White Paper
Pathways to Intensify Sustainable Forage Production in Kenya

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This White Paper describes the current situation of the Kenya's forage sub-sector and gives recommendations for sustainable intensification of forage production. As regards the current situation, it reports on available forage species and their quality, seasonality, preservation, forage seeds and planting material, fertilizer use, mechanisation, inputs and services, the forage market, education and training, innovations, sustainable forage production, and policies and regulations affecting the forage sub-sector. The paper further gives directions and recommendations to intensify forage production and enhance availability of quality forages, in order to drive an environmentally sustainable dairy sector towards increased productivity and enhanced competitiveness. This is an output of Theme 2: "Forages and Nutrition of Dairy Cows" of the Netherlands East African Dairy Partnership project (NEADAP). NEADAP is an initiative led by the Netherlands Government aimed at 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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Introduction

SNV Kenya through it Kenya Market-led Dairy Programme (KMDP) and WUR Livestock Research have taken the lead and developed a framework for Forage Quick Scans in Kenya, Uganda and Ethiopia, as part of Theme 2: "Forages and Nutrition of Dairy Cows" of the Netherlands East African Dairy Partnership project (NEADAP). NEADAP is an initiative led by the Netherlands Government aimed at learning and sharing amongst different dairy sectors and projects in East Africa.

This White Paper gives directions and recommendations for dairy sector stakeholders at all levels – from dairy practitioners to policy makers - who are engaged in dairy development, to intensify forage production in Kenya with the aim to improve the availability and quality of forages and rations fed to dairy cows. This will contribute to environmentally sustainable intensification of dairy production, enhance competitiveness of the sector, and climate smart solutions. The paper draws from a larger study of which the results are documented in NEADAP's Working Paper "Quick Scan of Kenya's Forage Sub-Sector, July 2019" (see: www.cowsoko.com/KMDP).

Dairy farming in Kenya is concentrated in the high altitude zones of North Rift, Central and Eastern regions. Here rainfall is high and (largely) bimodal (1,000 – 2,000 mm) and average temperatures are moderate (15-24 ℃). Dairy farming in this area is part of mixed crop-livestock systems, varying from intensive (zero-grazing) to semi-intensive (semi-zero grazing/improved pastures). The stock size of the dairy cattle industry in Kenya is estimated at 4.3 million animals (Odero Waitituh, 2017). It is mostly located in Central Kenya and North Rift.

The estimated number of small holder dairy farmers (with 1-5 cows) ranges from 0.8 to 1.8 million farmers (depending on the source and definition), producing 56% of the total milk supply, whereas the number of medium and large-scale farmers (15-30 cows and more) ranges from 3-4,000 producing 44% of the total milk supply (Mwendia et al., 2016). The segment of medium- and large-scale farms with herd sizes from 20 – 100 dairy animals and above is growing, which points at professionalizing and commercialisation of the dairy sector.

Dairy production in the country is characterised by low productivity, mainly due to nutritional constraints caused ineffective agricultural practices, use of outdated/unsuitable forage seeds and planting material and seasonality affecting availability of quantity and quality of forage available. There is a mismatch between the push for improved breeds with high genetic potential for milk production and the low availability of quality forages that should meet the nutritional requirements of these breeds. In the last 10 years, feed prices have increased by ca. 70%. Feed has thus a strong influence on the cost of milk production and the gross margin.

At present, the feeding costs of Kenyan dairy farmers represent 65-70% of the total production cost of one litre of milk (Perfometer Solutions, 2013). The use of poor-quality forages which are available in the forage market - at sometimes exorbitant prices – results in the need to use high levels of concentrates in the dairy rations used to produce milk. In addition to the generally poor quality of fresh and preserved forages, most areas experience an acute shortage of supply during the dry season.

Finally, it is evident that forage production per acre and forage quality needs to be improved for the Kenyan dairy farming sector, in order to increase production per animal and productivity per acre. This will result in reduced cost price of (raw) milk and enhanced competitiveness at farm and sector level.

1. Current situation of the Kenyan forage sub-sector

Forage species

In Kenya, forage species that contribute to ruminants' diets are mainly tropical grasses supplemented with forage legumes and crop residues. There is a wide variety of forage species used, depending on the agro-ecological zones, soil fertility and feeding systems. In intensive farming system under zero grazing, semi zero grazing, Napier grass (*Pennisetum purpureum*) is the most popular grass used, especially in medium altitude areas, where most of the dairy production is concentrated under mixed systems.

Rhodes grass along with Star grass (*Cynodon dactylon*) and Kikuyu grass (*Pennisetum Clandestinum*) are used for free grazing and hay making (mostly in the Rift Valley). The use of forage legumes is not widely adopted, albeit some species have potential and are used to some extent. These include, among others, vetch (*Vicia sativa*) and lucerne (*Medicago sativa*) in the highlands or under irrigation at lower altitude, and lablab (*Lablab purpureus*) in the relatively dry areas. Maize and Sudan grass silage are also used under these feeding systems. Maize having more potential in the higher altitudes and Sudan grass in the relatively dry areas.

In Kenya, the rangelands are highly degraded due to overgrazing and lack of control during grazing periods or over stocking rates. The main grass species found in free grazing on natural grassland systems include Kikuyu grass (*Pennisetum clandistinum*), Rhodes grass (*Chloris gayana*), Buffel grass/African foxtail grass (*Cenchrus ciliaris*), Masai Love grass (*Eragrostis superba*) and, in minor proportion, *Digitaria abyssinica*, *D. milanjiana*, Guinea grass *(Panicum maximum*), Giant star grass (*Cynodon plectostachyus*), Nandi Setaria (*Setaria sphacelate*), *Enteropogon macrostachyus*, and *Leptochloa obtusifolia*.

In arid and semiarid areas, the native grass species commonly found are *Themeda triandra*, *Sporobolus fimbriatus, Cenchrus ciliaris, Digitaria milanjiana, Digitaria abyssinica, Eragrostis superba, Eragrostis cilianensis, Eustachyus paspaloides, Aristida adscensionis, Aristida kenyensis, Panicum maximum, Cynodon spp., Bothriochloa insculpta, Heteropogon contortus*, and others. Some of the naturally grown legumes include *Stylosanthes scabra, macrotyloma axillare, Leucaena leucocephala, and Acacia spp.* Under this feeding system, minimum or no improvement of grassland has been carried out.

