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Pathways to Intensify Sustainable Forage Production in Ethiopia

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This paper describes the Ethiopian forage sub-sector. It covers a wide range of aspects, from technical aspects such as available forage species, quality, seasonality, preservation, seeds, planting material, fertiliser use, mechanisation, inputs and services, to more institutional aspects, such as the forage market, education and training, environmental footprint, and policy framework. The paper provides recommendations aimed at enhancing the 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 of the Dutch government for learning and sharing amongst different dairy sectors and projects in East Africa.

Table of Contents

Introduction

Dairy production system in Ethiopia can be classified into pastoral, agro-pastoral and sedentary dairy systems according to cattle feeding practices. Pastoral and agro-pastoral systems are mainly found in the lowlands. In the pastoral system, livestock production is the dominant form of production to sustain the livelihood. The agro-pastoral system combines both cropping and livestock production. Dairy production under both systems is low in terms of inputs and outputs, and based on indigenous cattle. These two systems are non-market oriented and most of the milk produced is kept for home consumption.

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.

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.Ethiopia has a large potential to develop a strong dairy sector. However, the current productivity is below full capacity due to technical (i.e., shortage in quantity and quality of feed and substandard feed management, health care, breeding and husbandry) and non-technical factors (i.e., poor supply chain efficiency, infrastructure and institutional support).

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. Sustainable livestock and crop production in Ethiopia can be achieved if drastic changes in livestock and land management systems are carried out. This requires a more efficient integration of livestock and cropping systems, better genetics, and a shift towards more intensive feeding systems, with more emphasis on cut and-carry feeding, forage production in the midlands and highlands, and rational grazing, particularly in the lowlands areas.

1. Current situation of the Ethiopia forage sub-sector

Over the last six decades, many efforts have been tried to improve multiple aspects of the dairy production system, including (i) animal breeding, feeding, and health care; (ii) services (veterinarian, AI); (iii) milk processing and formal marketing; (iv) infrastructure development; and (v) capacity building for technology generation and transfer. However, the dairy sector has not been able to take-off, and related to this, forage/fodder development has been very low.

Feed situation

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 109 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). Natural grass, with a maximum availability during the crop growing season (June to December), constitutes the main feed source in the different regions (Table 1).

Table 1. 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)**

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). In the highlands and mid-altitudes lands, grazing land is steadily decreasing due to land degradation, and conversion of grazing lands into arable lands due to population pressure. Natural pasture yields are around 1 t, 3 t, and 4-6 t of DM per ha in the lowlands, intermediate and high altitude areas, respectively (Tekalign, 2014).

Forage-related research

Forage research in Ethiopia is carried out by national and international institutes. At **Universities,** research on forage is very common. The Ethiopia Institute of Agricultural Research (**EIAR**) national research centres promote research in agriculture, agro-pastoralism, and pastoralism through market-competitive agricultural technologies. International Council for Research in Agro Forestry (**ICRAF**, also known as the World Agro Forestry Centre), encourages the use of forage trees that are highly nutritious for livestock. **ILRI** (International Livestock Research Institute) is working on forages in many tropical countries at different capacities and has a forage laboratory and gene bank for tropical forages in Addis Ababa.

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/).

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). In addition, while regulations and a quality control system have been defined for forage seeds marketed in the country, its application is not being enforced. About 50% of the enterprise's supply is purchased by NGOs, 48% by government offices and 2% by the private sector (Tekalign, 2014).

The existing condition of (i) unarticulated demand, (ii) weak quality control and seed certification system, and (iii) limited technical knowhow about forage seed production, management and commercialization, does not encourage the private sector and farmers to be engaged in forage seed multiplication and marketing. The use of improved forage species and varieties at present is insignificant, but will be critical in the near future if animal production is to be intensified in a sustainable way. Access to seed/plant material needs active facilitation.

Forage quality

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. 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 (Table 2).

Table 2. Relationship between forage quality : milk production: enteric methane emission (NEADAP: Kenya Forage Scan, 2019)

	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, DM: Dry mater.

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.

Seasonality, forage preservation and market

The agro-ecological zones between 1500 and 3200 MASL (called Weinadega and Dega) are those most productive. A wide range of crops is grown such as cereals, pulses, oilseeds, and coffee, and livestock production is common. In this mixed crop-livestock system, water is generally not limiting, except in the far north, and growing seasons are often very long, allowing 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.

In the lowlands, 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.

