agriculture (MoA), the Agricultural Transformation Agency (ATA) and the Indian Council of Agricultural Research (ICAR) have been jointly working to adopt and adapt a feed database tool from India into Ethiopian conditions to guide evidence-based decisions and to guide investment. However, the successful application of this tool requires reliable district-level data on land use, cropping patterns and livestock numbers, which is lacking at present (Gebreyohannes et al. 2021).

Communal grazing lands are the main source of dairy feed resources in Ethiopia. However, communal grazing lands are shrinking fast due to expansion of crop land and land degradation associated with over grazing and erosion. Communal grazing land improvement has been piloted in some places through participatory management, soil and water conservation and reseeding with improved forages to maximize total biomass yield (Woldewahid et al. 2013). Lessons from these experiences must be documented for scaling out to other places.

The extension system has been supporting integration of forage production with crop production by intercropping, alley cropping and as fences around homesteads. Also, a push-pull technology has been introduced by the International Centre for Insect Physiology and Ecology (icipe) to control crop pests there by promoting forage production. The 'push' refers to intercropping plants such as *Desmodium* that repel pests, alongside maize or sorghum in a field. The 'pull' refers to trap crops like Napier grass or *Brachiaria*, planted around the border of a field, pulling in the pest before it enters the primary growing area (Martin 2010). In the mixed crop-livestock production system where land holding is small such technology could help to integrate forage and crop production, thus, the technology should be scaled up to maximize the benefits of smallholder farmer. Where pastoral rangelands are invaded by unpalatable bushes like Prosopis, rangeland management and improvement must consider eradication of such invasive species as a priority intervention. Bushes could be used as potential feed resources for example, provided appropriate experiences available elsewhere are adopted to local conditions (Birch et al. 2016).

The quality of milk and the dairy products depend partly on the quality of feed consumed by the animals and partly on how the milk is handled. Aflatoxin, which is commonly found in inappropriately stored feeds, is a challenge in producing clean and safe milk. The risk of aflatoxin is high when using factory-produced compounded feeds, especially those with oilseed cakes as a constituent. Thus, regulatory processes need to be strengthened to control the quality of seed and seed-based feed products. At the same time, standards need to be set to ensure the quality of livestock products to supply quality and safe milk to consumers.

Inadequate/limited private sector investment in dairy value chain

Smallholder farmers keeping few crossbred and local breeds of cows are the major suppliers of milk, butter and cheese, most of which are sold through structured and unstructured market channels. This is because the number of medium- and large-scale commercial dairy farms is small. Currently, private sector participation in dairy input supply, service delivery and milk processing is limited to Addis Ababa and few regional cities and secondary towns. For instance, of more than 37 dairy processing plants in the country, 67% are in and around Addis Ababa. Ethiopian rural smallholder farms are highly fragmented and scattered making it difficult to collect and market milk and to deliver feeds and other inputs cost effectively unless the farmers organize themselves into dairy producers and marketing groups, associations or cooperatives.

Most of the dairy marketing cooperatives are operating in regional states and are not well connected to processors and other regular and reliable market outlets, thus perform poorly and their service to members are unsatisfactory often resulting in the collapse or closure of the cooperatives. Most farmers sell traditionally processed cooking butter and soft cheese ('ayib' in Amharic) in unorganized markets through dealers and brokers. Some of the cooperatives own only cream separators and churners limiting milk value addition to butter and cheese production. Currently, the number of organized dairy producer cooperatives and their membership has increased throughout the country. But largely, there are few cooperatives with limited membership making them unable to mobilize enough resources to adequately invest in milk collection, chilling and processing systems. Absence of evening milk collection forces farmers to sell morning milk only. This has lowered the bargaining power of producers and reduced the margin they get from sales of their milk. The price of fresh milk in the cities is high while farm gate milk price is low due to low number or absence of cooperatives that can collect and bulk milk from members and send it to processors.

