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NETHERLANDS EAST AFRICAN DAIRY PARTNERSHIP

Quick Scan of Ethiopia's Forage Sub-Sector

Netherlands East African Dairy Partnership (NEADAP)

Working Paper

Author:

Adolfo Alvarez Aranguiz (Wageningen UR, Livestock Research)

Jos Creemers (SNV Kenya)

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To be cited as: Alvarez Aranguiz, A., and Creemers J., 2019. Quick Scan of Ethiopia's Forage Sub-Sector, Working paper, Wageningen, Wageningen UR-Livestock Research.

This Working Paper describes the Ethiopia forage sub-sector and looks at available forage species, quality, seasonality, preservation, seeds, planting material and fertilizer use, mechanization, inputs and services, the forage market, education and training, environmental footprint, and policy framework. The report gives recommendations to enhance availability of quality forages, especially for the Ethiopian dairy sector. The report is part of Theme 2: Forages and nutrition of the Netherlands East African Dairy Partnership project (NEADAP), an initiative by the Netherlands government for learning and sharing amongst different dairy sectors and projects in East Africa.

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Milk Quality | Forage & Nutrition | Inclusive Business Models | Networking & Influencing | Innovation

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Acronyms

AEZs	Agro-ecological zones
BoAL	Board of Agriculture and Livestock
BRIDGE	Building Rural Income through Inclusive Dairy Business Growth in Ethiopia project
CIAT	International Centre of Tropical Agriculture
CIC	Chemical Industries Corporation
CP	Crude Protein
DairyBISS	Dairy Business Information and Support Services project
DA	Development Agent
DM	Dry Matter
DMI	Dry Matter Intake
DUS	Distinctiveness, Uniformity and Stability test
EAFIA	Ethiopian Animal Feed Industry Association
EA	East Africa
EDGET	Enhancing Dairy Sector Growth in Ethiopia project
EIAR	Ethiopian Institute of Agriculture Research
EM	Effective Micro-organisms
EKN	Embassy of the Kingdom of the Netherlands
ESE	Ethiopian Seed Enterprise
FE	Feed Efficiency
FCU	Farmers' cooperative union
GHG	Greenhouse Gases
ICRAF	World Agroforestry Centre (International Centre for Research in Agro-Forestry)
ILRI	International Livestock Research Institute
KMDP	Kenya Market-led Dairy Program
LMP	Livestock Master Plan
MASL	Metres above sea level
MjME	Mega Joules of Metabolizable Energy
MoAL	Ministry of Agriculture and Livestock
NARS	National Agricultural Research Systems
NDF	Neutral Detergent Fibre
NDFd	Neutral Detergent Fibre Digestibility
NGO	Non-governmental organization
NIR	Near Infra-Red
OCP	Morocco’s Office Cherifien des Phosphates
SNNPR	Southern Nation Nationalities and Peoples Region
SNV	Netherlands Development Organization
PMR	Partial Mix Ration
TIDE	The Inclusive Dairy Enterprise project
TMR	Total Mix Ration
WoARD	Woreda Office of Agriculture and Rural Development
WUR	Wageningen University and Research

Acknowledgements

This report on the forage sub-sector in Ethiopia is a Working Paper prepared under the umbrella of the Netherlands East African Dairy Partnership (NEADAP), and serves as a reference document and input for a Strategy Paper and Policy Brief for consideration by relevant Ethiopian agencies and stakeholders. NEADAP is financed by the Government of the Kingdom of the Netherlands in Kampala, Uganda.

The author, Adolfo Alvarez Aranguiz and Jos Creemers wishes to thank the stakeholders in Ethiopia (and abroad) who contributed to this report by patiently and diligently responding to the questions of the questionnaire, and by sharing their views and knowledge when being interviewed.

Special thanks goes to Nancy Kimaiyo Jerop of KMDP for helping in designing and administering the survey and analysing the responses, and to Seyda Özkan-Gülzari and Jan van der Lee, Wageningen Livestock Research, Jos Creemers, SNV Kenya (consulting for ProDairy EA Ltd) and Anton Jansen, team leader of SNV's Kenya Market-led Dairy Programme (KMDP), for giving valuable inputs to the survey and the report.

The author,
Adolfo Alvarez Aranguiz – Wageningen Livestock Research
Jos Creemers - SNV Kenya (consulting for ProDairy EA Ltd)

Executive Summary

Ethiopia has a potential to develop a strong dairy sector. However, the productivity is below its potential. This is due to technical (shortage in quantity and quality of feed, inefficient feed management and utilization, diseases and poor breeding strategy) and non-technical factors (poor infrastructure and institutional support). This report analysis the Ethiopia forage sub-sector and looks at available forage species, quality, seasonality, preservation, seeds, planting material and fertilizer use, mechanization, inputs and services, the forage market, education and training, environmental footprint, and policy framework. The report gives recommendations to enhance availability of quality forages, especially for the Ethiopian dairy sector.

Production of forage to feed animals is not a common practice. Grazing land constitutes 66 % of the feed resources for livestock (CSA, 2011).Increasing population and declining land productivity results in an increasing demand for arable land in Ethiopia, and reduces the amount of land available for natural grazing and forage production. According to the statistics of the Ethiopian Government, grazing land availability has shrunk from 30 % of the land cover in 1980 to 12 % in 2000.

Sustainable livestock and crop production in Ethiopia is dependent on drastic changes in livestock and land management systems. More efficient integration of livestock and cropping systems is essential to improve livestock productivity and sustainability of the mixed system. The key components of these changes are a shift towards more intensive feeding systems, with more emphasis on cut and-carry feeding, forage production in the midlands and highlands, and to rationalized grazing, particularly in the lowlands areas.

The production of adequate quantities of good quality forages, better nutrition, genetics, and the combination of these strategies, are the only way to economically overcome the feed shortage and improve milk/meat production in Ethiopia (Mayberry et.al., 2017). A strong dairy market, together with the allocation of land for fodder, and awareness of the potential of quality forage towards increased milk production are three important pillars to boost forage production. Population pressure on crop land expansion, seasonality in feed availability, and lack of knowledge on feed preservation calls for alternative ways of feed production, conservation and use (Table1, 2).

The non-technical factors usually require a medium tolong term solution, but in the meantime improvements can be done to alleviate the nutritional deficiencies of dairy livestock: (i) dairy farming system forage production improvement, (ii) multiplication and harvesting of forage seed and vegetative parts to maintain forage production over time, (iii) effective utilization and better management practices of the available feed resources to achieve higher feed efficiency, and (iv) implementation of climate smart agriculture practices to improve production and counteract land scarcity. Different practices and supplementation strategies could be applied, depending upon the forage type, access to and price of both forage and supplementary feeds in a given area. Haymaking practices can be improved and increased in order to enable a steady improved quality feed supply throughout the year. Better evaluation of the nutritive value of forage, concentrates, naturally-occurring grasses, and forage trees and shrubs (which are commonly used as feed resources during the dry season) could be important to enhance their proper utilization.

Once the non-technical factors start to improve, important points can be considered such as: (i) raise awareness of the need to produce forage to feed the animals and of quality to increase productivity and profit, with the result to have more commercial-orientated forage and animal production, (ii) develop and facilitate access to either new or improved forage species/varieties, new technology and machinery, inputs (i.e. seed and planting material, concentrate dairy feed, fertilizer, service providers, veterinary drugs, etc.), forage preservation techniques, particularly silage/haylage, and (iii) facilitate involvement of the private sector in the forage supply chain for future expansion.

Table 1. Summary of main problems faced by the forage sub-sector in Ethiopia

- Inconsistencies and informal character of milk market do not encourage farmers to produce forage
- Scarcity of land for forage production and production of forage for dairy cattle being uncommon, lead to insufficient quantity and quality of available forages; available forages have very low digestibility (crop residues e.g. straw and stover)
- Insufficient inputs for commercial feed
- Introduction, promotion and expansion of improved forage production is inadequate and slow
- Seasonality in the production of forage
- Feed preservation is non-existent (with the exception of haymaking)
- Inefficient feed utilization (unbalanced rations)
- Lack of feed testing
- Lack of awareness on the links between nutritional value of forage and animal production
- High cost of purchased feed (forage/concentrate/by-products)
- Forage market is informal and opportunistic
- Lack of seed/plant material of forage crops (including pasture grasses)
- Inefficient use of water.

Table 2. Summary of recommendations to enhance the forage sub-sector in Ethiopia

- Reinforce milk market development as the main driver to encourage forage production
- Introduce awareness on the importance of quality forage for milk production improvement
- Encourage the integration of livestock and crop practices (mixed system)
- Stimulate and facilitate the private sector in the production and commercialization of certified forage species/cultivars/varieties seed and plant material
- Collaborate with CIAT and promote new species that have recently been introduced, such as *Brachiaria* hybrids and *Panicum maximum cv*, and campaign for good management practices during land preparation, growth, harvesting, storage and feeding
- Improve land use and soil conservation, integrating forage production
- Introduce grass-legume forage mixes to improve protein production and soil conservation
- Improve management practices of commonly used varieties such as Desho grass, Napier, and Rhodes grass
- Introduce, promote and improve new preservation practices other than hay
- Support investment in the forage sub-sector, especially by incentivising youth service providers to create businesses specialized in different steps of the forage production chain (seed multiplication and supply, forage production and preservation contracting services, sales and maintenance of machinery, etc.)
- Introduce the notion of "quality" throughout the forage chain by promoting energy and protein rich forages, feed laboratories for analysis, pricing based on nutritive value, feed standards and good management practices
- Include and link forage production and ruminant nutrition in ATVET and college education and in farmer training and extension programs
- Campaign for good practices "from seed to feed" focused on productivity, quality and sustainability of agro ecosystems (conservation agriculture, reduction of GHG-emissions)
- Improve use and management of grassland; rehabilitate rangelands and communal land
- Improve soil and water management and use, focused on future generations
- Intervene in the forage market by setting-up strategic feed reserves in areas prone to drought and climate shocks.

Introduction

SNV Netherlands Development Organisation (SNV) and Wageningen University & Research (WUR) have implemented EDGET and DairyBISS projects and are now implementing the Building Rural Income through Inclusive Dairy Business Growth in Ethiopia (Bridge) project. These projects are funded by the Embassy of the Kingdom of the Netherlands in Addis Ababa. The Dutch Government also funds dairy programs in Uganda (TIDE) and Kenya (KMDP, 3R Kenya). This involvement in East Africa in 2018 led to a regional project for learning and exchange: the Netherlands East African Dairy Partnership (NEADAP). NEADAP focuses is on four themes: Milk Quality, Forage (and Nutrition), Inclusive Business Models and Learning & sharing of lessons learned. It covers 5 countries: Ethiopia, Kenya, Uganda, Rwanda and Tanzania . Implementing partners are SNV, Agriterra, WUR and Bles Dairies.

In NEADAP's Forage Theme, SNV and Wageningen Livestock Research developed a Scope of Works for Forage Quick Scans for Kenya, Uganda and Ethiopia. The quick scans focus on the current status of forage crops availability, production and preservation practices, technologies, mechanization and innovations. This includes forages produced and preserved by the farmer in different farming systems: intensive farming (zero grazing), semi-intensive (semi-zero grazing) and extensive livestock systems (grazing, ranching, agro-pastoralism).

The Ethiopian dairy and forage sub-sector

Farming systems in Ethiopia can be classified according to feeding cows' practices into pastoral, agro-pastoral and sedentary systems. Pastoral and agro-pastoral systems are mainly found in the lowlands where, for the pastoral system, livestock production is the dominant form of production to sustain the livelihood, without cropping, while the agro-pastoral system combines both cropping and livestock production. Dairy production under both systems is low in inputs and outputs, and based on indigenous cattle. These two systems are non-market oriented and most of the milk produced is used for home consumption.

In sedentary systems, which are predominantly found in mid-altitude to highland areas, the level of intensification may vary between small- and large-scale dairy systems. The small-scale dairy systems (1-2 cows) are mostly less intensified, with cows grazing when fresh grass is available, otherwise they are supplemented with other feeds like straw, hay or crop residues. Medium-scale dairy farms (3-15 cows) are mostly found closer to towns and are more intensive systems, where farmers use all or part of their land to grow improved pasture and forage, and purchase concentrates and fodder to complement the cow's diet. Large-scale dairy farms (>15 cows) under highly intensive production systems are mostly found around peri-urban and urban areas, in proximity to Addis Ababa and regional towns, as these take advantage of the demand for milk in urban markets. In most of these farms, crop residues are the main feed provided along with by-products and concentrates (Gizachew et al., 2016).

> **The agricultural regions in Ethiopia can be split into two main areas:**
>
> - The highlands (> 1,500 MASL) constitute 40% of Ethiopia's total landmass; here over 80% of the human population resides, and 90% of the livestock (75% of the cattle and sheep). The average annual rainfall exceeds 900 mm.
> - The lowlands (< 1,500 MASL) constitute 60% of the total territory; here only ca. 20% of the country's total population resides and only 10% of the livestock (including 70% of the goats and 100% of the camels). Rainfall is erratic and averages below 600 mm.

Smallholder dairy farmers, in all regions, base the diets of their cows in communal pasture lands (i.e., the major green and dry roughage feed sources), and crop residues (e.g., straw supplementing the diet).

Crop residues vary depending on the main crop in the area (wheat, teff, barley). The limitation of such feed resources is the very high content of neutral detergent fibre (NDF) that limits potential dry matter intake (DMI), together with low content of energy and protein.

The productivity of dairy cows is mainly based on good feeding practices. Given that the main ingredient in the diet of all ruminants is forage/fodder, its quality is key to animal production, fertility, health, welfare, and business profitability. In fact, cows prioritize the use of energy in the following order: (i) maintenance, (ii) milk, (iii) growth, and (iv) fertility, which means that a deficient or unbalanced diet can be the main cause of reduced production, body condition, and/or fertility. Backyard forage production and grassland development, through the incorporation of improved forages, are practices that need to be reoriented to increase efficiency. Research and extension should be directed towards the development of feeding systems that make better use of those local resources that are available throughout the year. Forage research needs to be directly linked to animal nutrition in order to develop more efficient systems. Due the particularity of the Ethiopian intensive crop/livestock mixed system (with high stocking rate), soil conservation, water use and education needs to be prioritized in any forage intervention to maintain productivity for future generations.

Methodology

The methodology of the quick scans consisted of a combination of desk study, questionnaires, interviews and field visits. This report concerns the forage sub-sector scan for Ethiopia. Annex 1 presents the list of key resource persons representing relevant organizations, who received a questionnaire or were interviewed. With a sample size of N=30 for the long questionnaire and N=10 for the short one, 30% of all organizations responded to the long questionnaire and 80% to the short. In addition, 38 persons were interviewed. The major limitations of this study were: (i) the small response to the survey due to poor internet connections, (ii) the lack of interviewed entrepreneurs engaged in forage production, and (iii) the lack of collaboration from the private sector involved with the forage chain.

The report itself is structured as follows: Section I describes the current situation, according to 13 topics: 1. Feed, 2. Forage species, 3. Seeds, planting material, 4.Forage quality, 5. Environment/climate/agro-ecological zones, 6. Seasonality, 7. Preservation of forage crops, 8. Forage market, 9. Inputs & services, .10 Mechanization, 11. Education and training, 12. Recent interventions on forage and 13. Policy framework. Section II. provides recommendations and includes suggestions for interventions, investments and policies to enhance the forage sub-sector in Ethiopia. The recommendations are geared to improve the current situation of forage production, preservation, quality and availability with a view to improve dairy rations, margins above feed costs, increase milk production, reduce (seasonal) scarcity and maintain milk production throughout the cow's lactation period, through **sustainable intensification**. In addition, it highlights dairy management practices that are environmentally sustainable. Finally, Section III lists conclusions.

Smallholder dairy farm (Amhara Region)

Medium-scale dairy farm (Adama Region)

Large commercial dairy farm (Adama Region)

Communal land (rainy season, South Achefer)

Land Potential: Maize, Rhodes grass and LabLab during rainy season (North Mecha)

Section I. Description of the Current Situation

1. *Feed resources for ruminants in Ethiopia*
2. *Forage species*
3. *Seed and planting material*
4. *Forage quality*
5. *Environment, climate and agro-ecological zones*
6. *Seasonality*
7. *Preservation of forage crops*
8. *Forage market*
9. *Inputs and services*
10. *Mechanization*
11. *Education and training*
12. *Recent interventions in forage*
13. *Policy framework*

Section I. Description of the Current Situation

The stakeholders interviewed indicated that many interventions and strategies have been developed during many years, but these have had inconsistent results. The failure of activities is attributed to the challenge of simultaneously tackling large areas and various aspects of the forage production chain. In other words, they were considered too ambitious, and this has probably diluted the impact of the projects. As a result, they suggested to focus the tasks in small areas or communities, instead of trying to cover big areas and/or many communities at the same time.

