Quick Scan of Kenya's Forage Sub-Sector

Netherlands East African Dairy Partnership (NEADAP)

Working Paper




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This document or Working Paper describes Kenya's forage sub-sector and looks at the current situation of 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, environmentally sustainable forage production and policies and regulations affecting the forage sub-sector. The Working Paper identifies gaps and gives recommendations to enhance availability of quality forages. It is a reference document for the development of a Strategy Paper and/or Policy Brief under Theme 2: Forages and nutrition of dairy cows, of the Netherlands East African Dairy Partnership project (NEADAP). NEADAP is an initiative by the Netherlands government for learning and sharing amongst different dairy sectors and projects in East Africa.

Table of Contents

List of Tables, Figures and Annexes

Acronyms

AEZ	Agro-Ecological Zones
ATC	Agricultural Training Centre
A.I.	Artificial Insemination
ASAL	Arid and Semi-Arid Land
BRIDGE	Building Rural Income through Inclusive Dairy Business Growth in Ethiopia
CA	Conservation Agriculture
CBO	Community Based Organisation
CIAT	International Centre of Tropical Agriculture
CP	Crude Protein
DairyBiss	Dairy Business Information and Support Project
DM	Dry Matter
DUS	Distinctiveness, Uniformity and Stability test
EDGET	Enhancing Dairy Sector Growth in Ethiopia
FE	Feed Efficiency
GHG	Green House Gases
GOK	Government of Kenya
ICARDA	International Centre for Agricultural Research in Dry Areas)
ICRAF	International Centre for Research in Agro-Forestry
ICIPE	International Centre for Insect Physiology and Ecology
IFPRI	International Food Policy Research Institute
ILRI	International Livestock Research Institute
KALRO	Kenya Agriculture and Livestock Research Organization
KEFRI	Kenya Forest Research Institute
KEPHIS	Kenya Plant Health Inspectorate Services
KLIP	Kenya Livestock Insurance Program
KMDP	Kenya Market-Led Dairy Program
LSF	Large Scale Farm
LULUCF	Land Use Land Use Change and Forestry
MASL	Metres above sea level
MjME	Mega Joules of Metabolic Energy
MALFI	Ministry of Agriculture, Livestock, Fisheries and Irrigation
MSF	Medium Scale Farm
NDF	Neutral Detergent Fibre
NDFd	Neutral Detergent Fibre Digestibility
NGO	Non-governmental organisation
NIR	Near Infra-Red
NIRS	Near Infra-Red Spectrometer
NPT	National Performance Trial
PMR	Partial Mix Ration
PUM	Netherlands Senior Experts Programme
SHF	Smallholder Farm
SNV	SNV - Netherlands Development Organisation
SOPs	Standard Operational Procedures
SPEN	Service Provider Enterprise Network
TIDE	The Inclusive Dairy Enterprise
TMR	Total Mix Ration
WUR	Wageningen University & Research

Acknowledgements

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

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Special thanks also to Nancy Kimaiyo Jerop of KMDP for helping to design and administer the survey and analysing the responses, and to Seyda Özkan-Gülzari Wageningen UR, Livestock Research and Anton Jansen, Teamleader of SNV's Kenya Market-led Dairy Programme (KMDP), for giving valuable inputs to the survey and the report.

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Introduction and Summary

This report

SNV Netherlands Development Organisation (SNV) implements the Kenya Market-led Dairy Program (KMDP), funded by the Embassy of the Kingdom of the Netherlands in Nairobi. The Dutch Government also funds dairy programmes in Uganda (TIDE) and Ethiopia (EDGET, BRIDGE and DairyBiss) and this involvement in East Africa led in 2018 to a regional project for learning and exchange: Netherlands East African Dairy Partnership (NEADAP). In NEADAP focus is on three themes: Milk Quality, Forage (and dairy cow nutrition) and Inclusive Business Models and sharing of lessons learned for 5 countries: Ethiopia, Kenya, Ruanda, Tanzania and Uganda. Implementing partners of NEADAP are SNV, Agriterra, WUR and Bles Dairies.

In the Forage Theme SNV Kenya/KMDP – with the support of WUR Livestock Research - takes lead and developed a framework for Forage Quick Scans for Kenya, Uganda and Ethiopia. The quick scans focus on the current status of forage crops availability, production and preservation practices, technologies, mechanisation and innovations. This includes forages produced and preserved by the farmer in different farming systems: intensive farming (zero grazing), semi-intensive (semi-zero grazing, grazing on improved pastures) and extensive livestock systems (grazing on natural grassland, ranching, agro-pastoralism). The study also pays attention to the commercial forage producers and agricultural contractors that have emerged in the Kenyan forage sub-sector.

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The approach of the quick scans consists of a combination of desk study, questionnaires, interviews and field visits. This report concerns the forage sub-sector scan for Kenya. Annex 1 presents the list of key resource persons representing relevant organisations who received a questionnaire or were interviewed. With a sample size of N=40, 85% of all organisations responded; in addition 25 people were interviewed. The questionnaire and the survey diagrams are in the Supplement to this report which is provided as a separate document. The respondents were selected based on an existing data base available at the SNV-offices in Kenya.

The report itself is structured as follows:

Section I. Analysis of the Current Situation, gives a summary of the responses to the questionnaire (and interviews) according to the 13 topics of the survey: 1. General constraints, 2. Forage species, 3. Forage quality, 4. Seasonality, 5. Preservation of forage crops, 6. Seeds, planting material and fertilizer use, 7. Mechanisation 8. Inputs & services, 9. Forage market, 10. Education and training, 11. Environmentally sustainable forage production, 12. Innovations, and 13. Policies.

Section II. Observations and Recommendations, includes suggestions for interventions, investments and policies to enhance the forage sub-sector in Kenya. The recommendations are geared to improve the current situation of forage production, preservation, quality and availability with a view to improve dairy rations, margins above feed costs, to increase milk production, to reduce (seasonal) scarcity and to maintain milk production throughout the cow's lactation period. In addition, it draws attention to forage management practices that are in line with most recent developments regarding environmentally sustainable practices, especially those related to soil and water conservation and greenhouse gas (GHG) emissions.

The Kenyan dairy and forage sub-sector

Kenya (with South Africa) is the leading milk producer in Sub-Sahara Africa. With a contribution of 4% - 8% to the Gross Domestic Production (GDP), the dairy sub-sector is the single largest sub-sector in Kenya (USAID, 2015; Bebe *et al.*, 2017). The total milk production is estimated at 5 billion litres (USAID, 2018). The sector provides income and employment to over 1.0 million households across the dairy value chain: farmers and their families, transporters, traders and vendors, employees of dairy societies, milk processors, input and service providers, retailers and distributors. Milk is consumed by most Kenyans on a daily basis, with an average annual per capita consumption of 115 litres milk equivalents. Growing population, urbanisation and middle class, drive the demand for milk and dairy products, which is expected to outpace local supply in the coming years.

Kenya covers a total land area of 56.9 million hectares of which 90% is classified as "agricultural land" based on average annual rainfall. High to medium potential agricultural land amount to about 10 million hectares, of which 60% is devoted to crop and dairy (milk) production in mixed farming systems. In this area also most forage production takes place. About 42.1 million hectares are of low potential and are used for extensive livestock production systems on mainly natural grassland, including ranching and (agro-) pastoralism. This area is also home to most of Kenya's national parks and conservancies and wildlife population. These Arid and Semi-Arid Lands (ASALs) cover over 80% of the country (GoK/FAO, 2019).

The soil groups found in central Kenya and its highlands are mainly Andosols and Nitisols. Nitisols found in the highlands of Kenya contain high concentrations of weathering minerals. Andosols, dark soils of volcanic structures known to have high potential for agricultural production, are commonly found along the East African Rift Valley in Kenya (FAO, 2015).

Dairy farming in Kenya is concentrated in the high altitude zones of North Rift, Central and Eastern regions (see Map 1). Here rainfall is high and bimodal (1,000 – 2,000 mm) and average temperatures are moderate (15-24 ℃). Dairy farming is practised here in a mixed crop-livestock system, varying from intensive (zero-grazing) to semi-intensive (semi-zero grazing/improved pastures). Extensive grazing on natural grassland is practised on Kenya's dry-lands or ASALs by (agro-) pastoralists and ranches.

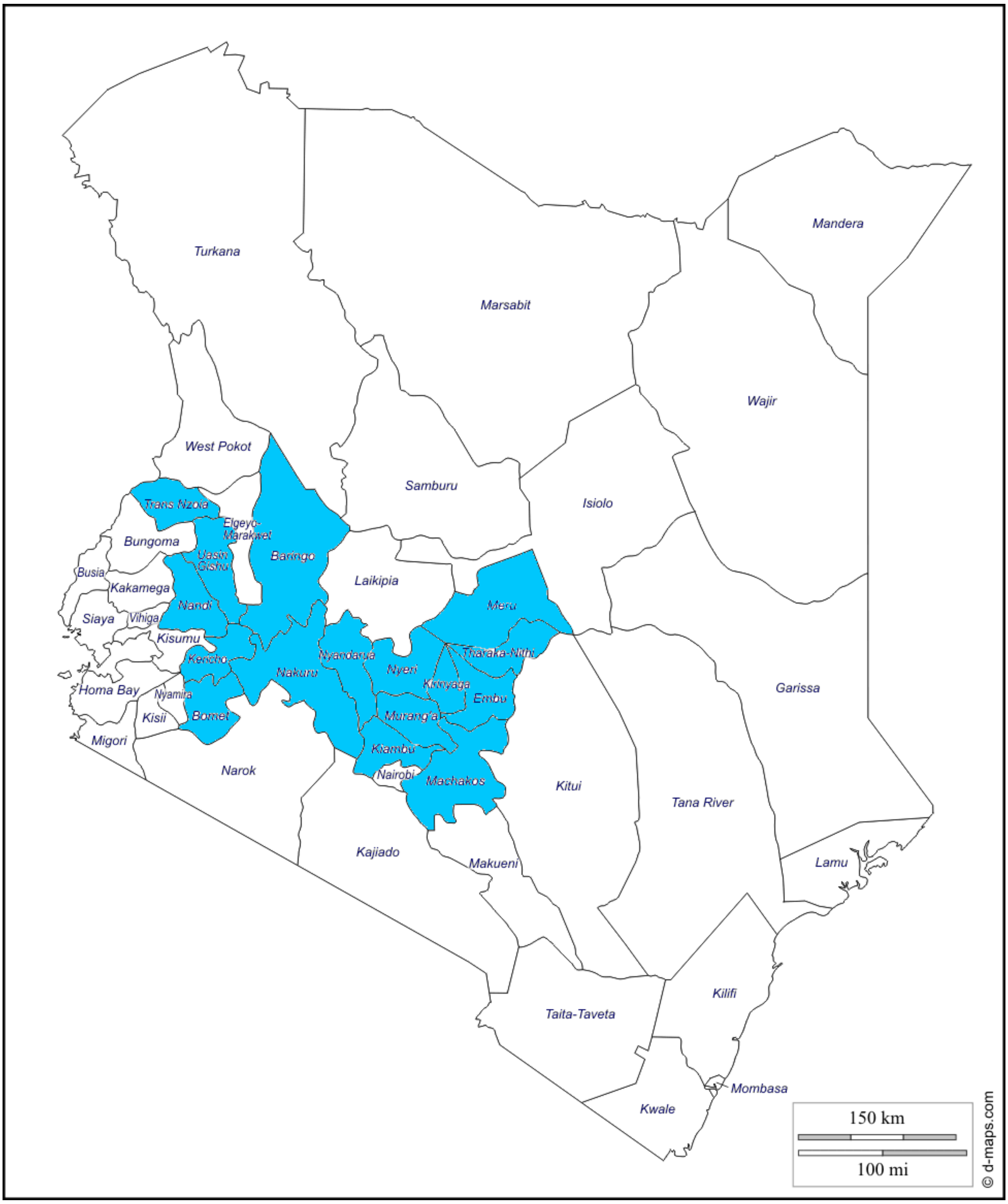
The stock size of dairy cattle industry in Kenya is estimated as 7.2 million animals (USAID-KAVES, 2017), mostly located in Central Kenya and North Rift. The estimated number of small holder dairy farmers (1-5 cows average) ranges from 0.8 to 1.8 million farmers (depending on the source and definition), 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).
There is a growing segment of medium and large scale farms with herd sizes from 20 – 100 dairy animals and above.

More than three-quarters of the households in Kenya's major milk sheds are dedicated to agriculture with 73% practicing integrated crop-livestock production system. Small holder farmers have on average 1-5 acres of land and use part of their farm for dairy under (semi-) zero grazing, with forage production or pasture in a mixed farming system with crop production. These small holder farmers often have to buy fodder to supplement the forages grown on-farm (e.g. Napier grass) and/or use food crop residues. The medium and large scale farms usually have sufficient land, but they often have forage shortages because of poor forage production planning and seasonality.

Increases in livestock production are generally the result of a larger animal population and/or improved productivity particularly in intensive farming systems. A 2012 study states that between 2012 and 2050 milk production will increase from 4 billion litres at an annual rate of 2.8% (FAO, 2017). The production increase is attributed to a larger animal population rather than to an increase in productivity, whilst an increase in productivity would be an indication of more efficient land use and efficiency in the production system. Additionally, between 2012 and 2050, improved productivity is estimated to contribute about 38.8 % increases in beef production.

The map of Kenya below (Map 1) shows the counties with a high potential for milk production. In some counties marked blue, dairy is prominent only in the higher parts e.g. Meru, Tharaka Nithi, Machakos and Baringo, whereas in certain Counties marked white there is dairy in the higher parts (e.g. Taita Taveta, Laikipia and Elgeyo Marakwet)

Map 1. Counties in Kenya with high potential for dairy (blue colour)



The productivity of dairy cows and the cost price per litre of raw milk produced, is mainly based on good feeding practices. Given that the main ingredient in the diet of all ruminants is forage, its quality is key to animal production, fertility, health and welfare, and business profitability. Cows prioritise the use of energy in the following order: (i) maintenance, (ii) milk, (iii) growth, and (iv) fertility. This means that a deficient or unbalanced diet can be the main factor of reduced fertility, body condition and production.

For the dairy sector in Kenya to achieve a progressive growth path and to increase competitiveness, focus needs be on intensified productivity, increased farm profitability and environmentally sustainable agricultural practises. Production growth to boost food security is best be achieved by sustainable intensification of dairy farming systems, not by increase in acreage (land-use change) and animals.
Forage is a major component in a cow's diet and high digestibility and nutritive value of forages, reduces feed costs and enables cows to express their genetic potential.

At present, the feeding costs of Kenyan dairy farmers represent 65-70% of the total production cost (Perfometer Solutions, 2013). In zero grazing and semi-zero grazing systems, concentrates account for 34% and 26%, respectively, of the variable costs of production, while forages account for 12% and 14% respectively (Wambugu et al., 2011). The share of forage and concentrates costs, including those of on-farm-grown forages, has increased over the years. 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.