Ethiopia's domestic and export market potential for dairy products is high. In addition to smallholder-based dairy production, a cluster approach could be implemented in dairy development and production to boost production and productivity and supply milk to the domestic market to cover the increasing demand and reduce import of powdered milk. In addition, a cluster approach eases input and service delivery and has the potential of improving the quality and safety of milk produced and supplied to the market. Given the highly fragmented nature of smallholder systems, and insufficient homestead water supply, milk produced by smallholder producers often does not meet export quality standards. Therefore, promising and reliable private investors must be selected, incentivized and supported to produce milk and value add for export and import substitution. Clusters can also serve as core dairy development and innovation centres for smallholder farmers participation through contractual agreement.

Contractual arrangement improves quantity and quality of milk supplied, and ensures sustainable supply of inputs, provision of services and market. Under such arrangements, private companies can also participate in extension and advisory service provision to farmers who can, in turn, supply milk to these companies. Seasonality in milk marketing results in price volatility (MoA and ATA 2019). Thus, milk produced in low demand periods could be linked to strategic milk reserve in the form of longer shelf-life milk and milk powder. Experience of setting up and using a strategic milk reserve is available from Kenya where the system has been used to protect smallholder farmers from fluctuating milk prices and improve the food security status of the country. Ethiopia can allocate resources to pilot a similar system.

Extension and research support

The extension and research support provided to the dairy sector is not enough to bring about the transformative change that is needed in the country's dairy sector. Dairy development requires specialized extension support and specialized institutional arrangements than the general agriculture extension system that is currently used in the country. The existing public sector dominated and production oriented extension approach must be changed to a market and commercial oriented extension service whereby both public and private extension agents advise and support farmers to produce profitable commodities, adopt appropriate technologies and practices, collect and communicate market-related information, identify profitable markets and buyers, link farmers to buyers, build marketing capacity of farmers and facilitate organization of farmers to conduct collective marketing of their produce (Gebremedhin et al. 2012). Experiences from countries such as India, which has a successful dairy sector, show that dairy-specific research and extension can be organized under one institution to provide extension and research support to smallholder dairy farmers, processors and input providers. The Indian Council of Agricultural Research-National Dairy Research Institute (ICAR-NDRI) generates all types of technologies that support dairy development in the country. Ethiopia could adopt a similar system for dairy development-focused extension and research support.

The role the private sector could play in providing extension service is recognized in the Ethiopian agricultural extension strategy (MoA 2017). The traditional public extension service must be diversified and supported by a pluralistic approach where private sector and non-governmental organizations provide the extension service to smallholder and commercial farmers to complement the services provided by government. Farmers' training centre-based capacity development must be supported by dissemination systems to improve the reach of the extension service to all beneficiaries. The media and information communication technology (ICT) sectors will play a key role in informing farmers about agricultural technologies and making advisory services accessible. Community radio and television can transmit extension messages and best practices in local languages.

ICT and cellphone-based interactive extension advisory platforms are commonly used in crop extension in Ethiopia; these could be adopted for dairy extension services. The Ministry of Agriculture and the Agricultural Transformation Agency (ATA) have started cellphone-based voice extension message to any farmer or private sector actor who can dial 8028 to receive information. In Kenya, the ADGG project is using the Kenya-based 'Green Dreams Tech' cellphone-based text message service to support dairy farmers registered in the ADGG platform, which could be institutionalized and scaled up in Ethiopia. Extension messages can be crafted in different languages and made available to farmers. In total, more than eight million digital text extension messages have been delivered to Ethiopian dairy farmers in the last six years using a cow calendar. There is need to consider reaching out to and working with local and national television and radio to engage in dairy extension and development activities, document experiences, and organize interviews and dialogue on selected topics and news. Documentary films on field days, field visits and workshops can be organized and shared through these media networks. Training manuals and supplementary documents can be posted in the Ministry of Agriculture website to make them accessible to beneficiaries.

Research in the dairy sector began when agricultural research was started in the country by the Ethiopian Institute of Agricultural Research (EIAR) and universities and colleges of agriculture. However, apart from the long-term evaluation of four local breeds (Boran, Horo, Barka/Begait and Fogera) and three exotic (Simmental, Jersey and Holstein-Friesian) crosses in four different agro-ecologies in Holetta, Bako, Adami Tulu and Melka Werer (Demeke et al. 2004), there has not been a clear breeding program to develop high-yielding adaptable breeds that fit the different agro-ecologies and production systems

The Jersey and Holstein-Friesian dairy cattle breeds are extensively used in the country under smallholder and commercial dairy settings. Other exotic breeds that could be better suited to different agro-ecologies and smallholder production systems need to be tested and recommended as an alternative to the existing breeds. There are some local breeds such as Begait and Borana that show good potential for milk production, besides being resilient. Based on earlier reports, these local breeds have demonstrated large enough levels of variations in lactation milk yield and lactation length (Yohannes et al. 2002) and reasonable levels in reproductive performance to significantly respond to genetic selection.