Seed and planting material

Availability of forage seeds/planting materials at the farm level remains low and is one of the main reasons why the improvement and development of forage production in Kenya is slow. Forage seed production and availability includes (i) formal registered and certified seed multiplication, and (ii) informal on-farm reproduction and channels for sharing of seeds or planting material.

To our knowledge there are about 20 companies in Kenya that supply certified forage seeds, including commercial maize seed used as fresh maize or maize silage to feed cows. Yet only nine of them have stocked forage seeds, such as maize, sorghum, lucerne, *Desmodium*, oats, Boma & Elmba Rhodes grass, Sudan grass, (sorghum × *drummondii*), sunflower, Columbus grass (sorghum x *Almum parodi*), and beans. The Kenya Seed Company (and its subsidiary Simlaw Seeds Company) is the main source of certified forage seed supply and distribution. In addition, only seven companies have forage seed multiplication sites. Sixteen entities, mainly public organisations (including KALRO and ADC) reproduce (non-certified) seeds informally.

The large-scale forage seed multiplication (certified and non-certified) is limited to less than six companies and KALRO. Most seed multiplication sites in Kenya are dedicated to the seed multiplication of grains, and vegetable seeds for human food, which have a higher and repetitive market demand in East Africa and beyond.

Forage quality

Low forage quality is one of the biggest constraints to higher milk production in Kenyan dairy farms. High neutral detergent fibre and lignin content, low energy and low crude protein, together with the low digestibility of the crude protein and of carbohydrates, are the common characteristics of most of the forages present in the farms (i.e. Napier grass, Rhodes and Kikuyu grass). This low quality forage is in part responsible for the low animal performance, high intensity of enteric methane emission and low profitability (Table 1).

Table 1. Example of forage quality and milk production relationship

(550 kg body weight (BW) stall-fed dairy cow, 150 days in milk, 70 days pregnant, DMI based on 1.3 % NDF, milk 3.7 % fat and 3.1 % protein. Milk price: KES 35/ltr, Napier grass price: KES 2.0, 1.6, 1.0 per kg (from poor to high quality)

Forage crop & cutting stage	NDF* g/kg DM	ME MJ* g/ kg DM	CP* g/kg DM	DMI* kg/day	Milk l/day	ME* %	MP* %	CH4* g/l	MAFC* KES/day
Napier > 120 cm	681	7.4	4.2	10.5	1.3	100	50	261	0
Napier = 120 cm	695	8.1	8.8	10.3	2.7	100	111	129	4
Napier < 60 cm low CP	630	9.0	12.5	11.3	6.4	100	132	51	115
Napier < 60 cm high CP	611	9.0	15.3	11.7	7.0	100	163	47	161

*NDF: Neutral-Detergent Fibre, ME MJ: Metabolisable energy in Megajoules, CP: Crude protein, DMI: Dry matter intake, MP: Metabolisable protein, ME%: ME supply as a percentage of total requirement, MP%: MP supply as a percentage of total requirement, CH4: methane, MAFC: Margin Above Feed Cost.

In most farms in Kenya, good agricultural practices are largely not applied, due to lack of knowledge, skills and a focus on quantity rather than quality. Most farmers and dairy extension workers also lack the ability to differentiate between high- and low-quality forages. Besides, many of them have a low income and are not able or willing to invest in best practices, or to pay for quality (inputs) products. This leads to a highly underdeveloped forage supply chain, which is merely based on volumes without any kind of standards or quality control/pricing system.

Seasonality, forage preservation and market

Forage production in Kenya is largely rain fed and seasonal and characterised by shortages in the dry seasons. Few farmers have good forage planning, stock of hay or silage to overcome the dry season. This leads to large fluctuations in the forage market and consequently in supply of milk to processors. The rainfall patterns in Kenya vary considerably from the (semi-) arid lowlands to the highlands with abundant rains, but even in the highlands there are dry seasons in between the bi-modal rainfall patterns.

The arid and semi-arid lands receive rainfall of circa 400-500 mm per annum whilst potential evapotranspiration ranges from 1,900-2,300 mm per annum and thus exceeds annual precipitation, resulting in water deficit. Mean annual temperatures range from 22 to 35 ℃ and relative humidity’s from 70-90%. Here the prevailing livestock system is (agro)-pastoralism with presence of local cattle breeds, small ruminants and camels.

The mid-altitude eastern region has mean annual rainfall of ca. 700 mm but in the hill masses it increases to ca. 1,050 mm. Annual evapotranspiration in this region ranges from 1,200-1,800 mm (KARI, 2001). The minimum mean annual temperatures vary from 14 to 22 ℃ while maximum mean annual temperatures vary from 26 to 34 ℃. In this area, dairy is an upcoming activity but still underdeveloped.

The high potential areas for dairy farming are in the Kenyan highlands. The Central and Eastern highlands receive bi-modal rainfall, the long rains occurring from March to May and the short rains from October to December. Annual rainfall is as high as 1,200 – 2,000 mm. Temperatures range from as low as 2 ℃ at night to a maximum of 25 ℃ during the day. Night frosts are common in farming areas high up the slopes of Mount Kenya, Mau and Aberdare Massifs.

The North Rift and Nakuru County primarily experience a uni-modal rainfall distribution, which starts in March/April and continues through to October/November with peaks in May and August. Average annual rainfall ranges from 1,200 to 1,600 mm and average annual temperatures from 14 to 28 ℃.

The most common method of forage preservation used in Kenya is hay. In recent years, silage has become more popular, but its use is still limited to the more progressive and commercialised farmers.
In Kenya, the predominant grass used for hay is Boma Rhodes, followed by natural grass, Kikuyu grass. Pastures used for hay making are often not fertilised or if so, only at very low application rates, and cut at flowering stage, which is too mature for good quality forage. During the last decennium, with the increased demand for forage, commercial forage producers are emerging in the market. These are mainly hay producers offering Boma Rhodes hay, natural grass hay and, to a lesser extent, lucerne hay.