The milk market is another area of concern as it is not strong (inconsistent demand and informal). Because of this, farmers are not confident enough to increase the land surface allocated to forage. The only exception is in Addis Ababa and surrounding areas, where there is a steady growth of the processed milk industry. Despite the fact that there are only few milk-processing companies, they are becoming well recognized. This increases the confidence of farmers in this area to allocate more land for forage production. However, in the rest of the country, the dairy sector and formal milk processors are at very early stages of development. As soon as the strength of the milk market in those areas increases, many farmers would be keen to set aside land surface for forage production.

Others factors that are impairing the adoption of fodder crops by farmers, according to interviews and survey responses, are related to the lack of (i) infrastructure, (ii) economic incentives, (iii) policies, especially those related to land use, and (iv) support of service delivery. Moreover, practical factors like land size, low awareness on the importance of forage in cow rations, and access to finance, seed and other farm inputs play a role.

These complementarities between technical and non-technical challenges need to be understood and considered for future interventions related to forage sub-sector and dairy sector development. Innovation capacity within the sector thus depends on the quality and density of interactive relationships between producers, enterprises (market), and public and private organizations that carry out research and training, provide advice or expertise in finance, coordinate and regulate.

1. Feed resources for ruminants in Ethiopia

In Ethiopia, the total annual biomass potentially available for animal feeding is 144.5 million tonnes, with a Metabolizable Energy (ME) and Crude Protein (CP) content of 890 x 10^9 MJ and 7.49 million tonnes, respectively. The total annual potential availability of forage (in million tonnes of dry matter (DM)) is around 110, which includes 5.8 of stubble biomass, 57.09 of grazing forage, and 46.9 of crop residues (mainly straw and stover) (FAO 2017).

Hay and crop residues plus natural grass constitute > 90% of the livestock diets in all the regions, whereas the use of improved forages represent < 0.35% of the diet, with the exception of Harari region where it is 1.68% (Table 3). Improved forage species and varieties are insignificant in use and importance, but will be critical in the near future to sustainably intensify animal production.

The four major regions in which the production of cultivated crop-based forage is the highest are Oromia, Amhara, Southern Nation Nationalities and People Regional (SNNPR) and Tigray. In these regions, the main forage sources for dairy cattle, after natural grass, are stover and straw (Table 4) (FAO 2017).

Table 3. Main livestock feed sources by region, in percentages (Yilma et al., 2011)

Region	Natural Grass	Crop Residues	Improved Forage	Hay	By Products	Others	Total	Total livestock (2007/08)*
Tigray	38.37	39.17	0.35	16.86	1.62	3.62	100	7.513.000
Afar	88.25	6.67	0.09	1.63	0.93	2.42	100	6.824.400
Amhara	43.72	36.35	0.31	15.72	0.54	3.35	100	26.695.600
Oromia	66.65	24.80	0.11	3.22	0.91	4.3	100	38.445.200
Somali	80.21	18.44	-	0.53	0.29	0.53	100	3.702.800
Benshangul/Gumuz	86.63	7.56	0.03	1.19	0.24	4.34	100	820.400
SNNP	70.54	22.69	0.17	2.00	0.63	3.98	100	16.199.400
Gambella	93.92	4.03	0.28	0.03	0.63	1.12	100	363.400
Harari	38.57	47.93	1.68	3.78	6.71	1.33	100	87.000
Dire Dawa	71.51	19.73	0.24	1.42	2.94	4.16	100	264.100
Total Ethiopia	**59.53**	**28.27**	**0.20**	**7.36**	**0.79**	**3.86**	**100**	**100.915.300**

* Adapted from Agricultural Sample Survey 2007/08, CSA (cattle, sheep, and goat)

Table 4. Main crop residues used in the main crop regions.

Region	Main crop residues used as forage (in order of importance)
Oromia	Maize stover Sorghum stover Wheat straw Teff straw
Amhara	Sorghum stover Maize stover Teff straw
SNNPR	Maize stover Sorghum stover Teff straw
Tigray	Sorghum stover

Agro-industrial by-products, mainly from vegetal oil, breweries and flour industry, constitute another component of the livestock diets. These ingredients are usually used to feed dairy cows or in fattening farms during key moments of the production cycle. Commercial compounded concentrate feeds are currently operational across the regions [Oromia region (37%), Addis Ababa region (31%), Amhara (13%), SNNPR (13%), and Tigray region (6%)]. Average percentage change in the price of compound feeds suggests an average increase of 85% over five years with an estimated annual rate of increase of 17 % per year. Maintaining the desired level of nutritional and quality standards of feed ingredients and compound feeds is a challenge for commercial feed producers, the regulatory body and livestock producers. Lack of confidence of livestock owners in the quality of compound feed is another reason for not using such feeds. There is also a need to update and implement feed standards.

Table 5. Summary of main feed gaps
Feed is not available in sufficient quantity/quality
Inefficient utilization of crop residues
Low and irregular supply of agro-industrial by-products
Scarcity of quality grazing land
Inferior quality of compound concentrate feed
High cost of concentrate feed and processed crop residues (hay/straw)
Low levels of skills and knowledge related to ruminant nutrition

2. Forage species

The largest feed resource in Ethiopia are natural pastures, with a maximum availability during the crop growing season. Pasture growth is a reflection of the annual rainfall distribution pattern, and this has different characteristics according to the agro-ecological area. Around 736 species of grasses, 358 species of legumes, and 179 species of browse trees fit for animal feeding have been identified (Ethiopia's CBD 4th Country Report, 2014). Highly palatable indigenous forage species include *Trifolium spp., Eragrostis, Cynodon, Digitaria, Paspalum, Panicum*, *Pennisetum*, *Setaria*, *Acalypha fruticosa*, *Cordeauxia edulis*, *Acacia nilotica*, *A. Senegal*, and some wild edible plant species (which are threatened with extinction). Overgrazing and poor management practices favour the growth of invasive plant species causing a shift in the plant composition of pastoral grazing and decreasing their livestock carrying capacity. These invasive species include *Acacia mellifera* and *A. nubica, Raphanus raphanistrum, Prosopis spp.,* and *Partinium hysterophorus* (Ethiopia's CBD 4th Country Report, 2014).

In the lowlands, arid and semiarid areas, grazing feed sources are mostly communal with strong seasonality in supply due to rainfall patterns and overgrazing. In these regions (i.e. Afar, Somali, Benishangul-Gumuz, Gambella, Dire Dawa, and parts of Oromia and SNNPR) natural pasture is the sole forage source of livestock feed, and represents more than 80% of the total livestock feed (Yilma et al., 2011). They comprise a wide range of grasses, legumes, and shrubs, and are predominantly owned by the community. During these past years, the increase in commercial cultivation (e.g. sugar cane) and land use changing patterns (i.e. lack of land fallow for regeneration) has caused a decline in the use of grazing as a source of livestock feed. Other major issues affecting these lowland grasslands are deficient management, short growing season (it only suits fast-maturing plants), limited rainfall and recurrent droughts, shrub invasion, the disappearance of better quality and palatable species of grasses, and overgrazing and nutrient depletion of the soil. In this area, native pasture yields one ton of dry matter per ha or less (Tekalign, 2014).

In the highlands and mid-altitudes areas, the most common grassland species are *Andropogon, Avena, Eragrostis, Eleusine, Cynodon, Cyperus, Digitaria, Paspalum, Panicum, Hyparrhenia, Pennisetum, Setaria, Trifolium* and *Medicago species*. Grazing land is steadily decreasing due to population pressure, land degradation, and conversion of grazing lands into arable lands. This especially affects mixed crop-livestock system. The high stocking density and intensity of land cultivation is out of proportion to the land carrying capacity, circumstances that cause rapid and strong soil degradation. In intermediate and high altitude areas, the natural pasture yields are around 3 tons of dry matter per ha, and 4-6 tons of dry matter per ha, respectively (Tekalign, 2014). Grazing land accounts from 38.37% in Tigray to 70.54% in SNNP of animal total feed (Table 3). The size and quality (species composition, vigour and palatability) of communal grazing land has reduced substantially over the past years. However, it is important to remark that some farmers' groups are starting to take initiatives to improve communal lands with different management solutions, such as (i) seeding improved species (Rhodes grass), (ii) stop grazing or controlled grazing, and (iii) hay-making and seed production.

The area under improved pasture and forage crops is increasing in government ranches, state farms, farmer demonstration plots, commercial dairy producers, and fattening enterprises. Some smallholder farms have started to use improved forage, but this only represent < 0.2% of the total feed offered to livestock (Yilma et al., 2011). Yield of improved pasture ranges from 6 to 8 t DM/ha, forage legumes range from 3 to 5 t DM/ha, and tree legumes 10 to 12 t DM/ha (Tekalign, 2014).

According to the desk study, and in coincident with interviews and questionnaire responses, the most common improved species of forage crops are oats (*Avena sativa*), vetch (*Vicia spp.),* Desho grass (*Pennisetum pedicellatum*), Napier/elephant grass (*Pennisetum purpureum*), fodder beet (*Beta vulgaris*), siratro (*Macroptilium atropurpureum*), *Desmodium spp*., cowpea (*Vigna unguiculata*), lab lab

(*Lablab purpureus*), *Panicum spp*., Rhodes grass (*Chloris gayana*), lucerne (*Medicago sativa*), *Phalaris spp*., *Trifolium spp*., *Sesbania spp*., *Leucaena spp,* Sweet lupine *(Lupinus angustifolius L.)*, and tree lucerne/tagasastes (*Cytisus proliferus*) (Annexe 5). Improved forages represent < 0.15% of the total livestock feed balance, according to FAO 2018, and < 0.1% of the total energy required by Ethiopia livestock.

Forage research

Forage research in Ethiopia is carried out by national and international institutes. The main national and international organizations involved in forage development are:

Universities' research in agriculture is very common and a lot off information is available, most of this research focuses on food production, but over the last years research on forage crops and livestock has been increasing.

EIAR (Ethiopia Institute of Agricultural Research) national research centres promoting research in agriculture, agro-pastoralism, and pastoralism through market-competitive agricultural technologies. Under EIAR, ten research centres around the country work in different fields related to agriculture and livestock.

ICRAF (International Council for Research in Agro Forestry), also known as the World Agro Forestry Centre, encourages the use of forage trees that are highly nutritious for livestock. At the moment it has four ongoing projects: (i) Agro-Biodiversity and landscape restoration for food security and nutrition in Eastern Africa, (ii) Trees for Food Security 2: Developing integrated options and accelerating scaling up of agroforestry for improved food, (iii) Provision of Adequate Tree Seed Portfolio in Ethiopia and, (iv) Reversing Land Degradation in Africa by Scaling-up Evergreen Agriculture.

ILRI (International Livestock Research Institute) is an international institute working on forages in many tropical countries at different capacities. It has a forage laboratory for tropical forages in Addis Abeba.

The main weaknesses of forage research in Ethiopia are (i) insufficient collaboration and coordination within and between national and international research centres, (ii) the need of stronger connections between forage- and animal nutrition research, (iii) absence of effective models to bring research (i.e. new seed varieties) to the farmer: route to market, distribution network and training in best agronomic practices, and (iv) the tendency that policy makers think – or are made to belief - that with much local research ongoing, there is no need to actively encourage the private sector seed companies to enter the forage market.

Table 6. Summary of improved forage species/varieties access gaps
Not much interest from seed companies/seed producers to enter the forage seed market
Lack of interest from farmers to harvest seeds (NGO's and Government distribute seeds for free)
Uncertain forage seed market (unknown demand)
Not very attractive market, especially for perennial species
Lack of knowledge on forage crop production and utilization in the farming community
Lack of awareness of the influence of forage quality on animal production
High cost of improved seed species/varieties (and/or planting material)
Weak milk market does not encourage farmers to allocate land for forage production
Scarcity of resources for local scientific and applied research in forage

3. Seed and planting material

Ethiopia has large potential to produce seed. Many of the temperate and tropical pasture grasses and forage crops that have been tested and grown in Ethiopia have had no problem in flowering and setting seeds. This provides a good opportunity for the country to establish a local seed multiplication sector within the existing farming system, which in the long run could provide potential to export forage seeds to other African countries. Conservation and use of grass germplasm made a significant contribution to the economic development of Ethiopia through the national pasture and forage research program. ILRI has done a lot to fill the current gap in seed production and distribution, by collecting grasses from different parts of Ethiopia and getting access to international collections of forage grass germplasm (https://www.ilri.org/).

Seed system

The current forage-seed system in Ethiopia is underdeveloped. Seed production and marketing are generally informal and mainly dominated by informal seed dealers and farmer-to-farmer exchanges. This situation makes access to improved forage seed/planting material very difficult (Fikre, 2018). The majority of forage seed is exchanged by farmers through informal non-monetary transactions. About 60-70% of forage seed used by smallholder farmers is saved on-farm or exchanged among farmers, and only 20-30% is purchased locally through retailers (Sahlu et al., 2008).

Formal channels for forage seeds need to follow the regulations of the Ministry of Agriculture and Livestock (MOAL). Anyone who wants to engage in seed multiplication, processing, import, or export, by law needs (i) to obtain a competence assurance certificate from the MoAL/BoAL, (ii) register their fields for inspection, (iii) provide proof of the parental material of the registered variety, and (iv) include private sector/companies licensed to trade the approved varieties.

The National Variety Release Committee (NVRC) authorizes the actual release of the varieties. The crop varieties released in the most recent year are provided in the registry book together with their cropping season and respective agronomic and morphological descriptors. For imported varieties, the importer must first apply to the MoAL for registration, submit an application to the EIAR, and then follow the regular process (Getnet et al., 2012) (http://www.moa.gov.et/).

If a new variety is approved, individual and institutional applicants are notified by the Animal and Plant Health Regulatory Directorate of the MoAL. Until 2016 the Directorate has released 38 varieties of 19 species (Annex 3).

The implementation of seed inspection and certification depends on the Bureau of Agriculture and Livestock (BoAL) at regional state level. The management of all 10 seed testing laboratories has been given to the regional Bureaux: Ambo and Assela for Oromiya Region, Durbete, Gondar, Debre Markos and Dessie for Amhara Region, Axum and Mekelle for Tigray Region; and Durame, and Wolaita for SNNPR) (Thijssen et al., 2014).

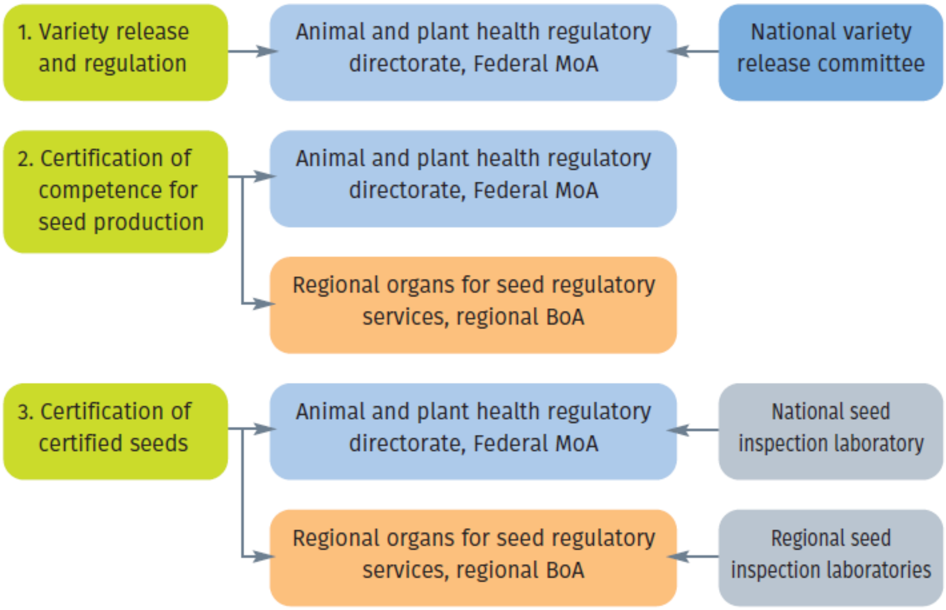

Figure 1. The institutional set-up of seed certification

Source: National Consultation Workshop. Forage and Forage-Seed Industry Development for Improved Livestock Production and Productivity. 30 November 2015, Addis Ababa, Ethiopia.

Seed suppliers

The supply of improved forage seeds is limited to some NGOs and government institutions. The types and amount of forage seeds produced and marketed in the country is very limited. In addition, while regulation and quality control system are in place for forage seeds marketed in the country, its implementation and application is not enforced.

The main species supplied by NGOs and Government are: oats, vetch, Rhodes grass, Napier/elephant grass, *Sesbania* ssp, Desho grass, cowpea and, to a lesser extent, lucerne, *Desmodium* ssp, *Brachiaria* ssp, and fodder beet.

According to the survey, interviews and our desk study, the weakness of the seed supply system is due to many factors such as (i) lack of effective extension service providers focused on forage crop development in relation to livestock production, (ii) poor development of forage seed producer enterprises, (iii) dispersed market, (iv) weak linkages between suppliers and buyers, (v) a general lack of market information, and (vi) poor coordination among seed producers, extension services and other market actors, all of which limit the viability of the forage value chain. The absence of a formal forage seed market system has generated a distortion of the market, with widespread marketing of poor-quality seeds and seeds from unidentified sources by traders (Toleda, 2019).