Dairy production in the country is characterised by low productivity, mainly due to nutritional constraints. There is mismatch between the push for breeds with genetic high potential for milk production and the availability of quality forages that can meet the nutritional requirements of these breeds, and the skill levels to manage these cows and high quality forages and pastures, among the majority of farmers. This applies not only to small holders, but also to most medium and large scale farms. It is thus fundamental to provide good quality rations to dairy cattle and enough nutrients – and in a well-balanced ration - in order to optimise production.

It is evident that for the Kenyan dairy farming sector to increase production per animal, productivity per acre and to reduce feeding cost, both forage production volumes and forage quality need to improve. While at the same time management practices for these improved higher quality forages and (balanced) rations, should not increase enteric methane intensity emission per animal.

In addition to generally poor quality of fresh and preserved forages due to poor management practices and unimproved forage seeds and planting material, the quantity and quality of forage available show also seasonal fluctuation. Most areas experience an acute shortage of supply during the dry season and the available forages during this period is of very poor quality.

In ASALs most efforts made by stakeholders on forage production have focused on volume rather than quality, often because the concern was on maintenance of the animal and availability of roughages during drought, to reduce mortality rates which can be as high as 40-70% during severe droughts in recent years (Kajiado CIDP, 2018).

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 (including grasses), crop residues, agro-industrial by-products, natural pastures, shrubs and forage trees), and (ii) appropriate supplementation with concentrates rich in energy and protein of low quality natural pasture and crop residue-based diets, to achieve higher feed efficiency.

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

Field of brachiaria in Meru County

Table 1. Main problems faced by the forage sub-sector in Kenya
• Limited access to - and availability of - improved forage seed/plant material. • Mismatch between policies of Government departments for "breeding" and "feeding". • Seasonality of forage production (highly rain dependent). • Insufficient quantity and quality of forages (which includes pastures). • Use of very low digestible forages. • Low quality forage in the forage market. • Low feed efficiency/high feeding cost due to low quality forage and unbalanced rations. • Absence of reliable forage & feed testing facilities. • Inefficient forage preservation (and ineffective). • Lack of economic analysis and pricing based on nutritional value, trading standards not based on quality indicators (DM, ME, CP). • Lack of forage development plan on farm level, but also regional (e.g County) or national. • Low skills/education level on forage production and preservation. • Weak relation between agronomy of forages and animal nutrition. • Low level of mechanisation. • Limited forage crop options and possibilities for crop rotation. • Subdivision of land and urban expansion. • Climate change. • Weak link between health, food safety and feed safety.

Table 2. Recommendations to enhance the forage sub-sector in Kenya
• Fast track access to new (better) certified forage species/cultivars/varieties through facilitating and stimulating seed companies to import and register suitable seeds, hand in hand with local research. • Promote new species, including legumes, 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 management practices of commonly used varieties such as Napier grass and Boma Rhodes grass. • Promote and improve preservation practices and methods – those currently used and new ones – and facilitate access to new technology. • Recognise investors in commercial forages and agricultural forage contractors as entrepreneurs; create enabling environment for investments to expand commercial forage production and mechanisation. • 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 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 and connect forage production and animal nutrition in student education and farmer training and extension programs. • Link forage and animal production sectors and create a dynamic cooperation and "growing together approach". • 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. • 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.

Section I. Analysis of the Current Situation

Farming systems

1. *General constraints*
2. *Forage species and research*
3. *Forage quality*
4. *Seasonality*
5. *Preservation of forage crops*
6. *Seeds, planting material and fertilizer use*
7. *Mechanisation*
8. *Inputs and services*
9. *Forage market*
10. *Education and training*
11. *Environmentally sustainable forage production*
12. *Innovations*
13. *Policies*

Farming systems

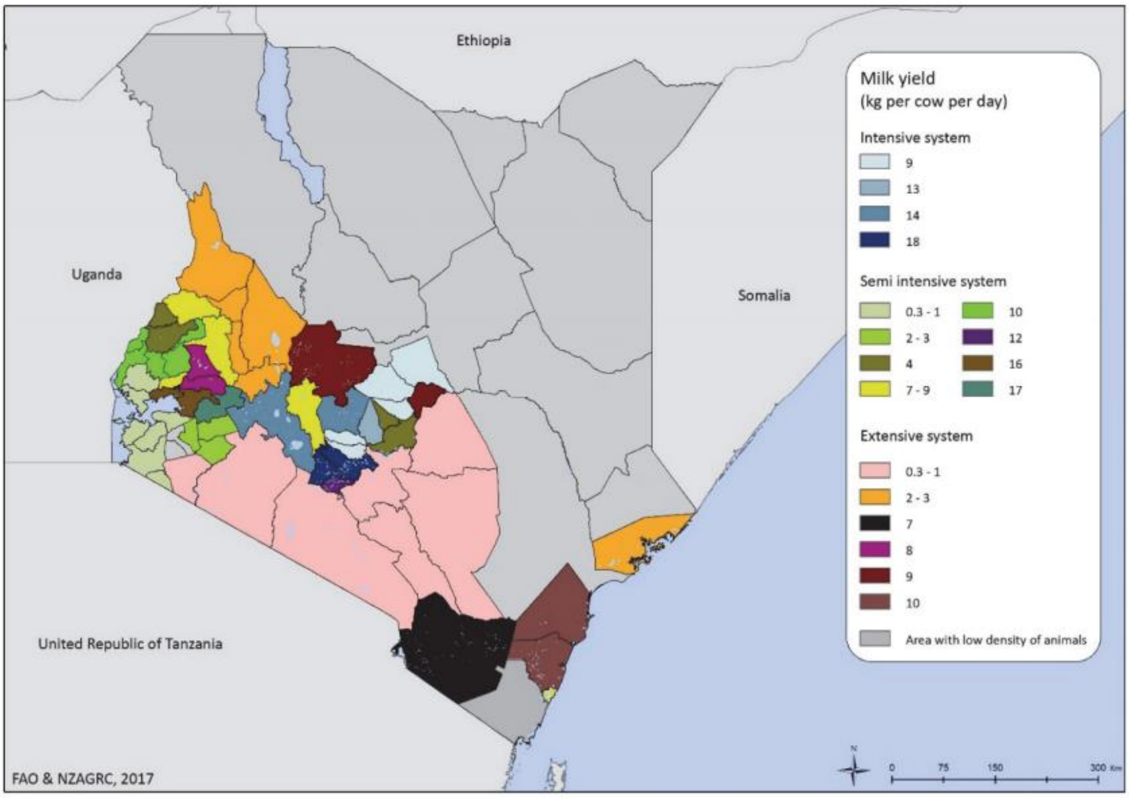
In Kenya two distinct farming systems for dairy cattle can be distinguished: (i) zero-grazing, a cut and carry feeding system also known as stall feeding, and (ii) free grazing on improved pasture or natural grassland. Also referred to as intensive and extensive farming systems, respectively. In the survey we asked the respondents to give their answers based on these two farming systems.
In between the zero-grazing and grazing farming systems, lies semi-zero-grazing or a semi-intensive farming system, which combines stall feeding and grazing on pastures (ILRI 2017, KALRO 2018).

In the zero-grazing system, cattle are confined in stalls and all their feed requirements are brought to them. In free grazing farming systems, cattle are kept on pasture where they obtain the largest proportion of their feed, often with some additional supplementation during milking or during periods of drought.

The choice of the farming system is normally motivated by a desire to optimize the limiting resource. In areas of high population density, land tends to be the limiting factor, whereas in free grazing systems labour is the limiting factor. Expenditure on purchased feeds and concentrates are higher in zero-grazing systems than in free grazing systems.

Irrespective of the farming system, most farms in Kenya produce milk below the potential production levels of their dairy animals. This is mainly due to (i) low quality forage (ii) unbalanced diets, and (iii) (seasonal) forage shortages with low ability to cope with dry periods (ILRI, 2017).

Map 2. Milk yield per cow per day in different farming systems in Kenya (FAO and NZAGRC, 2017)



1. General constraints

The response of the stakeholders who participated in the survey in relation to the general constraints in the Kenya forage sector was as follows:

> **Q2 "Select the five most important constraints that prevent an increase in forage production and preservation in Kenya".** Availability of forage seeds or plant material is the biggest hindrance to improved forage production (15.2%), together with lack of awareness, knowledge and skills (15.2%) how best to grow and make use of forages in an effective way. This is followed by low level of mechanisation (12.7%) and competition over land use by food for human consumption (10.2%) (Survey Diagrams; Figure 1.1).

> **Q3. "List at least three important reasons why in Kenya production of quality forages (high nutritive value) is still deficient".** Likewise, 27.7% of the respondents mention seeds and planting material as the root cause along with lack of knowledge and management skills (20.8%). Availability of land (5.4%) only comes after mechanisation (6.9%), financial constraints (6.9%) and entrepreneurial skills (6.2%) of the farmers (Survey Diagrams; Figure 1.2).

2. Forage species and research in forages

In Kenya, forage species that contribute to ruminants' diets are mainly tropical grasses supplemented with forage legumes and crop residues. Depending on the agro-ecological zones (see Annex 2), soil fertility and feeding systems, multiple species are found.

Q 4. "What are the 3 most common forage species used by dairy farmers in different farming system?"

Intensive farming system: zero grazing, cut-and-carry, urban and peri-urban

(Survey Diagrams; Figure 2.1)

The information gathered in the questionnaire indicates that *Pennisetum purpureum*, *Chloris gayana*, *Zea maize*, *Medicago sativa*, are the most common forage species used by dairy farmers in zero grazing (cut-and-carry) systems, rating 33.3%, 20.7%, 17.2%, and 8.0%, respectively, with the rest of species rating less than 2.4%. Napier grass (*Pennisetum purpureum*) is the most popular grass used under this system (i.e., 33.3%, based on our questionnaire), especially in medium altitude areas, where most of the dairy production is concentrated under mixed systems. According to KALRO, (KALRO, 2018) of all forages used by small holder farmers 70% is Napier grass.

The most commonly grown Napier grass varieties include: Bana grass, Clone 13, French Cameroon, Kakamega 1, 2 and 3, Ouma and South Africa. The varieties Kakamega and Ouma, developed by KALRO, are resistant to smut-and-stunt disease and are those most used in central and part of eastern Kenya, where this disease is most common (KALRO, 2018). Other grasses, frequent in this system, but to a lesser extent than Napier grass, are Rhodes grass (*Chloris gayana*) 20.7%, based on our questionnaire, and Kikuyu grass (*Pennisetum clandestinum*).

Most of the improved varieties of these grasses and the breeding of new varieties are available and have been developed outside Kenya (e.g., Callide, Katambora and Toro Rhodes Grass or Acacia and Whittet Kikuyu Grass) and are not yet available in Kenya (CIAT, 2018). Difficulties encountered when trying to introduce them in the country - amongst others with the registration process - hamper their use, which explains the fact that farmers and seed producers keep using old varieties such as Boma, Elmba and Pokot Rhodes. After more than 40 years using the same varieties mostly under poor agricultural management practices, the quality of these grasses has decreased significantly, especially because of the use of on-farm self-collected seeds and the wrong height/moment of cutting for forage.

Semi-intensive farming system: semi zero-grazing and grazing
(Survey Diagrams; Figure 2.2).
Under this system and based on the response received, Rhodes grass (*Chloris gayana*) is the most common grass (33.3%), followed by Star grass (*Cynodon dactylon*), and Kikuyu grass (Pennisetum *Clandestinum*), with 8.3% and 7.3%, respectively. Napier grass (*Pennisetum Purpureum*) is still an important species used for “cut and carry” but here it competes in importance with Brachiaria species. Many other species are used under this system, but at a much smaller scale (between 5.2% and 1%) (Survey Diagrams; Figure 2.2). Rhodes grass along with Star grass (*Cynodon dactylon*), Kikuyu grass (*Pennisetum Clandestinum*) are used for free grazing and hay making (mostly in the Rift Valley).
The most common Rhodes grass varieties used are Boma, X-Tozi, Elmba, Mbarara and Masaba. Boma Rhodes hay is the most popular hay in Kenya, but as for Napier and other grasses, the use of old varieties and deficient grass management practices result in low quality grass/hay (KALRO, 2018, National Crop Variety List, 2018).

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, and lablab (*Lablab purpureus*) in the relatively dry areas.
Maize and Sudan grass silage are also used under this feeding system but, surprisingly, the respondents do not see maize playing an important role in this farming system. Forage maize could serve in a grazing system as a rotational crop, and silage could be used to feed dairy cows during the dry season and even year round next to grazing.

Recommended forage crops by the respondents of the survey include Napier grass, maize, sorghum, giant setaria, giant panicum, Guatemala grass, Sudan grass, Columbus grass, sweet potato, and the tree legumes *Leucaena* spp., *Calliandra calothyrsus*, *Sesbania sesban*, and are also used under semi-zero grazing system in the warm and wet medium altitude areas.

Extensive farming system: free grazing on natural grassland (ranching and agro-pastoralism) (Survey Diagrams; Figure 2.3).
Natural grasslands are adapted to specific local growing conditions and can be found in most agro-ecological zones. Their species composition changes according to conditions. In Kenya, the rangelands are highly degraded due to overgrazing and lack of control over the grazing periods or stocking rates.
According to the respondents, the main grass species in this system of ranching and Kenyan natural grasslands include Kikuyu grass (*Pennisetum clandistinum*) (31.9%), Rhodes grass (*Chloris gayana*) (14.9%), Buffel grass/African foxtail grass (*Cenchrus ciliaris*) (14.9%), Masai Love grass (*Eragrostis superba*) (8.5%). Grasses used in minor proportion (each below 5%) include *Digitaria abyssinica, D.milanjiana, Guinea grass (Panicum maximum), Giant star grass (Cynodon plectostachyus),* and Nandi Setaria (*Setaria sphacelate), Enteropogon macrostachyus* and *Leptochloa obtusifolia*.
The main legume species mentioned by respondents is Lucerne (*Medicago sativa*) but other species also found in this farming system include *Glycine wightii, Clitoria ternatea, Crotolaria spp., Rhynchosia spp*., and *Stylosanthes guianensis* (Survey Diagrams; Fig.2.3).

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 is made. Management practices are not in place, and degraded grassland and forage scarcity during the dry season are common.

The rating of the most mentioned forage species used by dairy farmers in the three farming systems under consideration is shown in the following graph (Figure 1).

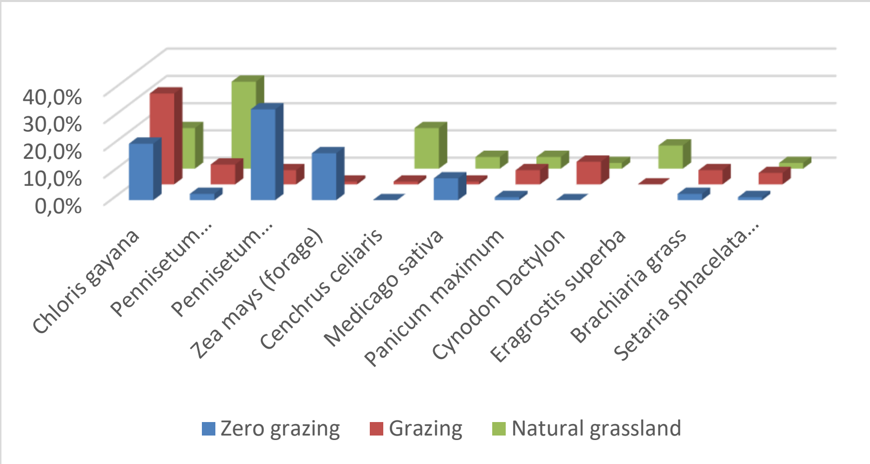


Figure 1. The most common forage species used by dairy farmers in the Kenyan farming systems

Q 5. "Which forage species, in order of importance, do you think give the best return for the dairy farmer in the different farming systems?"