Several cereals are commonly grown in the country: wheat, barley and rice, whose straws can be used as forage. Straw is generally preserved in loose form or bales. Stover is commonly referred to as the stem and leaves of grain maize after the cob has been removed. Stover is left in the field and cows can feed on the stover; in some cases, stover is collected, stored or stacked near the farm compound, grinded and mixed in the cow’s ration.

Silage is mainly prepared from maize, Napier grasses or sweet potatoes vines (Lukuyu et al., 2013), but also whole plant oats and sorghum are being ensiled. The most common methods of silage making are plastic drums, pit silage (underground), and bunker silage (above ground). Commercialization of maize and sorghum silage in small or large wrapped bales has also come up in the past 2-3 years.

Scarcity, low quality and seasonality are characteristics of the forage market in Kenya. Although demand is still largely seasonal, there is increasing "year round" demand for forages due to a growing number of dairy cows, milk production and ongoing investments in dairy. Most commercialising smallholders, often in the urban and peri urban areas without land to grow forage, have to buy forages during the larger part of the year. This is also the case on medium and larger farms with limited forage production often due to poor planning of forage crop production, they also have to buy forage during the dry seasons. This is a pull factor for a large hay market that has emerged over the past 10 years.

Fresh Napier grass and roadside grass are commercialised between farmers within proximity, but the hay market controls the forage market and is predominantly volume-based. Kenya Bureau of Standards developed a hay standard to provide guidelines for minimum nutritional, weight and safety requirements of commercial hay in order to facilitate trade, but its application needs to be enforced to become effective (Grass Hay, Kenya Bureau of Standards, 2018). In the Naivasha area, some large scale professional growers of irrigated lucerne are operational.

Inputs and services

Feed manufacturers, seed and fertiliser companies who supply their products through agents and agro-vet shops, suppliers of farm machinery, repair work shops, agricultural contractors, hay and other commercial forage producers, soil and feed laboratories, private advisors on forage production, preservation and dairy nutrition and many others, constitute the cluster of input and service providers for Kenyan dairy farmers producing or buying forages.
Government institutions, such as the Ministry of Agriculture, Livestock, Fisheries and Irrigation (MALFI), KALRO, farmers' organizations and cooperatives, NGOs or individual farmers can be other channels of providers, especially as regards the supply of seed and plant material. Farmers have expressed their concerns regarding the quality of inputs (e.g. seeds/planting material, dairy meals, fertilisers, hay). This is partly attributed to weak regulatory framework and enforcement mechanisms and partly to business ethics of private sector.

Mechanisation

The mechanisation level of operations in the forage sub-sector is generally low, especially with smallholders. In larger farms and amongst commercial forage producers, there is presence of hay balers, 1-2 row and even of late 4-6 row maize harvesters. Recently, in commercial forage production, machinery able to make baled silages has been imported.

There are various companies and dealerships importing forage harvesters, shredders or balers from Turkey, Brazil, Europe, USA, India and China based in Nairobi, Eldoret and Nakuru amongst others. Some of these also sell imported or locally manufactured low-cost forage shredders or pulverisers for smallholder farmers to chop maize for maize silage. For grasslands and forage crops, machinery for medium and large-scale farms is imported.

Technical quality of the performed task e.g. cutting, chopping, crushing, maceration and/or compaction is at times questionable if the best result, reducing losses during preservation, is the desired objective. Timely and regular maintenance and availability of spare parts can be challenging adds to quality losses and hence the final quality of the forage when fed.

Forage-related research

Forage research in Kenya is carried out by national and international institutes. The main national organisations involved in forage development are: KALRO (Kenya Agricultural and Livestock Research Organisation), KEFRI (Kenya Forest Research Institute), CIAT (International Centre of Tropical Agriculture), ICIPE (International Centre for Insect Physiology and Ecology), ICARDA (International Centre for Agricultural Research in Dry Areas), ICRAF (International Council for Research in Agro Forestry), and ILRI (International Livestock Research Institute). The main weaknesses of forage research in Kenya are:

(i) Lack of collaboration and coordination within and between national and international research centres.
(ii) Lack of a strong connection between forage- and animal nutrition research.
(iii) Disconnect between research and market needs (e.g. better quality forages for dairy cows with potential of high milk production).
(iv) Lack of effective models to bring research (i.e. new seed species, cultivars, varieties) to the farmer: route to market, distribution and training.

(v) General belief of policy makers and/or regulators that, with the amount of ongoing local research, there is no need to actively encourage private seed companies to enter into the forage market with already existing varieties grown outside Kenya, and with a proven record in tropical climate and similar soil conditions.

Education and training

Various studies (SNV-KMDP/PKF, 2013; ICRAF, 2018) on education and training in the Kenyan dairy sector have highlighted the lack of practical training and skills development (i.e. good agricultural practice at farm level). Reference to SNV-KMDP/PKF and ICRAF is made to as an example. Similar studies were done by GIZ which confirmed these findings.

Government extension services which used to take it upon them to train farmers in agronomic and dairy husbandry practices have been considerably reduced since the Structural Adjustment Programmes in the 1990s. The remaining government extension service is not focused on quality forage production for dairy cows with a high genetic potential for milk production; the lack of knowledge in this field makes them ineffective. Private advisors specialised in forage and dairy nutrition provide their services to medium and large-scale farms, as these can pay for them.
At the same time, Agricultural Colleges and Universities are more focused on research and education at academic level, with little connection to the field and the needs of the market.

Next to the importance of professionals in the forage sub-sector being trained by specific vocational or higher professional training programmes, and the availability of enough capacity in the knowledge and research institutions, it needs to be noted that the average age of the targeted group of practicing dairy farmers or farm owners attending trainings and field days is very high. Involving youth in in dairy farming is still very dependent on ownership of land and cattle, which is often in the hands of their parents.

Environmentally sustainable forage production

In 2010, Kenya's national GHG emissions equated about 73 MT (million tons) of CO_2-eq. About 40% of agricultural emissions in Kenya come from manure left on pasture (37.2%), application of synthetic fertilizer (1.8%), and manure applied to soils (1.2%). Enteric fermentation takes up about 55% of the agriculture sector's emissions (FAOSTAT, 2019).