During the three to five months of the main/long rainy season, forage grows in abundance, but the lack of preservation techniques leads to its inefficient use, resulting in compromised hay quality and preservation. Adoption rates of preservation technologies in Ethiopia has been very poor, because of lack of awareness and/or knowledge, prioritization of crop farming over farmland for forage production, lack of inputs (e.g. seeds, machinery), etc. The improvement of

the current fodder (hay) preservation practices requires training and education, as well as access to better machinery and technology.

Commercial forage production is not common, and the forage market 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 forage is sold by bag, cart, or bales. The growing livestock sector has caused a constant increment of demand for fodder and forage, and hence, prices have been on the rise since 2006 (Tesfaye et al., 2010).

Inputs and services

The main input and service provider in the country, especially for smallholder farmers, is the national extension service. The number of private service providers in the entire country totals only ca. 350, including animal health and breeding services. Most service providers focus on food crop production. It is critically important that extension services raise awareness of the likely benefits of feeding animals with improved forages, as well as on how to grow forage seed and plant material.

In many regions, the lack of water to irrigate cultivated forages during the long dry season limits the options available to produce improved forages. 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. The potential for irrigated forage is unexploited and yet there is a great opportunity for producing seasonal and long-term irrigated pasture and forages (Mengistu et al., 2006).

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. In Ethiopia, the land is a state property that is rented for different uses, a direct intervention of the Government to encourage grow fodder and produce fodder seeds would lead to increased forage production. Planting forage to feed animals is not a common practice in Ethiopia and faces many challenges (Table 3).

Table 3. 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.

2. Challenges in the forage sub-sector

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 200 days per annum).

The main drivers identified for the forage sector in Ethiopia are listed in Table 4.

Table 4. Drivers of Forage Sub-Sector Transformation
• Milk market (Strong demand and modernized value-chains)
• Increasingly binding land- and water-constraints (land allocation)
• Technology-driven yield increases (improved seeds, quantity and quality of fertiliser)
• Decelerating demand for cereals – accelerating demand for meat, dairy and process goods
• Faster urbanization
• Public investments: road and port infrastructure, urban versus rural
• Education and awareness

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.

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 should carry on, along with new technologies aimed at helping farmers improve both activities through crop-livestock integration under sustainable intensification practices.

Annex 1 offers a number of technical options. Preservation methods will need to deal with Ethiopia's rain patterns and with innovative aspects, specifically relating to water management. Both can help with seasonality management along with herd management, herd record keeping systems, land capacity (stocking rate), and the calving/mating season. These can be especially important in rangeland areas where irrigation, forage preservation, or water management innovations may be more difficult to apply (Annex 2).

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.

Numerous smart agricultural practices can prove useful to improve the forage situation in Ethiopia (Annex 3). 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.

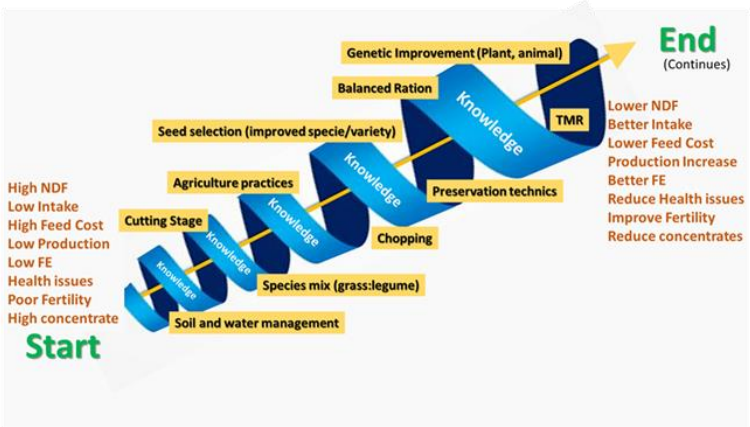

Figure 1. Upscaling recommendation to improve forage sub-sector

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.
2. Implantation of perennial forage species and controlling the free grazing of animals.
3. Re-seeding natural grasslands/rangelands.
4. Controlling animal access (partial or total closure).
5. Adjusting stocking rates.

6. New technologies (GPS, satellite images, electronic pastoral control, remote sensing).

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.

For many of the above-mentioned activities, mechanisation will be important. Scale 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 should be promoted at all scales to facilitate access to machinery, technology and preservation methods.

The boosting of a private forage sector needs to be prioritised for future expansion and business creation. The emergence of the private sector as a strong player in the forage sector (including seed production and commercialisation, forage production and mechanisation and service providers) is constrained by bureaucratic hurdles and a perception that they compete with public services.

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.

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. The forage sub-sector in Ethiopia shows a number of strengths, weaknesses, opportunities and threats that need to be considered to address improvements (Table 5).