Based on the responses given to the questionnaire (Survey Diagrams; Figure 2.1) Maize (*Zea mays*) is gaining in popularity (17.2%) as a forage crop in zero grazing systems. It is easier to ensile than Napier grass. The maize varieties used are the same as those used for human consumption due to the absence of forage maize varieties in the local market. In zero grazing systems, responses to the questionnaire indicate that forage maize (26.7%) gives the best returns for the farmers, followed by Rhodes grass (16.3%) and Lucerne (15.1%). It is very likely that the respondents are referring to Rhodes hay and Lucerne hay bought in the forage markets. Only 7% of the respondents mentioned Napier grass as the forage species that gives the best returns (Survey Diagrams; Figure 2.4). This could be and indication that Napier grass is not used effectively, meaning it is used when it is overgrown and not at the optimum stage when nutritive values are high. Useful grasses such as giant setaria (*Setaria splendida*), giant panicum (*Panicum maximum*), Guatemala grass (*Tripsacum laxum*), Sudan grass (*Sorghum sudanense*), Columbus grass (*Sorghum almum*), oats (*Avena sativa*), are also mentioned in the response to the questionnaire.

For *Sorghum*, Dobbs and Serena are the most popular varieties yet E6518, BJ-28, Ikinyaruka, E1291, BM-30 varieties are also available (Leldet interview 2019). Sorghum was not mentioned in our questionnaire as giving the best returns.

Lucerne (*Medicago sativa*) is the highest rated legume in the questionnaire (8.0%, Survey Diagrams; Figure 2.1). The response of Lucerne in zero grazing systems, at the farm level, is often disappointing as Lucerne is grown in AEZ and soils not suitable for the crop due the low pH. Other useful legumes, to provide protein, include Desmodium (green *Desmodium intortum* and silver leafed *Desmodium incanum*), the agro forestry tree Calliandra (*Calliandra Calothyrsus*), stylo (*Stylosanthes guianensis),* lab-lab (*Lablab purpureus*), lupins (*Lupinus albus*), velvet or mucuna beans (*Stizolobium* spp.) and vetch (*Vicia* spp.) which are also grown but in small quantities. Sweet potato vines (*Ipomea batatas*), variety Mafuta (especially for forage), is also a common crop used as a protein source.

In cold wet high-altitude areas, the predominant natural grasses, i.e., Kikuyu grass and oats grass (*Avena sativa*), are found in natural association with clovers such as Kenyan white clover (*T. semipilosum*). It is worth mentioning that temperate grasses and crops such as rye grass (*Lolium perenne*), tall fescue (*Festuca arundinaceae*), cock's foot (*Dactylis glomerate)*, oats and brassicas (kale, fodder beet and turnips) could be developed in this area with big production potential.
Overall, 8-10 commercial grasses are contributing to 20-25% of total sown pastures (KALRO 2019).

Q 6) "What are the main constraints for forage production in the dairy farming systems and for commercial forage producers?"
In the zero grazing system, land availability (50% of the respondents) is seen as a major constraint for forage production in Kenya. Awareness, availability, affordability of and access to improved forage seeds is also perceived as a constraint (15.4%) (Survey Diagrams; Fig.2.8). In grazing and natural grassland production systems, land availability (16.7% and 12%) is still seen as a major constraint but there are other limitations playing an import role. In the grazing system, lack of water (15.4%), knowledge (15.4%), improved seeds (13.8%), and good pasture management practices (10.8%) are all considered to be constraints (Survey Diagrams; Figure 2.9, Figure 2.10). In the natural grassland system, climate change (20%) is mentioned as the major limitation, followed by poor management skills (12.7%) and organizational skills (12.7%) (Survey Diagrams; Figure 2.10). For commercial forage producers, according to the results of the questionnaire, the major constraint for forage production is seen as the need for appropriate machinery for the scale of the enterprise (23.2%) followed by availability of forage seeds (16.1%), and climate change (16.1%) (Survey Diagrams; Figure 2.11).

Q 7)" What new forage species (energy/protein rich) do you think can be introduced in the dairy farming systems?"
Figure 2.15 (Survey Diagrams) provides an overview of the three farming systems (zero grazing, semi-zero grazing, free grazing on natural grassland) and the species considered as promising by the respondents. The Figure shows that (i) *Brachiaria* is seen as the most promising forage crop in all three systems; (ii) Lucerne is also seen as a crop with potential in zero grazing as well as in (semi) grazing systems despite the often discouraging results obtained in practice.

Commercial forage producers

During the last years, 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. Baled grass hay offered in the market weighs between 10 – 15 kg, whereas Lucerne bales weigh between 15-20 kg.
Baled maize- and sorghum silage have recently been introduced as commercial forages. The bales compacted and wrapped in polythene are available in various sizes between 50 -1000 kg.
In the last years, through Climate Smart *Brachiaria* Program (Gonzalez et al., 2016), different improved *Brachiaria* varieties have been tested in the country and recommended for their use. In fact, according to the questionnaire, there is a good perception for the potential use of these improved species in the three dairy farming systems. These include *Brachiaria* Basilisk, MG4, Piata, Xiaraes, and Mulato II. Also, since 2015, Tropical Seeds Company markets, through its local agent Advantage Crops Ltd, *Brachiaria* Hybrids, that include Mulato II, Cayman and Cobra. Also, *Panicum maximum* varieties such as Masai, Mombasa and Tanzania have been promoted with very good results, yet in our questionnaire the perception for these Panicum varieties' is low (0.7%).

Forage related research

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

KALRO (Kenya Agricultural and Livestock Research Organization), which is currently focused on (i) improving resistance of Napier grass to "Stunting Disease", a disease caused by phytoplasma that especially affects Western Kenya, and (ii) Head smuts disease", a fungal (*Ustilago kameruniensis*) disease that affects 60% of all SHF in Kenya causing losses of 40 - 90% (KALRO 2019), (iii) "Snow Mould Fungal Disease a fungal disease caused by *Beniowsia spheroidea,* which is recognized by white spots on leaves and stems of most Napier grass varieties in Kenya and for which clone 13 is resistant, (iv) *Helminthosporium spp* or leaf spot, which is particularly a problem in Western Kenya. Also, KALRO is running trials with sweet lupines, which are intended to be used as protein sources.

KEFRI (Kenya Forest Research Institute) national research centre promoting agroforestry trees.

CIAT (International Centre of Tropical Agriculture), promotes grasses such as *Brachiaria* and *Panicum maximum* as potential alternatives to Napier grass. These two species, originally from Africa, have been improved in South America and new hybrid varieties and cultivars are now being introduced in Kenya. The results obtained so far with these two species are very promising, especially on all what relates to quality, but future evolution will especially depend on management and farm practices.

ICIPE (International Centre for Insect Physiology and Ecology) developed the push-pull technology over the past 20 years. This simple cropping strategy simultaneously addresses five key constraints of cereal–livestock mixed production systems in Africa – insect pests (stem borers), the parasitic weed *Striga* (and other weeds), poor soil fertility, soil moisture management, while also addressing the need for high quality animal feed. Silverleaf *Desmodium* (*Desmodium uncinatum*) plays an important part in this strategy as it (i) stimulates suicidal germination of *Striga* and inhibits its growth, (ii) is a high quality animal forage, (iii) is an efficient nitrogen fixing legume which therefore improves soil fertility, (iv) is a perennial and conserves soil moisture and continually improves soil health. Research focusses on introduction of the technology to drier areas and use of improved varieties (Napier, *Desmodium*) and different species (*Brachiaria*).

ICARDA (International Centre for Agricultural Research in Dry Areas) is promoting rangeland grasses like Cenchrus *ssp*. for the dry areas and is located at the ILRI offices in Nairobi.

ICRAF (International Council for Research in Agro Forestry) also known as World Agro Forestry Centre, encourages the use of forage trees that are highly nutritious for livestock, a variety of up to 9 leguminous forage trees, including *Calliandra calothyrsus*, *Sesbania sesban, Leucaena leucocephala and Morus alba*.

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

The main weaknesses of forage research in Kenya are (i) the lack of collaboration and coordination within and between national and international research centres, and (ii) the lack of a strong connection between forage- and animal nutrition research, (iii) a 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 varieties) to the farmer: route to market, distribution and training, and (iv) the tendency of policy makers and/or regulators to belief that with much local research ongoing, there is no need to actively encourage private seed companies to enter the forage market, with existing species and varieties with a proven record in tropical climate and similar soil conditions.

In this light it is also difficult to understand why Kenyan government and farmers are searching for genetically the best possible exotic bulls for milk production, and not for genetically the best possible globally available forages that are adaptable to tropical climate, resistant against diseases and pests, and tolerant to long periods of drought.

Table 3. Summary of forage species/cultivars/varieties access gaps
Complicated/slow system to register/authorise new and improved species/cultivars/varieties
Uncertain market (unknown demand/re-planting not frequent enough), which is perceived as small
Not very attractive market, especially for perennials and plant reproduction species
Lack of knowledge of good agricultural practices by the users of the seeds (farmers)
Lack of awareness of the impact of forage quality on animal production and reduction of feed costs
High seed cost for improved varieties
Lack of local research on improved local species/test and comparisons with imported improved species/cultivars/varieties
Lack of knowledge among farm advisors/extensionists on production, conservation and efficient utilization of quality forages

Brachiaria

Rhodes grass

Cows grazing on star grass

Lucerne

Kikuyu grass clover mixture

3. Forage quality

Low forage quality is one of the biggest constraints to higher milk production in Kenyan dairy farms. High NDF 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 (high NDF content) also is the reason for reduced animal feed intake, low production and high feed cost. These forage characteristics added to the animal genetics that are pushed into the market (high performance Holstein-Friesian bulls) give most farmers a big challenge to unlock the genetic potential of these cows and make them productive and profitable. Besides, these tropical grasses have very thick stems that contain high levels of intracellular water. This fills up the rumen with a lot of water and fibre, reducing the animal's dry matter intake and production of milk and meat. It also makes it difficult to wilt the grass unless the stems are chopped into smaller pieces to facilitate wilting (the evaporation of water).

Q 32)" What improvements and changes need to be made by commercial forage producers to improve forage production in terms of yield and quality?"

Q 32 and 33 which are presented at the end of the questionnaire, are presented here under the heading forage quality. According to the survey, the most effective improvements to increase forage yield are related with better management practices (35%), soil and fertilization (23%) and the use of improved forage varieties (16%) (Survey Diagrams; Figure 9.5). Forage quality is seen by the respondents as an important point to be addressed. This can be achieved through introduction of new forage species and varieties, but if not well managed it will not be effective. Equally better management of current forages in the market will be effective as well. The respondents to the questionnaire indicated that to improve forage quality, commercial forage producers need to implement better forage crop management practices (47%), followed by the use of improved/new varieties (27%), quality standards (15%), education and skills training (9%), and machinery (2%). When a new species is introduced, this may require an extra investment if different machinery is required for planting and/or harvesting of particular forage crop (Survey Diagrams; Figure 9.6).

In order to target quality, nutrient parameters need to be measured, fast, reliable and affordable. This requires NIR equipment with regression lines for tropical forages, which are currently not available in Kenya. The absence in Kenya of accredited laboratories with the correct NIR regression lines to reliably analyse nutrient content of feeds and forages, makes that reliable data are difficult to obtain.
The lack of feed analyses also makes it difficult to balance the animal ration to improve feed efficiency and margins above feed cost. For tropical grasses, predictions of animal responses are highly dependent on accurate values for NDF, lignin (ADL), CP and soluble protein, and rates of digestion for carbohydrates and protein. Most of the grasses used in Kenya show low crude protein, which may limit milk production since microbial growth is limited by the ruminal protein availability rather than by carbohydrate availability (Juarez Lagunes et al., 1999).

Q 33)" What affects production levels and cost price of raw milk mostly: the quality of forages or of compounded feeds (please explain)?"

Fifty six percent of the respondents indicated that forages in the ration of dairy cows affect production level and cost of production the most. The influence on production level and costs of production of concentrates was considerable smaller (25%) (Survey Diagrams; Figure 9.7).

The concept of quality forage and the relation to nutrition (intake), production, farm economics (optimum production, margin above feed costs) and profitability, needs to be strongly developed within the farmer community and other stakeholders. This needs to be explained in such a way that farmers start to realise the importance of forage quality for the profitability of their enterprise. This will also be the way to change the current forage market that is based on volume and largely benefits commercial forage producers at the expense of farmers. In addition to knowledge of the nutritive value to be able to understand the market value (vis-a-vis other available feeds in the market), farmers need to become more knowledgeable of the cost of on-farm forage production (Figure 2).

Figure 2. Quality concept dynamic change

A lactating cow needs ca. 11% of its body weight in energy for maintenance and 5.2 MjME (Mega joule of Metabolic Energy) per litre of milk produced. For example a 500-kg cow producing 10 litres needs 55 MjME for maintenance + 52 MjME for milk produced, which totals 107 MjME/day. In addition, it needs 15% CP (Crude Protein), minerals and vitamins (Morgan J., 2005). This cow would require 12 kg DM of well managed Napier grass (50- 60 kg fresh Napier grass, fertilized and with a 6 weeks cutting interval). Currently, the main forages used in Kenya are (i) Napier grass – which under the prevailing management practices can offer circa 6 MjME/kg DM (Dry Matter) and 6% CP –, and (ii) hay, with an average ME of 5-6 MJ/kg DM and 4% CP. These type of quality forages will not be able to cover the nutrient requirements of the dairy cow, as these fibrous and low-density forages are limiting the dry mater intake of dairy cows before they cover their nutrients requirement levels.

The effect of better-quality forage on the margin above feed cost and methane intensity, has been calculated using Rumen8 total diet ration balancing software and is shown in Annex 3 (example Napier grass). The potential for milk production of Napier grass increases with better quality Napier to 7.0 ltr/day and the margin above feed cost can increase from 0 to 161 KES/cow/day, while methane intensity reduces from 261.9 – 47.3 gr/ltr when fed better quality Napier grass (adapted from Perdok H., 2018).

In most farms in Kenya good practices are however abundantly lacking, due the lack of knowledge, skills and a focus on quantity rather than quality. Most farmers 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 better practices, or to pay for quality products. This leads to a highly underdeveloped forage supply chain, which is merely based on volumes without any kind of standards or quality control.