The dairy cattle sector in Kenya is responsible for about 12.3 MT CO_2-eq. The GHG profile is dominated by methane, nitrous oxide (N_2O) and carbon dioxide (CO_2), which respectively contribute 95.6%, 3.4% and 1.0% of total emissions. At the national level, the emission intensity of milk produced in Kenya is on average 3.8 kg CO_2-eq/kg FPCM.
Sustaining an ever increasing population of ruminants consuming (low quality) forages poses a dilemma: while exploiting their ecological niche, forage-fed ruminants, and more so forage of low nutritional value, produce large amounts of enteric methane, a potent greenhouse gas. Resolving this quandary would allow ruminants an expanded role in meeting growing global demands for livestock products (Guyader. et al, 2016).

The growth of agricultural output in Kenya is constrained by many challenges including soil erosion, low productivity, agro-biodiversity loss and soil nutrient depletion. Land exploitation devoid of proper compensating investments in soil and water conservation will lead to severe land degradation. About 30 % of the Kenya's landmass is subject to severe land degradation (Mulinge et al., 2016). This is reflected by the current land preparation practices and systems used (e.g. overstocking, monocultures, intensive and repeated soil disturbance, low level of soil fertility maintenance)

Innovations

In the past 10 years research institutions, government, farmers and dairy cooperatives, private sector and development organisations have made efforts to enhance the forage sub-sector. Several studies on the animal feed and forage sub-sectors were carried out or facilitated by several donor funded programmes. These and other studies contain a wealth of information on the Kenyan feed and forage sub-sectors, including recommendations for innovations and enhanced policy framework. In addition, handbooks, training material and standard operation procedures have been developed to enhance agricultural practices.

A number of innovations resulted from these projects and from collaboration with the private sector. In the last years, through the Climate-Smart Brachiaria Program (Gonzalez et al., 2016), different improved Brachiaria cultivars and hybrids have been demonstrated in the country and recommended for their use. Also, Panicum maximum cultivars/ varieties have been promoted with very good results. Maize silage has increasingly been adopted as a preserved forage. Recently investors have piloted business models like professional contracting services to harvest and ensile maize (and to a lesser extent also oats and sorghum), as well as services for baled silages, exemplifying that there is an emerging concern and market for higher quality forages. The bales are compacted and wrapped in polythene and are available in various sizes between 50 -1,000 kg. A software for cow ration balancing and optimisation has been introduced and was adapted to East African conditions and needs (Rumen8).

KALRO does research on the use of lupins for intensive farming systems as a protein source. Sweet lupins next to a good source of protein in the diet of dairy cows can also contribute to maintain soil fertility in a crop rotation system on farms, and its demands towards the pH of the soil is less than other legumes. With increasing shortages of protein in the feed market and hence increasing prices of protein rich feed ingredients, it will become more interesting for farmers for whom land is not a limitation to grow protein themselves.

For extensive farming systems KALRO is testing rangeland grasses *Chenchrus ciliaris, Enteropogon macrostachys, Chloris roxburghiana and Eragrostis superba.* These grasses can be used to re-establish degraded soil/area, planted in mixtures. Their nutritive value for grazing cows depends on their stage of maturity. *Chloris roxburghiana and Eragrostis superba* are currently tested in the National Performance Trials (NPT).

Policies and regulations

Formal channels for forage seeds need to follow the regulations of the Kenyan Plant Health Inspectorate Services (KEPHIS) and include private sector/companies licensed to trade the approved varieties. The registration process involves two main steps: (i) National Performance Trials (NPT) and (ii) Distinctiveness, Uniformity and Stability (DUS) tests. The informal seed system is largely driven by individual farmers, farmer groups, Kenya Agricultural and Livestock Research Organization (KALRO) and Agricultural Training Centres (ATC).

Seed companies collaborate with KEPHIS in the certification of all commercial forage seeds. Testing is carried out on a regular basis at the production and processing stages. Seeds for exportation and local consumption are required to meet international standards as per International Seed Testing Association (ISTA). Informal channels trade seeds that do not necessarily pass through the regulations (nor are certified).
In spite of liberalisation of the seed sub-sector, the registration and multiplication of new forage species and varieties is a slow and cumbersome process that restrains, and to some extent discourages, local and international seed companies to register and disseminate forage and grass seed varieties suitable for Kenya's agro-ecological conditions and superior to what is available in the market (Sikinyi, 2010). This for example means that forage maize varieties or improved varieties of Boma Rhodes and Kikuyu grass are not available in Kenya.

The Livestock Feed Policy addresses the challenges in the livestock feeds in the country in the context of feed production, conservation, quality and regulatory framework, research and extension, and sets clear roles of institutions involved in feed regulation. The policy is broadly guided by the following specific objectives: (i) to attain self-sufficiency in feed and forage production in all ecological zones on an environmentally sustainable basis, (ii) To promote and establish conservation of forage resources, (iii) To ensure availability of quality animal feeds for domestic and export markets, (iv) To promote research on utilization of new technologies in animal feedstuffs, and (v) to develop appropriate institutional frameworks for the feed industry. The GoK may consider utilizing available tools to realize these specific objectives more efficiently.

2. Challenges in the forage sub-sector

In the underlying study and in the chapter above, several constraints that affect the forage sub-sector - and hence the dairy sector- were identified. These can be listed and consolidated under 3 themes.

Quality fodder (availability, accessibility, choice)

- Limited access to - and availability of - improved forage seed/plant material.
- Insufficient quantity and quality of forages and pastures.
- Lack of forage development plan on farm level, but also regional (e.g. County) or national
- Limited forage crop options and possibilities for crop rotations.
- Sub-division of land and urban expansion.
- Climate change.
- Low level of mechanisation at different scale of farming systems.

Animal-environment interaction

- Mismatch between policies of Government departments for "breeding" and "feeding".
- Low feed efficiency/high feeding cost due to low quality forage and unbalanced rations.
- Inefficient forage utilisation (low Feed Efficiency) due to poor quality.
- Weak links between agronomy of forages and animal nutrition.

Knowledge transfer and dissemination (extension, training, awareness)

- Seasonality of forage production (highly rain dependent) and lack of fodder plan (-ning).
- Inefficient forage preservation (and ineffective).
- Use of very low digestible forages.
- Low quality forage on farms and in the market.
- Absence of reliable forage & feed testing facilities.
- Lack of evaluation of feed cost and pricing based on nutritional value, trading standards not based on quality indicators (DM, ME, CP).
- Low skills/education level on forage production and preservation.
- Weak links between health, food safety and feed safety.