Table 5. SWOT of the forage subsector 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	**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

• 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	• 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.

3. Way forward

Table 6 contains recommendations at stakeholder level for strategies and interventions to address these topics and, by doing so, to enhance the forage sub-sector and the dairy sector at large, through intensified environmentally sustainable forage production.

Table 6. Recommended strategies and interventions for stakeholders in the forage sub-sector

Strategy	Stakeholder	Intervention
Develop modular curriculum emphasizing climate smart forage production from "Seed to Feed to Milk"; Disseminate to the farmer a full package of requisite practical knowledge and skills	Government	Restructuring extension services Rural training centres Facilitate access to social media to be use as teaching tool in rural areas Enhance Private consultants sector Involve all stakeholders to ensure distribution networks, availability of new technologies and knowledge. Encourage and implement different aspects of the chain, from seed to feeding Investing knowledge exchange and transfer in the younger generation Include and connect forage production and animal nutrition in student education and farmer training & extension programs. Facilitate access to social media to be use as teaching tool in rural areas Access to wireless phone to improve knowledge transfer
	University and Research Institutions	Connect forage production and animal nutrition Intermedium degree for specially topics related with forage/animal production Expose students to practice "on the farm and in the field"
	Private Sector	Collaborate in the knowledge
	Farm Community	Apply best practices learned to improved forage production
	International Organizations, NGOs	Help with the introduction of new technology, education systems, and divulgation on forage production and utilization Monitoring new innovations to ensure their success
Increase high quality forage production for better feed efficiency and profitability through sustainable intensification	Government	Conservation-based forage development strategies Encourage and assist establishment of forage/feed processing plants Provide training and the necessary technical support to the farmers to build their awareness and skills in improved forage production Supporting business development services Develop feed/forage quality control system (standards) Promotion of fodder production through the revision of land allocation rules Revising the land policy to incorporate forage production/grazing areas Policy on grazing use rights Integrated land, water, soil resources development strategy Silvopastoral/Agroforestry expansion Encourage the establishment of a forage bank in potential feed deficit areas Encourage and provide incentive for feed processers in the livestock development potential areas Future forage development interventions should give more focus to forge crops that combine high yield potential with good nutritional quality

		Technical and capacity building support to smallholder farmers and private sector actors interested in commercial forage and forage seed production Support established of cooperatives and farms associations
	University and Research Institutions	Develop of crops for more intensified sustainable forage production Promote the use of new species Forage development focus on high yield potential with good nutritional quality
	Private Sector	
	Farm Community	Awareness for deliberate production of feed for dairy cattle Improve pasture use through appropriate grazing land management system Implementation of Silvopastoralism/Agro-forestry expansion
	International Organizations, NGOs	Provide training and the necessary technical support to the farmers to build their awareness and skills in improved forage production
Improve sustainable milk production intensification through forage production	Government	Animal breed policy need to be related to forage quality Conservation-based forage development strategies Revision of the land allocation policy framework to enable investments to promote fodder production and trade Revising the land policy to incorporate forage production/grazing areas Integrated land, water, soil resources development strategy Encourage the establishment of a forage bank in potential feed deficit areas Natural resources governance Develop of potential irrigation plan
	University and Research Institutions	Animal breed need to be considered during forage development Drought resistance forage development Improve native varieties
	Private Sector	Improve machinery and services New technology introduction Forage production under irrigation
	Farm Community	Animal breed targets need to be highly related to potential forage quality production Improve pasture use through appropriate grazing land management system Silvopastoralism/Agro-forestry expansion
	International Organizations, NGOs	Collaborate in “livestock: climate change: forage” policy development
Encourage & enable Private Sector involvement to create a vibrant and competitive forage sub-sector	Government	Recognise investors in commercial forages and agricultural forage contractors as entrepreneurs Support investment in the forage sub-sector Facilitate creation of businesses specialised in different steps of the forage chain Adjust taxes system to forage/seed producers and service providers
	University and Research Institutions	Link research and education with private demand
	Private Sector	Increase seed supply Improve forage contracting services quality Introduce technical sale strategy Upgrade maintenance of scaled machinery Training employees on forage production technics Use quality standards to price forage
	Farm Community	Create a consistent demand Request for high quality forage Use quality standards to price forage
	International Organizations, NGOs	Support private initiatives Collaborate in forage business development Support entrepreneurs projects
Improve access and availability of seed and plant material	Government	Developing appropriate legislation to forage seed variety release and certifications Maintaining a commitment to develop, register and release new high yielding/quality varieties Develop a realistic seed quality standard in terms of species characteristics Supporting forage seed production activities (smallholder farmers could be engaged in forage seed production and marketing) Stimulating involvement of the private sectors Providing credit facilities to seed producers/traders