The Farmers' Cooperative Unions (FCUs) could play a vital role in seed and fertilizer distribution and coordinate potential credits that are offered by various financial institutions through FCUs to farmers. At the moment, the FCU's participation in the seed supply chain to small farmers is growing, but generally FCUs main focus is on the commercial food crop sector (Dawit et al., 2010).

Seed production

There are only a few private operators in forage seed production (Anno seed company, https://ethiopianseedassociation.wordpress.com/anno-agro-industry-profile/, Eden Field – Agri Seed Enterprise, http://www.edenfieldagri-seed.com/, and a group of small forage seed entrepreneurs), all of them with very limited capacity.

Seed production of agricultural crops is the mandate of the Ethiopian Seed Enterprise (ESE), formerly Ethiopian Seed Corporation, which is a state-controlled company set up in 1979. It is responsible for the production of seeds for all crops (cereals, legumes, fruits, vegetables and forage) but, except for small amounts of oats and vetch seeds, it does not have a seed multiplication program for forage crops (Fikre et al., 2018).

The existing situation of (i) an unknown demand, (ii) weak quality control and seed certification system, and (iii) limited technical knowhow about forage seed production, multiplication, management and commercialization, does not encourage the private sector and smallholder farmers to be engaged in forage seed multiplication, distribution, and marketing.

The current local forage seed production systems adopted in the country are:

1. Contracting farmers to grow or collect seeds – this has been the most successful method of producing forage and browse seeds in Ethiopia (Mengistu et al., 2017).
2. Producing seeds on ranches, mostly focused on perennial legumes and grasses.
3. Producing seeds in specialized plots; this is undertaken in a few areas by some governmental and non-governmental organizations.

Major forage seed types harvested are cowpea, vetch, lablab, axillaris, siratro, stylos, Desmodium, oats, Rhodes grass, Panicum, and multi-purpose tree, with tree lucerne (Tagasaste), Leucaena and Sesbania being dominant. The most abundant plant material comes from Desho grass and elephant grass, and more recently, from Brachiaria.

In summary, improved seed/plant material availability has the potential to drastically increase Ethiopia's forage production. The current release of forage seed varieties, certification, and quality control programs are inconsistently enforced and weak.

Table 7. Summary of seed, planting material gaps
Free distribution of seed/plant material decreases interest in seed production as a commercial business
Doubtful forage seed production
Processing and distribution network
Poor awareness the effect of quality forage on animal productivity (relationship between forage quality and dairy cow production potential)
Lack of involvement of private seed producers (farmers, private companies)
Lack of information on the national demand for forage seeds
Poorly developed seed marketing systems
Lack of financial incentives for forage seed prices
Informal production and trade of forage seed
Lack of technical support

4. Forage quality

According to the Country Feed Balance (FAO, 2018) "*The difference between availability of feed resources as dry matter (DM), ME and CP and the requirements of all animal species (i.e. feed balance) showed that feed deficiency in Ethiopia is 9 per cent as DM, while ME and CP deficiencies are 45 per cent and 42 per cent deficient respectively*". These numbers clearly show the lack of quality feed.

The concept of quality forage needs to be developed within the farmer community and stakeholders. The relationship between forage quality and animal production needs to be explained in such a way that farmers start to realise the importance of quality, so that they can change the current forage market concept (Figure 2). Feed quality and feed efficiency (FE) are highly related and are key aspects in improving productivity in a climate-smart way, applying agricultural practices that can adapt to and mitigate the impacts of climate change, but also have the potential to increase food production.

Figure 2. Quality concept in dynamic change

Along with a limited quantity, imbalanced nutrition is a major factor responsible for low livestock productivity. A balanced ration is needed as it contributes to improving animal performance, as well as to reducing production costs. A lactating cow needs ca. 11% of its body weight in energy for maintenance and 5.2 MjME (MegaJule of Metabolic Energy) per litre of milk produced: e.g. a 500-kg cow producing 10 L needs 54 MjME for maintenance + 52 MjME for milk produced, which totals 107 MjME/day. In addition, it needs 15% CP (Crude Protein), minerals and vitamins (Morgan J., 2005). Typically, the forage ration of a milking cow in Ethiopia has an energy content below 7 MjME/kgDM, a protein content below 6% CP, and a NDF% over 60%; this implies the need of very high amounts of concentrates (>60% total diet DM) in order to produce reasonable amounts of milk, but this also increases production costs and could compromise animal health. Feed quality and feed efficiency (FE) are closely related and are key aspects to improve productivity in a climate-smart way (Table 8, focusing on enteric methane as one of the greenhouse gasses emitted by cows).

Table 8. Relationship between forage quality : milk production: methane emission

	NDF* (%)	ME* (MJ/kg/DM)	CP* (%)	DM* Intake (kg/cow/day)	Milk (L/cow/day)	Enteric Methane Emission (CH4/L Milk)
Low Quality Napier > 120cm	681	7.4	4.2	10.5	1.3	262
Medium Quality Napier = 120cm	695	8.1	8.8	10.3	2.7	129
High Quality Napier < 60cm	630	9.0	12.5	11.3	6.4	51

*NDF: neutral detergent fibre, ME: Metabolic energy, CP: Crude protein

Along with a limited quantity of forage, imbalanced nutrition is a major factor responsible for low livestock productivity. A balanced ration is needed as it contributes to improving animal performance, as well as to reducing production costs and enteric methane emissions.

The farmers that are using improved forage have been trained and have good knowledge of its management in relation to quality. Moreover, techniques to improve the nutritional value of crop residues (i.e. straw), such as the use of urea or biological treatments (e.g. Effective Micro-organisms), have been applied. However, the use of these technologies has been limited due to the lack of inputs and resources.

Ensuring feed/forage safety (mycotoxin content), quality, and preservation is one of the key challenges of the commercial feed sector. It is also of high importance for the livestock producers and consumers of animal source foods. Among feed safety issues, the recent detection of high aflatoxin levels in milk and compound feeds (Gizachew et al., 2016) has raised serious concerns on ensuring the desired quality and safety of feed along the food value chain. Additionally, the need for maintaining the desired level of nutritional and safety standards of forage (hay/straw), single source feed ingredients, and compound feeds is another challenge for commercial forage/feed producers, and a concern for the regulatory body and livestock producers.

Table 9. Summary of forage quality gaps
Lack of forage production knowledge
Stakeholders are not familiar with quality concepts of feed and forages for ruminants
Lack of knowledge of the relationship between forage quality and animal productivity
No access to professional laboratory for nutritional forage analysis
Lack of feed and forage quality standards
Variable and unpredictable fodder quality due to gaps in fodder management
Products lack a guaranteed minimum nutritional level and customers usually take what is available
Low use of genetically improved seed/plant material (cost-availability)
Deficient use of fertilizer
Poor monitoring and management of soil fertility (soil sampling/management)

5. Environment, climate and agro-ecological zones

Ethiopia, being near the equator and with an extensive altitude range, has a wide range of climatic features, suitable for different agricultural production systems (Amhede et al., 2017) (Figure 3). Rainfall in Ethiopia is correlated with altitude. Generally, the average annual rainfall of areas above 1,500 MASL exceeds 900 mm. In the lowlands (below 1 500 MASL) rainfall is erratic and averages below 600 mm. In the north of the country, the rainfall pattern is mainly bimodal, with the shorter of the seasons around March/April; the second rainy season often begins around June/July. Between these extremes, in the central highlands, there is a tendency for the two seasons to merge. The lowlands of the east and southeast contrast with the rest of the country by having a bimodal rainfall distribution and having marginal rainfall for crop production. Temperature and rainfall, in combination with topography and soils, determine moisture availability, which determines vegetation and agricultural productivity (Annex 4).

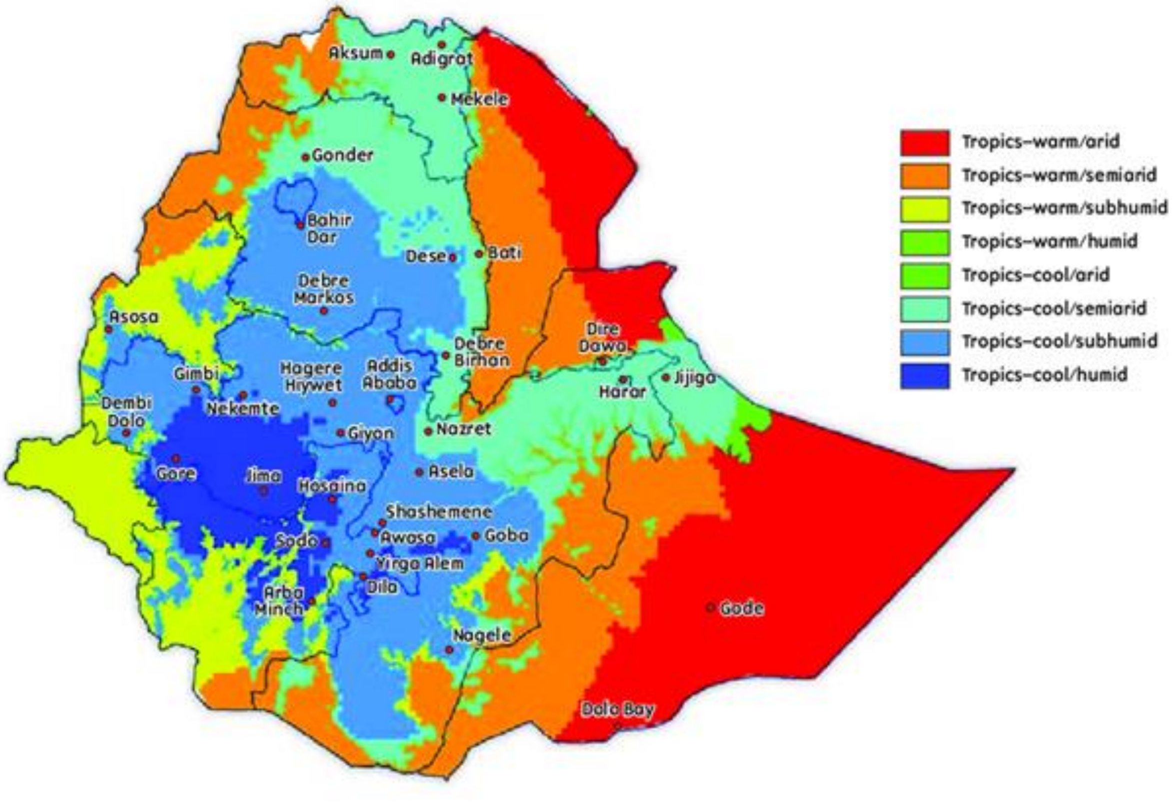

Figure 3. Ethiopia, Climatic map (Amede et al., 2017)

Soil-wise, a big proportion of the country's landmass is covered by Leptosols, Nitisols, Cambisols and Regosols, in order of their importance (IUSS, 2015). Soils are generally low in available nitrogen and phosphorus and cannot produce high crop yields unless these are supplemented.

Out of the total Ethiopian arable land area (15,119,000 ha, Word Bank 2016), annual crops cover approximately 74.2%, while perennial crops covers 6.0%, pasture lands 8.7%, fallow 7.6%, woodlands 0.8% and others 2.7% (CSA, 2008-2009). Land, water and feed resources are declining and there is a big competition to have access to them. Limited availability, seasonal variability and poor quality of feed are widely perceived as the most limiting factors in dairy production, but many productive forage species have been tested in the different AEZs with very good results (Annex 2). Rangeland covers about 61-65% of the total area of the country and is characterized by arid and semi-arid agro-ecologies experiencing a relatively harsh climate with low, unreliable, and erratic rainfall. These areas are home to 12-15% and 26% of the human and total livestock population, respectively (Abate et al., 2009).

The extent of cropping and the type of crop, in turn, determine the quantity, quality and distribution of animal feed resources throughout the year and thus control the animal production system of the area (Tolera et al., 2007). The multitude of AEZs are traditionally classified into five traditional categories based on altitude and temperature: Bereha (hot and hyper-arid), Kola (warm, semi-arid lowlands), Weinadega (temperate, cool sub-humid, highlands), Dega (cool, humid, highlands) and Wurch (cold highlands) (Annex 7). However, the amount of rainfall and its distribution are also used to classify the five common categories into eight agro-ecological zones, according to MoA cited in Mengistu (2006). In Table 10, these AEZs are listed along with their corresponding major agro-ecologies.

Table 10: Agro-ecological zones of Ethiopia (Mengistu, 2006)

Zone	Altitude (MASL)	Mean rainfall (mm)	Temperature (°C)	Major agro-ecology
Bereha (dry-hot)	500–1500	<900	>22	Lowland (<1500 masl)
Erteb Kola (sub-moist warm)	500–1500	900–1000	18–24	
Weinadega (dry-warm)	1500–2500	<900	18–20	Midland (1500–2500 masl)
Weinadega (sub-moist cool)	1500–2500	900–1000	18–20	
Erteb Weinadega (moist-cool)	1500–2500	>1000	18–20	
Dega (cold)	2500–3500	900–1000	14–18	Highland (> 2500 masl)
Erteb Dega (moist cold)	2500–3500	>1000	10–14	
Wurch (very cold or alpine)	>3500	>1000	<10	

In the higher part of the mountains (so-called Wurch), plants are exposed to intense radiation, which causes an increase in the plants temperature, this being much greater in the aerial parts as opposed to their underground parts. The rate of transpiration is higher than water uptake by plant and, despite the non-limiting moisture effect, plants are adapted to moisture deficiency (Mengistu, 2006). The soil is often shallow but rich in organic matter.

The agro-ecological zones between 1500 and 3200 MASL (Weinadega and Dega) are those most productive. A wide range of crops are grown and livestock production is common. In these mixed crop-livestock systems, water is generally not limiting, except in the far north, and growing seasons are often very long, with two crops per year in some areas. Due to the high population, farming is dominated by smallholders. Medium to large-scale dairy farming is found around big towns and cities only. In the highlands, plant growth is limited by the low temperatures and the high animal stocking density. High cultivation intensity is out of proportion to the land carrying capacity (FAO 2011).

In the lowlands, at altitudes between 500 and 1500 MASL (Kola), the growing seasons are short to very short, and only drought resistant crops can be grown where irrigation is not possible (Mengistu, 2006). This zone is dominated by pastoralists who depend on livestock for their living. The major feed resource is native vegetation and thus net livestock productivity is very variable over time. The short growing season only allows the growth of fast maturing plants. Limited rainfall and recurrent drought, shrub invasion and overgrazing are major issues within the lowland grasslands.

Overgrazing and seasonal feed shortages are recurring problems across the country.

Table 11. Summary of environment/climate/agro-ecological zones gaps
High agro ecological zone variability
High soil/grasslands degradation
Low adaptation of best agricultural practices
Productive farming systems not well adapted to zones characteristics
Poor knowledge and awareness of climate smart agricultural practices
Lack of governmental support to develop climate smart agricultural practices
Absence of skills to apply climate smart agricultural practices

Communal Land (South Achefer)

Manure drying

Manure composting

Manure application

6. Seasonality

In all parts of the country, there is marked seasonality defined by the rain pattern. The gap in the availability of forage between the short and long rains is not as serious as the one between the long and short rains. During the three-five months of the main/long rainy season, relatively abundant forage is available, but no use of preservation techniques leads to inefficient use, resulting in compromised hay quality and preservation.

Over time, several forages have been tested in different AEZs, and considerable efforts have been made to test their adaptability under varying agro-ecological conditions. This has resulted in a selection of useful forages for different AEZs, but still, only a small number of dairy farmers are trying to implement them. Overall, there has been limited spontaneous introduction of improved pasture and forages due to land scarcity and crop-dominated farming systems. Improved forage renders higher yield and, if it is harvested at the right stage, increases nutritional value of the forage, and expands the productive season.

In many regions, the lack of water to irrigate cultivated forages during the long dry season limits the options available to produce improved forages. This was mentioned by a majority of survey respondents and interviewers. Irrigation-based forage production is a good opportunity for dairy farmers in areas with irrigation potential. Small-scale traditional irrigation has been practised for decades throughout the highlands; medium- and large-scale irrigation schemes are of more recent origin, mostly in the Rift Valley for cash crops. There is some irrigated forage in the Rift Valley where a lucerne-Rhodes grass mixture is grown for commercial fattening and dairy farming. The potential for irrigated forage is unexploited and there is a great opportunity for producing seasonal and long-term irrigated pasture and forage crops (Mengistu et al., 2006).

Fodder trees and shrubs have also been tested and introduced as another interesting source of forage, due to their capacity to retain their feeding value into the dry season. They have shown great success in the areas of the country with the highest potential. *Sesbania sesban*, which grows naturally in most Ethiopian regions, is a good example of this. The leaves can also be harvested and dried into leaf meal to be used as supplement feed during periods of shortage.