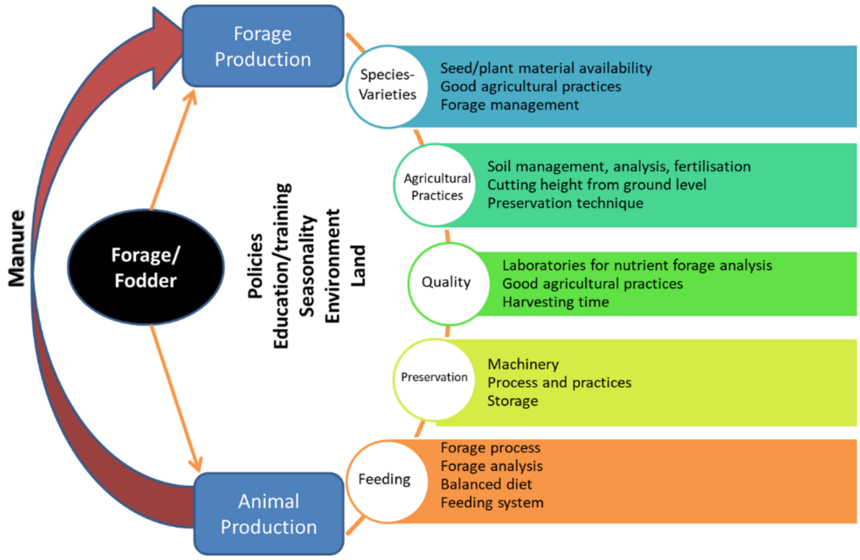

Figure 1. Full package concept

3. Towards intensified environmentally sustainable forage production

3.1 Improved quality and quantity of forages for increased productivity

Forage species/varieties

Improved or new forages (species/ cultivars/ varieties) need to be either developed or imported, and locally tested. Good quality seed and plant material (certified) should be easily accessible to farmers. There is need for better orchestration of introduction of new forage crops, emphasising complete solutions from seed to feed in demonstration sides that are widespread and easily accessible for farmers. Training and extension should be carried out with main emphasis on best management and good agronomic and feeding practices for the new species/varieties introduced, but most important delivered by competent trainers to ensure information is not contradictory.

The identification of better dual-purpose food/feed varieties already in the global market is required, especially for cereal, pulses and oil crops. The increasing competition in the market for single source concentrate ingredients and coupled to this the looming protein shortage in the nearby future, will also require increased acreages of high yielding protein crops. To make maximum use of these forage crops - and forage production to stay competitive with food production - specific management skills and knowledge is required. In the medium- to long-term, an effective and dynamic system of seed/plant material certification and commercialisation needs to be developed and synchronised with the new advances in genetically improved materials.

Collaboration between regional, national and international institutions working on forage and pasture grass development is needed, but this should be linked to animal scientists specialised in ruminant nutrition. New species/ varieties with high potential nutrient content, especially energy and protein need to be introduced and tested on their suitability for different agro ecological zones and feasible animal production target (milk/growth/weight gain).

Forage quality

Forage quality is the main driver to improve milk production (Juarez Lagunes et.al. 1999). The execution of well-known good management practices on the forage species currently used, such as Napier grass, Rhodes grass, Kikuyu grass, maize, sorghum, natural (native) grassland, and others, needs to focus on quality (nutritive value and digestibility) (Annexe 1). Future actions should consider improved forage quality e.g. through better seed species/ cultivars/ varieties, use of conservation agriculture, improved crop nutrition, crop protection and adapted cow breeds (including crosses) with a higher feed conversion that are able to utilize rations with a higher NDF content (common for tropical forages) more efficiently.

Steps to improve forage testing need to be made to facilitate the sub-sector with feed testing facilities (stationary or future handhelds), that have access to Near Infra-Red Spectrometer (NIRS) regression lines. These NIRS analyses reports can be linked to "total diet ration balancing software" to enhance cow rations, increase feed efficiency, optimize milk yield and reduce feed costs, whilst also reducing enteric methane emissions per litre of milk or kilogram meat produced.

Management of seasonality

An increase in the availability of quality forages throughout the year is needed, to reduce the fluctuation in milk supply and associated problems like underutilisation of processing capacity. Innovations in this regard can vary from basic reoriented practices to new high technology that could involve investments.

Commercial production of forages should be further promoted to increase the forage offer in the market, not only in terms of volumes, but especially regarding quality of forages incl. pasture grasses. Demand for forages will increase in the near future, not only in the high potential dairy Counties but also in arid and semi-arid lands. This requires huge investments and requisite skills and knowledge to create economies of scale necessary to make the required scale of machinery economically viable. Private sector involvement and creating conducive enabling environment (land, infrastructure and public services, fiscal incentives, amongst others) seem indispensable.

The involvement of agricultural machinery suppliers and forage contractors or service providers should be promoted at all farm scales. Silage can be promoted as well as alternative preservation methods such as haylage, dehydration, palletisation, and compaction.

Seasonality management can also be enhanced by improved water management: encouraging drip irrigation with rainwater and runoff water harvesting, including water ponds, earth dams, plastic-lined water ponds, water pans in rangelands as water sources and solar/wind pumps as energy sources.

Access to quality forage seeds, the use of pre-treated seed, water efficient species/cultivars/varieties, and the selection of species to be grown according to local conditions (arid and semiarid land, altitude and soil conditions), all contribute to more climate resilient farming systems.

3.2 Animal-environment interaction

Rangeland restoration and management

A right balance between feed supply (carrying-capacity) and animal demand (requirements for livestock and wildlife) needs to be considered in natural grasslands and rangelands, which include most of the country (>80%). Natural occurring (native) grass species in these areas need to be prioritised for soil restoration, but improved species adapted to the (local) conditions should also be considered.

Over-sowing or re-seeding natural grasslands/rangelands with grasses, legumes, shrubs or establishing tree cover to restore degraded areas, improve soil cover, increase plant density, and increase the quality and the quantity of grassland forage supply, is very important for the future of land and water conservation and forage production in those areas.