To mitigate the effects of climate change, research aimed at selecting high-yielding milking cows among some of the local breeds should be prioritized. Improvement of such promising indigenous breeds should be immediately initiated by leveraging on the ADGG performance recording and genotyping platforms, as the basis for improving dairy and meat production and productivity traits as well as adaptation of selected breeds to local condition. Supportive breeding policies and indigenous breed improvement strategies have been developed by the Ministry of Agriculture. However, breeding programs need to be developed to translate breeding policies and strategies into action. The research system should proactively engage staff and mobilize resources to implement these strategies, including application of genomic and reproductive technologies that enable producers to significantly reduce generation intervals, and thus increasing rates of genetic gain.

Genetic improvement programs require long-term financial and human resources which cannot be sustainably committed by the public sector. There are efforts to establish large farms such as the Didu Tiyura, Sheraro, Andassa and Horro ranches for indigenous breeds improvement. The ranches capacity must be strengthened and supported to engage in long-term breed improvement through public, private or public-private partnership arrangements. Universities could also engage their staff in improving local breeds available in their regions.

In the pastoral areas, as part of initiatives to improve farmer resilience and adaptation to climate change, the indigenous breeds can be the basis for improving milk production and productivity. In the mixed crop-livestock system where market for fluid milk is poor, farmers in these areas could be supported with inputs and services to specialize in the multiplication and supply of crossbred heifers rather than in milk production.

Most of the country's dairy genetic improvement support has focused on addressing the supply of semen and training of AI technicians to provide the service. However, the lack of feedback mechanism to evaluate the progress and challenges on the use of AI has limited the improvement of livestock genetics. The situation is now changing with the establishment of a national dairy performance recording database by the Ministry of Agriculture with the support of the Natural Resources Institute of Finland (LUKE)-supported 'Capacity building in herd performance recording and genetic improvement to strengthen the Ethiopian dairy development' project and the ILRI-led ADGG project. The national agricultural research system (NARS) must proactively engage in strengthening the existing data collection system, harmonizing and scaling up animal identification, registration and data collection, and consolidate the establishment of a one national database and use the data to support genetic improvement nationally. The first set of genomic evaluation results have been released and top bulls and cows identified and catalogued. Therefore, all efforts by national research systems, universities and ongoing and future dairy projects should be all linked to this national database. Capacity for genomic analysis must be created locally to sustain the genotyping of local and improved breeds and use the information for genetic improvement.

At the same time, research on the feed and feeding and animal health must complement genetic improvement. The causes for high young stock mortality must be identified and controlled. Diseases of economic importance for dairy must be studied and control measures implemented.

Animal identification and performance data recording

Genetic improvement in dairy cattle requires comprehensive data recording and analyses. Efforts so far initiated by NAGII and its predecessor the National Artificial Insemination Center (NAIC) initially focused on production and distribution of semen and training of AI technicians, but the calves born from the semen distributed from NAGII cannot be traced due to lack of records and feedback mechanisms. This has made monitoring of progress in the improved genetics distribution and utilization across the country difficult for both researchers and extension agents.

To address this problem a national dairy performance recording database has been established and data from smallholder dairy producers and small- and medium-scale commercial dairy farms from four regions is now routinely captured at the national level with the support of projects such as LUKE, ADGG (https://www.adgg.ilri.org/uat/auth/auth/login) and PAID. The database adopted an international identification system for dairy animals. The data collected

at the national level, and genomic information has been used, for the first time in Ethiopia to rank bulls and cows based on their estimated genomic breeding values and selected top-ranking bulls will be used for future genetic improvement, thus replacing the use of uncertified bulls. The catalogue has also been published online to make it accessible to farmers and dairy sector players. The selected bulls and cows were recently showcased in a virtual bull and cow parade that was organized by ILRI and partners. The selected best bulls will be used for semen production by NAGII and others will be certified for natural mating. The ADGG platform is also providing information that will enable farmers to make informed decision to cull or retain animals in the herd based on the gEBV information. This data can also help farmers to improve the management of their cows based on yield performance and genetic merit. It will also assist in valuing of heifers and cows for sale.