Dairy farmers in Kenya have predominantly Holstein Friesian cows. This large framed breed has a high yield potential, but also a high nutrient requirement. To be able to satisfy this requirement and obtain high yields in a profitable way, the availability of high-quality forage is very important, meaning high digestibility (NDF 35-40%), and high energy values (>10.5 MjME), and well-preserved in the case of silage, haylage or hay. Under the current conditions, forages in Kenya that fall into this category are maize silage, sorghum silage, and lucerne hay, and well-managed fresh grass. Future actions should consider improved forage quality e.g. through better seed varieties, use of conservation agriculture, improved crop nutrition, crop protection and cow breeds (including crosses) with a higher feed conversion that are able to utilize rations with a higher NDF content more efficiently.

Mycotoxins

Another point to consider are the mycotoxin levels in feeds and forages, causing food safety issues through the milk. Aflatoxins, the most widely known mycotoxin, occur in many animal feed concentrates including cereal grains, soybean products, oil cakes (from groundnuts, cottonseed, sunflower, palm, and copra), and fishmeal. Brewers grains (a by-product from the production of cereal-based alcoholic beverages) can have high levels too. Pasture grasses, hay, straw, and silage are more prone to contamination with other types of moulds such as Fusarium and the mycotoxins they produce (e.g. Vomitoxin and Zearalenone). (Grace, 2013). Over a 4-month period, samples taken from a corn silage trench were found to have levels of aflatoxin B1 ranging from 25 to 40 µg/kg. This aflatoxin formation seems to be related to the process of ensiling, where under unfavourable circumstances high temperature can develop, followed by mould growth and subsequent toxin formation (EFSA, 2004).
In general, livestock in intensive systems are at higher risk of dietary exposure than animals in extensive systems. Worldwide, a high and increasing proportion of dairy cattle are kept in intensive systems; aflatoxins are thus likely to be an increasing problem.

The occurrence of mycotoxins is influenced by weather and poor storage, given that high moisture and temperature provide the ideal environment for moulds that produce mycotoxins. But also by drought causing stress during germination and growth of the plant (CAC, 1997). Mycotoxins can also be soil born, where moulds naturally are present in the soil and survive on crop residues particularly seed heads of aflatoxin susceptible crops. Good agronomic practices to avoid or limit occurrence of mycotoxins include soil testing, applying recommended nutrition levels for crops, protection against pests and weeds, avoiding over-population and encouraging crop rotation to avoid crops stress especially during germination and growth. Further, mechanisation, improved forage preservation systems and better storage, are required to reduce mycotoxin content in feeds and forages (CAC 1997).
High levels of mycotoxins/aflatoxins result in losses in milk production, animal health and fertility issues, and even potential losses of cattle.
Additional losses occur in the livestock sector if grain (and other animal feed ingredients) do not meet standards for animal feed. Moreover, the nutritive value of grains and cereals is reduced by contamination with the mould that produces aflatoxins. Economic loss also occurs if livestock products do not comply with the standards for aflatoxins in human foods (Grace, 2013).

Table 4. Summary of forage quality gaps
Absence of accredited laboratory for nutritional analysis based on NIR regression lines for tropical forages
Lack of forage quality standards or pricing system
Lack of familiarity with quality concepts by stakeholders
Lack of knowledge as regards forage quality/animal productivity relationship
Variable and unpredictable forage quality due to gaps in forage management
Products lack a guaranteed minimum nutritional level and customers usually take what is available
Exotic animal breeds need high quality forage to express genetic potential (and avoid negative energy balance)
Farmers are reluctant to pay for quality
Lack of adequate farm machinery and skills for operation and maintenance
Limited harvesting and preservation capacity which affects production per unit, nutritional content and market value
Poor use of genetically improved seed/plant material (cost high-availability low)
Poor monitoring and management of soil fertility (soil sampling/management/rotation)

Harvesting hay at seeding stage

Harvesting oats for silage at an early cutting stage

4. Seasonality

Forage production in Kenya is largely rain fed and seasonal and characterized by shortages in the dry seasons. Few farmers have good forage planning or stock of hay or silage to overcome the dry season. This leads to large fluctuations in the forage market and milk supply. 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 rains.

The ASALs receive rainfall of circa 4-500 mm per annum whilst potential evapotranspiration ranges from 1,900-2,300 mm per annum and exceeds annual precipitation, thus resulting in water deficit (Map 3). 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.

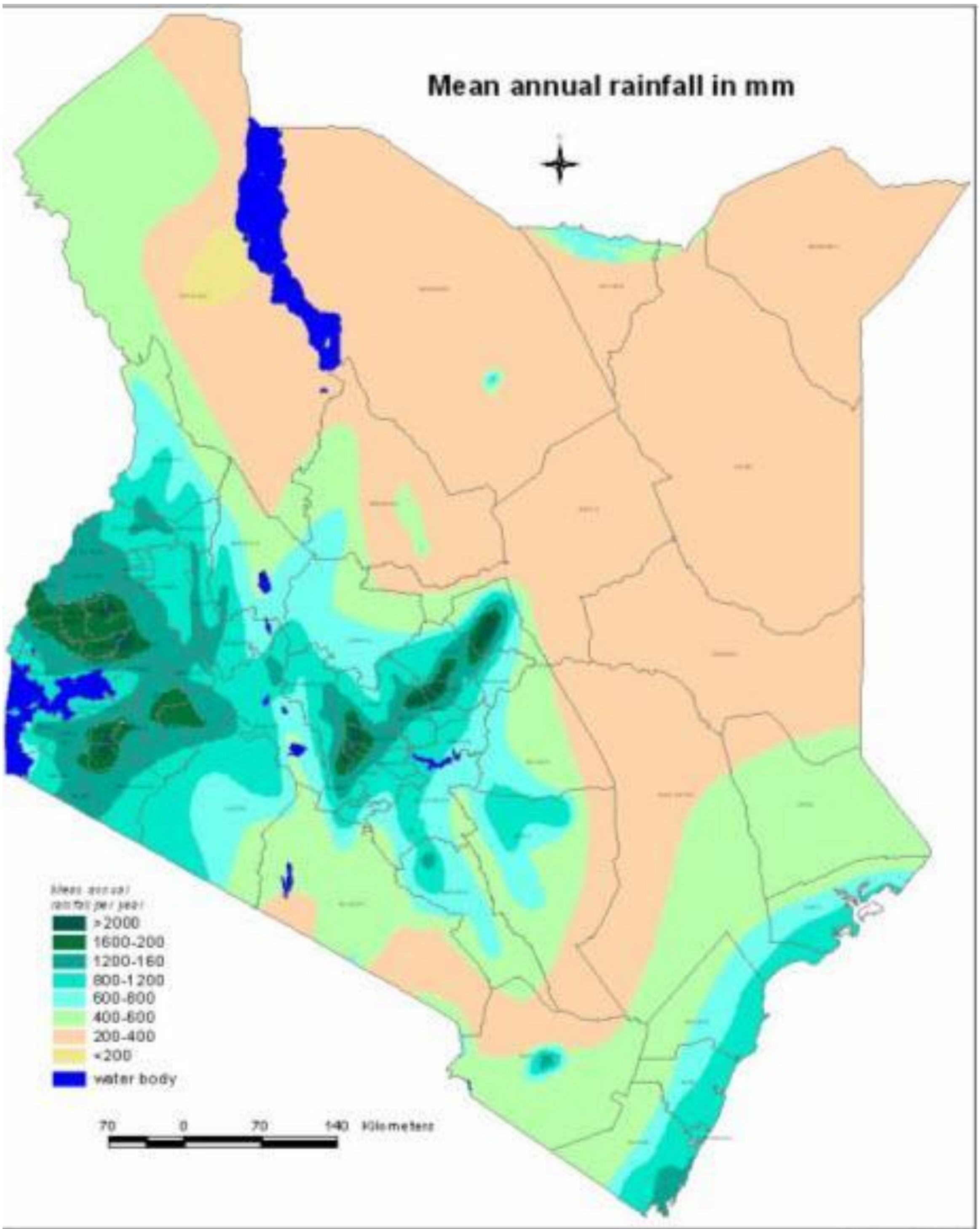
The mid-altitude eastern region has mean annual rainfall of ca. 700 mm but in the hill masses it increases to ca. 1,050 mm. Annual evapotranspiration exceeds the amount of rainfall and ranges from 1,200-1,800 mm (KARI, 2001). The minimum mean annual temperatures vary from 14 to 22 ℃ while maximum mean 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 ℃.

Low and increasingly erratic rainfall with frequently prolonged dry spells are the cause of shortages of forages in the semi-arid areas. Forage availability closely follows the rainfall pattern, with in mid-altitude zones and especially the highlands adequate forage supply during the wet season(s), but with shortages in between seasons. Unless the farmer has silages or hay to cover the dry period until the next rains start. In most areas, forage shortage occurs from January to May while in mid-altitude Eastern region this occurs from July to October. The proportion of farmers that experience shortage of forages is relatively high (79 - 99%) (Njarui et al., 2016b), which has a direct impact on livestock productivity, both for milk and meat.

In many areas, annual total precipitation exceeds plant requirements, but the seasonality of the rainfall causes water shortage at specific time periods with symptoms of heat stress in forage crops. Water use/harvesting can be planned and managed in a more effective way. Improving water-use efficiency requires a combination of practices such as the selection of adequate plant species, water harvesting and storage, and/or irrigation.



Map 3. County boundaries and mean annual rainfall in Kenya

Climate stressors and climate risks due to climate change

Higher temperatures are likely to expand production of commercial grain maize and beans into higher elevations but farming in lower elevations is expected to see yield losses of up to 20 percent due to heat stress and shifting rainfall patterns. With some areas (like central Kenya) becoming unsuitable for production (FEWSNET 2010, USAID 2018). Maize can be damaged by temperatures over 35 ℃, which are increasingly common in lowland regions. This will also eventually affect forage crops and it is therefore important that different forage species and varieties, are readily available for farmers and commercial forage producers to anticipate on these climate changes.

Shifting production to higher elevations as temperature rises and evaporation rate increases, puts current production areas at risk from heat extremes and increasing pests and diseases. It is expected that inter-seasonal rainfall variability, frequency and intensity of rainfall increases. In arid and semi-arid regions, pastoralism is the dominant production system. High temperatures are expected to increase heat stress and pest and disease incidence in livestock and (forage) crops, leading to reduced reproduction, growth rates and milk production, crop damage and degraded crop and pasture land.
The Government and other stakeholders are implementing many interventions that have direct and/or indirect relevance to climate change adaptation and mitigation. The interventions also cover the agricultural sector. (GoK, 2017) Examples include:

- Agriculture: Promoting irrigated agriculture, promoting conservation agriculture, value addition to agricultural products, developing weather-indexed crop insurance schemes, support for community based adaptation including provision of climate information to farmers, enhanced financial and technical support to drought resistant crops.
- Livestock and pastoralism: breeding animals tolerant to local climatic conditions, weather-indexed livestock insurance, establishment of fodder banks, documenting indigenous knowledge, provision of water for livestock and humans, early warning systems for droughts and floods, and vaccination campaigns.
- Water resources: enforcement and/or enactment of laws for efficient water resource management, increasing capture and retention of rainwater, water quality monitoring, de-silting rivers and dams, protecting and conserving water catchment areas, investing in decentralized municipal water recycling facilities, campaigns on water harvesting, developing hydrometric network to monitor river flows and flood warning.

Q 12) "Which forage crops and preservation technologies are best suited to reduce the problem of seasonality?"
In zero grazing systems, maize silage is the preferred option (40.7%), followed by silage from other forage species (37%). In extensive grazing systems, hay (31.8%) and improved grass species (29.7%) and silage (22.7%) are considered the best suited preservation options to reduce the problem of seasonality. In free range systems, grass management (33.3%) is considered as the most important tool to cope with forage shortage during the dry season, followed by improved species and hay (24.2% each) (Survey Diagrams; Fig. 5.11, 5.12, 5.13).

Q 13)" Where do you think commercial forage production will be developed in the future?"
The respondents indicated that forage production is likely to develop in the midlands (18.75%) and highlands (15.25%). The semi-arid lands were seen as less favourable for forage crops (11.1%). In the urban and peri urban areas, commercial forage production is not expected to develop in the future due to the land pressure in these areas (Survey Diagrams; Figure 5.14).

Q 14) "Where do you think commercial milk production will be developed in the future?"
The respondents indicated that in all areas, from highlands to lowlands, and in the urban and peri-urban areas, commercial milk production will continue to grow or develop in the future (Survey Diagrams; Figure 5.15).

Table 5. Summary of seasonality gaps
No forage production or storage plan
Lack of drought tolerant forage species, seeds, and planting material
Poor preservation practices
Low forage storage capacity
Poor water management (storage, irrigation)
Poor herd management and planning (stocking rate, calving/mating season)
Absence of regional or national forage bank or strategic reserve to cope with prolonged droughts

Maize crop affected by drought

Naivasha star grass affected by drought

Storage of hay bales

Maize silage

Lucerne hay

Overgrown Napier grass

5. Preservation of forage crops

Q8) "What are the three most common forage preservation methods used in the dairy farming systems and by commercial forage producers?" The response to the question shows that, overall, hay making is the most common way of forage preservation while ensiling is becoming increasingly important (Survey Diagrams, Figure 5.1, 5.2, 5.3, 5.4). The standing hay is used in grazing systems as an intervention to deal with periods of scarcity.

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.

Hay

In Kenya, the most common methods of hay making used by farmers are loose hay (45%), box baling (45%) and machine bailing (10%) (Lukuyu et al., 2013). Commercial producers use baling machines (old machinery and not very well maintained). The predominant grass used for hay is Boma Rhodes, followed by natural grass, Kikuyu grass, oats, and Sudan grass. Pastures used for hay making are often not fertilised or with very little fertiliser and cut at flowering stage, which is too mature for good quality forage. For example the nutritive value of Rhodes Hay decreases with aging typical values of Rhodes hay at 90% flowering CP 50 g/kg DM, ME 6.4 Mj/kg DM, NDF 750 gr/kg DM.

Gross margins show that small holder farmers incur huge losses when hay making. This is attributed to the high cost of planting material and labour cost and explains the poor grassland management practices and the low quality of the hay. At small scale hay making is thus not profitable. Hay making could be encouraged at group or cooperative level on larger tracts of land to reach economies of scale. This could justify investment in machinery and equipment resulting in higher capacity/ha during harvesting and preservation.

It should be noted that weather conditions in Kenya are not ideal for hay making. The grass grows during the rainy season, which complicates the wilting process and makes it difficult to bale at the right moisture content to avoid heat in the bale. High moisture content in the grass when baled causes the growth of mould and increases the risk of mycotoxins.

Straw and stover

Several cereals are commonly grown in the country: wheat, barley and rice, whose straws can be used as forage. If weather conditions are favourable, the straw can be stored immediately after harvest. Yet, in order to minimise the danger of heating in the bale and moulding, straw is often left drying in the field before harvest. 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 near the farm compound, grinded and mixed in the cow's ration. Nutritive value and digestibility of straw and stover is very low. For example wheat straw CP 38 g/kg DM, ME 6.35 Mj/kg DM, NDF 780 gr/kg DM.