Herd management, grazing agreements, stocking rate, herd movement systems, and the calving/mating season need to be considered, especially in rangeland areas where irrigation or water management innovations are not possible to apply. Management techniques such as "temporal closure", "permanent closure"," weed and bush clearing through chemical, or mechanical processes"," rotational grazing", and "forage banks (protein banks)", should be considered according to local conditions and opportunities.

New technologies in grassland management and utilisation of technology such as GPS, satellite images, electronic pastoral control, remote sensing, and electric fences ("solar wires") are available worldwide, but special training and personal capacitation is required.

Environmentally sustainable forage production

Land degradation, GHG emissions, effluent management, and plastic residues are the main environmental issues associated with forage production. In order to reduce land degradation and foster land restoration and assure "RESOURCES SECURITY", the involvement of the national and County Governments is critical, as are all other interest groups and stakeholders (land and water users). Conservation agriculture and sustainable rangeland management are crucial to reduce environmental impact on land-use.

Regarding GHG more research may be needed on the net impact of intensified sustainable forage production on GHG emission, but it is safe to say that feed efficiency (FE) and balanced rations, play an important role in increased milk production and reduction of enteric methane per animal product. The use of high-quality and digestible forages and grasses, in well-balanced rations, will increase the ability of cows to turn feed nutrients into milk and meat.

Manure utilisation and management can be improved offering training and education in conjunction with scaled machinery to facilitate its management and use. Farmers in urban and peri-urban settings with big herd sizes and little or no land available, should be assisted to develop a plan for manure storage and environmentally responsible disposal. Sustainable management and application systems will need to aim at reducing nutrients losses from manure, thus maximizing the benefits and minimizing the need for artificial fertilizers. With the increment of forage conservation, agricultural plastic residues will increase, thus plastic bulking, collection and recycling systems need to be put in place.

3.3 Dissemination of information, knowledge and skills transfer

Knowledge and skills, management capacity

Great emphasis must be placed on the development of knowledge and skills needed to successfully introduce and manage best practices and innovations. A very strategic and well-designed educational/training system needs to be developed for all forage related topics and for various agro-ecological environments.

The curriculum should have a strong skills-based component and address all levels of the forage chain, including forage preservation and mechanisation, in an integrated approach with ruminant nutrition. The relation between forage production and the animal's nutritional requirements should be introduced and implemented vigorously at relevant universities and training institutes in Kenya.

In the traditional institutions of knowledge sharing universities, research institutes, and NGOs, young professionals are getting chances to gain experience and knowledge, however there is a disconnect and huge gap in practical knowledge of processes on the farm. Among dairy farmers, the primary producers, there is the perception that they do not receive any support or benefit from knowledge-based institutions. This weak link is hindering the need to apply new insights and technologies quickly.

Even more so, initiatives are needed to encourage and allow young people to take up the profession of dairy entrepreneur. This requires a change in traditional structures of handing over farm ownership from generation to generation. It will be more attractive for financial and training institutions to invest and convene agricultural entrepreneurs of a younger generation who will quickly pick up the advantages of supporting technologies provided by the internet and its applications.

Smart agricultural practices

Numerous interventions, (new and existing) technologies and modalities can be used to improve the forage situation in Kenya. Some require new technology and considerable investments. Smart-agricultural practices (e.g. conservation agriculture, improved breeding and health practices) related to forage continues with the selection of the right forage species/varieties that are well-adjusted to the farming system and local conditions (soil, water and climate) and is followed by feed balancing to eventually reflect in the production of the animal.

4. Way forward

Forage quality and scarcity have been identified as amongst the key factors determining growth and competitiveness of dairy (and beef) production and the livestock sector at large. Over the past years, many farmers and stakeholders such as agricultural contractors, dairy cooperatives, dairy advisors, government officials and researchers, have increased awareness as regards to the importance of year round quality forages in ruminant's ration to stabilize milk production. Current innovations need to be scaled-up and others introduced and fast-tracked, to keep improving forages, forage related input and service provision and the adoption rate of farmers, to create positive impact on the farm operations in general, and on feed efficiency and realizing the optimum production potential of the dairy cow in particular. These innovations at different steps in the forage value chain should address a number of topics, putting the farmer in the centre as visualised in the diagram on the next page.

a) Agronomy and forage market: smart-agricultural practices, new preservation techniques, scaled technology and machinery, enhanced professionalization of forage contracting services, trading and pricing of feeds and forages based on their nutritive value.
b) Breed and animal nutrition: choose "suitable breeds for the available feeds" and optimize milk production by linking forage quality to ruminant nutrition including feed safety.
c) Private sector input suppliers: quality input supplies and services, including distribution of forage seeds and plant material, fertilizers, farm machinery and soil & feed testing facilities.
d) Seed multiplication and supply: availability (through registration and dissemination) of high performing forage species and varieties in terms of nutritive value and production per acre.
e) Education, research and extension: effective knowledge chain with the aim to intensify forage production in an environmentally sustainable way.
f) Policies and regulations: conducive policies and regulations to drive innovations, including forage seed availability, and (other) private sector investments in the forage sub-sector, including encouraging agricultural entrepreneurship among youths.

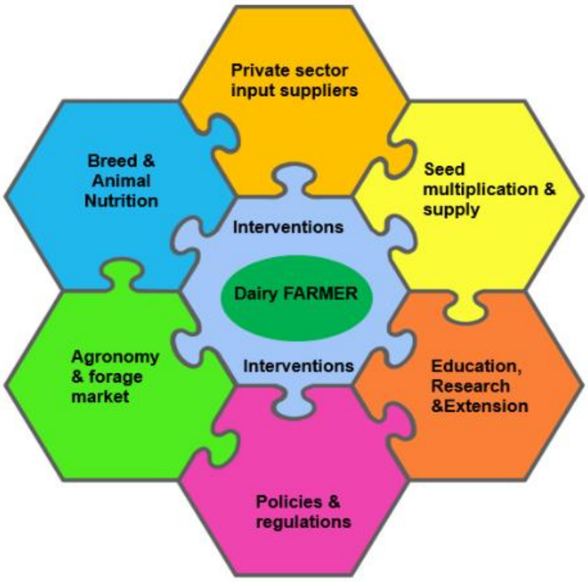

Figure 2. Diagram of interventions in the forage value chain

Table 2 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 2. 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	Restructure extension services and enhance rural practical training centres (e.g. ATCs) Facilitate access to social media to be used as teaching tool in rural areas. Enhance private consultants' sector. Involve all stakeholders to ensure distribution networks, availability and dissemination of new technologies and knowledge. Encourage and implement different aspects of the chain, from seed to feed. Invest in knowledge transfer and exchange focused on youth. Create an enabling environment for young dairy entrepreneurs. Include and connect forage production and animal nutrition in student education and farmer training & extension programs.