The livestock identification and traceability system that is being piloted by the Ministry of Agriculture to identify live animals for export should align with the dairy identification system so that the country has a unified national system with information on Ethiopia's livestock herd. Sustaining the use of the animal identification system requires the procurement, printing and distribution of ear tags, ear tag applicators and ear tag printers to NAGII and the regional AI centres. The system needs to be scaled to the rest of the country, with resources duly allocated to sustain the process. Stakeholder engagement with regional government and development partners are ongoing to ensure the sustainability of the data capture, database and genetic evaluation programs.

Data collected in different research centres and universities should be linked to the national database to support evidence-based decision-making of smallholder farmers about their animals animal management and resource allocation. Such effort will also enable genetic evaluation across different agro-ecologies.

Data recording is the basis for sustainable long-term genetic improvement. So far, promising results have been realized but the sustainability after the current projects end remains a challenge, thus strong ownership and investment by the government in partnerships to ensure continuity with similar projects in future is needed. To achieve this, creation of a platform of professionals from different research institutions and academia, which links them to regional institutions such as the African Animal Breeding Network (AABNet) (http://animalbreeding-africa.org/index.html) can sustainably support the ongoing genetic evaluation work in the country. Also, adequate resources need be continuously allocated/made available to sustainably implement the recording, genotyping, evaluation, and monitoring of the data generated after ongoing and new initiatives are harmonized with government plans. Awareness also needs be created at different levels of the dairy value chain on the importance of the national dairy performance recording database to guide and monitor genetic progress. Farmers must be trained to understand the importance of collecting data on their dairy animals.

But data collection alone by farmers, which is then passed on to regional and national databases, is not enough to maintain a working national dairy performance recording database. Farmers also need feedback from the analysis of the data collected from their animals so that they can see the benefits and outcomes of the data they collect and be encouraged to continue participating in the system. Feedback to farmers should be timely and regular to support decision-making on culling, and valuing of animals based on their genetic potential so that farmers can know whether to cull or retain male calves. Farms whose bulls are selected based on their estimated breeding value should be rewarded and semen from those bulls used for AI and future genetic improvement. Farmers who own elite bulls could benefit from selling them at a higher premium to semen processing laboratories or from the semen produced and sold or by using them for natural mating services, or export in the long run. Besides, farms that keep records of their cows will be linked to markets where their heifers and dairy cows can fetch better prices, with NAGII certifying such animals.

The lack of an animal identification system is a constraint for animal and animal product traceability, for disease control, animal movement control, trade and genetic improvement. A national proclamation has been ratified by the Ethiopian government to support use of movable assets including livestock as collateral to get in kind and cash loan. Animals to be used as collateral need to have been identified and certified by a nationally authorized government institution. The NAGII-led genetic evaluation and ranking will provide the needed certification process. Thus, the loan system should consider including data on the genetic potential of bulls and cows. Owners of cows with records of higher milk yield would be able to repay loans within shorter periods than owners cows with lower milk yield. In the same way, milk

production data should be considered as one criterion for securing higher loans for herd replacement, farm expansion and purchase of inputs and services.

The existing animal identification system is fragmented and not standardized. Different research institution, universities and private farms follow different number systems. If the use of these separate systems persists, animals cannot be uniquely identified nationally. To address this problem, NAGII has adopted an international standard animal identification system and farms must now follow a standard system of animal identification. The NAGII is expected to draft a guideline for stakeholders on the establishment and adoption of a national identification system.

Strengthening regulatory framework and enabling environment

Dairy transformation requires developing a smallholder incentive package aimed towards empowering smallholder farmers' bargaining power, improving market access and income, creating a legal and regulatory framework, designing investment incentives and setting up support institutions.