		Maintaining seed security stocks Involvement of various national stakeholders Linkage of forage seed production, supply and market systems Networking as joint effort to strengthen national forage seed programs Stop providing free forage seeds Support established of cooperatives and farms associations Adjust taxes system to forage/seed producers and service providers
	University and Research Institutions	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
	Private Sector	Engaged in forage seed production and marketing
	Farm Community	Engaged in forage seed production and marketing Awareness of the importance of seed quality
	International Organizations, NGOs	Stop providing free forage seeds Support private sector in seed production and commercialization
Land	Government	Revision of the land allocation policy framework to enable investments to promote fodder production and trade Government policy on grazing use rights in the highlands Revising the land policy to incorporate forage production/grazing areas Integrated land, water, soil resources development strategy Silvopastor/Agroforestry expansion Encourage the establishment of a forage bank in potential feed deficit areas Improve pasture use through appropriate grazing land management system Natural resources governance

4. Conclusions

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, not the least farmers and private sector; (iii) link feed/forage and animal production, (iv) address environmental sustainability issues, and (iv) support a strong education/training and extension process, with monitoring of the outcomes of innovations to ensure their success.

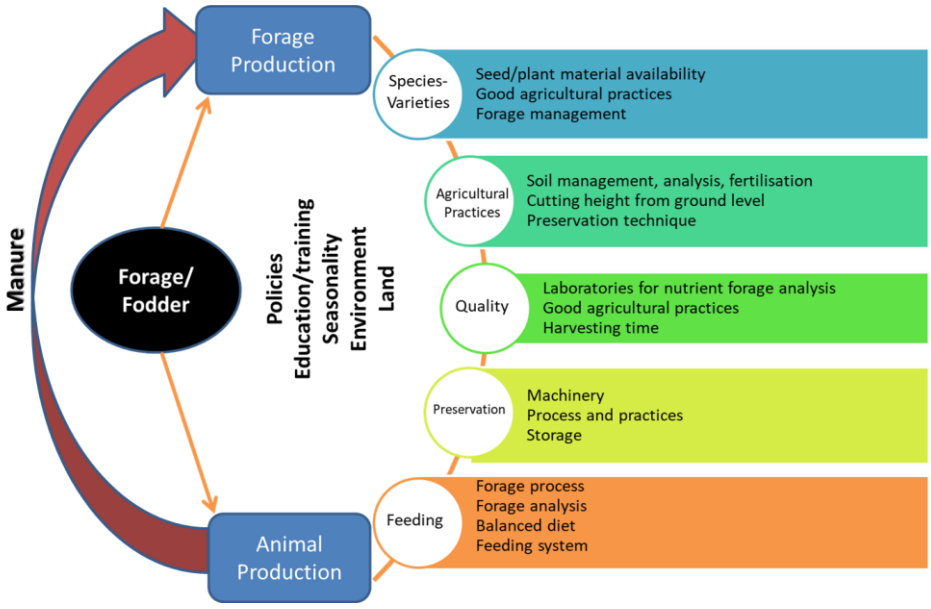

Figure 2. From seed to milk, full package concept for forage sub-sector development

Feed and forage, in both quantity and quality terms, and unbalanced rations, affect the performance of milking animals and, consequently, cause high costs of production and contribute to greater greenhouse gas emissions per litre of milk produced. Since feed cost is the most important factor in livestock production, enhancing the availability of quality (preserved) forages year-round (and preferably on-farm) is key to increase the productivity of dairy cows, reduce feed costs, and reduce the enteric methane emission per litre of milk produced. So far, most efforts made by stakeholders on forage production have focused on volume rather than forage quality, often because the concern has been on maintenance of the animal and stocking rates, especially in the arid and semi-arid regions. From now onwards, nutrient production per acre needs to be prioritise to target efficiency in land use and animal productivity.

If the target is animal productivity, forage quality should be given priority and 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 adaptation), mechanisation, feed testing and education/training and dissemination of knowledge to the farmer to ensure adaptation and sustainable implementation.

Three important pillars to boost forage production include (i) a strong dairy market, (ii) the allocation of land for fodder, and (iii) awareness of the need for quality forage (Table 7).