In areas where farmers practice crop rotation or have sufficient land, short-cycle forage crops have been grown. These crops have been reliably introduced over a wide range of sites, but they are most appropriate for farmers who rely on dairy production for their main income. Annual leguminous species mixed with cereals provide the best quantity and quality of forage in highland areas, whereas annual legume forages optimize forage production in middle altitude and lowland areas. But so far, all these techniques have been applied to a very small extent only.

Table 12. Summary of seasonality gaps
None existing seasonal feed plan (feed budget)
Low adaptation and implementation of preservation practices
Shortage in storage capacity
Poor water management (harvesting, storage, irrigation)
Poor herd management and planning (stocking rate, calving/mating season)
Absence of regional or national feed bank for weather emergency situations in critical areas

Communal land (North Mecha, dry season)

Communal land (North Mecha, rainy season)

7. Preservation of forage crops

Adoption rate of preservation technologies in Ethiopia has been very poor. This could be because of different reasons, such as lack of awareness and/or knowledge, prioritization of farmland for crop farming over forage production, and lack of inputs (e.g. seeds, machinery), among others.

In Ethiopia, the main feed preservation method used at present is haymaking, and the most common method of hay making used by farmers is loose hay. Bailing is practiced by retailers and only in specific regions of the country. This agrees with the feedback from all respondents.

Making hay from cultivated perennial fodder with specific species (e.g. alfalfa, Rhodes) is very uncommon, the hay usually is harvested from natural grassland. In the past years, as a result of seed distribution interventions, many smallholder farmers started to make hay from Rhodes grass (they could get 4 cuts/year). Also, in specific regions, communal grassland has been closed to direct grazing, and is used exclusively for hay, which is evenly shared between the farmers. Silage (25-45 % DM), haylage (55-75% DM) or other preservation methods are only used in the few farms with foreign investment or in research centres, but is completely absent among farmers.

Table 13. Summary of preservation methods gaps
Lack of adequate storage facilities
Limited machinery available
Limited preservation methods (hay) used
Limited knowledge on preservation technology
Difficult to introduce new technology
Lack of machinery to encourage new preservation techniques
Limited access to preservation technology for smallholders

Bagging Hay


Traditional hay or straw storage (East Arsi area)

8. Forage market

Commercial forage production in Ethiopia is not common, only smallholders in central highlands, such as Sululta, Sheno, Holeta and other areas around Addis Ababa produce hay in bales or piles and sell it to retailers. But even in these regions of greatest potential (> 6,000kg/ha), given the inadequate management practices and lack of knowledge, its annual production is commonly around 3,600 kg/ha.

According to our survey and interview results, the forage market in Ethiopia is informal and opportunistic through the season. No standards are in place and client perception is the quality driver. Forage quality is measured by visual inspection, smell, and experience. Weight is estimated based on wet weight and is sold by bag, cart, or bale.

Forage traders and retailers control the trade of hay and straw. They either buy harvested hay, pay ahead for the grass harvested in the following season, or harvest the hay on their own. Then, they bale the dry hay. Another modality is to buy crop residue, mainly straw, from the common crop in the area, bale it with their own machinery, and then store it and wait for buyers. It is common to find brokers that mediate between hay/straw producers and forage traders/retailers. These basically arbitrate the transactions and connect producers with consumers or retailers. The cost of these brokers is around 5-10% of the final cost, depending on the season.

The market for these traders are smallholders, urban/peri-urban commercial dairy farmers, live animal exporters, feedlots and, occasionally, government and NGOs, when during drought conditions, emergency feed relief operations are carried out in pastoral areas. Smallholders and commercial farmers generally purchase a fraction of their fodder and forage needs. There are competing demands for fodder and forage beyond feeding livestock, which include the construction of mud houses, use in mattresses and export to Djibouti for the quarantine station.

Hay is mostly available in abundance from September to November and prices are heavily dependent upon the effect of weather, area, time of the year, and demand vs. supplies. From the harvesting season (December-January) to the dry season (May-June), usually the price of hay and straw doubles. The growing livestock sector has caused a constant increment in demand for fodder and forage, and because of it, prices have been on the rise since 2006 (Tesfaye et al., 2010).

At the moment, not many organizations are focusing on feed/forage commercialization. They include the Ethiopian Animal Feed Industry Association (EAFIA), which was established in 2006 and has 15 members. Its activities are devoted to policy advocacy and training services for its members. The Lalisa Feed Traders Cooperative is a small group of traders who buy and sell teff/wheat/barley straws. Also, some primary cooperatives and farmer unions are starting to purchase feed in bulk as service to their members. Purchasing feed is a cash transaction; credit is not available from the seller and there is no evidence of buyers borrowing money to buy feed.

Table 14. Summary of forage market gaps
Forage production is not a recognised economic activity
The forage market is unpredictable
Informal forage market
Characterized by lack of standards
Not quality-oriented
Lack of knowledge and skills about quality aspects of forage
Poor marketing
Poor market-orientation

Informal Forage Hay/straw Market (Amhara Region)

9. Inputs and services

The main input and service provider in the country is the national extension service, especially for smallholders. This is, in fact, a common perception among the people from the forage sub-sector (interviewers and survey results). The extension service in Ethiopia flows from the Federal level --> the region --> the zonal level --> woreda level (Woreda Offices of Agriculture and Rural Development, WoARD), and finally --> the kebele level, where development agents (DAs) assigned to each rural kebele provide assistance to farmers (Figure 4). Farmers are organized into groups of 25-30 households that are subdivided into 1-5 social network groups, in which one farmer is in charge of five farmers. Model farmers are in charge of these groups. The 25-30 member groups differ between kebeles depending on the number of farmer households in the kebele. There are three DAs for each kebele, and one DA supervisor and one veterinary officer per three kebeles. DAs report to their supervisor, who reports to Woreda office, which reports to the zonal office then to the region and finally to the Federal government. However, the service is not efficient. The farmers generally complain that they are not getting adequate technical support . This could be related to technical limitations of the DAs or to the fact that DAs might pay less attention to forage extension and give more priority to other activities.

The number of private agricultural service providers in the entire country totals ca. 350, including animal health and breeding services. Most service providers are focused on crop production. However, the technology available is often outdated and not suitable for the agro-ecological conditions. Farmers also need access to further mechanized field operations to improve productivity, such as seedbed preparation and row planting. There are a few unions and cooperatives that act as agro-dealers and supply agri-chemicals, feed and vegetable seeds, but this is still not relevant at country level.

Most private and farmers union-feed processing plants are currently facing serious challenges in analytical services, mainly due to high cost and inadequate service delivery. There is a lack of well-equipped and accredited labs to satisfy the commercial feed sector. To date, only one commercial lab is available, BLESS Laboratory (http://blesslaboratory.com/), which only undertakes a modest number of analyses on feed quality. EIAR Holetta (Ethiopian Institute of Agriculture Research) provides services as well. Together with ILRI nutrition lab in Addis, there is an established community of practice.

Cereal straw is primarily transported from nearby rural sites for sale to peri-urban dairy farmers by people with or without the help of donkeys. It is also common for women to transport teff and finger millet straw on their backs for sale to peri-urban dairy farmers. Trucks are used to transport loose hay produced at relatively distant sites from dairy farmers. In situations where the hay production site is close by, mule carts are commonly used. A small number of dairy farmers who are members of the Anan Robsan Dairy Cooperative (located in and around Nekemte town in East Wollega Zone of Oromia Regional State, western Ethiopia) use trucks to transport purchased feeds like baled hay and concentrates from Addis Ababa.

Improving infrastructure and services is needed if the forage sub-sector needs to be developed. Despite the large infrastructure investments undertaken by the Ethiopian government over the past ten years – including roads, electricity, telecommunication coverage, and radio access (ASE, 2009) – accessibility by road to rural areas remains limited. The Rural Access Index was 21.6% in 2016, signifying that only around 22% of the rural population had access to a “decent” road within a 2 km distance (World Bank, 2017). Infrastructure development is especially important for the development of the private sector, including input and service providers.

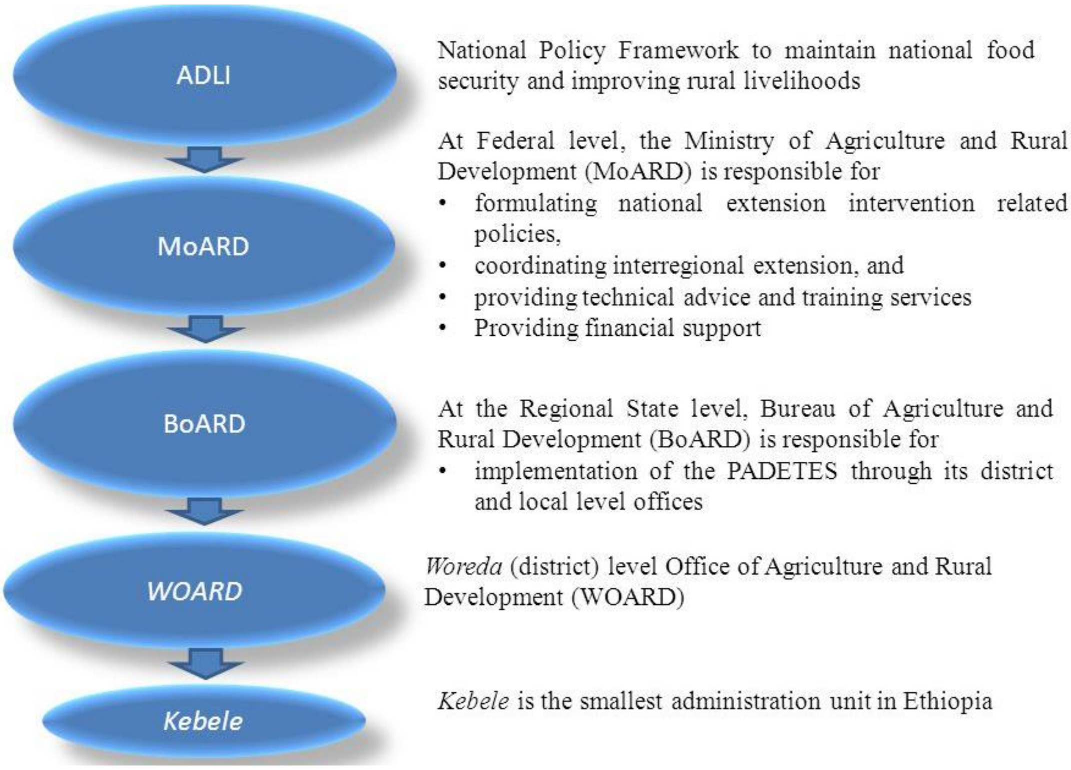

Figure 4. Organization of the Extension Service (Kidanemariam, 2011)

Soil fertilization

The declining productivity of Ethiopian soils has been associated with the loss of soil organic matter. Crop residues are largely being used for animal feeding, construction, fuel, and bedding. Therefore, a minimum amount of it is returned to the soils (FAO, 2018). Moreover, 80% of manure is used as cooking fuel and the frequency of legumes in the cropping sequence in the Ethiopian highlands is < 10% (Tamene et al., 2017). Due to these factors, along with the poor use of fertilizer, Ethiopian soils are accelerating their degradation and contributing to a reduction of water soil infiltration, permeability and water holding capacity (Hurni et al., 2015).

The use of synthetic fertilizers and improved seeds is quite limited, despite government efforts to encourage the adoption of modern intensive agricultural practices. Only 30 to 40% of Ethiopian smallholder farmers use fertilizer, and the average application rate is around 40 kg per hectare, which is very low compared to other East African countries, and significantly below the recommended rates (MoARD, 2012). This is due to multiple factors including: high price of fertilizer, shortage in input supply, late arrival, weak transport system, and low education status of the household (Endale et al., 2010).

Urea and DAP (di-ammonium phosphate) are the only fertilizers that have been used for the past four decades in Ethiopia. This is based on the fact that nitrogen and phosphorus, in that order as per plant needs, are the most limiting nutrients in its soils. Teff, wheat, maize and barley are the crops with the highest fertilizer requirements (IFDC 2012).

Morocco's Office Cherifien des Phosphates (OCP), the world's largest phosphate exporter, signed an agreement with Ethiopia in 2016, according to which they will cooperate with the state-run Ethiopian firm Chemical Industries Corporation (CIC) to enable the construction of a new fertiliser plant in the town of Dire Dawa. The project is expected to produce 2.5 million tonnes of fertiliser by 2022, and a second phase would increase production up to 3.8 million tonnes by 2025 three years later.

Table 15. Summary of input & service provider gaps
Market uncertainty
Mainly based on public extension service
Big investment required (especially in the extension services)
Lack of business-oriented entrepreneurs
Absence of private service providers
Limited financing opportunities
Lack of knowledge
Absence of technical skills among sales representatives
Poor manure utilization practices to maintain or improve soil fertility
Poor crop rotation practices
Soil degradation
Need for soil tests
Soil organic matter is depleted and not replaced
High synthetic fertilizer prices

10. Mechanization

Ethiopia is an agricultural country that predominantly depends on animal power for agricultural works, from land preparation to harvest and transport. Agricultural mechanization is low, but there is an increasing interest driven due to an increase in labour cost. For example, about one quarter of wheat production is harvested by combine-harvesters, and there is a speedy emergence of commercial service providers for ploughing, harrowing and harvesting. This is having a large effect on labour productivity.

Machinery cost is one of the main reasons for the inexistent mechanization, along with difficulties to access to credit and imported machines, and lack of scaled machines for smallholders. Moreover, skilled available mechanics and operators and access to spare parts are often a challenge, but this should improve over time as mechanization grows.

The private sector has considerably helped in the take-up of mechanization, but the public sector has an important role to play in capacity building and improving knowledge and awareness, as well as facilitating imports and enabling suppliers of credit to facilitate access.

Commercial farmers/state farms own 60% of tractors, with the remaining 40% owned by service providers. In the case of combine-harvesters, 90% are owned by service providers, which play a massive role in delivering services to (food) crop farmers (Friew, 2015).

Agriculture mechanization is concentrated largely in the Arsi/Bale area, Western Tigray, and parts of the Somali region. This could be attributed to the presence of commercial crop farms, medium scale farms, interventions, higher rural wages, flat and stone-free terrain, and the possibility of two harvests/year.

Mechanization in forage crop production, preservation and use is very small (confirmed by survey and interviewers). Only few balers for straw bailing are available in barley/wheat production zones. Manual choppers are only found in few smallholder farms. Locally made automatic choppers are offered in some regions by service providers. Now, this kind of machinery is not affordable for smallholders.

Table 16. Summary of machinery gaps
Affordability
Unscaled machinery
Old machinery
Lack of skills to repair and maintain the machines
Scarcity of parts
Absence of maintenance and repair services providers
Lack of skilled operators
Lack of investors (big investment needed for an unstable market)

Land preparation (Amhara Region)

11. Education and training

According to the ILRI study (Asfaw at el, 2016), econometric analyses reveal that one of the most important factors that positively influences farmers' willingness to pay is their awareness regarding seed and plant material. This finding indicates the critical importance of extension services in raising awareness of the likely benefits of feeding animals with improved forages, as well as on how to grow forage seed and plant material. There is also a need to use promotional materials and advertisements to raise awareness of, and generate demand for, seed and plant material among smallholder farmers. Forage seed prices will have to drop significantly in order to make it more attractive for farmers to purchase directly from seed producers or seed dealers.

Although farmers are facing critical shortages of feed supply, efforts to produce improved forage crops are generally very small, unless there is project support. When farmers get project support, they become very keen and show good performance in improved forage production. However, the main challenge is sustaining that level of performance when the project phases out.

There are currently 45 public universities with agriculture programs, with a total of 74 Masters and 22 Doctoral programs related to agriculture in Ethiopian public universities (Shibru et al., 2016), also 60,000 development agents are trained in Agricultural TVET colleges. According to the 2007 Ethiopian census, the largest first languages are (i) Oromo language, (ii) Amharic, (iii) Somali, (iv) Tigrinya, (v) Sidamo, (vi) Wolaytta, (vii) Gurage, and (viii) Afar. This needs to be considered before any intervention. English language is not as common as in other East African countries.

Table 17. Summary of knowledge/education/training/awareness gaps
Shortage of resource in the extension service
Lack of awareness on forage/animal relationship
Limited curriculum in the education systems on forage production
None existence of a plan on forage knowledge propagation or dissemination
No connection between local research and farm development

12. Recent interventions in forage

During the last six decades many efforts have been addressed to improve multiple aspects of the dairy production system, including (i) animal breeding, feed, and health; (ii) services; (iii) milk processing and formal marketing; (iv) infrastructure development; and (v) capacity building for technology generation and transfer. The most remarkable interventions on forage in the last years according to the interviewers, responses and desk study are listed in Table 18. However, the dairy sector has not been able to take-off, and because of this, the forage sub-sector development has been very low. In order to increase the impact of forage innovation, a holistic and integrated approach is needed.

Table 18. Main interventions related to forage development in Ethiopia.