The quality of inputs (semen, feed, genetics, veterinary drugs and vaccines, and equipment) and services provided by public and private institutions; the safety and quality of milk and dairy products delivered to the market; and high aflatoxin contamination in feed and milk are major problems in the dairy sector today that require a strong regulatory body to address for the sector to grow. The semen supplied to the farmers from government and private suppliers needs to be certified and regulated based on internationally accepted quality standards. The importing and exporting of animal genetic materials must follow the guideline developed by the Ministry of Agriculture (2011). To ensure the safety and quality of milk and other dairy products that are delivered to the market, legal frameworks need to backup all other efforts. A quality-based milk pricing policy could be introduced to incentivize farmers to produce and maintain the quality of milk. Milk collection centres must be equipped with the necessary equipment and have trained dairy technicians to test the quality of milk delivered by smallholder farmers for on spot quality control. Milk delivered to processors and to consumers' should be checked regularly to maintain its quality standards. Dairy cows' movement from place to place must be controlled through proper animal identification and movement tracking systems to avoid diseased animal movement and enable tracing and monitoring of diseases and relevant data collection.

The compound feed supplied to dairy farms must be randomly and consistently checked for quality and presence/ absence of dangerous chemicals, including aflatoxin to ensure feed quality, milk quality and consumer safety.

Human resources development and knowledge management

Human resource development is central to dairy sector transformation. Transformation requires skilled manpower to ably manage the different critical value chain processes. The capacity of extension agents and service providers to support smallholder farmers must be strengthened through hands-on and knowledge-based vocational training. Training centres can be organized through public, private or public-private partnerships. Dairy farmers need to be trained by experienced extension agents in farmer training centres or through online outreach programs and farmer-to-farmer experience exchange visits. Printed materials (manuals, leaflets, posters, etc.) and training videos that support dairy producers need to be developed and packaged in simple and easy-to-use ways for better learning and experience sharing among farmers.

A standardized curriculum for technicians who would deliver animal breeding and health services needs to be developed and implemented at the national level, on the basis of which AI technicians should be trained and evaluated. The skill of AI technicians must be enhanced through continuous professional development and competency tests. Training materials for farmers must be translated into local languages and made accessible. Currently, there are different extension materials produced and distributed by different organizations and development programs. These training materials must be standardized nationally and made available from a central source to avoid confusion in messaging and save resources. The experience of documenting lessons learned from research and development interventions is poor. Thus, government must create dairy knowledge centres that could be used as a source of knowledge and experience for researchers, extension agents, farmers and private sector actors and as a platform for documentation. Success in dairy development is available elsewhere, which could be adopted through experience sharing visits to countries in Africa and Asia.

Organizational structure

Dairy sector development is complex, given the numerous and different stakeholders and actors involved. The actors include those working in extension services, development, research, value addition, input supply and service delivery. Dairy development interventions are currently working in fragmented ways, and resources and efforts, especially those that are commonly required by many, are not harmonized leading to duplication of roles and efforts and poor overall return on total investment and development of the dairy sector. Establishing an umbrella organization such as the ‘Ethiopian Dairy Board (EDB)’ whose core duties would be to oversee, regulate and coordinate the resourcing and development of the dairy sector in the country, is recommended. The EDB should be a legal entity established by the government. It would be led a by board consisting of representatives from government, private sector, research institutions, dairy producers and processors and professional associations, etc. The examples and models of dairy boards in Kenya and India could be adapted to the Ethiopian condition. The mandate of the

Kenya Dairy Board, for example, includes licensing, inspecting, surveillance and certifying locally marketed, exported and imported milk to assure consumer safety from physical, biological, chemical and adulteration hazards. It also promotes

the consumption of milk and dairy products (Corne et al. 2016), besides using the resources at its disposal to finance key activities including supporting the national dairy recording system. Similarly, dairy development in India is led by an independent institute that supports the entire dairy development of the country. Ethiopia could benefit from such focused institutional arrangements to bring about faster transformation in the sector.