Table 7. 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 forage crops for milk production
- Encourage the implementation of integrating "livestock:crop" practices (mixed system)
- Stimulate and facilitate the private sector in the production and commercialisation of certified forage species/cultivars/varieties seed and plant material.
- Promote new species that have recently been introduced, such as *Brachiaria* and *Panicum*, and campaign for good management practices during land preparation, growth, harvesting, storage and feeding.
- Improve land use and conservation integrating forage production.
- Introduce grass: legume forage mix to improve protein production and soil conservation
- Improve management practices of commonly used varieties such as Desho grass, Napier, and Rhodes grass.
- 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 specialised in different steps of the forage chain (seed multiplication and supply, forage contracting services, sales and maintenance of scaled machinery, etc.).
- Introduce the notion of “quality” in the full 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 forage production and ruminant nutrition in student education and farmer training and extension programs.
- Improve use and management of grassland.
- Campaign for good practices “from seed to feed” focused on productivity, quality and sustainability of agro ecosystems (conservation agriculture, reduction of GHG-emissions).
- Rehabilitate and conserve 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.

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Annexes

Annex 1. List of potential Innovations for sustainable intensification

Innovation	Interventions
	Short Term
Zero Grazing	• Adapt animal housing to zero grazing system • Use of dual purpose varieties, such as sorghum, wheat, barley, maize, sweet potato • Intercropping using oats/vetch, lablab/maize, legumes/maize, sorghum or cassava • Integration of livestock and crop production: 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 once) • Harvest seed/split improved forage using 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 • Fertilisation • Irrigation • Pasture management • Increase nitrogen availability after drought, using legumes, manure and fertilizer
Improving utilization of crop residues and agro-industrial by-products	• Urea treatment • Chop / pulverization • Total mixed ration (TMR) • Soaking with water/molasses • Sweet potato vines silage
Mechanization	• Develop animal-powered mechanization: inexpensive, functional, and able to be built by locals with local materials • Communal machinery: mixers, balers, choppers • Scale 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 balance • 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, such as 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*),

Incorporation of seed technology	• Coated seed, with:
	  ○ 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 polymers

Improving utilisation of crop residues/industrial by-products	• Application of second generation biofuel technologies • Reintroduction of existing techniques, such as use of urea, chopping, TMR, pulverisation
Forage quality	• Introduction of quality concept and animal production relationship • Laboratory analysis development • Mycotoxins control
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 • Herd management: Mating, stoking rate... • Agroforestry • Feed bank (assisting poor areas to cope with adverse conditions), utilizing grass from roadsides, National Parks, and public land
Research	• Novel germplasm • Business models
Grassland management	• Stocking rate control • Grazing management • Grassland regeneration • Legume introduction • Agroforestry/silvopastoral system develop • High technology tools implementation

Annex 2. 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, palletisation Specialised 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 Pre-contracting acquisition/sale	Knowledge Lack of business approach
Improve water management	Government policy; Land/water access, increase potential irrigation areas Financial support: Credit/loan Technical assistance Increase water storage	Collective action Policies Infrastructure Finance Knowledge
Grassland management	Government assistance: Satellite follow-up of grassland evolution, development of communication system Herd management: Stocking rate adjustment, calving/mating season adjustment, rotational grassing, feed budgeting, storage Agroforestry/silvopastoral systems development	Collective action Policies Infrastructure Finance Knowledge
Feed bank *(assisting poor areas to cope with adverse conditions)*	Government/International organisation collaboration National Feed Inventory (FAO) Implementation of new techniques Increase storage facilities Follow forage/fodder evolution through satellite scanning	

Annex 3. Smart agricultural practices for sustainable intensification

Innovation field	Innovation practice	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 Maximise 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 forage 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 Plant survival
	Silvopastoral/agroforestry system (ASAL areas) • Native pastures over sown with legumes	Yield-quality Seasonality Feed security
	Increase cutting height from ground level	Quality Increase plant life span (perennial species)
Preservation	Haylage (40-45% moisture)	Forage quality Seasonality Market
	Grass silage (70-65% moisture)	Forage quality Seasonality
	Pelletisation	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 (ammonisation): 5% urea/water solution, spray on the forage (1:1) and storage under cover 2-3 weeks.	Quality Improve digestibility by 10% Improve intake by 50% Decrease mycotoxin risk
	Microbiologist treatments (microbes, fungus...)	Quality Improve digestibility by 10% Improve intake by 50%
	Second generation biofuel technics	Quality Improve digestibility by 30% Improve intake by 50%
	Mixing: On farm (scale mixers) Commercial (TMR/PMR)	Increase Intake Decrease selection
	Protein supplementation	Increase digestibility
	Forage analysis	Feed efficiency Maximise profits
	Ration balance	Feed efficiency Maximise 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 stabilisation Emergencies

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