Project	Donor	Implementers	Topic	Forage Intervention
DairyBISS *	Embassy of the Kingdom of Netherlands (EKN)	WUR	Dairy development, including the forage sub-sector	Grazing dairy cattle in Ethiopia. Training.
BRIDGE*	Embassy of the Kingdom of Netherlands (EKN)	SNV and WUR	Dairy development, including forage sub-sector	Start in 2019
CASCAPE*	Embassy of the Kingdom of Netherlands (EKN)	WUR and partners in Ethiopia	Best practices in agricultural production in Ethiopia	Backyard fodder production. Urea treated straw.
EDGET*	Embassy of the Kingdom of Netherlands (EKN)	SNV - Makeke University	Forage seed distribution and training	Seed/PM distribution. Training.
INNOVATION LAB FOR SMALL SCALE IRRIGATION	USAID	ILRI	Irrigation systems	Smallholder irrigation
Africa RISING*	USAID	ILRI, CGIAR	Training of trainers (ToTs)	Innovation on: Tree lucerne Desho grass Napier grass
FEED*	USAID-funded Livestock Systems Innovation Lab and Kansas State University.	ACDI/VOCA	Increase the incomes of smallholder farmers	Feed Enhancement. Seed/PM distribution. Training.
SIMLESA	Australian Government	CIMMYT	Sustainable Intensification of Maize-Legume cropping system for food security in East and Southern Africa	Intensification of maize/legume production
FeedSeed Pilot project	GIZ	GIZ/ILRI/CGIAR	Forage seed business entrepreneur development	Increase forage seed availability
RD4		SARI	Feed sector	Livestock feed sector in SNNPR

*Reference: DairyBISS, BRIDGE, CASCAPE, EDGET, Africa Rising, The Feed Enhancement for Ethiopian Development (FEED) (FEED. ACDI/VOCA. 2018).

13. Policy framework

Although knowledge about technology and production is needed, this is insufficient to improve productivity in dairy farms and enhance forage production. For market-driven innovations to succeed, commensurate organizational, institutional, and policy changes are required (Tesfaye et al., 2010).
The development of the Ethiopian dairy sector, including forage production, has primarily been conditioned by milk demand-related factors rather than by the availability of technological options (i.e., feeding, breeding, animal health) as needed to overcome the supply-side constraints. This is evident when comparing the degree of development in different regions. Moreover, the milk market in Ethiopia is constrained by the highly seasonal demand given that Orthodox Christians refrain from consuming dairy products during fasting periods (a total of up to 200 days per annum).
The Ethiopian government has identified dairy development as one of the economic drivers of the country and has taken steps to support this. The development of a strong dairy sector will be the driver to forage development in the country. Another critical issue where the government needs to play an important role would be access to land for forage development, and access to seed and plant material.

Table 19. Factors affecting grazing land availability in different Regions.

Reasons	Region
Expansion of urban and peri-urban areas	Hawasa
Expansion of coffee production	Dale
Establishment of new public facilities	Amhara
Development of swampy areas for crops	Fogera, Alamata
Expansion of weeds	Fogera, Alamata, Miesso
Resettlement programs	Amhara
Water logging and soil degradation	Alamata
Deforestation and timber business	Fogera highlands
Seasonal droughts	Miesso, Tigray

Land

The land structure of Ethiopia, where the land is a state property, depends on governmental decisions. The communal grazing policies lead to households keeping livestock beyond the carrying capacity of the grazing land, which degrades the land and contributes to low animal performance. The use and management of grazing lands is based on rainfall patterns. During the dry period, most dairy cattle graze, and during the rainy period, the dairy cattle are fed at the farm. Both at the end of the dry season and at the end of the main rainy period, elders of the communities close the communal grazing lands. After the rainy period, it is strictly forbidden to either cut the grass or to let the cattle graze on it. At the end of September, the grazing lands are reopened. These regulations allow the regrowth of sufficient grass and reduces the negative impact of livestock on the land.

Until now, all productive lands have been allocated for food crop production, whereas forage production has been concentrated in marginal land that is not suitable for food crop production (Mekuria et al., 2018). This partitioning has been done without any cost-benefit analyses. However, for mixed crop-livestock dairy farmers in peri-urban areas, it is possible that improved forage production in the most fertile land is more cost-effective than cereal crop production. Thus, land allocation should be based on a proper evaluation of the opportunity cost using the land for either crop or forage production. The analysis should also consider the possibility of (i) renting land for forage production from those farmers who have large land holdings, (ii) reducing the number of livestock, (iiii) keeping only the most productive animals and, (iv) allocating some cropland for improved forage production. According to the people interviewed and the survey responses, the decrease in grazing land is related to factors that differ from one region/area to another (Table 19).

Formal seed sector

The creation of the right conditions and promotion of the private sector involvement in the forage sub-sector need to be considered as priorities, together with a number of potential measures to promote seed and plant material production, and commercialization (Table 20).
Special interventions related to grassland or communal land also need to be considered. Overgrazing and seasonal feed shortages are recurring problems within the country. Ethiopia's grazing lands are classified as being in either "poor" or "very poor" condition and will deteriorate further without immediate action. Even protected national parks are encroached by livestock and flora is often cut and carried to be sold as animal feed. Feed supply, in particular grass and fodder, will most likely be the main physical constraint to further livestock productivity. By 2028, all agro-ecological zones will be dramatically deficient in feeds if the current growth in stock numbers continues (Shapiro et al., 2017).

Table 20. Seed and plant material: production, commercialization and promotion

Policy	• Credit facilities to seed producers • Contract seed production • Supporting cooperative forage seed production • Maintaining seed security stocks • Develop appropriate legislation for forage seed variety release and certification • Ensuring that the technical procedures are flexible and appropriate for variety release and certification • Realistic seed quality standards set within the capability of local farmers
Increasing informal farmer-based multiplication systems	• Farm participatory research on forage seed production systems • Broadened appreciation on the multiple role of forages • Initial seed multiplication and seed availability
Increasing formal sector involvement	• Maintaining a commitment to develop, register and release new high yielding varieties • Initiating basic seed production of varieties • Stimulating involvement of the private sector
Formation of farm managed systems	• Suitable institutional arrangement • Selection of pioneer seed production • Identification of distribution channels • Need for financial capacity to trade in seed • Facilities for processing and storage
Role of research, higher learning institute, extension, international centres and NGOs	• Conducting research, training and extension in forage seed production • Coordinating research, training and extension with regions • Develop projects and programs to improve legislation, production and supply systems • Exchange of germplasm materials and beyond
Proper linkage and support needs (government)	• Involvement of all stakeholders • Linkage of forage seed production, supply and market • Training technical personnel and farmers • Research effort on farm-managed forage seed systems • Exchange of information • Networking as joint effort to strengthen national forage seed programs

Section II. Recommendations

From the theoretical study, the field visits, the interviews and the answers to the questionnaires, the main drivers of the forage sub-sector in Ethiopia identified are summarized in Table 21. The development of these aspects will drive, in one way or another, the development of the forage sub-sector of Ethiopia, and consequently the growth of the dairy industry in the country.

Table 21. Drivers of Forage Sub-Sector Transformation
Milk market (strong demand and modernized dairy value chains)
Increasingly binding land- and water-constraints (land allocation)
Technology-driven yield increases (improved seeds, quantity and quality of fertilizer)
Decelerating demand for cereals – accelerating demand for meat, dairy and processed goods based on balanced diet for the population
Faster urbanization
Public investments: road and infrastructure, urban versus rural
Education and awareness

In order to improve the forage sub-sector with a positive impact on the animal production sector, innovation is needed. This should (i) address different aspects of the chain, from seed to feeding, (ii) involve all relevant stakeholders; (iii) link plant and animal production; (iv) be environmentally sustainable, and (iv) support a strong education/training process together with extension and monitoring of the new innovations to ensure their success.

Some of them can be applied under the current context (i.e., short-term innovations), which include existing policy, infrastructure, education, and market conditions. Others are more complex and require a medium to long-term time frame (Table 22). These need to be put into practice in coordination with changes in critical limitations (policy, infrastructure, education, market) so that it generates a real impact in the sector.

According to the data analysis of the current situation, potential interventions are many, but we need to (i) prioritise those that will have a high impact, and (ii) ensure their continuity over time. Potential actions that meet these criteria are developed in more detail below.

Table 22. List of potential innovations

Short Term	
Innovation	Interventions
Zero grazing	• Adapt animal housing to zero grazing system • Use of dual purpose food crop varieties: Sorghum, Wheat, Barley, Maize, Sweet potato • Intercropping: Oat/vetch; Lablab/maize; Legumes/maize, sorghum or cassava • Integration of sacrificial forage; thinning; conserving crop biomass prior to harvest; leaf stripping; cutting standing crops after maturity; cutting dry crop stubbles; cutting stubble regrowth • Tree legume like fences
Seed and plant material	• Initial seed and plant material availability through Government/NGOs (just ones) • Harvest seed/split improved forage: on-farm micro nurseries, (shrub/trees - fruit, wood, fuel, fodder trees); forage/fodder seed production; plant parts for propagation, • Sale of the seed/planting materials (extra income)
Land Productivity	• Utilization of improved forage • Smart agriculture practices (e.g soil testing, conservation agriculture, landscape conservation)

	• Fertilization based on soil testing • Irrigation • Improved pasture management • Increase nitrogen availability after drought: Legumes; Manure; Fertilization
Improving utilization of crop residues and agro-industrial by-products	• Urea treatment • Chop / pulverization • Total mixed ration (TMR) • Soaking with water/molasses
Mechanization	• Develop animal-powered mechanization: inexpensive, functional, and able to be built by locals with local materials • Communal machinery: mixers, balers, choppers • Scaled machinery
Improving utilization of grasslands and communal lands	• Adjustment of stocking rates • Paddocking • Animal access control • Over seeding • Under seeding • Partial or total closing • Introduction of improved species • Seed legumes for soil improvement • Rotational / rational grassing
Education/training	• Feed budgeting • Feed balancing • Categorize animal for feed requirement • Improve animal access to water
Long Term	
Improved species/varieties	• Seed/plant material certification • Access to quality fodder seeds • Introduction of new species : Burgundy bean (*Macroptilium bracteatum*); Moringa (*Moringa olerifera);* Tedera (*Bituminaria bituminosa* var. albomarginata); Cassia (*Cassia sturtii*); Curly Mitchell grass (*Astrebla lappacea*); Pinto peanut (*Arachis pintoi*); Perennial soybean (*Neonotonia wightii*); American jointvetch (*Aeschynomene americana*); Sweet potato vines silage
Incorporation of seed technology	• Coated seed: Fungicide for disease protection; Insecticide for protection from insects; Immediate nutrition for seedling; Seed dormancy breaking properties; Ant and bird protection; Legumes can be pre-inoculated; +Water retention
Improving utilization of crop residues / industrial by-products	• Application of second generation biofuel technologies • Reintroduction of existing techniques : Urea; Chopping; TMR; Pulverization
Forage quality	• Introduction of quality concept and animal production relationship • Laboratory analysis development • Mycotoxins control (Table 26)
Boost the forage private sector	• Promote commercial fodder production • Promote commercial seed production/commercialization • Promote contracting services • Promote agribusiness clusters
Seasonality	• Improve water management • Forage preservation (Table 24) • Herd management: Improved breeds, Mating, stoking rate... • Agroforestry • Feed bank (assisting poor areas to cope with adverse conditions); Utilization of roadside grass; National Parks grass; Public land grass
Research	• Novel germplasm • Business models

Grassland management	• Stocking rate control • Grazing management • Grassland regeneration • Legume introduction • Agroforestry/silvopastoral system develop • High technology tools implementation

High impact interventions for zero grazing systems

An increasing number of Ethiopian farmers intensify their farms and choose to apply zero grazing as a feeding strategy for their cattle. Zero grazing could be an interesting way to improve dairy production and land utilization in Ethiopia, especially for intensive, semi-intensive and extensive mixed systems. During the rainy period, the soil is not suitable to keep the dairy cattle outside, but if dairy cattle are kept in the barn, improvements in forage production, animal housing conditions, and forage preservation are required. Furthermore, zero grazing is less labour intensive, which enables household members to engage in other activities. The combination of zero grazing with backyard forage production can be an interesting way to boost forage production in smallholder farms. A backyard forage strategy can also provide a base for farmers to establish grazing management groups or pastoral associations to control grazing on common lands and cropped areas.

The Ethiopian mixed crop-livestock systems may be maintained until a stronger milk market develops in the future and helps establish a dense milk collection network and an attractive payment system. In the meantime, dairy/crop mixed systems can carry on, along with new technologies aimed at helping farmers improve both activities through crop-livestock systems integration (Table 23).

Table 23. Crop-livestock integration techniques

Strategy	Farm system	Limiting Factors	General Comments
Backyard Forage	Zero grazing Intensive mixed	Seed Availability Many areas, too small to have impact	Useful point of entry for new species Ideal for annuals species
Under sowing	Commercial forage Intensive mixed Extensive mixed Pastoral	Seed Availability Knowledge Machinery	Annuals species Self-sustaining Human food.
Overshowing (coated seed, bomb seed, ...)	Commercial forage Intensive mixed Extensive mixed Pastoral	Seed Availability Suitable delivery systems for large inaccessible sites	Ideal for grassland recovering Post seeding management is critical
Stock exclusion areas, paddocking	Extensive mixed Pastoral	Seed Availability Appropriate policy on utilization Adoption of cut and carry management.	Control of degradation Fodder production Legume introduction Management
Intercropping	Intensive mixed Extensive mixed	Seed Availability Knowledge	*Desmodium* under coffee and citrus Vetch/oats......
Fences and silvo-pastoral system with Leguminous Trees	Zero grazing Intensive mixed Extensive mixed Pastoral	Lack of awareness Stock control Seed density Management	Some excellent results with *Leucaena*, *Sesbania*, tree lucerne
Forage Strips	Zero grazing Intensive mixed	Availability of suitable grasses and companion legumes. Knowledge	Potentially very important tool to be used

Existing techniques, such as the use of dual-purpose food/feed varieties, offer the opportunity to considerably increase the profitably of mixed-farming. However, they require strategic management to achieve optimal forage and grain yield. Knowledge of the nutritional value of existing varieties of cereal crops and other animal feed is needed. Examples of these dual-purpose crops are (i) sorghum varieties that can produce ca. 40% of the total dry matter as grain and ca. 60% as stover, (ii) sorghum or maize varieties with brown midribs, as the stover is 10% more digestible than the white ribbed varieties, (iii) sweet potato, which is seen as a potential dual purpose crop because of its high productivity, low input requirements, and its usefulness for both food and high protein feed, and (iv) annual varieties of wheat and barley that tolerate one cut and can then recover to produce a grain or hay crop.

Intercropping can be another interesting technique to be used for livestock-crop systems integration. Oats and vetch intercropping has performed well over a wide range of Ethiopia AEZs, with oats showing good tolerance at relatively low soil fertility and poor drainage sites and vetch providing food/protein feed. Lablab intercropping with maize has shown increases in fodder dry matter and maize grain yields (Kabirizi et.al., 2019). Lablab is very productive at lower altitudes (as opposed to alfalfa that does not persist in Ethiopia under rainfed conditions), competes well with weeds, and can be a good source of protein for the animals (Mengistu, 2002). Also, legumes such as *Lablab purpureus, Desmodium spp., Stylosanthes spp., Arachis pintoi* and *Vigna unguiculata spp*. (cowpea) can be intercropped with food crops, such as maize, cassava and sorghum, with very good results.

Other alternatives for crop utilization under mixed livestock-crop systems integration include:

(i) sacrificial forage during mid-late reproductive phases, when there is little prospect of a commercial grain harvest, such as after a drought event
(ii) thinning (maize, sorghum), planting at high density, and then thinning the crop to ensure high grain yield
(iii) conserving crop biomass prior to harvest, where crops may be cut either for hay (usually early in reproductive growth) or for whole-crop silage (later in reproductive growth); this option can be attractive at times when there is a scarcity of fodder in other regions
(iv) leaf stripping, which involves the removal of lower leaves of crops such as maize, finger millet, sorghum, wheat and sugarcane until these crops reach a critical growth stage for grain or sugar production
(v) cutting standing crops after maturity, where livestock utilise both the grain and the stover; this is often done to carry other fodder over into the summer period when it may be in short supply
(vi) cutting dry crop stubbles after harvest; this is traditionally done in many cropping systems
(vii) cutting stubble regrowth after harvest; this often occurs with weak perennials such as grain sorghum; if the crop is not killed at harvest, re-sprouting of shoots can occur, producing new vegetative biomass that can be grazed.

The role of each mode of use within a mixed farming system will depend on factors such as crop-to-livestock balance, climate, timing, and magnitude of feed gaps. Fences and surrounded areas with forage shrubs/trees can be an important contribution of protein sources to the animal's diet. Also, they can be planted as intensive backyard plots; commonly used species include *Leucaena leucocephala, Gliricidium sepium, Calliandra calothyrsus,* and *Sesbania* spp.