Establishment of strong multi-purpose dairy cooperatives

The work of cooperatives in agricultural and rural development has yielded significant results in different continents and countries (Nuredin and Lee 2015). Cooperatives are effective in helping rural smallholder dairy farmers to access inputs, market, services and credit cost-effectively. Cooperatives also enable farmers' ability to pool their milk, chill and even process it, thereby guaranteeing market for milk at better prices. Some cooperatives also provide their members with inputs such as feeds, extension, breeding and clinical services. Cooperatives are viewed as potentially important vehicles for community development since they can solve local problems by mobilizing local resources into a critical mass, and by virtue of being locally owned and controlled, cooperatives can keep profits and responsibility in the hands of local citizens (Zeuli et al. 2004).

The dairy development experience of many developed and developing countries is linked to their success in organizing dairy producers in cooperatives. The perishable nature of dairy products and the range of skills involved in dairy production and marketing, requires several services that can best be provided by cooperative action. For instance, the Fonterra Co-operative Group Limited is a New Zealand multinational dairy cooperative owned by around 10,500 New Zealand farmers responsible for approximately 30% of the world's dairy exports. In the USA, the top three cooperatives are Dairies Farmers of America, California Dairies Inc and Land O'Lakes Venture37, Inc. The success of India to become the world's third biggest milk producer is because of cooperatives. Thus, dairy development in Ethiopia cannot be realized without organizing dairy farmers into cooperatives especially in the mixed crop-livestock production system where smallholder farmers live scattered in the highlands of Ethiopia. Milk produced by households cannot be linked to a sustainable market unless farmers are organized into cooperatives, establish collection centres equipped with coolers and chilling equipment and vehicles for transporting milk to processors. The establishment of dairy cooperatives as agents of innovation and as platforms for experience sharing, training of farmers, and influencing members for common good should be supported. These unions can help members to carry out livestock data recording, genetic improvement and can sustainably support scaling up of dairy extension services.

Dairy value chain actors and engagement modalities

Dairy value chain actors

Because of the complexity of the dairy value chain, various public and private-sector actors are involved in, and support the development of, the chain. These players include actors in input supply, service delivery, regulatory management, finance, research, development, professional and cooperative development, and producers' and processors' unions, etc. They must be organized to support the development of the dairy sector.

Dairy value chain actors' engagement modalities

The engagement of the different actors could be at different levels, but with a focus on championing inclusive and participatory processes. The following platforms are suggested to strengthen the engagement of dairy value chain actors in the sector:

Ethiopian Dairy Board

To spearhead the dairy development in Ethiopia, the establishment of the Ethiopian Dairy Board (EDB) as a legal entity is a priority as suggested in different stakeholders' discussion platforms. Relevant direct actors in the dairy sector, responsible government agencies, professional associations and other development partners in the dairy value chain will be represented in the EDB as defined in the EDB structure. The EDB is expected to chart the way for national dairy development and persistently support and regulate implementation of activities geared towards the sector's development. Key actors in the dairy value chain will use this platform as an influencing instrument by generating policies, strategies, and regulations supportive to the sectors' development.

The Rural Economic Development and Food Security platform of the Ministry of Agriculture

The Rural Economic Development and Food Security (RED&FS) platform of the Ministry of Agriculture is an existing platform of government and development partners organized to harmonize efforts and resources for a common goal. This platform could be used to address some of the critical issues in dairy development and mobilize resources for selected priority interventions.

Dairy value chain actors' platform

This platform will ensure participation of all actors in the dairy value chain. Members will contribute to the sector's development and participate in drafting policies, strategies and regulations, and identifying bottlenecks to be addressed by government or development partners. Periodic meetings will focus on critical problems in dairy development in the country and look for solutions to these challenges. It will also discuss the emerging trends of the problems identified. Research institutions, which should be part of this platform, will take up research on the problems identified by this group. The platform can also play a role in designing dairy research and extension approaches for approval by government. These platforms could be organized at regional and national levels. The Ministry of Agriculture and the regional bureaus of agriculture will have an oversight role to strengthen these platforms. Necessary resources for such platforms could be mobilized from government, the private sector and development partners. Such platforms could also be used to mobilize finance for research and technology generation and multiplication of innovations by smallholder farmers.