	University and Research Institutions	Connect forage production and animal nutrition Provide Intermedium Degree for special topics related to forage/animal production. Expose students to practical work “on the farm and in the field”.
	Private Sector	Collaborate with university and research knowledge institutions to transfer latest knowledge to farmers.
	Farming Community	Adopt and apply sustainable practices to intensify sustainable forage production. Empower youths and women to become dairy entrepreneurs. Transition to economically sustainable and technology based dairy farms
	Development partners (NGOs, donors)	Assist with the introduction of new technology, strengthen education systems, and divulgation of sustainable forage production and utilization Monitor new innovations to ensure their success. Encourage and facilitate youths and women become dairy entrepreneurs.
Intensify forage production (productivity and quality) as the main driver to improve profitability of dairy farms in a sustainable way	Government	Fast-track access to new (better) certified forage species/varieties. Rehabilitate and conserve rangelands. Intervene in the forage market; develop feed quality control system (standards).
	University and Research Institutions	Develop forage crops for intensified sustainable forage production. Promote the use of new forage species in collaboration with dairy extension workers/ consultants. Focus on forages with high nutritional value and yield potential (DM/ha).
	Private Sector	Commercialization of new (better) certified forage species/varieties. Encourage and offer better preservation practices and methods. Introduce the notion of “quality” and unpack it to farmers in economic benefits. Advice and avail the breed that fits the feed.
	Farming Community	Make use of new species and improved varieties. Improve forage management and utilization from seed to milk. Intensify environmentally sustainable forage production. Continuously improve soil and water management. Use forages at the best “quality stage”.
	Development partners (NGOs, donors)	Assist in the improvement of feed efficiency. Promote and improve preservation practices and methods. Introduce new technologies for forage production intensification.
Optimize milk production through sustainable forage production intensification	Government	Align animal breeding policy with available forage quality. Focus forage development strategies on forage preservation. Revise/reform land allocation policy framework to enable investments which promote fodder production and trade. Revise/reform the land policy to incorporate forage production/grazing areas. Develop an integrated land, water, soil resources development strategy – including irrigation strategies - for sustainable natural resource management. Encourage the establishment of forage banks in feed deficit areas.
	University and Research Institutions	Consider best suitable animal breeds in line with forage development strategies. Include water efficient and drought tolerant species and varieties in forage develop-ment plans/strategies. Improve native forage varieties.
	Private Sector	Improve machinery and services. Introduce new and scaled technology. Invest in preservation & irrigation of quality forage production.
	Farming Community	Relate and align choice of animal breeds to forage quality available. Enhance pasture-use through sustainable grazing and land management systems. Continuously adopt and invest in technologies to develop the dairy farms Adopt, practice or expand silvo-pastoralism/agro-forestry.
	Development partners (NGOs, donors)	Collaborate in “livestock - forage – nutrition - climate change” policy development.
Encourage & enable Private Sector involvement to create a vibrant and competitive forage sub-sector	Government	Recognise investors in commercial forages and agricultural machinery contracting services as entrepreneurs. Promote investments and support investors in the forage sub-sector. Facilitate creation of businesses specialised in different steps of the forage chain. Offer conducive fiscal incentives to forage and seed producers and agricultural contractors in forage sub-sector.
	Universities and Research	Link research and education with market needs and demand.
	Private Sector	Increase seed supply in affordable sized package. Apply best agricultural practices in commercial forage production and contracting services, with focus on high nutritional value of fresh and preserved forages. Introduce technical sales strategy. Increase availability and assure maintenance and repair of scaled machinery.

		Train employees on forage production technology. Differentiate quality standards and price systems.
	Farming Community	Create/assure consistent demand. Request high quality forages. Use quality standards to assess and value forages.
	Development partners (NGOs, donors)	Support private investments/innovations in the forage sub-sector. Collaborate in forage business development. Support entrepreneurial projects.

In the **short-term,** the required steps to alleviate nutritional problems of dairy animals are (i) effective utilisation and better management practices of the available forage resources, i.e. forage crops, crop residues, agro-industrial by-products, natural pastures, shrubs and forage trees, and (ii) appropriate supplementation in well balanced rations, with concentrates rich in energy and protein of low quality natural pasture and crop residue-based diets, to achieve higher feed efficiency.

Different practices and supplementation strategies could be applied depending on the type, accessibility and cost or price of forages and supplementary feeds in a given area. Good forage preservation practices, particularly as regards hay and silage making, should be much encouraged in order to enable a steady supply of quality roughages out of currently available sources, throughout the year. Assessment of the (actual) nutritive value of forages, concentrates, natural grasses and forage trees and shrubs (which are commonly used as feed source during the dry season) could be important to enhance their optimum utilisation.

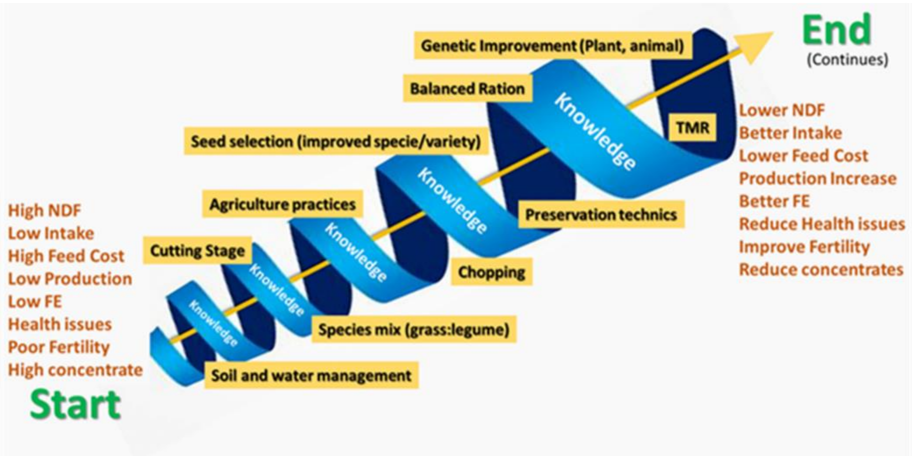

Figure 3. Upscaling short-medium term recommendations to improve forage quality and nutrition of dairy cows