High impact interventions to facilitate seed/plant material access

Access to seed/plant material needs to be facilitated. However, in order to ensure the continuity and effectiveness of the intervention, this should be followed by a good training and extension service. Also, to ensure long-term sustainability and economic viability, forage development programs should include local seed production. Many different species will be required given the wide range of AEZs and farming systems in Ethiopia, but at this stage, in order to meet the forage seed needs of a forage development program, it is recommended to initiate the local production of seed of key species only. In the short term, the following activities could be carried out to facilitate seed/plant material/shrub/tree access and future expansion to smallholders: (i) on-farm micro nurseries, (ii) on farm forage/fodder seed production, (iii) plant parts for propagation, and (iv) nurseries of multi-purpose shrub/trees - fruit, wood, fuel, and fodder trees. At the same time, this activity can be an opportunity for extra income.

In the long-run, an effective and dynamic system of seed/plant material certification and commercialization needs to be developed and synchronized with the new advances in genetically improved materials. The strategy to boost forage production and infrastructures to develop a formal forage market needs to be based on encouraging the private sector to supply on a competitive basis. The enterprise sector in Ethiopia is constrained by poor generation and adoption of appropriate technologies relevant to the sector, coupled with ineffective dissemination of existing technologies. There is little access or appropriate linkages to markets and other infrastructures.

Public or NGO engagement in the distribution of seed and plant material may make sense in areas where the involvement of the private sector is not currently profitable, and/or is too risky. However, ultimately, the private sector will need to be able to operate profitably for its businesses to be sustainable in the long-term.

Collaboration between local, national and international institutions working on forage development is needed, as well as their cooperation with animal scientists. New species/varieties with high nutrient potential production, especially energy and protein need to be tested and introduced according to region conditions (ex. drought tolerance, soil conditions) and animal production target (milk/meat).

High impact interventions to improve land productivity through sustainable intensification

Land productivity is still far from the biological production potential. The increase in animal performance per unit of land is the way forward to improve land output and deal with the land scarcity challenge. Integrating genetic resources of improved tropical species (*Brachiaria, Megathyrsus, Andropogon, Pennisetum, Chloris*, among others) could be a very useful tool for this purpose. For zero grazing and intensive mixed systems, backyard forage production can be the best option to introduce improved forage species. For either communal land, extensive mixed system, or pastoralism, the gradual replacement of native pastures by improved forage species can be an alternative. Management practices like (i) climate smart agriculture practices, (ii) soil management, (iii) water management, and (iv) pasture management, are needed to boost the effectiveness of improved varieties introduction.

After droughts, nitrogen (N) availability is the main production-limiting factor in grazing in the tropics. Therefore, the association of grasses (Poaceae) with legumes (Fabaceae) constitutes the first low-cost tool at hand to increase N availability. Moreover, the combination of grasses and legumes in the same paddock will provide better quality forage for the animals and help maintain soil functions.

High impact interventions to manage seasonality / forage preservation

Preservation methods will need to deal with Ethiopian rain patterns. Other innovations, specifically relating to water management, can also help with seasonality management. This includes water harvesting and storage, irrigation, and use of drought resistant and water-efficient species/varieties. Rainwater and runoff water harvesting includes water ponds, earth dams, plastic lined water ponds, water pans in rangelands, grown water use solar/win pumps, wind pumps and drip irrigation.

Currently, there is an estimated 3,798,782 ha of land suitable for irrigation in the seven river basins across the country, including the regions of Afar, Benishangul, Gambella, Oromia and Tigray. This is an alternative to rain-fed dependent agriculture and provides opportunities for expansion of mixed agriculture systems in the lowlands, which are predominantly inhabited by agro-pastoralists. Areas for potential irrigation under different irrigation systems to be devoted to high quality forage production (alfalfa, Sudan grass, maize, sorghum etc.) should be mapped out. Alternative irrigation systems need to be established to facilitate forage production and support communities in planting and managing upgraded forages. This can be achieved by actions that can range from basic reoriented practices to investments in high technology (Table 24). Moreover, to manage seasonality, improved breeds, herd management, herd record keeping systems, land capacity (stocking rate), and the calving/mating season need to be considered, especially in rangeland areas where irrigation, forage preservation, or water management innovations could be more difficult to apply.

Table 24. Tools for seasonality control

Target	Innovation	Bottleneck
Improved species/varieties	Drought resistant More yield/quality	Access Cost
Improved fodder preservation	Technical support Improve actual preservation techniques (silage, hay, bailage): Training Machinery New preservation process/techniques: Haylage Compaction Dehydration Pelletize Specialize machinery: Multi bailage High-compaction systems Precision chopper / kernel crushers Conditioners	Skills Knowledge Access to new technology Access to new machinery Investment/ Access to finance
Promote commercial fodder production	Legal/financial recognition like economic activity Financial support: Credit/loan access Taxes Professional support (business and technical): Business plan Training/technical advice Encourage youth farmers/entrepreneurs	Lack of business approach Financial Investment Market
Promote agribusiness clusters	Farmers-forage producers-retailers-Government	Collective action Policies Infrastructure
Promote contracting services	Professional assistant (business and technical): Business plan Training/technical advice Financial facilities: Credit/loan Leasing Encourage young entrepreneurs	Lack of business approach Finance Investment Market Infrastructure
Feed budgeting	Storage Precontracting acquisition/sale	Knowledge Lack of business approach
Improve water management	Government policy Land/water access Increase potential irrigation areas Financial support Credit/loan Technical assistant Increase water storage	Collective action Policies Infrastructure Finance Knowledge
Grassland management	Government assistant: Satellite follow-up of grassland evolution Development of communication system Herd management: Stocking rate adjustment Calving/mating season Rotational grassing Feed budgeting Storage Agroforestry/silvopastoral system development	Collective action Policies Infrastructure Finance Knowledge
Feed bank (assisting poor areas to cope with adverse conditions)	Government/International organization collaboration National Feed Inventory (FAO) Implementation of new techniques Increase storage facilities Follow forage/fodder evolution through satellite scanning	

Forage preservation options need to be considered. In addition to hay, silage and haylage can be good options to (i) deal with an unexpected situations, (ii) overcome seasonality, (iii) improve forage quality, and (iv) ensure stability in milk production.

The improvement of the current fodder preservation (hay) practices requires demonstration, training and education, as well as access to better and new and scaled machinery and technology. This includes conditioners, multi-bailers, precision choppers etc. Grass/crop silage needs to be promoted and alternative preservation methods such as haylage, dehydration, pellets, compaction and others need to be considered (Table 25).

The installation of static plants for dehydration, compaction or pelleting to reduce volume could also be developed if potential regions for commercial forage growth are far from animal production areas; in these cases, transport cost and road infrastructure need to be considered. These kind of techniques can also be contemplated if fodder/feed banks are to be established to deal with emergencies in fragile areas where climate extreme conditions are more frequent.

Table 25. Forage preservation techniques

Intervention	Farming system	Limitation	Advantages
Bailage	All systems	Manually is labour intensive Requires investment (machinery)	Easy to transport
Silage	Zero grazing Intensive mixed Extensive mixed	Requires machinery	Quality forage
Chop	Zero grazing Intensive mixed Extensive mixed	Labour intensive Requires investment (machinery)	Easy to pack and transport Increase feed intake
Pulverization	Commercial forage Zero grazing Intensive mixed Extensive mixed	Labour intensive Requires investment (machinery) Usually, low quality feed	Easy to pack and transport Increase feed intake
Compaction/blocks	Commercial forage producers Zero grazing Intensive mixed	Requires knowledge Availability of inputs	Easy to pack and transport Quality feed
Pellet	Commercial forage producers	Investment costs Requires knowledge	Easy to pack, storage and transport Increase feed intake

High impact interventions to enhance feed quality and assure feed safety

Forage quality is another important point to be addressed. The potential intervention to improve forage quality can be achieved not only through the introduction of new species and varieties but also through management strategies as described in Table 26.

Table 26. Forage quality improvement techniques

Forage/fodder	Innovation practices	Potential improvement
Napier/Elephant grass	Cut-and-carry system Cut at 5-10 cm from ground level Cut before stem elongation (8-9 leaf stage) N Fertilization Manure application Silage Intercrop with legume (*Desmodium, Pigeon pea, Calliandra, Stylosanthes etc.*) Use of new varieties	Increase plant life span Fodder quality Soil improvement (N-fixation, break up of hardpan) Feed planning/reserve Seasonality Disease resistant
Rhodes Grass	Cut at 5 cm from ground level Cut before stem elongation (5-6 leaf state) N Fertilization Manure application Silage	Increase plant life span Fodder quality Soil improvement (N-fixation) Feed planning Reduce Seasonality

	Legume mix Use new varieties	Higher yield and more nutritive
Desho grass	Cut and carry system Cut at 8-10cm from ground level Cut before stem elongation (4-5 leaf state) N Fertilization Manure application Legume mix Use new varieties Good soil preparation before implantation To improve grazing land Silage	Increase plant life span Fodder quality Soil improvement Soil erosion control Seasonality Increase plant life span Rehabilitate degraded land
Brachiaria spp/Panicum maximum	Legume Mixes: Ex. (*Clitoria ternatea, Macroptilium atropurpureum, Stylosanthes guianensis and Stylosanthes seabranna*) cut 10 cm above soil level, *Brachiaria brizantha, Clitoria ternatea, Leucaena spp.,* (28:52:20) Brachiaria/Panicum maximum intercropping with annual crops like maize (Brachiaria need to be seeding 25-35 days after the maize)	Opportunity to feed fresh, hay, silage (depending on availability of leguminous crop seeds) Silvopastoral systems Fast turnover
Natural grassland	Cut at 5-8 cm from ground level Cut before stem elongation of predominant grass specie N fertilization Manure application Varieties identification Reseeding, grass/legume (direct drilling) Silvopastoral system development	Increase plant life span Increase soil covert Increase plant population Better soil conservation Fodder quality Soil improvement (N-fixation) Seasonality Increase plant life span
Lucerne	Cut 10% flowering	Protein source Forage quality Increase plant life span
Desmodium	Intercropping with different grasses. Seedling growth of Desmodium is especially slow; therefore, existing grass should be closely grazed throughout the establishment period to enhance legume establishment. Recommended seeding rates are 3 to 5 kg/ha on a clean-tilled seedbed and 5 to 10 kg/ha on established grass sod. Inoculum is recommended when sowing on virgin land.	Protein source Forage quality Soil improvement, permanent soil cover Availability of inoculants
Sesbania sesban	Increase seeding density (10cmx10cm) Cut at 10-15 cm from ground level Cut every 45 days	Increase yield Seeding rate/ha Protein source How often will Ss re-grow
Lablab	5 to 8 t DM/ha Fresh: ME 10- 11, CP% 20-30, NDF% 35-40 Silage: ME 9- 10, CP% 20, NDF% 50	Protein source Cutting stage

First of all, nutrient parameters need to be measured and for this, laboratories for forage/feed analysis are needed. They should offer precise and fast analysis and should be easily accessible. They could include equipment for on-site measurements, such as NIR, which can be calibrated and contrasted with wet chemical analyses to ensure that local results are adjusted to local forage characteristics (the use of foreign standards can drive to imprecise estimations and inefficient results). However, as a starting point regression lines based on tropical forages can be used (e.g. from the ILRI lab). The establishment of a good laboratory will allow the generation of feed standards adjusted to the agro-climatic and economic conditions prevailing in the country. With the development of a local NIR calibration, a portable handheld NIRS linked to "ration balancing software" could be used to increase feed efficiency and milk yield, while reducing GHG emissions (such as the Rumen8 total diet ration balancing software introduced in Kenya). The application of feeding standards by advisors and farmers requires information on the nutritive value of available feed ingredients, the amount of feed intake, and the requirements of the animals. To improve efficiency and impact, the laboratories should be linked with key actors (research, academia, development organizations, international institutions) engaged in forage, animal nutrition and the feed value chain (Table 27).

Table 27. Feed testing innovations

Innovation	Impact
Development of professional forage laboratory analysis system	High: possibility to balance diets, increase FE, reduce GGE, improve farm profitability
Local lab NIRS calibration needs to be contrasted with local wet chemistry analysis	High: accuracy, better calibration, dry/homogenized sample for better reading, time needed, and logistic support.
University/Research institutes collaboration	Medium: Credibility and trickle-down effect
On-farms NIRS calibration based in local Lab NIRS calibrations	High: Results are rapid, can be incorporated into management decisions very fast. Multiple reading from the same forage, to assess variability in your feed. Less accuracy than lab analysis (availability, affordability and calibrations available)
Affordable and easy access to forage analysis	Medium: Would create a big data base for future development and forage innovation

A variety of products and strategies are available to mitigate the effects of mycotoxins in dairy cattle. With increased emphasis being placed on prevention, practices to curb aflatoxin begin with choices made in the field, including the selection of hybrids, tillage, rotation, and harvest practices. Farmers have to be aware of the weather conditions that favour the production of aflatoxin during the growing season. Storage of grain and finished feed should be in a clean, dry space where there is adequate ventilation and protection from moisture and microbial contamination (Table 28).

Table 28. Practices to reduce mycotoxin risk in forages
Crop rotation
Variety selection
Field crop residue management
Harvesting time according to weather conditions
Mechanization, to improve preservation process (faster, more efficient)
Preservation process adjusted to the conditions (weather conditions, field conditions, crop conditions)
Storage, dry and well ventilated
Use of right inoculant (Inoculant to reduce fungal growth)
Awareness
Standards

High impact interventions to improve crop residues use

It is crucial to improve the use of crop residues, which are widely available in all the regions. From simple techniques such as (i) chopping or pulverization, (ii) soaking with water or molasses, (iii) addition of urea or biological treatments, to more technical ones such as (i) having it mixed in a total mixed ration (TMR), (ii) pelletizing or, (iii) new second generation biofuel technologies (Blümmel et al., 2018) can be implemented for such purpose.

Agro-industrial by-products can be used as complementary feeds to improve forages utilization in areas where they are easily accessible at a reasonable cost. There is an informal market of by-products from different industrial sectors (vegetal oil, flours, brewers) that need to be addressed to more formal channels, with standards and quality control to create a consistent, credible market, addressing business and food security.

The adoption of a TMR that incorporates crop residues and/or hay (straw) together with other ingredients is among the technological alternatives to enhance the utilization of low-quality roughages, and therefore increase feed efficiency and economic returns from the livestock production. The production of TMR can be commercialized, offering investment, and creating job opportunities.

The utilization and introduction in the cow's diets of these by-products or improved crop residues need to be taught to farmers and extension service to ensure their efficient utilization and profitability.

Smart agricultural practices for sustainable intensification

Numerous smart agricultural practices can prove useful to improve the forage situation in Ethiopia (Table 29). Smart agricultural practices related to forage start with the selection of the right species/varieties, adjusted to the farm system and local conditions (soil, water, climate), and need to be reflected in animal production. Many of these practices could be based on reinventing and reorienting current practices, but it is also important to consider the importance of policy changes and infrastructure improvement for the success of many of these potential innovations. Precision farming technologies include (i) using drone and satellite imagery to facilitate early problem detection and alerts, (ii) measuring nutrients and other key parameters in soil, feed and leaf, (iii) affordable data-based precision farming tools to extensively and sustainably increase forage/crop yields. Precision irrigation monitoring and management, that includes wireless underground systems, can be useful in the future. In animal production, especially milk production, water is a critical "ingredient" in a cow diet, but it is very deficient in Ethiopian cows' diet. The importance of water, supply, source, and quality need to be explained to farmers to create awareness of water requirements and, at the same time, provide tools to improve the current situation. Water storage and supply are critical and its careful and correct use should be encouraged.