Silage

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). Most silage is used on farm but in recent years baled silage was introduced to the market. The cost of growing maize or other forage crops to be ensiled, constitutes the major part of the total cost of silage, followed by labour costs and transport. The latter can sharply increase if the maize is grown far from the cows (for example on leased land). The lack of high capacity machinery for chopping, kernel crushing, speed of work, compaction and coverage, combined with the lack of know how about the ensiling process, makes that the preservation process is usually not optimal and the silage of low quality due to harvesting and storage losses. Under the SNV/KMDP project, service providers and machine contractors with better equipment than those commonly used, have emerged in the last couple of years. Both for small scale farms (e.g. Service Provider Enterprise Network SPEN) and medium and large scale farmers (e.g. Maize Train concept) and have been instrumental to improve the silage making process. SPEN groups offer silage services to small holders with machinery (forage shredders) scaled to small holder needs.

Baled silages

Contractors and commercial forage producers have emerged in Eldoret-Kitale (maize silage) and near Athi River (sorghum Sudan grass) with machinery that produces baled silage, in round vacuum packed bales varying between 50-100 kgs, 350-400 kgs and 1,000 kgs depending on the machinery used. Baled grass silage or haylage could be an excellent alternative to hay, especially under difficult weather conditions (rainy), as this could help improve quality and reduce losses, as well as reduce the risk of moulding and mycotoxin contamination.

> Q 9) "List at least three most common causes for post-harvest losses in the forage production and preservation chain?"
> According to the respondents, poor agricultural practices during crop production causes the major post-harvest losses (34%), whereas poor storage of hay (dry place) (24.4%) and fermentation (11%) (anaerobic conditions for silage) are the other important causes of losses (Survey Diagrams; Fig. 5.5).

> Q 10) "What farming practices can dairy farmers adopt to prevent or reduce harvest and post harvesting losses?"
> The respondents rated applying good practices during crop management, harvest and storage (each 25%) as the key factors to reduce post-harvest losses (Survey Diagrams; Figure 5.6).

> Q 11) "Which other conservation methods or technologies do you think could be introduced in the current dairy farming systems?"
> Silage making is particularly seen as a potential method to improve intensive farming systems (61.5%). For more extensive grazing systems, grass management is an important option (66.7% for natural grassland grazing and 27.3% for improved pasture grazing), except for cut-and-carry systems. For commercial forage producers, grass management (33.3%), use of improved species (24.2%), and hay (24.2%) are the preferred options (Survey Diagrams; Fig. 5.7-5.10).

Table 6. Summary of preservation methods gaps
Lack of scaled machinery, inappropriate machinery, poor maintenance
Lack of skills to operate and maintain modern machinery
Limited preservation methods (hay and silage)
Knowledge on preservation technology is lacking
Difficult to introduce new technology
Difficult to import machinery
Limited access to preservation technology for small holders

Wilting of grass

Hay making and baling

Silage making at a smallholder farm by Service Providers Enterprise Network

Ineffective way of drying oats in a barn

Maize chopped at 1 cm pieces and with a kernel crusher

Sorghum haylage

6. Seed, planting material and fertilizer use

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. Unlike the maize seed system for food, which is highly developed and controlled in Kenya, the formal forage seed system with professional and commercial seed companies actively involved is underdeveloped.

> Q 16) "In your opinion, what is the availability of the listed seeds/plant material in the market? "
> The respondents of the questionnaire have a general low opinion about the availability of forage seeds varieties. The planting material/seeds most easily accessible are Napier grass (planting material), Rhodes grass (seeds) and maize varieties. These are wrongly perceived as "forage" maize, as all maize varieties in Kenya are specifically bred for grain production (Survey Diagrams; Figure 6.1). Availability of forage crops seeds is low (56%), with only 12% of the respondents mentioning forage crop seeds/planting material being easily available and accessible.

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 completion of these two steps takes around 2-3 years (two growing seasons plus time associated with paperwork) at a cost of approximately US$ 3,000/variety (Sikinyi, 2010). This, together with an unpredictable market, unknown demand, and lack of knowledge and awareness of farmers about the management and benefits of different forage species and varieties, are the main reasons for reluctance of international seed companies to introduce new forage species and varieties in Kenya. Until last year, KEPHIS-NPT was based on yield: for a new variety to be approved its yield performance needs to be 10% greater than the existing ones. Now the new NPT for forage includes "specific characteristics" of the species/variety such as nutrient content, digestibility of the whole plant, drought resistance, disease resistance, etc., in addition to yield.

> Q 17)" What are reasons for low availability of seeds in the market (incl. new varieties or species not yet registered in Kenya)?"
> The reasons the respondents of the questionnaire gave for the low availability of seeds are (i) unfavourable government policies/regulations (34%), (ii) knowledge-gap on the relation between the agronomy of forage crops and animal requirements (26%), and (iii) low availability and access to the seeds and plant material due to lack of distribution network and marketing efforts (Survey Diagrams; Figure 6.2).

The informal seed system is largely driven by individual farmers, farmer groups, Kenya Agricultural and Livestock Research Organization (KALRO) and Agricultural Training Centres (ATC). Forages propagated vegetative include Napier grass, sweet potato vines, and Kikuyu grass. Seed-producing ones include vetch, lupine, *Desmodium*, forage trees, and Lablab.

> Q 18)" How would you increase the availability of seed/plant material?"
> Based on the survey, the most needed action is (i) changing the government policies and regulations on forage seeds and planting material, e.g. simplify the importation, testing and registration processes (39%), (ii) the increase in the availability of seed and plant material, and (iii) encouragement of international seed producers to enter the Kenyan market with forage seeds (Survey Diagrams 2; Figure 6.3).

Q 19) "How would you engage dairy farmers to use improved forage seeds/plant material for planting?"
To encourage farmers to use the improved forage seeds in the future, respondents agreed that training of farmers in all farming systems (> 72%) will be necessary to reap the benefits of improved seeds/plant material (97%) (Survey Diagrams; Figure 6.4).

Seed suppliers

To our knowledge there are about 20 companies in Kenya that supply certified forage seeds, including commercial maize seed that is used as a fresh maize or silage maize to feed to cows (see Annex 5). 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. In addition, only seven companies have forage seed multiplication sites. 16 mainly public organisations (including KALRO and ADC) from many more of their farms dispersed over Kenya reproduce (non-certified) seeds informally. The Kenya Seed Company (and its subsidiary Simlaw Seeds Company) is the main source of certified forage seeds supply and distribution. Annex 6 present a list of forage species found in Kenya.

KALRO is a main governmental organization working on forage seeds and plant propagation. Napier grass remains the main focus of KALRO at this moment due to vast acreage of Napier grass in Kenya, but KALRO also developed several Brachiaria cultivars (like Basilisk, Piata, MG4, etc.) which are now available. KALRO Lanet and Ol Joro Orok are also working on the supply of protein-based forage seeds such as pink clover, lucerne, lupins, vetch, *Calliandra*, tree lucerne and *Sesbania*. KALRO Embu produces and sells green leaf *Desmodium*, sweet potatoes, *Calliandra* and *Leucaena*. During this past year, KALRO has created a "Seed Enterprise" aimed at directly commercialising seed and plant materials.

Seed production

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.

Seed quality control

Seed companies collaborate 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 export 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 certified). The current problems as regards availability and access to reliable and quality forage seed and planting material is likely to be exacerbated by the increased forage demand resulting from increased demand and consumption of milk (-products) and beef.

Soil fertilisation

Most of the agricultural soils in Kenya have inherently low soil fertility, low soil moisture retention and high erodibility, and have been intensively farmed by small holders. The decline in crop and pasture yields, soil physical and chemical properties, vegetation cover and biological diversity has been affected significantly over time. The most critical limiting nutrients are N and P; K, S and some micronutrient deficiencies (e.g. Zinc and Boron) are often diagnosed.

Good soil management practices such as use of manure, compost, use of a crop specifically to incorporate it in the soil (green manure), mulching crop residues, rotation with grain legumes, grass-legume intercropping and cereal-legume multicropping systems, conservation agriculture and agroforestry are starting to be introduced, but so far, this is at a small scale. In Kenya, most synthetic fertilisers are applied to maize, rice and horticultural crops. Yet (also) for these commercial crops, the fertilizer (organic and synthetic) application (per ha) is often below what is applied and recommended. The matrix below shows - for comparison - fertilizer use in Kenya and in the Netherlands. Compared to commercial maize, fertiliser use on forages is still very low.

Factors that have an influence on the fertiliser use include the price, the household income, and the education level of the household head. The main fertiliser types used for maize production are calcium ammonium nitrate, urea, compound fertilisers such as diammonium phosphate (DAP) and ammonium sulphate and NPK blends such as 23:23:0 and 17:17:17.

Fertilizer use in Kenya versus Netherlands for nitrogen, phosphorus and potassium (FAO 2015)

	Kenya	Kenya	Netherlands	Netherlands	
Fertilizer use	**2000**	**2014**	**2000**	**2014**	
Commercial maize million ha	1.57	2.12			
Fertilizer N (kg nutrients / ha)	13.2	20.3	320.7	274.5	
Fertilizer P (kg nutrients / ha)	17.6	18.3	57.9	14.8	
Fertilizer K (kg nutrients / ha)	2.3	5.7	59.7	20.8	

Table 7. Summary of seed, planting material and fertilisation gaps
Limited offer/choice
High prices
Knowledge-gap on how to grow and use
Poor awareness of effect on animal productivity (relation forage quality and production potential of dairy cow).
Need for soil testing
Poor manure utilisation practices
Poor crop rotation
Poor soil conservation

7. Mechanisation

The mechanisation level of operations in the forage sub-sector is generally low, especially with small holders. There is presence in larger farms and amongst commercial forage producers of hay balers, 1-2 row and even of late 4-6 row maize harvesters. Recently also machinery that can make baled silages have been imported by investors in commercial forage production. 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 (Brazagro, Massey Ferguson, New Holland, John Deere, FMD EA importing Noguiera from Brazil, Rift Valley Machineries and Holman Bros EA in Nakuru, Kentrac, Agri Assist/Dejirene Ltd and R.M. Patel & Partners in Eldoret, and others). Some of these also sell imported or locally manufactured low-cost forage shredders or pulverisers for small holder farmers to chop maize for maize silage.

Q 15) "Which measures need to be taken - at various levels e.g. farm, policy, seed supply, mechanisation - to improve the quality or forages?"

The most important measure mentioned to improve the quality of forages was the quality and supply of forage seeds (access, availability) (30.6%). Enhancement of mechanisation from seed to feed (24%) was also raised as a measure to improve forage quality (Survey Diagrams; Figure 5.16).

Q 21, Q 22)" What is the mechanisation level for forage production and preservation for the small, medium and large scale dairy farmers?"

Respondents indicated that the mechanisation level with the small holder farmers is low irrespective of the crop grown (Survey Diagrams; Figure 7.1). The mechanisation level on medium and large-scale farms is considered between intermediate and high, irrespective of the crops grown (Survey Diagrams; Figure 7.2). Medium and large scale dairy farmers start to mechanise milking and forage harvesting and preservation. However, support services are missing and unless the market for farm machinery and farm equipment and the related service industry starts expands, this will remain a static position (Survey Diagrams; Figure 7.3).

According to Lukuyu et al., 2013, labour constitutes the highest cost of production for all forages, with the cost of planting materials, especially forage seeds, coming second. This may be due to high cost of seed, inaccessibility of seed, and governmental rules and regulations restrictions in the forage seed delivery system. This situation, especially the forecasted increase in labour costs, could be a future driver of mechanisation in the forage/animal production sector.

Q 23) "What do you think is the main mechanisation problem that is currently hindering the production, quality and utilization of forages on dairy farms?"

According to the survey, lack of appropriate machinery in terms of type and scale is seen by the respondents as the largest constraint for intensive mechanisation (from planting to harvesting to feeding out) (41%). Cost of mechanisation is rated second for all farming systems (27.8%). It is rated first for commercial forage producers, with knowledgable and skilled operators being another concern for this group (Survey Diagrams; Figure 7.4).

Service providers and commercial forage producers are the most mechanised stakeholders in the forage chain. Yet they face main challenges as old-model used machinery is with lack of maintenance and replacement parts and the poor skills of operators. Import restrictions and financial constraints are the main causes of this situation, along with the unpredictable market that drives investors to be very cautious at investing in machinery and technology. Lack of qualified operators and mechanics further contributes to this.

Q 24)" Would you prefer to promote on-farm mechanisation or use of skilled contractors with appropriate machinery in different dairy systems?"
While there is a demand for skilled contractors, on-farm mechanisation is also seen as a future solution to reduce the burden of an often-heavy workload on the farms and shortage of labour (Survey Diagrams; Figure 7.5).

Q 25)" What solutions do you suggest for enhanced mechanisation of forage production and preservation in small holder, medium and large scale dairy farms?"
The respondents rated the importance and need of skilled contractors in small holder systems higher (19.5%) than in medium and large farms (9.2%). The option of scaling the machinery is indicated as another solution to enhanced forage production in Kenya (9.2% for SHF and 17.2% for M&LHF) (Survey Diagrams; Figure 7.6).

For grasslands and forage crops, machinery for medium and large-scale farms is imported. Availability of spare parts can be challenging. In large scale forage production systems use of high capacity machinery for ploughing, planting, harvesting, chopping, mowing, ensiling and baling is essential for spearheading high quality forages and reaching economies of scale. At the same time, there is a need and market for smaller scale machinery (1-2 row harvesters, forage shredders, etc.) for other scales of operations such as in the small holder dairy farms.

Table 8. Summary of machinery gaps
Unscaled machinery
Old machinery
Not easy to import
Lack of skills to repair and maintain the machines
Scarcity of spare parts
Lack of skilled operators
Lack of investors (big investment needed for an unstable market)

Chaff cutter for hay and Napier grass

Chopper for maize or Napier grass

Giro mower cutting pasture

Wilting oats before ensiling

Baling of maize (silage)

Harvesting maize silage by contractors

8. Inputs and services

Feed manufacturers, seed and fertilizer 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, private advisors on forage production, preservation and dairy nutrition and many others, constitute the cluster of input and service providers in the forage value chain.

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.

Q 26)" What is your perception of the quality of the input suppliers and service providers in relation to forages, on a scale of 1 - 5 (1 = poor, 5 = excellent)?"
The perception of the quality of the input suppliers and service providers ranges from below average to average. Services like supply of inputs for silage making, agricultural contractors and feed laboratories are perceived as either low or not existing (Survey Diagrams; Figure 8.1).

Q 27)" Which services, according to you, are missing in the Kenyan forage market?"
Lack of a quality feed lab and of feed standards was mentioned by 34.6% of the respondents as the major missing link, followed by training for extension services (23.1%), seeds of forage crops (15.4%), contracting services (13.5%), and market improvement (11.5%) (Survey Diagrams; Figure 8.2).