In the **medium to long-term**, important points to consider are (i) enhanced access to new or improved forage species/ cultivars/varieties which allow for increased Dry Matter (DM) intake and higher nutritive value for the dairy cows, (ii) introduction and use of appropriate technology and machinery for forage production and preservation, (iii) inputs (i.e. planting material, concentrated dairy feed, fertiliser, veterinary drugs, etc.), (iv) feed and forage testing facilities, and (v) education and practical training on forage production, preservation and dairy nutrition.

Forage research should be directed towards the development of feeding systems that make better use of those local resources that are available throughout the year. It needs to be directly linked to animal nutrition and farm economics, in order to develop commercial and environmentally sustainable solutions. Local research should work with the private sector to assure that research and innovations find a route to 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 Kenya. Rather, 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 and dissemination of forage seeds/planting materials, or through local breeding and propagation. This should go hand in hand with the development of a national forage and grassland curriculum, with focus on meeting the nutrient requirements of the (high producing) dairy cow.

Based on these short, medium and long term interventions, a consistent road map needs to be developed and put in place, stimulating and facilitating stakeholders to work in concert with the aim to increase farm performance and farm profitability. To be able to achieve this, it is crucial to realize the central role of the dairy farmer and to facilitate him/her to access the requisite inputs, services, knowledge and skills, and to adopt and implement the promoted good agricultural practices.

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Annex 1. Innovations to improve performance of forage species currently used

Forage	Innovation practices	Potential improvement
Napier grass	Cut at 5-10 cm from ground level Cut before stem elongation (8-9 leaf state) N Fertilisation Manure application Silage Intercrop with legume (*Desmodium*, pigeon pea, calliandra, stylo, centrosema etc.) Use of new varieties	Increase plant life span Forage 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 Fertilisation Manure application Silage Legume mix Use new varieties	Increase plant life span Forage quality Soil improvement (N-fixation) Feed planning reduce seasonality Higher yielding and more nutritive
Kikuyu grass	Cut at 5cm from ground level Cut before stem elongation (4-5 leaf state) N Fertilisation Manure application Legume mix Use new varieties	Increase plant life span Forage quality Soil improvement (N-fixation) Seasonality Increase plant life span
Brachiaria spp/ Panicum maximum	Legume Mixes: Ex. (*Clitoria ternatea*, *Macroptilium atropurpureum*, *Stylosanthes guianensis* and *Stylosanthes seabranna*) cut 10 cm about 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 cm from ground level Cut before stem elongation of predominant grass specie(s) and season N fertilisation Manure application Varieties identification Reseeding, grass/legume (direct drilling)	Increase plant life span Increase soil covert Increase plant population Better soil conservation Forage quality Soil improvement (N-fixation) Seasonality Increase plant life span
Maize silage	High chopped corn silage (40 -50 cm from ground level) Maize/Sesbania (70:30) intercropping	Energy source Planting at the same time / Harvesting time – ensiling
White Sorghum	Headlage (Silage from the head of plant only)	Energy source
Forage Sorghum	Silage	Energy source
Lucerne	Cut 10% flowering	Protein source Forage quality Increase plant life span
Desmodium	Intercropping with different grasses. Seedling growth of Desmodium is especially slow; there-fore, 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 Cut at 10 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

Annex 2. Tools for seasonality control

Target	Innovation	Bottleneck
Improved species/varieties	Drought resistant More yield/quality	Access Cost
Improved forage preservation	Technical support Improve actual preservation techniques: silage, hay, baling - Training - Machinery New preservation process/techniques: - Haylage - Compaction - Dehydration - Pelletisation Specialise machinery: - Multi balage - High-compaction systems - Precision chopper / kernel crushers - Conditioners	Skills Knowledge Access to new technology Access to new machinery Investment/ Access to finance
Promote commercial forage 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 policies - Land/water access - Increase potential irrigation areas Financial support: credit/loan Technical assistant Encourage rainwater harvesting 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 - Grassland inventory (pasture library) - Feed budgeting - Storage	Collective action Policies Infrastructure Finance Knowledge
Feed bank (assisting poor areas to cope with adverse conditions)	Government/International organisations collaboration National Feed Inventory (FAO/MALFI) Implementation of new techniques Increase storage facilities Follow forage evolution through satellite scanning	

Annex 3. Summary of smart agricultural practices to improve forage supply and quality

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-Yield
	Provide farmers/advisors with decision tools	Yield-quality ; Maximise profits
	Inputs (manure and composts, crop residues, fertilizers)	Yield-quality (increase soil organic matter and improve soil structure)
	Crop rotation	Yield-quality (soil conservation) Crop health/soil nutrient management Decrease mycotoxin contamination
	Zero / minimum tillage	Yield (soil conservation)
Seed/Plant material	Coated (with water absorbent materials like super absorbent polymers (SAP))	Yield-quality (improve germination in 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
	Silvo-pastoralism/agroforestry system (ASALs) - 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
	Silage (70-65% moisture)	Forage quality; Seasonality
	Pelletization	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	Stem crusher	Increase Intake Increase rumen soluble sugar Availability Improve digestibility
	Chopping	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 10% Improve intake 50 % Decrease mycotoxin risk
	Mixing: - On farm (scale mixers) - Commercial (TMR/PMR)	Increase Intake Decrease selection
	Protein supplementation	Increase digestibility
	Forage analysis	Feed efficiency; Maximise profits
	Forage based ration balancing	Feed efficiency; Maximise profits
Machinery	Direct drillers	Yield-quality (grasslands)
	Conditioners	Quality
	Precision choppers	Quality
	Multibalers	Quality
	Mixers	Increase Intake, Decrease selection Increase 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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