Table 29. Potential climate smart agricultural practices

Innovation field	Innovation practices	Expected forage improvement
Soil	Soil tests (every 4 years)	Yield-quality (assess soil nutrient availability)
	Nutrient replenishment	Yield-quality
	Intercropping	Quality
	Provide farmers/advisors with decision tools	Yield-quality - Maximize profits
	Organic inputs (manure and composts, and crop residues)	Yield-quality (increase soil organic matter and improve soil structure)
	Crop rotation	Yield-quality (soil conservation) - Decrease mycotoxin contamination
	Zero-minimum tillage	Yield (soil conservation)
	Legumes incorporation	Yield-quality
Seed/plant material	Coated (with water absorbent materials like super absorbent polymers (SAP)	Yield-quality (improve germination on dry areas)
	Pre-treated	Yield-quality (improve germination)
	Use of improved seed/plant material	Yield-quality
	New species: Moringa: For forage production; Grasses (Festuca, triticale); Legumes: *Progardes Desmanthus*	Yield-quality
Plant	Grass/legume mix: grassland/pasture/rangeland	Quality – yield – persistency
	Harvest time (physiological stage)	Plant life span - Plant survival
	Silvopastoralism/agroforestry system (ASAL areas) Native pastures sown over with legumes	Yield-quality – Seasonality - Feed security
	Increase cutting height from ground level	Quality - Increase plant life span (perennial species)
Preservation	Haylage (25-45% moisture)	Forage quality – Seasonality – Market
	Grass silage (55-75% moisture)	Forage quality – Seasonality
	Pellet	Seasonality – Storage – Market - Emergencies
	Dehydration	Seasonality – Storage - Market – Emergencies
	Bales compaction	Seasonality – Storage – Market – Emergencies

	Densified Feed Block:	Seasonality – Storage - Emergencies
	Use of right Inoculant	Quality - Decrease mycotoxin risk
Feeding	Stems crasher	Increase intake - Increase rumen soluble sugar availability - Improve digestibility
	Chop/chaff	Increase intake - Reduce selection - Increase digestibility
	Urea treatment (ammonization): 5% urea/water solution, spray on the forage (1:1) and storage under cover 2-3 weeks.	Quality - Improve digestibility 10% - Improve intake 50 % - Decrease mycotoxin risk
	Microbiologist treatments (microbes, fungus...)	Quality - Improve digestibility 10% - Improve intake 50 %
	Second generation biofuel techniques	Quality - Improve digestibility 30% - Improve intake 50 %
	Mixing: On farm (scale mixers) Commercial (TMR/PMR)	Increase Intake - Decrease selection
	Protein supplementation	Increase digestibility
	Forage analysis	Feed efficiency - Maximize profits
	Ration balance	Feed efficiency - Maximize profits
Machinery	Animal-powered mechanization	Yield-quality
	Direct drillers	Yield-quality (grasslands)
	Conditioners	Quality
	Precision choppers	Quality
	Muti-balers	Quality
	Mixers	Increase Intake - Decrease selection - Feed efficiency
Market	Offer new products: Haylage; TMR/PMR; high compacted bales; Dehydrated forage; forage pellets; feed/forage blocks.	Seasonality – Storage - Market stabilization - Emergencies

High impact interventions addressing rangeland restoration and management

For grassland and communal land, measures need to be implemented to improve quality, recover degraded areas, and increase productivity. Any intervention in this communal land needs to be taken together with the community related to the land. The following options can be considered:

1. **Sowing pilot or mother plots** on part of the paddock, so that farmers can see the improvement and expand the area over time. Implementing an annual renovation plan for a small area each year can help. Through this system, farmers may find that livestock will also help spread seed out of this focus plot into surrounding areas on the farm. If possible, consider to add a fast-growing improved grass species that can provide quick feed and green cover, just before the wet season kicks in. Ensure livestock are kept out until seedlings are well established and allow them to set seed.
2. Encouraging the **implantation of perennial forage species and controlling free grazing** of animals. Free roaming animals can destroy perennial forage crops and discourage farmers from investing on forage production. Controlled grazing practices (rotational) can help grassland productivity and quality at the same time, improving animal productivity. In very densely populated and intensively cropped areas, it might be worth to adopt a zero-grazing system.
3. **Re-seeding natural grasslands/rangelands** with either selected native forages, improved grasses, legumes, or shrubs and trees to restore degraded areas, improve soil cover, increase plant density, and increase the quality and the quantity of grassland forage offer. This will be very important for the future of land conservation and forage production in those areas. The potential techniques that can be used for re-seeding rangelands could be air seeding (by plane), bomb seed, pellet seed, and seed coated with hydrogel, anti-birds, or insecticides. To increase the efficiency of any of these techniques, a high instant stocking rate after seeding is recommended to increase seed/soil contact. Some less effective seeding practices could involve seeding through the animals, grazing pasture when plants are seeding and moving animals to areas for reseeding. The animal's movement to reseeding areas needs to be made on a daily basis.

4. **Controlling animal access** (partial or total closure). The temporal exclusion of grazing animals applied in spring allows an increase of rhizomal biomass production in natural pastures with a long history of overgrazing. This response occurs due to the predominance of tropical grasses with creeping growth habit, which also have a high aboveground: belowground biomass ratio. In this sense, spring deferment could be recommended as a sustainable practice to restore overgrazed grasslands.
5. **Adjusting stocking rates**. A right balance between feed offer and animal demand (livestock and wildlife) needs to be considered in natural grasslands and rangelands, which include most of the country (>80%). Natural species in these areas need to be prioritized for soil restoration, but improved species adapted to the conditions also can be considered.
6. **Agroforestry/silvo-pastoral systems** is recognized as an important component of climate-smart agriculture. It can be promoted with the introduction of dual-purpose crops, legumes, horticulture, dates, fruit trees and nuts within and between fodder products to enhance income from cash crops. Likewise, integration has begun with the physiology of the grass as a driving factor. The system basically works with a combination of annual crops (teff, beans, corn, wheat, barley, sorghum and others) and trees associated with forage species (annual or perennial). There are several possibilities of combining agricultural, livestock and forestry components, considering space and time available, resulting in different integrated systems. This technological solution has a big potential but needs to be adjusted to conditions (agro-ecological, social, logistics, etc) (Dawson et al., 1014).

Other management techniques such as ”weed and bush control through chemical or mechanical processes”, “legume inter-seeding”, “rotational/rational grazing”, “paddocking”, and “forage banks (protein banks)” can be considered according to local conditions. The establishment of pastoralist grazing cooperatives and community groups to manage community contingency grazing, fodder production, and utilization can be supported.

New technologies in grassland management and utilization of “information technology” such as GPS, satellite images, electronic pastoral control, remote sensing, and electric fences are available worldwide, but special training and personal capacitation will be required in terms of using the equipment and managing such systems.

The improvement of grasslands will encounter political, social, economic, and bio-physical difficulties that have to be addressed before any potential execution. Strategies to alleviate the problem of rangelands degradation must be multi-disciplinary, because each component is equally crucial.

The promotion of fodder production as a cash crop can widely drive mechanization through the use of fodder shredders, balers, silo compressors, etc. For many of the above-mentioned activities, mechanization will be important. Scaling of machinery for smallholders farms or communal machinery through cooperatives, farmer unions, farmer groups, or private service providers, are options to be considered according to the region/community characteristics and this can be promoted at all scales to facilitate access to machinery, technology and preservation methods. The machinery needs to be inexpensive, functional, and able to be fabricated locally, with local materials, to ensure future repairmen service and availability of spare parts. It can include simple animal-powered mechanization or manual choppers, but also more complex machines, such as balers, mini wrapper-cum-balers, TMR mixers, and automatics choppers.

High impact interventions to boost private sector development into the forage sub-sector

The boosting of the forage private sector needs to be prioritized for future expansion and business creation. The emergence of the private sector as a strong player in the forage sub-sector (including seed production and commercialization, forage production, mechanization and service provision) is constrained by bureaucratic hurdles and a perception that they are competing with public service providers. The public sector needs to find mechanisms and strategies to encourage the involvement of the private sector and provide them with an equal opportunity. The emergence of an effective pluralistic service-delivery system can ensure access of smallholder dairy producers to appropriate and affordable technologies and support services from the private sector, whilst allowing the public sector to gradually withdraw from service delivery and focus on regulatory function and quality assurance. However, private sector capacity needs (in entrepreneurship, leadership and partnerships), market linkage, business development service, and access to knowledge, resources and infrastructure all have to be addressed. The capacity of the public sector for taking on regulatory and quality assurance functions effectively needs to be strengthened alongside private sector development.

One of the most important futures research areas could be around a detailed characterization of the public and private forage seed and plant material production and marketing. This, in turn, would help to develop business models and public-private partnerships for the sustainable development of the forage sub-sector. Incorporation of novel germplasm into applied breeding programmes and transgenic cultivars have the potential to play a critical role in fulfilling the increasing demand for animal products (Rahul et al., 2018). Despite their limitations, dairy cooperatives still have a potential role to play to ensure cost-effectiveness in service delivery by providing/coordinating them and to facilitate linkages between producers, enterprises, R&D services and policymakers. Appropriate loan and other rural financial products need to be designed for supporting smallholder dairy and private service provision.

Knowledge and skills, management capacity

Training, education, and awareness raising has to target individual farmers, trainers and other stakeholders in the chain. In the short term, actions could include simple tools such as having a feed plan, balanced diets, and categorising animals according to requirements. For this, farmers need to learn about the "feed:animal production" relationship. The development of a feeding budget that covers the whole year with allowances for dry seasons can be an easy starting point to help manage seasonality. Such feeding plans will depend on the agro-ecological zone. To be competent, smallholder dairy producers need an appropriate, affordable and easily accessible full package of production technology.

The farmers need to properly understand the benefits of improved forages, know about the cost of production, and have the necessary technical know-how for their proper establishment, management and utilization. The extension system should demonstrate climate smart agricultural practices and more effective ways of utilizing the established forage crops to enhance livestock productivity and economic wellbeing of the farm households.

Much greater emphasis must be placed on the development of the knowledge and skills needed to successfully introduce and manage innovations. It is recognized that animal performance, and especially milk production, is much more dependent on the quantity and quality of feed eaten than on other aspects of animal production. Furthermore, the feed strategy addressed to improve the forage quantity and quality production and utilization needs to be based on knowledge so that it becomes permanent and dynamic. For this, a very strategic and well-designed educational/training system needs to be developed for all forage chain topics and addressed to all levels of the forage chain. Designed and implemented sustainable community-based management systems for forage production, preservation and sustainable utilization can be very helpful in this regard. Land degradation, GHG emissions, effluent management, and plastic residues are the main environmental issues associated with forage production that need to be targeted. In order to reduce land degradation and foster land restoration, the involvement of the Government is critical, but measures need to be taken along with the involvement of all stakeholders and under consensus.

High impact interventions to reduce environmental footprint from livestock through forage

An increase in feed efficiency based on high quality forage production and adapted/improved breeds could be an effective tool to decrease enteric methane emissions. The use of high-quality forage in combination with balanced diets increases the ability of cows to turn feed nutrients into milk. When there is an increase in cows' feed efficiency, a smaller amount of nutrients is excreted in the manure and urine. At the same time, an increase in animal productivity associated with an increase in feed efficiency can allow a reduction in the stoking rate. Implementation of any strategy to mitigate enteric CH_4 must consider the impact of these on other GHG emissions (e.g., N_2O) from (i) the dairy production unit, and (ii) associated agricultural practices. Adoption of mitigation strategies by dairy producers will depend on these considerations as well as on the feasibility of implementation, economic impact, and regulatory policy (Knapp et al., 2014).

Manure utilization can be improved through training and education in conjunction with scaled machinery to facilitate its management and use. Manure can also be used for biogas production, yet this can compete with its use as soil amendment. With the increment of forage conservation, plastic residues will increase, thus recycling systems need to be put in place via woreda offices, input/service providers, and farmers.

Section III. Conclusions

The constraints mentioned in this report need to be carefully analysed for the different regions of the country, as each has its own characteristics, agro-ecological as well as institutional, social, market and infrastructural. Feed and forage in both quantity and quality terms, as well as unbalanced rations affect the performance of milking animals. Since feed cost is the most important factor in livestock production, enhancing availability of quality (preserved) forages – year-round and preferably on-farm – is key in increasing productivity of dairy cows and reducing feed cost per litre of milk produced. So far, most efforts made by stakeholders in forage production have focused on volume rather than quality, often because the concern was on stocking rates and maintenance of animals, especially in the arid and semi-arid regions.

If the target is animal productivity and use of requisite breeds, forage quality has to get more priority and be linked to animal nutrition. For this, many aspects of the forage production process need to be considered, including the use of improved forage varieties, forage management and agricultural practices, forage planning and preservation (seasonality, climate change), mechanization, feed testing and education/training. All these aspects need to be addressed together instead of individually, meaning to connect plant science (agronomy) and animal science (ruminant nutrition). This plant-animal relationship is depicted in Figure 5 below. In the particular Ethiopian circumstances, land availability and soil management are important points that need to be considered in any forage development project.

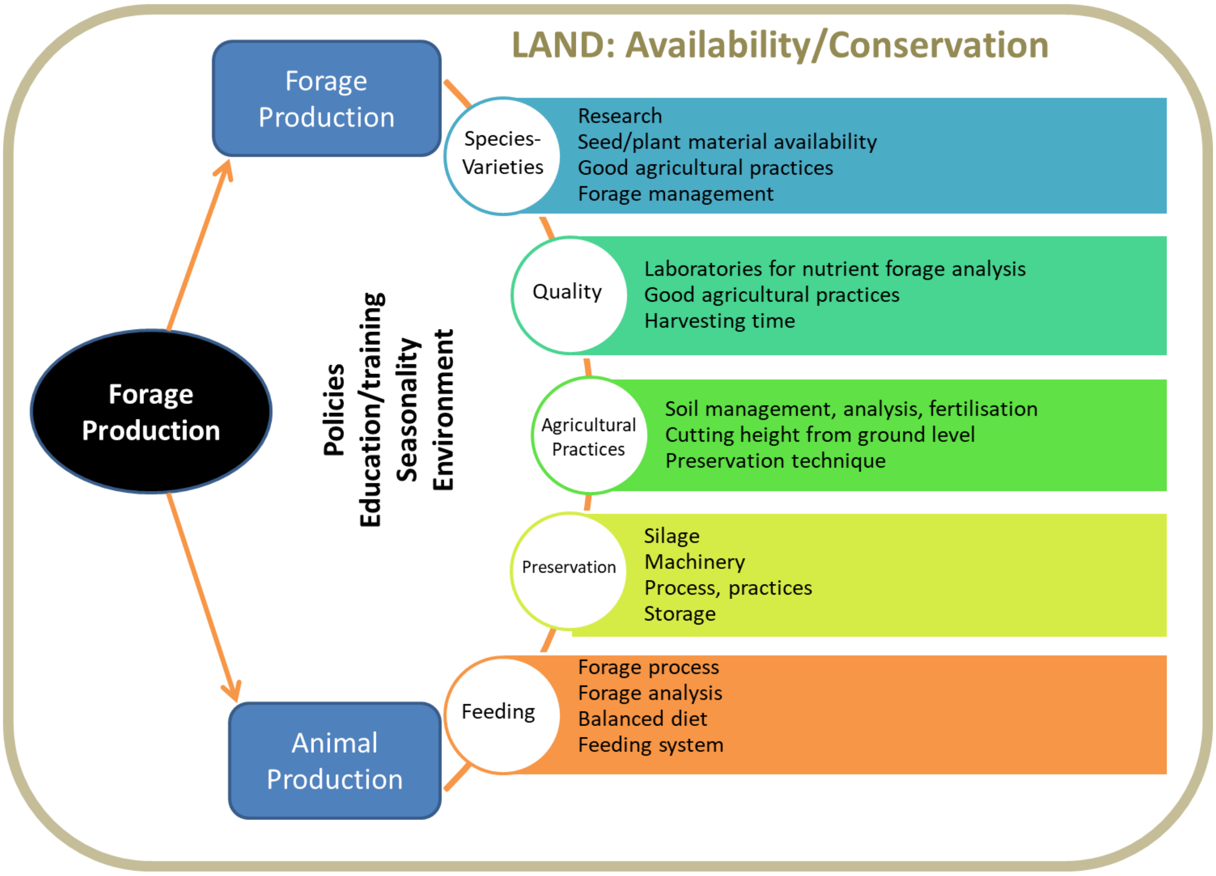

Figure 5. Key aspects that need to be considered to improve the Ethiopian forage sub-sector

Forage research should be directed towards the development of feeding systems that make better use of those local resources that are available year round. It needs to be directly linked to animal nutrition and farm economics, in order to develop commercial and environmentally sustainable solutions.

It is critical to engage the private sector into the forage chain to assure that research and innovations find a route to the market. Local forage and livestock research and phytosanitary regulations should encourage national and international seed companies to register and market suitable forage seed varieties in Ethiopia. Local research can seek partnerships with international players for optimal ways to fast-track access to improved forage seeds and planting material for farmers, be it through importing, registration, distribution and dissemination of forage seeds and planting materials, or through local breeding and propagation. This can go hand in hand with the development of a national forage and grassland curriculum, with a focus on meeting the nutrient requirements of the dairy cow.

In summary, the forage sub-sector in Ethiopia shows a number of strengths, weaknesses, opportunities and threats that need to be considered to address improvements (Table 30).

Table 30. SWOT of the forage sub-sector in Ethiopia.

Strengths • Suitable soils and agro-climate for forage production • Good agro-ecological conditions for production of forage seed • Abundant research available on species and varieties of forages (research experts exist) • Commitment from governmental and non-governmental organizations in boosting forage production • National policy framework and increasing public investment in rural roads and ICT infrastructure • Increasing demand for forage • Crop-livestock, use of crop residues in feeding livestock • Forage identified as priority livestock development issue	**Weaknesses** • Inconsistent milk market • Land tenure and user rights issues • Rain-dependent forage production • Inefficient public and private forage seed supply systems • Difficulties in scaling technologies to improve forage production and quality • Decreasing availability of grassland • Only hay as forage preservation method • Low use of improved forages • Low awareness on the economic returns of forages • Free/below cost distribution of forage seed/plant material • Lack of implementation of existing regulations on forage seed and forage market • Infrastructure problems • Unknown demand for forage seed • Limited knowledge in forage production/animal nutrition • Limited linkages between forage research and users • Livestock-crop competing claims on land and water • Missing policy measures on the improvement and management of communal grazing land and waste land
Opportunities • Good agro-ecological conditions for production of different forage species (resilience) • Farmers are open to allocate land to forage production • Commitment from (non-)governmental organizations in boosting forage production • Availability of research institutes • Availability of a basic forage-seed pool at ILRI and genetic diversity in Ethiopia • Crop-livestock-forage system intensification can be sustainable and environmentally friendly • Growing forage market • Improved varieties tested in the country • Fast increasing demand for milk and others livestock product • Water available for irrigation • Responsive farmers • Room for introducing new crops	**Threats** • Poor awareness on forage/animal production relationship • Lack of access to finance for forage production at large scale • Limited experience in forage-seed standards and certification • Lack of technical knowledge on forage production and use • Poor public capacity for regulation and quality control of input supply for forage production • Limited coordination among actors in addressing the development challenges in the forage sub-sector • Policy limitations to provide an enabling environment for innovation in the forage sub-sector • Decline of soil fertility • Climate change impacts • Increasing urbanization creates pressure on land for forage • Poor Infrastructure • Seasonal unavailability of forage • Very limited use of forage seed and forages by smallholder farmers.