Livestock insurance

The Kenyan Government together with the private insurance sector started implementing the Kenya Livestock Insurance Program (KLIP) in 2014. KLIP is an index-based livestock insurance program that uses satellite technology to protect pastoralists in the remote, arid and drought prone rangelands of Kenya from the impact of extreme weather. The program currently covers close to 90,060 livestock units, and has made pay outs of more than KES 700 million to 32,000 pastoralists since inception.
Pastoralists in Kenya are at the forefront of climate change, with extreme weather posing a potentially fatal threat to their livestock. Climate change related droughts are a major source of vulnerability for those who depend on livestock for income and food in the Arid and Semi-Arid Lands (ASAL) of Kenya. Livestock losses alone have accounted for approximately 70 percent of the US $ 12.1 billion losses caused by droughts between 2008 and 2011. Without adequate protection and response measures, the impact of drought on livestock threaten to cause setbacks to the overall economy.

When drought becomes particularly severe, pay outs are triggered based on the index data and are directly transferred to the pastoralists with the help of mobile payment systems (M-PESA technology). With these payments, pastoralists can purchase water and forage to sustain livestock such as camels, goats and cattle through the drought period. This agriculture insurance initiative is not only an efficient financing tool but it also helps vulnerable communities avoiding catastrophic livestock losses in the first place and thus reduces the negative impact of climate change.

The lack of transition to a sustained agricultural development is attributed to a mixture of continued high risk issues: inadequate provisioning of improved technologies, large swings in domestic cereal prices, and continued weakness in input and output marketing. The weakness in markets is associated with both the lack of roads and an underdeveloped private marketing and transportation network.

Table 9. Summary of input & service provider gaps
Market size and uncertainty (low buying power farmers)
Business ethics and tendency to push products into the market (irrespective of quality and benefits for the farmer)
Lack of business-oriented entrepreneurs
Finance
Limited knowledge and ability to give the right advise with the product or service
Low skills level of technical staff

Parameter	Unit	Result	Guide Low	Guide High	Low	Optimum	High
pH		6.60	6.00	7.00			
Phosphorus	ppm	215	20	100			
Potassium	ppm	581	485	969			
Calcium	ppm	3623	3281	3480			
Magnesium	ppm	271	358	537			
Manganese	ppm	182	100	250			
Sulphur	ppm	74.39	20.00	200.00			
Copper	ppm	3.47	2.00	10.00			
Boron	ppm	0.27	1.00	2.00			
Zinc	ppm	9.81	4.00	20.00			
Sodium	ppm	72		< 286			
Iron	ppm	152	150	350			
C.E.C	meq/100g	24.85	15.00	30.00			
Aluminium	ppm	987		< 1200			
EC (Salts)	uS/cm	455		< 800			
Organic Matter	%	4.14	3.00	8.00			

Sample Name : Silage

Parameter		Unit	Result
Energy	E	MJ/Kg	11.0
Protein	Protein	%	9.16
Fibre	Fibre	%	13.5
Fat	Fat	%	4.14
Ash	Ash	%	4.98
Starch	Starch	%	26.8
Acid detergent fibre	ADF	%	17.2
Neutral Detergent Fibre	NDF	%	35.9
Sugar	Sugar	%	0.77
Digestibility (NCGD)	NCGD	%	70.0
Dry matter	DM	%	37.7

Soil analyses and feed analyses are important services for the farmer to guide farm management

Land preparation before planting

Contractor making the silage bunker

Promoting Brachiaria grass

9. Forage market

Q 29)" What kind of forages can you find nowadays being offered for sale in the market (e.g. fresh/green forages, imported forages, grass hay, wheat straw, silage, etc.)?"

According to the respondents of the questionnaire, hay (31.4%) is the main product in the market, followed by fresh cut forages (26.7%), maize silage (16.2%) farm by-products (9.5%) and straw (8.6%), Lucerne hay (5.7%) and sorghum silage (1.9%) (Survey Diagrams; Fig. 9.1).

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 small holders with small land size, often in the urban and peri urban areas, have to buy forages the larger part of the year, and also medium and larger farms with limited own forage production resort to buying during the dry seasons. This is a pull factor for a large hay market that emerged over the past 10 or so years. During the dry season prices may more than double.

The hay market is predominantly volume based. Quality is usually low due to late cutting (overgrown) lack of fertiliser application resulting in low nutritive value and low digestibility. Farmers usually lack the ability to differentiate between good and poor quality hay. There are few emerging commercial grass hay producers that try to position themselves on basis of quality. Among the hay used, Boma Rhodes hay is the most common, followed by natural grass hay. 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 be effective (Grass Hay, Kenya Bureau of Standards, 2018). The successful application and impact of the Standards will highly depend on the availability and quality of feed laboratories. The question that arises from the KEBS standard is "What will happen to hay that does not meet the required standard"? It is noted here that a pricing system based on (variable) nutritive value and dry matter, would be a more adequate than a system of fixed standards.

In the Naivasha some large professional growers of irrigated Lucerne are operational. They dry and sell the lucerne in bales of 18-20 kg. Recently investors have piloted business models for baled silages, exemplifying that there is an emerging concern and market for higher quality forages.

Financial services are very weak for forage producers, as "forage production" is not recognised as being a mainstream "agricultural business" by banks and financial institutions, as opposed to cash crops like maize or wheat. Lack of skills, knowledge and marketing are areas that also need to be improved. In addition to this forage market there is a (localized) market for by-products from agro processing industries, notably pineapple cuttings from Delmonte (Thika), brewers (spend) grain or brewers "waste" from the beer breweries. Both by-products have high nutritional value but due to the high moisture content, need to be well-handled, stored (moulds, mycotoxins) and added to the ration in the right proportions.

Among the hay used, Boma Rhodes hay is the most common, followed by natural grass hay. 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 be effective (Grass Hay, Kenya Bureau of Standards, 2018). A pricing system based on (variable) nutritive value and dry matter is more adequate than a system of (categorized) fixed standards. The successful application and impact of the Standards will also depend on the availability and quality of feed laboratories.

Commercial production and trading of maize silage emerged in some parts of the country 5-8 years ago, e.g. Ndykak in Nakuru, Kruger Farm in Eldoret and Gogar Farm in Rongai. The recent investments in highly professional silage balers by FIT Ltd, AusQuest Farm, Leketeton Farm and others in North Rift shows that this is now slowly being upscaled and professionalised, although still in piloting stage. Fresh Napier grass dominates the sales between farmers that live close to each other.

None of these supply chains – either hay, lucerne, maize silage or by-products from agro-processing industries (i.e. pineapple cuttings from Delmonte, spend grain from the breweries), are quality controlled. Quality is an issue across the commercial forage supply that can lead to farmers paying high prices for low nutritional value (especially common in the hay market).

Q 30)" How would you define the actual forage market (e.g. seasonal, opportunistic, formal/informal, quality control, standards, etc.)?"

Forage trading is carried out through formal and informal channels. The informal channel includes farmers and small traders who directly buy from small producers – even the localised trading of fresh forage (e.g. Napier grass and grass cut along the roadside) between one farmer and another – and it is the dominant channel of forage trade. The formal channel comprises commercial forage producers, traders, and agro vets that purchase forage from medium- and large-scale producers and directly deliver the forage to dairy farmers, ranches and cooperatives. They are licensed for forage trade. The respondents in the questionnaire defined the Kenyan forage market mainly as seasonal (45%) and informal (32%) (Survey Diagrams; Figure 9.2).

Dairy cooperatives have also gone into growing of grass for hay production (to sell hay bales to their members) on leased land or in a profit sharing arrangement with the land owner, including County Governments. Examples are Muki Dairy Farmers Cooperative Society in Nyandarua County, Ndumberi DFCS and Githunguri Dairies (Kiambu County). The model relieves the farmers from incurring further transactional costs by sourcing for forage on their own. Scaling could be an incentive to analyse the hay on nutritive value and to assure a fair price based on the quality of the hay.

Table 10. Summary of forage market gaps
Forage production is not a recognised mainstream economic activity by financial institutions
Unpredictable market (partly seasonal)
Informal
Lack of pricing mechanism based on quality, lack of standards
Volume based and not quality-oriented
Lack of reliable feed testing
Lack of knowledge and skills
Poor marketing

Demonstration of Brachiaria & Panicum

Round bales of hay

Maize grown for forage

Storing baled maize silage

Sorghum ready to be harvested and ensiled in ASAL

10. 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 is made to for example. Similar studies were done by GIZ which confirmed these findings.

Ericksen, P et. al. 2018. mentions that despite years of investment in developing and disseminating improved forages for on farm use, uptake in Kenya (and Ethiopia) remains low. Chokoma, I.C., 2012 writes that most research work on forage production in Zimbabwe has been conducted at research stations and of late efforts are being made to conduct them on-farm. There is low adoption of forage production techno-logy in the small-scale farming sector as evidenced by poor management practices and low forage yields. A deeper understanding of the farming systems in these areas, farmers' perceptions of forages and constraints limiting improved forage production is key to all research work. In Kenya the situation in regard the uptake of research results seems to be very similar. Strategies on utilization of research results involve institutional support, farmer training, farmer-to farmer extension, farmer field schools, farmer participation in research work, identifying gender roles, costs involved and appropriateness of technologies under which the small scale farmers operate. (Chokoma, I.C., 2012).

Government extension services who 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. This gap has been partly filled by extension services of dairy cooperatives, processors and animal feed manufacturers, and by development partners and projects who are capacity building training and extension staff of dairy cooperatives and lead farmers, and – also – private dairy advisory services which are emerging (Katothy et. al. 2016).

Private advisors specialised in forage and dairy nutrition tend however to focus on medium and large-scale farms, that have more ability to pay for their services. A problem in this regard is that everybody can register as a dairy advisor or consultant without any entry barrier and quality control mechanism irrespective of their knowledge.

At the same time Agricultural Colleges and Universities have focused more on research and education at academic level, with little connection to the field and the needs of the market: i.e. practical skills and good agricultural practices. This general lack of practical knowledge and skills-based training and curriculum in the dairy sector, applies equally or especially to forage production, preservation and dairy nutrition. Forage production is part of crop production in the curriculum of Agricultural colleges and Universities with little connection to dairy nutrition. Dairy nutrition is part of animal nutrition and the focus in this subject is on feed formulation for monogastric rather than ruminants who need forage based rations.

Q 35)" What is the availability and quality of education and training on forage production, preservation and inclusion of dairy cow ration formulation in the country?"

Among the respondents of the questionnaire, (i) 34% answered that training is not available, (ii) 27% that it is not available for the majority of farmers, (iii) 15% that is available but not targeting the right group, (iv) 9% that it is available only in institutes of higher education, and (v) 3% that contradictive information is provided, thus confusing farmers (3%) (Survey Diagrams; Figure 10.1).

Q 36)" What knowledge and skills are lacking in regard to forage production and preservation?"

Good agricultural/farming practices is considered by 22.8% of the respondents as the key missing skill causing the gap in forage production and preservation in Kenya; 21.1% indicated that there was an overall lack of knowledge and skills (Survey Diagrams; Figure 10.2).

Q 37)" Who should provide this training?"

According to the survey, this training should be provided by either (i) government institutions (33.9%), (ii) private sector (30.5%), or (iii) a combined effort of the public and private sector (13.6%), (Survey Diagrams; Figure 10.3).

Q 38)" Who should be trained?"

According to the survey, all the stakeholders involved in forage production need to be trained. These were rated as follows: (i) farmers (18.2%), (ii) training and extension staff (18.2%), (iii) commercial forage producers (17.6%), (iv) farm workers (17.0%), (v) agricultural contractors (14.8%) and (vi) dairy (ruminant) nutritionists (14.2%) (Survey Diagrams; Figure 10.4).

The conclusion is that all the recommendations on forage production proposed in this report need to be supported by a strong education/training plan addressed to all stakeholders in the chain, which is not in place at the moment.

Table 11. Summary of knowledge, education, training awareness gaps
Reduced government extension service, gap not filled by the private sector
Lack of practical knowledge and skills on forage crop production, preservation
Hence lack of training facilities that focus on practical skills training in forage production and ruminant nutrition
Lack of awareness / knowledge of the relationship between forage and animal nutrition
Lack of curriculum for practical knowledge and training on forage production and dairy nutrition at all levels
Lack of market-led research, training and education

Practical skills training of farm managers

Practical skills training of farmers on a dairy training farm

11. Environmentally sustainable forage production

Forages are essential for the successful operation of animal production systems. This is more relevant to ruminants which are heavily dependent on forages for their health and production in a cost-effective and sustainable manner. While forages are an economical source of nutrients for animal production, they also help conserve the soil integrity, water supply and air quality (Chaudry, 2008).
To maintain sustainability, it is crucial that forage based animal production systems remain profitable and environmentally friendly, while producing nutritious foods of high economical value. Thus, it is pertinent to improve the nutritive value of grasses and other forage plants in order to enhance animal production to obtain quality food. It is also vital to develop new forages which are efficiently utilised and wasted less by involving efficient animals. A combination of forage legumes, fresh or conserved grasses, crop residues and other feeds could help develop an animal production system which is economically efficient, beneficial and viable. Also, it is crucial to use efficient animals, improved forage conservation methods, better manure handling, and minimum fertilisers to maximise animal production without damaging the environment (Chaudhry, 2008)

However, sustaining an ever-growing population of ruminants consuming forages poses a dilemma: while exploiting their ecological niche, forage-fed ruminants produce large amount 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).

Livestock supply chains account for 7.1 GT (giga tons) CO2, which is equal to 14.5% of global anthro-pogenic green-house gas emissions. Cattle (beef, milk) are responsible for about two-thirds of that total, largely due to methane emissions resulting from rumen fermentation (FAO, 2017a). Of the three major GHGs, methane (CH_4) takes the largest share (43%) while nitrous oxide (N_2O) and carbon dioxide (CO_2) are the gasses responsible for about 29% and 27% of sector's emissions globally, respectively.

In 2010, Kenya's national GHG emissions equated about 73 MT (million tons) of CO2 equivalents (GoK, 2015). 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 (Figure 3) (FAOSTAT, 2019).

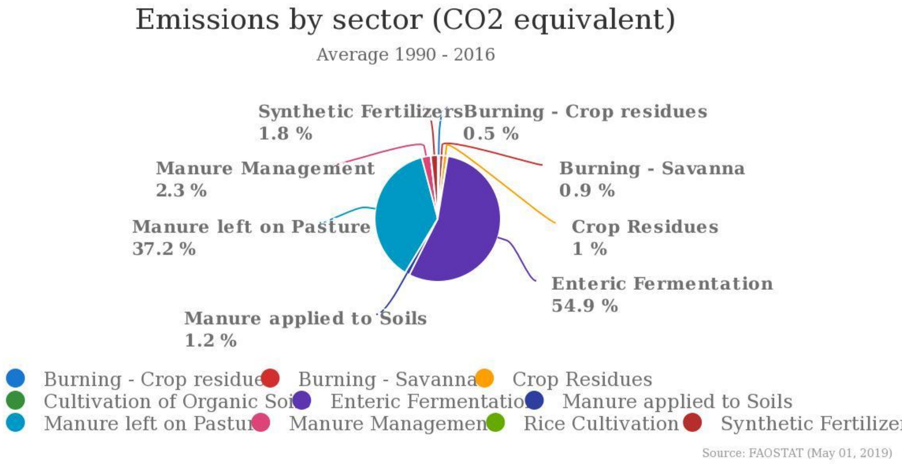
The dairy cattle sector in Kenya is responsible for about 12.3 MT CO2 equivalents. The GHG profile is dominated by methane (95.6%); nitrous oxide (N2O) and carbon dioxide (CO2) contribute 3.4% and 1% of the total emissions, respectively. At national level, the emission intensity of milk produced in Kenya is on average 3.8 kg CO2 eq./kg FPCM. Emissions were on average 7.1, 2.1, and 4.1 kg CO2 eq./kg FPCM for extensive, intensive, and semi-intensive systems, respectively (FAO and NZAGRC, 2017) (Maps 4 and 5). Emission intensity in the Netherlands dairy sector is 1.2 – 1.6 kg CO_2eq./kg fat and protein corrected milk (FPCM) (FAO, 2010).