Projects supporting dairy development in Ethiopia

Ethiopia has been receiving substantial financial and technical support from donors and development partners to transform the livestock sector in general and dairy production in particular. These initiatives have had positive impact and benefitted farmers by increasing household income and improving livelihoods. Organizations such as ILRI, SNV, the United States Agency for International Development, ACDI-VOCA and Land O'Lakes v37 Inc have implemented such projects in the past. Current projects in the livestock sector include some that are being funded by the World Bank, the African Development Bank, the European Union, the Bill & Melinda Gates Foundation and the Government of Netherlands. The projects are supporting research, development and extension in both pastoral areas and mixed crop-livestock production systems.

For the desired outcome and positive impacts, the ongoing projects should collaborate to exploit potential complementarities and synergies. The EDB or the RED&FS would be best placed to coordinate the related programs and projects.

Conclusion

The dairy sector has great potential for growth in Ethiopia. Concerted sustainable efforts from government and private sector are required to address the challenges hindering the growth of the sector and develop short-term and long-term plans of action to mitigate the bottlenecks in the sector. Current efforts from different actors in the dairy value chain are worth acknowledging but are not enough, are fragmented, project driven, and lack continuity in area and type of intervention. Thus, both government-led platforms of actors and private sector investment are necessary to address current dairy development challenges. Private sector investment must be encouraged to lead the transformation of the sector. Research must be strengthened to adapt or generate technologies appropriate for the smallholder farmers to improve the productivity of their dairy enterprises. The process of decision-making in the dairy sector must be supported by evidence generated from national and international institutions and development partners. The sustainability of dairy development will only happen if the private sector fully participates and takes a lead in the overall development of the dairy sector. Government and NGO support should complement and not take over the role of the private sector. At the same time, the dairy extension service should be support for successful dairy sector development.

Recommendations

To following recommendations can help transform dairy production from subsistence to commercial market-oriented enterprises in Ethiopia.

- A sustainable inputs production and marketing system should be established by engaging and supporting private sector investment can help in stabilizing fluctuations in input supply prices.
- The regulatory institutions should be strengthened to play their role in setting standards and regulating and standardizing inputs, products and services provided by the public and private sectors.
- Establishing dairy clusters in high-potential areas can boost dairy production and productivity to meet growing demand and reduce reliance on imported dairy products. Increased production will create opportunities for export of surplus produce.
- Dairy development requires a specialized market oriented and pluralistic extension and institutional arrangements thus, strengthen public extension service and support other actors of the dairy value chain to participate in input supply and extension service.
- Research must devote resources to select high-yielding and tropically adapted milking cows from among local breeds. The improvement of promising indigenous breeds should be initiated and supported as the basis for improving dairy and meat production.
- A breeding policy that targets indigenous breed improvement is needed in the country. The Ministry of Agriculture and private sector partners should work towards strengthening existing breeding facilities (e.g. ranches and research institutions) and the establishment of new ones to support genetic improvement of indigenous breeds. The research system should also mobilize resources to implement the breeding policy, including by application of genomic and reproductive technologies to increase rates of genetic gain.
- Dairy extension and development support from public and private should consider a value chain approach to addresses specific nodes of the dairy value chain.
- The private sector should be incentivized so that it can fully participate of in dairy development.
- Promote milk consumption and integration of dairy development with ongoing government programs (e.g. nutrition, school milk feeding). The seasonality in milk consumption and price volatility should be addressed through the establishment of a strategic milk reserve as part of the food security initiatives of the government.
- Market linkage of smallholder dairy farmers with processors should be strengthened by organizing producers in marketing associations and cooperatives.
- At an early stage of the dairy development, both public and private sectors should have a role to play in isolation and jointly. To attract the private sector to invest in dairy, the government must share investment risks by strengthening public-private partnerships that will enable government to gradually reduce its role in dairy development. Selective government investment is required in logistics and cold chain facilities to lay a foundation for the private sector investment.
- Develop local capacity to manufacture dairy equipment, and to produce qualified technicians and extension agents who can support extension services for dairy producers.

- Set up and put into effect an animal identification and performance data recording system to support sustainable dairy genetic improvement. All existing animal identification and performance data recording systems should be supported and aligned with ongoing efforts and future projects in dairy genetics improvement.
- The current ADGG breed recording platform should be used as a basis for ca sustainable breeding program to be scaled up for dairy and other species. employ available ICT to capture data, deliver extension message and provide feedback, and genomic technology for early detection and selection of superior animals

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