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Annexes

Annex 1. Key resource persons

Annex 2. Agro-ecological zones (AEZ) of Ethiopia

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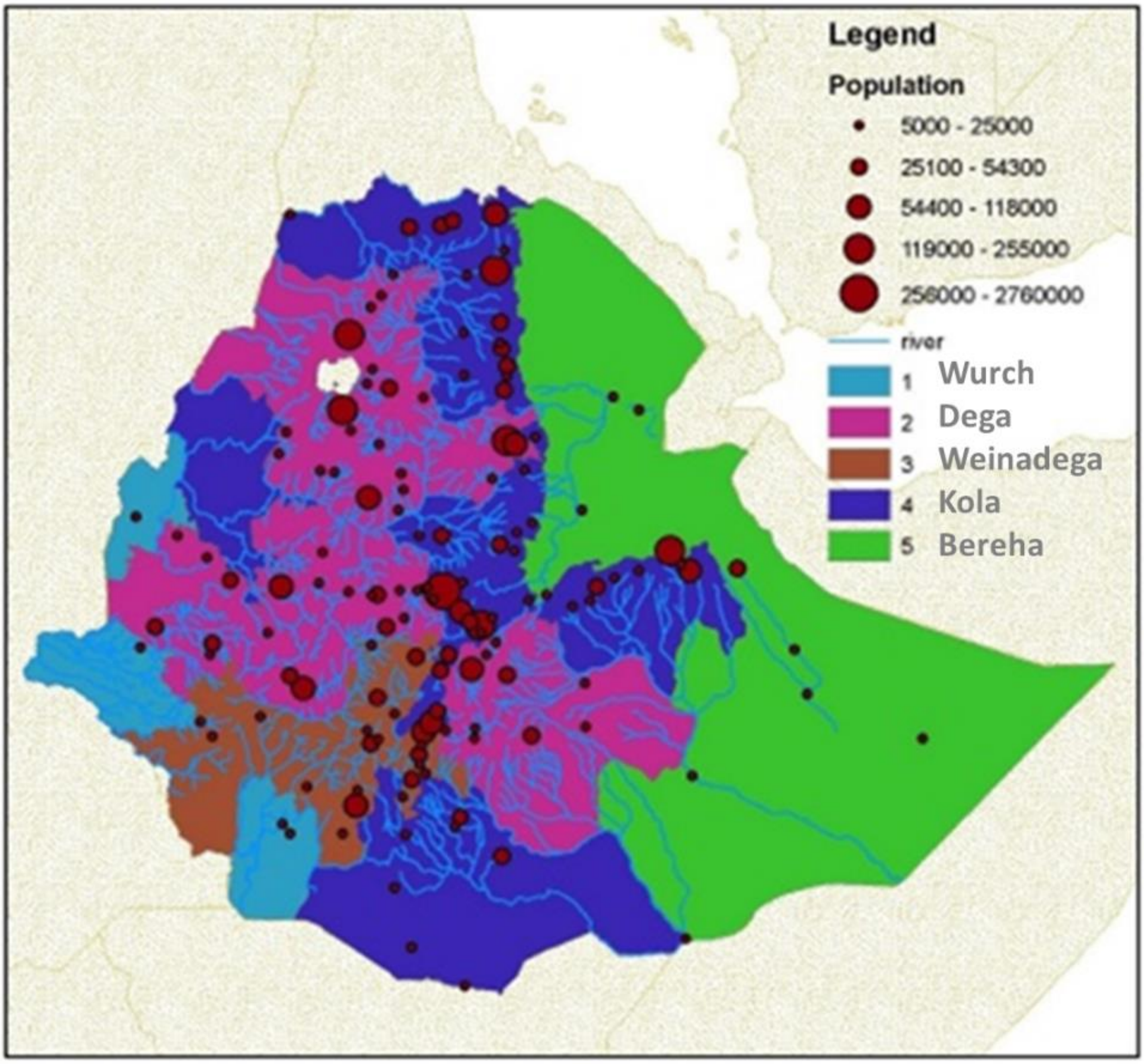
Annex 5. Forage species in Ethiopia

Annex 1. List of key resource persons

Name	Organization
Extended questionnaire	
Abule Ebro	ILRI
Alemayehu Mengistu	Addis Ababa University
Getnet Assefa	EIAR
Bimrew Asmare	Bahir Dar University
Bedasa Eba	ILRI
Yenesaw (CASCAPE)	Bahir Dar University
Asemu Tesfa	Andassa Livestock Research Center
Adunga Tolera	Hawassa University
Aklilu Mekasha	Melkassa Agricultural Research Center, EIAR
Short questionnaire	
Bishaw Zewdie	ICARDA
Abdena Asebe	ILRI
Assemu Tesfa	Andassa Livestock Research Center
Desalegn Ayichew Walle	Andassa Livestock Research Center
Sisay Tilahum	EIAR/SoRPARI
Aiebu Nurfets	Hawassa University
Aschalew Tsegahun	EIAR-Holleta
Bert Flier	Alfa Fodder and Dairy Farm
Persons interviewed	
Alemu Wolde	MOAL
Melesse	MOAL
Daniel Mekonnen	MOAL
Mekonnen Abohaye	Livestock office (Mecha district)
Yassin Wassie	Agro-industrial by-product input supplier
Dr. Kidane Gebre Meskel	EIAR Debre Zeit Agricultural Research Centre
Haymanot Addis	Feed the Future staff
Bert Flier	Alfa Fodder and Dairy Farm
Dr. Alieu Sartie	ILRI
Yenesaw Abebe	Bahir Dar University
Dr. Asamnew	Bahir Dar University
4 Officials	Extension office (Wereta)
Fetalew Adamu	Former Edget-SNV
Sintayehu Seneshaw	Wereta Extension officer
Alefe Mekte	Wereta Extension officer
Tadesse	Wereta Extension officer
Teshome Melese	Wereta Extension officer
Manager	Milk Collection Center Wereta
Asemu Tesfa	Andassa Livestock Research Center
Desaleng Ayichew	Andassa Livestock Research Center
Wondimagegne Tess	Andassa Livestock Research Center

Aschalew Tsegahum	EIAR-Holleta
Dr. Fekade Feyessa	EIAR-Holleta
Dr. Muluneh Menta	EIAR-Holleta
Manager	Holland Dairy
Abdena Asebe	ILRI
Tesfaye Tadesse	ILRI (Zwai)
Yiseraw Wubete	ILRI (Zwai)
Dr. Belete Shenkute	Arsi University
Dr. Abera Gebessa	Arsi University
Farm Manager	Arsi University Farm
Takele	Arsi zone livestock expert
Getinet Lemma	Farmer. Tiyo district/Oda Dawata Kebele
Delelegne muluneh	Farmer. Tiyo district/Oda Dawata Kebele
Wayneshet Kassaye	Tiyo district/Development agent at Oda Dawata Kebele
Mesfin Haile	Limu Bilbilo district/Lemu Dima dairy producers cooperative
Dida	Limu Bilbilo district/Lemu Dima dairy producers cooperative
Dr. Jemal Edris	Semen Mecha, Merawi district livestock office

Annex 2. Agro-Ecological Zones (AEZs) Map (Source: Ethiopian Development Research Institute(EDRI) and IFPRI Ethiopia Strategy Support Program 2 (IFPRI-ESSP2) Seminar Series November 20, 2009)



Annex 3. Forage species and varieties released by EIAR since 1976.

(Source: Crop Variety Register, ISSUE No. 19, Ministry of Agriculture, June 2016)

Species	Variety	Year of release	Breeder/Maintainer
Tree lucerne (*Chamaecytius prolifer*)		1992	HARC/EIAR
Elephant grass (*Pennisetum purpureum*)	ILCA-16984	1984	
Rhodes Grass (*Chloris gayana*)	Massaba	1984	HARC/EIAR
Panicum (*Panicum colloratum*)	Colloratum	1984	HARC/EIAR
Dolicos lablab (*Lablab purpureus*)		1984	HARC/EIAR
	Gebis -17	2016	Bako ARC/OARI
	Beresa-55	2016	Bako ARC/OARI
Phalaries (*Phalaries aquatica*)	Sirosa	1982	HARC/EIAR
Trifolium (*Trifolium quartinianum*)		1976	HARC/EIAR
Vetch (*Vicia dasycarpa*)	Lana	1976	HARC/EIAR
	Lalisa	2011	SARC/OARI
	ICARDA-61509	2012	HARC/EIAR
	Gebissa	2011	SARC/OARI
	Abdeta	2011	SARC/OARI
Cow pea (*Cowpea unguiculata*)	Sewinet	2009	Pawe ARC
	Temesgen	2014	Humera ARC (TARI)
Andropogon (*Andropogon gayanus*)	Dirki Ayifers	2009	Pawe ARC
Pigeon pea (*Cajanus Cajan L.*)	Dursa	2009	MARC/EIAR
	Kibre	2014	Humera ARC
	Tsegab	2014	Humera ARC
Oats (*Avena sativa*)	Bonsa	2011	SARC/OARI
	Bona-bas	2011	SARC/OARI
	CI-8237	1976	HARC/EIAR
	SRCPX80Ab2806	2015	HARC/EIAR
	SRCPX80Ab2291	2015	HARC/EIAR
	CI-8251	2013	HARC/EIAR
Sesbania (*Sesbania macrantha*)	DZF 092	2012	DZARC/EIAR
Pennisetum polystachion	Nechsare	2014	Pawe ARC/EIAR/
Panicum maximum	Degun geziya	2014	Pavve ARC/EIAR/
Lupin (*Lupinus spp.*)	VVelela (SW-001)	2016	Holetta ARC/EIAR
	Sanabor	2014	ARARI and Andassa ARC
	Vitabor	2014	ARARI and Andassa ARC
Alfalfa (*Medicago sativa*)	Alfalfa-1086	2016	ELFORA Agro-Industries Plc/H ARC/EIAR
	Alfalfa-ML-99	2016	ELFORA Agro-Industries Plc/HARC/EIAR
	Alfalfa DZF-552	2014	DZARC/EIAR
Pennisetum sphacelatum	Shebela sar	2014	DZARC/EIAR
Cynodon aethiopicus	DZF-265	2105	DZARC/EIAR
Brachiaria mutica	DZF-483	2105	DZARC/EIAR

Annex 4. List of most adaptive and productive forage species for the different AEZs (Source: Ethiopian Institute of Agricultural Research, 2012)

Forage species	Adaptation
Legumes	
Lablab (*Lablab purpureus or Dolichos lablab*)	Mid to low altitude
Lucerne or Alfalfa (*Medicago sativa*)	High to low altitude
Common vetch (*Vicia dasycarpa*)	High to mid altitude
Greenleaf/silverleaf desmodium (*Desmodium spp*)	Mid to low altitude
Cow pea (*Vigna ungulculata*)	Mid to low altitude
Stylosanthes spp	Mid to low altitude
White clover (Trifolium repens)	High to mid altitude
Maku Lotus (Lotus pedunculatus)	High to mid altitude
Grasses	
Napier grass (*Pennisetum purpureum*)	Low to mid altitude
Rhodes grass (*Chloris gayana*)	Low to mid altitude
Guinea grass (*Panicum maximum*)	Low to mid altitude
Desho grass (*Pennisetum pedicellatum*)	Mid and high altitude
Brachiaria spp	Low to mid altitude
Oat/Triticale	Mid and high altitude
Sudan grass	Low to mid altitude
Setaria (*Setaria sphacelata*)	Mid to low altitude
Colombus grass	Low to mid altitude
Buffel grass (*Cenchrus Ciliaris*)	Low to mid altitude
Phalaris (*Phalaris aquatica*)	Mid to low altitude
Browse Trees	
Pigeon pea (*Cajanus cajan*)	Mid to low altitude
Leucaena (*Leucaena leucocephala*)	Mid to low altitude
Griricidia (*Griricidia sepium*)	Mid to low altitude
Tagasaste or Tree Lucerne (*Chamaecystisus palmensis*)	Mid to low altitude
Sesbania (*Sesbania sesban*)	Mid to low altitude

Annex 5. Forage species in Ethiopia Source: (Adapted from Mengistu A, Kebede G, Feyissa F, Assefa G (2017). Review on Major Feed Resources in Ethiopia: Conditions, Challenges and Opportunities. Acad. Res. J. Agri. Sci. Res. 5(3): 176-185)

Common Name	Scientific Name
Acacia	*Acacia spp*
Birch leaved acalypha	*Acalypha fruticosa*
Amba grass, Tambuki grass	*Andropogon spp*
Peanut	*Arachis pintoi*
Common needle grass	*Aristida adscensionis*
Oats	*Avena sativa*
Axiliaris	*Axiliaris*
Fodder beet	*Beta vulgaris*
Congo Signal	*Brachiaria Ruziziensis*
Bracharia varieties	*Brachiaria spp*
Kale	*Brassica oleracea*
Turnips	*Brassica rapa var. rapa*
Pigeon pea	*Cajanus cajan*
Calliandra	*Calliandra calothyrsus*
African Foxtail grass	*Cenchrus celiaris*
Rhodes grass	*Chloris gayana*
Chicory	*Cichorium intybus*
Butterfly/Blue pea	*Clitoria ternatea*
Yeheb bush	*Cordeauxia edulis*
Sun hemp	*Crotalaria juncea*
Hemp varieties	*Crotolaria spp*
Star grass (Naivasha, Bermuda)	*Cynodon dactylon*
Star grass varieties	*Cynodon spp*
Lucerne tree/tagasastes	*Cytisus proliferus/Chamaecytisus palmensis*
Bundleflowers	*Desmanthus*
Silver leaf desmodium	*Desmodium incanum*
Green leaf desmodium	*Desmodium intortum*
African Couch grass	*Digitaria abyssinica*
Jarra Digit grass	*Digitaria milanjiana*
Finger millet	*Eleusine spp*
Needlegrass Mopane grass	*Enteropogon macrostachyus*
Stink grass	*Eragrostis cilianensis*
Love grass	*Eragrostis superba*
Teff	*Eragrostis teff*
Red Rhodes grass	*Eustachyus paspaloides*
Tall Fescue	*Festuca arundinacea*
Soybean	*Glycine max*
Perennial Soybean	*Glycine wightii*
Gliricidia	*Gliricidium sepium*

Black spear grass	*Heteropogon contortus*
Barley	*Hordeum vulgare*
Giant Thatching grass	*Hyparrhenia rufa*
Sweet potato	*Ipomoea batatas*
Lab Lab	*Lablab purpureus*
Sprangletop	*Leptochloa obtusifolia*
Leucaena	*Leucaena leucocephala*
Rye grass	*Lolium perenne*
Lupins	*Lupinus albus graecus*
Sweet lupins	*Lupinus angustifolius L*
Siratro	*Macroptilium atropurpureum*
Lucerne varieties	*Medicago sativa*
Guinea grass	*Megathyrsu maximus/ Panicum maximum*
Panicum varieties	*Panicum ssp*
Bahia grass	*Paspalum dilatatum*
Kikuyu grass varieties	*Pennisetum clandestinum*
Desho Grass	*Pennisetum pedicellatum*
Napier grass	*Pennisetum purpureum*
Tropical kudzu	*Pueraria phaseoloides*
Snout bean	*Rhynchosia spp.*
Sesbania	*Sesbania sesban*
Foxtail Millet	*Setaria italica*
Nandi Setaria Grass (Golden Bristle)	*Setaria sphacelata cv Nandi*
Giant Setaria	*Setaria splendida*
Wood grass	*Sorghastrum nutans*
Columbus grass	*Sorghum almum*
Forage sorghum	*Sorghum drummondii*
Sudan Grass	*Sorghum sudanese*
Sorghum	*Sorghum vulgare*
Dropseed grass	*Sporobolus fimbriatus*
Velvet /Mucuna beans	*Stizolobium spp*
Stylo	*Stylosanthes guianensis*
Stylo (pencilflower)	*Stylosanthes scabra*
Red oat grass	*Themeda triandra*
White Clover	*Trifolium repens*
Guatemala grass	*Tripsacum laxum*
Triticale	*Triticosecale*
Wheat	*Triticum spp*
Vetch	*Vicia sativa*
Cowpea	*Vigna unguiculata*
Maize	*Zea Mays*

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