The activities and processes that contribute towards the GHG emissions from dairy cattle sector in Kenya are shown in Map 5. The GHG profile of milk in Kenya is dominated by methane 95.8%, while the nitrous oxide (N2O) and carbon dioxide (CO2) contribute 3.4% and 1% of the total emissions, respectively. Approximately 88% of the emissions arise from methane produced by the rumination of cows and 11% from the management of stored manure. Emissions arising from other sources make a negligible contribution to overall emissions (FAO and NZAGRC, 2017).

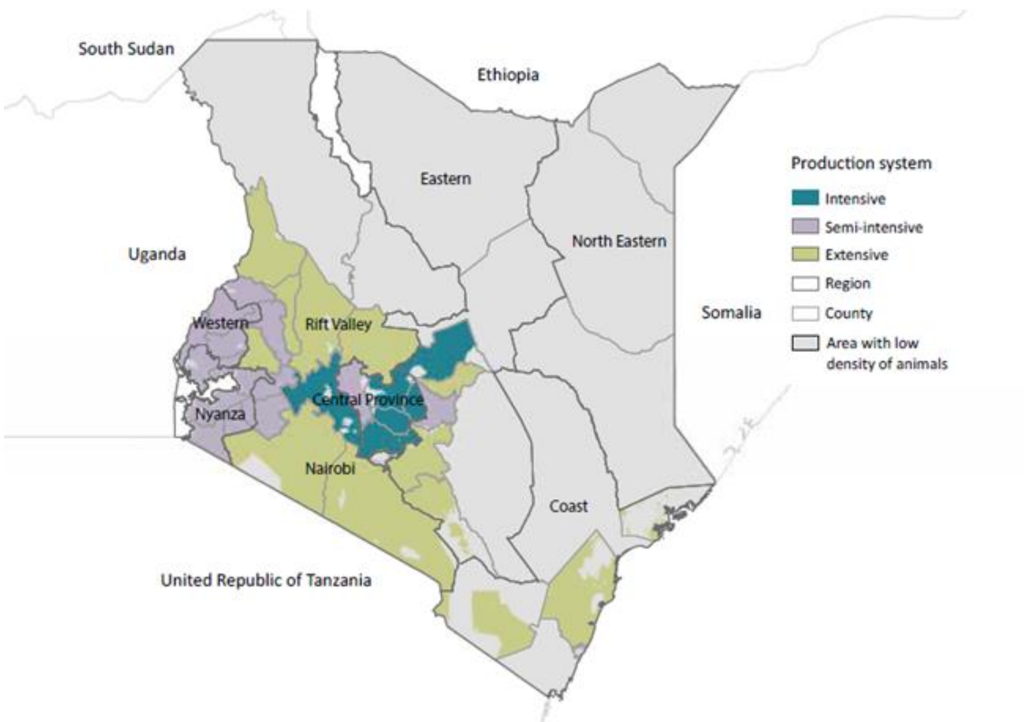
To be able to reduce enteric methane emission in ruminants less fibrous and more balanced rations need to be fed, or cows need to graze on pastures with grasses or grass/legume mixtures that are less fibrous and have a higher protein content. Besides the availability and accessibility of improved forage species and varieties, also agronomic practices need to improve to intensify sustainable production per hectare. For example increase in area under maize production and the total maize production in Kenya more than doubled since 1961, but the grain yield per hectare is somehow steady between 1.0 and 1.5 tons. The years where a higher yield/hectare has been achieved can be attributed to more favorable (climatological) growing conditions (Annex 7).

Conservation Agriculture (CA) systems can be used to intensify maize grain and forage maize production as well as production of other forage crops. These (CA) systems utilize soils for the production of crops with the aim of reducing excessive mixing of the soil and maintaining crop residues on the soil surface, in order to minimize damage to the environment. The three principles of conservation agriculture are: minimum tillage and soil disturbance, permanent soil cover with crop residues and live mulches, crop rotation and intercropping. Conservation agriculture is 20 to 50 percent less labour intensive and thus contributes to reducing greenhouse gas emissions through lower energy inputs and improved nutrient use efficiency. At the same time, it stabilizes and protects soils from breaking down and releasing carbon to the atmosphere (FAO 2018c.).

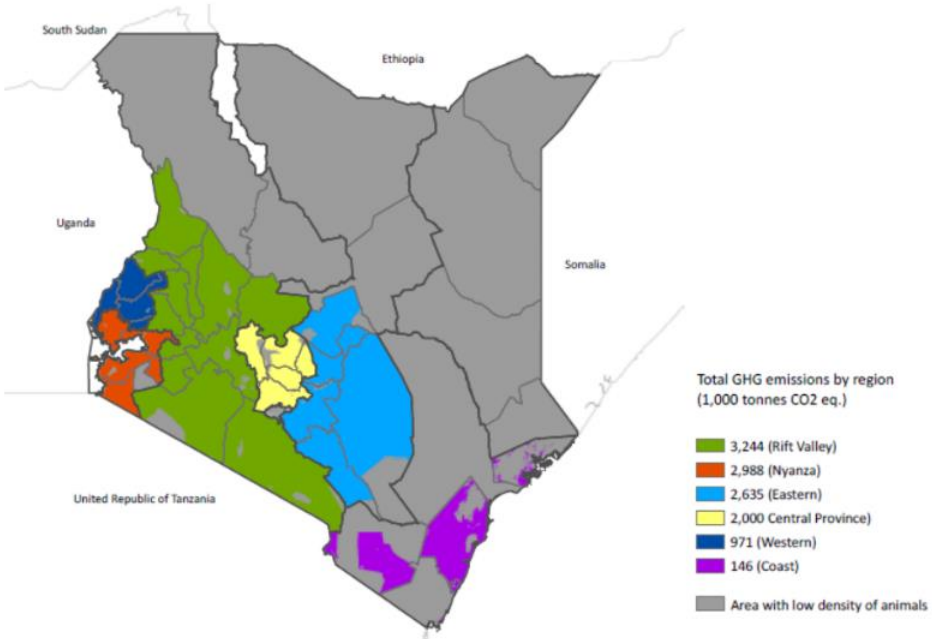
Figure 3. GHG emissions by Kenya's agricultural sector (CO_2 equivalent) Average 1990-2016 (FAOSTAT, 2019)



Map 4. Localisation of dairy cattle production systems (FAO and NZAGRC, 2017)



Map 5. GHG emissions from milk production in different regions of Kenya (FAO and NZAGRC , 2017)



Q 39)" How do you rate the effect on the environment of current agricultural practices as regards forage production and preservation?

Respondents consider that the effect of current practices of forage production and preservation on the environment is either neutral (59%), or negative (23%) (Survey Diagrams; Figure 11.1).

Q 40)" What is in your opinion the contribution of current forage production and preservation towards an environmentally sustainable dairy industry?"

According to the respondents 47% the contribution of current forage production practices as neutral, whereas 29% consider that current practices contribute positively towards a sustainable dairy industry (Survey Diagrams; Figure 11.2).

Q 41)" Which good practices, interventions would you recommend as regards the forage sub-sector to reduce the (negative) impact on the environment?"

Better land management practices was the option chosen by 22.7% of the responders, followed by manure management (20.5%), and the use of forage-based ration balancing (13.6%) (Survey Diagrams; Figure 11.3).

Q 42)" What other recommendation do you have – beyond forage production and preservation - for reduced environmental footprint for the Kenyan dairy industry?"

The three main recommendations the respondents gave to reduce the environmental footprint of the dairy industry in Kenya were (i) advising the farmers on forage based ration balancing for their dairy cows (28.9%), (ii) installing and producing biogas at the farm level (18.4%), and (iii) a change in breeding strategy (13.2%) (Survey Diagrams; Figure 11.4).

Q 43)" Are there any regulations/policy requirements in place that you are aware of to reduce the environmental impact of livestock production systems (national or County level)?"

The majority of the respondents consider that there are no regulations/policy requirements in place they are aware of, to reduce the environmental impact of livestock production systems on either County or at national level (69%) (Survey Diagrams; Figure 11.5). However, the new Crops (Food Crops) Regulation Act, 2018 recently (March 2019 announced) seeks to tighten regulations governing food production, processing and marketing.

Q 44)" In your opinion, how likely do you think farmers/commercial forage producers will adopt practices that will contribute to a better environment, but may require an investment? What will trigger them?"

For farmers to adopt and implement practices that will contribute to a better environment the respondents believe that farmers would do so if they get an economic incentive (47%). Other considerations included (i) increasing awareness by training and educating farmers (19%), and (ii) new policies and regulations to adopt practices which initially will need an investment (19%) (Survey Diagrams; Figure 11.6).

From the environmental point of view, land degradation (Annex 8) and GHG emissions from livestock need to be considered. 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 W. et al., 2016). Conservation agriculture can be a solution to reverse soil degradation using good agronomic practices, such as minimum tillage, improving soil structure and compaction, soil pH correction, efficient use of manure and crop residue management. These practices need to be improved to contribute to increased soil organic matter content and to recycle nutrients. Adoption of conservation agriculture in Kenya is still low, with less than 30,000 farmers practicing conservation agriculture covering less than 1% of the total arable land (FAOSTAT 2014).

Soil conservation measures remain important in all AEZ to protect soils from erosion and exhaustion. This includes afforestation, avoidance of overgrazing, rainwater harvesting in dams or reservoirs and implementation of agronomic practices mentioned earlier - and others like strip cropping, contour ploughing, terracing and alley cropping.

To encourage conservation agriculture, the demand for crop residues as forage for livestock needs to be reduced by promoting use of more energy-dense feed rations for animals. An analysis of mixed crop-livestock farms in Western Kenya and Ethiopia's Rift Valley showed that by closing the maize yield gap and replacing some maize residues with Napier grass, soya bean meal and molasses in the diets of dairy cattle, most farmers would be able to retain at least 1 ton per hectare of crop residues in their fields. A second benefit would be increased livestock productivity (FAO 2014).

Crop residues left in the field, return the carbon fixed in the crops by photosynthesis to the soil and the resulting improvement in soil health and fertility, leads - over time - to reduced fertilizer use and CO2 emissions. Other relevant green house gas (GHG) emissions from agriculture, namely methane and nitrous oxides can also be reduced within a conservation agriculture (CA) environment with some complementary practices (Corsi, S et. al., 2012).

For enteric methane emission reduction, the best approach is to increase ruminants' feed efficiency through a balanced diet based on high quality forages, and the production of high quality (preserved) forages following good agricultural practices from "seed to feed". High quality forage production is directly linked to feed efficiency and feed efficiency is closely related with environmentally friendly production systems (Figure 4).

Figure 4. Relationship between forage quality and methane emission reduction

Increased feed efficiency is one way around the dilemma. Another way is by raising ruminants in systems using forages, some of the methane emissions can be offset by preserving or enhancing soil carbon reserves, thereby withholding carbon dioxide from the air. Similarly, well-managed systems based on forages may reduce synthetic fertilizer use by more effective use of manure and nitrogen-fixing plants, thereby curtailing nitrous oxide emissions. The potential environmental benefits of forage-based systems may be expanded even further by considering their other ecological benefits, such as conserving biodiversity, improving soil health, enhancing water quality, and providing wildlife habitat (Guyader et al, 2016).

It is worth mentioning here that fertilizer consumption in Kenya and application per hectare is still very low on a global level (Annex 9) (FAO, 2018c, World Bank, 2017). SNV-KMDP on the other hand worked on improved use of quality forages as well as on balancing rations of dairy cows, through a combination of interventions, for small holder, medium and large scale farmers, through improvement of on-farm establishment and preservation of forages, and by promoting the Service Provider Enterprise model, agricultural contractors (Maize Train) and commercial forage producers (hay and baled silages).
Part of this entails a collaboration with CIAT for demo plots on nine Brachiaria ssp, Panicum ssp as well as protein rich forages. KMDP also started a pilot on 25 small, medium and large dairy farms with Rumen8, a total diet dairy ration balancing software. This software, adjusted to the Kenyan context and needs (including a regional Feed Library with over 230 local feeds and forages), will be available for Kenyan dairy advisors and teaching or training institutions as a diagnostic, advisory and training tool for forage-based feed formulation, including enteric methane emission per litre of milk produced. References to the different models and interventions introduced into the Kenyan dairy sector by KMDP are given in section 12: Innovations.

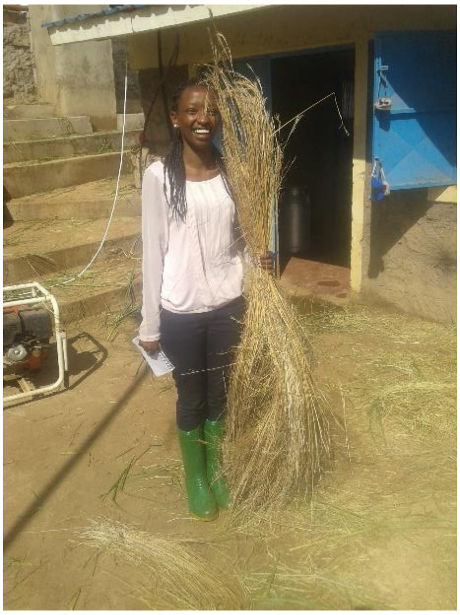
Improved forages, as well as urea-molasses blocks may reduce emissions by 6-12% and 8-24%, respectively in Kenyan farms. However, the adaption of these strategies may be limited due to lack of land availability, capital or seeds (Ericksen and Crane, 2018).

It is important to note that the expected reductions in CH_4 emissions should not be superseded by increases in N_2O or CO_2 emissions e.g. fertiliser application or transport associated with introduction of a new or a combination of species. In order to make sure strategies that reduce the emissions in one part of the system do not lead to increased emissions in another part, monitoring and verification tools are needed. Some of the global or farm models (CLEANED, FEEDPRINT, GLEAM) can be used for this purpose.

Table 12. Summary of sustainable forage production gaps
High zone variability and productive systems not well adapted to zones' characteristics
High soil/grasslands degradation
Poor agricultural practices in soil management, forage crop production and preservation
Lack of knowledge on relationship quality of forages, feed conversion and GHG emissions
Lack of (holistic) research and little connection to promoting good agricultural practice
Lack of feed testing facilities, in particular for tropical forages
Lack of governmental policies and strategies

Young heifers feeding on oats hay. Oats hay is of low nutritional value and difficult to digest for young ruminants

Young heifers feeding on young Napier grass gives good response in growth.



Overgrown grasses used as forage have low nutritional value and digestibility

Alley cropping of Napier grass and Leucaena. Hedges of leguminous trees at 5 meters apart give the grass the benefit of Nitrogen fixation of the trees and the leaves can be mixed with grass into a more balanced ration for dairy cows

12. Innovations

The questionnaire also included a section on innovations related to the forage sub-sector and dairy nutrition. Innovations were defined broadly and include amongst others good agronomic practices, new forage species or varieties, best practices in silage making and baling of silages, better/new and machinery and technologies, new approaches to practical training, new business models such as specialised service providers and agricultural contractors for forage production and preservation, software for balanced dairy ration calculation.

Q 45) "During the past 5 years, you may have observed some of the innovations that are listed below. Please confirm by rating their impact (high, low, or not observed)".
A total of 16 different innovative activities were listed in the questionnaire and the respondents were asked to rate the impact of each innovation. Those considered as having a high impact were the following: (i) improved methods of forage production and preservation (> 50%), (ii) training (>50%), (iii) introducing new species (47.1%), (iv) improved hay production (44.1), (v) intensification and mechanisation (38%), balanced feed rations (38%), and conservation agriculture (38%). (Survey Diagrams; Figure 12.1).

Q46) "Which other innovations would you like to add Please indicate their impact (high/low)."
The respondents consider that, if the gap between the genetic potential of the dairy animal and the available quality of feed and forages is reduced, this would have a high impact (38.5%). Forage preservation technology (30.8%) and education & training (11.5%) were also mentioned as being high impact innovations. Others like feeding of the dairy animals, utilization of leguminous crops, better storage and feed manufacturing all scored below 10% (Survey Diagrams; Figure 12.2).

Q 47)" What aspects need to be considered before a new intervention is introduced or put into action? Please rate from 1 - 5 and explain (1 = low importance, 5 = high importance)
According to the survey, all proposed aspects (policy, market, technology, knowledge and skills, finance, social/cultural behaviour) need to be considered, especially with attention to finance, knowledge and markets (Survey Diagrams; Fig 12.3).

Innovations observed by this study

In the past 10 years research institutions, government, farmers and dairy cooperatives, private sector and development organisations have made efforts to enhance the forage sector.
Several sector studies on the animal feed and forage sub-sectors were carried out or facilitated by donor funded programmes such as the East African Dairy Development Programme (Gates Foundation), USAID/Land O'Lakes Kenya Dairy Sector Competitiveness Programme, Kenya Market Trust, SNV Kenya Market-led Dairy Programme, USAID KAVES Fodder Value Chain Analysis, and the FAO funded Community Initiatives Facilitation and Assistance (CITA) that compiled a (draft) national livestock feed resources and needs assessment for ASAL areas, just to mention a few. 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 SOPs have been developed to enhance agricultural practices.

Kenya Government, through the Ministry of Agriculture, Livestock, Fisheries and Irrigation (MALFI), in February 2019 published the draft reviewed National Livestock Policy that includes chapters on the feed and forage sub-sectors, including policies on forage research and education. There is a draft National Livestock Feeds Policy (2009), and through various Government Bills the sector is regulated e.g. as regards feed standards (KEBS) that are now also being applied to certain forages (amongst them grass and lucerne hay), and importation and registration of forage seeds (KEPHIS). There is also a National Climate Change Action Plan.

These sector studies, handbooks and the policies and regulations, are important for good understanding of the state of affairs in the feed sector, and also to seek for more conducive policy and regulatory framework. However they usually do not drive innovations, which are usually market-led and initiated by the private sector, although sometimes promoted and supported by public or donor funding in public-private partnership. A number of them as pilot projects, of which it is hoped that they will be upscaled through follow-up investments by the investors involved, or through replication (crowding-in) by others.

During this study and based on literature review, interviews and own observations in the field, the consultants came across a number of such innovations, which are listed and categorized below, taking the concept of innovation broadly. Some of them have already been briefly discussed in the previous sections, but are brought together in this chapter.
At this point the consultants wish to mention that the listing below, likely is not complete and was also much informed by the work and the reports of KMDP in the past 8 years. This may have resulted in overlooking of some innovations driven by other stakeholders in the sector.

Forage species, seeds and planting material

KALRO (cultivars) and CIAT (hybrids) developed and actively promote Brachiaria ssp and Panicum ssp (CIAT) through demonstration plots for farmers in Meru, Eldoret and Sagana, in collaboration with SNV/KMDP. KALRO is active in multiplication of pasture and legume seeds at their research stations and farms for sale to farmers. Advantage Crops Ltd and Amiran market the Brachiaria hybrid varieties (Cayman, Cobra, Mulato II) originally developed by CIAT. Advanta Seeds introduced a forage sorghum under the name Sugargraze and a pearl millet under the name Nutrifeed in Kenyan, while also Leldet Seed Company Ltd from Lanet brings forage sorghum varieties in the market. So far no specific forage maize varieties are known to be registered in Kenya. Encouraging seed producers and seed distributers to register these specific varieties can be an enormous benefit for dairy farmers who make maize silage for their herds.

Maize silage in Kenya is often characterized by high NDF content, low NDF digestibility and low starch content of the silage, because the maize varieties used are grain producing varieties and bred to stay green long without logging and ripen thereafter quickly within a short period.

Based on the current research of KALRO other interventions in regard to the availability of seeds and plant material or forages can soon be expected. 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. Availability of certified quality seeds and an intensive distributor network will be essential for farmers to pick up the growing of lupins. 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).

A public-private co-investment funded through the Netherlands Organisation for Scientific Research (NOW), started in 2019 through a partnership between CIAT, ILRI, NARO, Barenbrug SA and Advantage Crop Ltd, to support the professionalization of the dairy sector. The aim of this project is to develop viable business models for forage seed production and marketing that assure economically sustainable access to high quality forage seed to diverse clients in Kenya and Uganda.

Other initiatives to improve the availability of protein sources through plant material, either as forage or as an ingredient in compounded feeds or cow rations, have been noted. For example (a) a pilot project around lake Victoria to dry and process water hyacinth into animal feeds or to feed the leaves as fresh forage, (b) commercialization through large scale plantations of forage shrubs as protein source for compounded feeds, (c) introduction and commercialization of duckweed, and (d) a few years ago the introduction of hydroponics. These have shown different levels of success and have not been upscaled yet; some are still in the research (pilot) phase.

Forage quality, seasonality and preservation

Various parties like SNV have supported introduction and adoption of good agricultural practices for land preparation and crop management such as minimum/zero tillage, conservation agriculture, improved soil fertility through liming, use of farmyard manure and increased fertilizer applications, forage crop management and preservation. For example, for hay and silage making to enhance production, nutritive value and to cope with seasonality.

This has partly taken the form of stimulating dairy cooperatives to go into large scale hay production for sales to their members, and processors like NKCC linking commercial hay producers to the cooperatives they source milk from. Yet the market for hay has remained to be largely volume based. Others – notably SNV's KMDP but also EADD and Land O'Lakes - have promoted maize and other silages (oats, sorghum, grass), next to rehabilitation of pastures and piloting of improved grasses and protein rich forage crops.

In all these activities it is abundantly clear that management of the forage crops and the process of hay and silage making is key, as is scaled machinery with the right capacity that assures speed of work to assure quality of the (preserved) forages. Introducing new species or new seed varieties will only then yield higher nutritive value, if managed well and (also) if fed in a well-balanced ration. This is well documented in various reports prepared by SNV KMDP, e.g. reports 34, 38 and 41 on https://www.cowsoko.com/programs/kmdp/publications

The use of total diet ration balancing software (like Rumen8), when based on accurate and reliable feed analyses, will assist qualified dairy advisors and extension officers to justify the cost of different ration ingredients - be it locally grown or imported against their actual nutritive value (DM, ME, CP, NDF) when used in in ration formulation for ruminants.

Also upcoming start-ups and pilots like the use of water hyacinth as a forage (or to use the dried leaf meal of water hyacinth as an ingredient of compounded feeds in a dairy cows ration), propagation of duck weed and duckweed fern, or commercialization of fodder trees and shrubs in areas that are not suitable for such production systems (plantations), will ultimately be tested through their cost price in relation to their nutritive value. Independent, accurate and reliable feed laboratories can play an important role in these processes.

The Kenyan government is scaling up an innovative livestock insurance programme that uses satellite imagery of drought hit areas to offer a safety net to vulnerable livestock keepers. This could be worked-out further into a programme called "Feed on Offer" in Australia, which helps (sheep) farmers based on satellite images of the biomass of native grassland in planning. The combined satellite images and the feed library allow the users to estimate respectively the quantity (carrying capacity) and the nutritive value of their pastures. Animal performance is determined by the quality and quantity of pasture available and when this is known, better decisions can be made on allocation of stock to pastures (stocking rates) or supplementary feeding.

Mechanisation, inputs, service providers

In the previous pages under 7. Mechanisation, mention was made of enhanced availability in Kenya of scaled machinery for maize silage making with stationery and tractor/PTO driven forage choppers and 1-2 row forage harvesters, and self-propelled 4-6 row forage harvesters. This has gone hand in hand with emergence of specialised service providers (SPEN concept for small to medium farms) and agricultural contractors (Maize Train concept for medium to large farms) for various size of farmers and scale of operations. Key for optimisation of these concepts is that choppers or harvesters have kernel crushers and there is sufficient capacity (including transport) to ensile chopped maize, oats or sorghum within 12 hours with adequate chopping length, compaction and coverage (Ettema, F.H., 2019, Kilelu, C.W. et al., 2018, Ayuya et. al. 2019). As regards feed testing an interesting initiative is being undertaken by Crop Nutrition to partner with international agencies to get access to NIR regression lines for tropical forages, whilst elsewhere pilots are being carried out with handheld NIRS for soil and feed analysis, although still in a research phase.

Forage markets (commercialisation of forage supply)

In response or to complement the grass and lucerne hay market, commercialisation of silages as a more nutritious forage is being piloted by investors in baling equipment for compaction and vacuum packing/wrapping of silage (or fresh chopped maize) in foil. There are currently several machines in the market that can bag or bale silages in units of 50-100 kgs, 350-400 and 1,000 kgs. If well baled and polythene wrapping is not damaged, these bales have a shelf life of several years. This is well described in the report by (Ettema, F.H., 2019). Ettema points out the challenges of this model and the Maize Train concept, in order to maintain good quality and be competitive in the market. Other innovations in the market are to pelletize or make brickets of shredded dried forages like grass, lucerne and stovers, or used in forage-mixtures.

Knowledge, education, skills

Various approaches were identified by the consultant, to transfer and exchange knowledge for adoption of good agricultural practices and development of practical skills in forage production, preservation, feeding and total diet ration calculation. These vary from forage demos (including new seed species/cultivars/varieties), field days, farmer study groups, local and international exchange visits (seeing is believing), Guidelines and SOPs, training modules and Practical Dairy Training Centres, involvement and coaching by international experts (e.g. PUM Netherlands Senior Expert programme), to co-financing and technical advice of investors through Innovation or incubator projects. Here also EADD's publication "Feeding Cattle in East Africa" can be mentioned.

An interesting pilot was undertaken by KMDP through the introduction and contextualisation of Rumen8 to the East African conditions and needs. Rumen8 is a total diet dairy ration calculation software that links forage quality to dairy nutrition and farm economics. It has shown to be a very useful diagnostics, advisory and education tool, provided it is used by persons with good understanding of ruminant nutrition and quality of forage crops and forages used in the farm.

Environmentally sustainable forage production

Innovations in good agricultural practices (from seed to feed), mechanisation and other inputs and services that contribute to sustainable intensification of forage production through enhanced soil and manure management, improved forage quality and digestibility with the same or increased yields/ha, are needed they have generally a positive impact on (reduced) enteric methane production of the dairy herd in Kenya/East Africa. Though there is needed to further assess or determine the net effect that these improved species/cultivars/varieties, practises and innovations have on total GHG emissions, and also to differentiate between intensity of emissions (per litre of milk or kg of meat) and total emissions at animal or farm level. Figure 5 shows the effect on production and GHG emission of interventions in feed and forage supply to dairy cows (FAO, 2018).

The three pictures below show foliage of *Leucaena leucocephala, Calliandra calothyrus and Sesbania sesban*. These leguminous fodder shrubs assist to minimize deficiencies in the basal ration of dairy cows quantitative and qualitative. Lower enteric methane production of legumes is attributed to lower fibre content (NDF) and faster rate of passage of the feed through the rumen. It needs to be mentioned that at one point leguminous forage trees in intensive farming systems, need fertilizer application of Phosphate and Potassium. The introduction and use of Rumen8 software in addition enables calculation and prediction of the effect of improved (lower fibre content), balanced (higher in protein) dairy rations in terms of optimum milk production and the effect on enteric methane production at cow level and per litre of milk.

Integrating manure management with (well managed) biogas generation and use, also contributes to more environmentally sustainable farming systems.

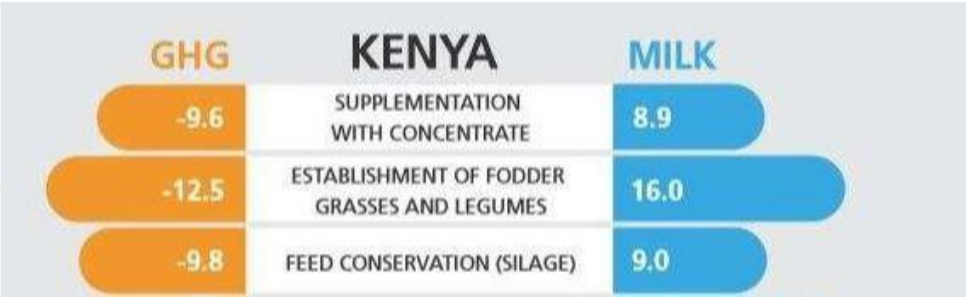


Figure 5. Effect of feed and forage interventions on milk production and GHG emission (FAOb, 2017)

*Leucaena leucocephala (*Source: Feedipedia, 2019)

Calliandra calothyrsus
(Source: Feedipedia, 2019)

Sesbania Sesban
(Source: Feedipedia, 2019)

13. Policies

The desk study looked at various policies and regulations related to the animal feed and forage sub-sector, without the objective of being exhaustive but rather to highlight a number of key issues and the most relevant policy documents and responsible government agencies.

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 setting clear roles of institutions involved in feed regulation. The policy will broadly be 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 feeds industry.

A further Policy states:

- National Government will i). Facilitate demand driven research on disease resistant and high yielding forages and appropriate forage types for each agro-ecological zones, ii). Establish and strengthen soil testing laboratory services for sustainable soil health.
- County Governments will promote adoption of appropriate forage varieties and invest in forage productivity enhancing technologies.
- Both levels of government will i). Take measures to identify a wider range of forage types that facilitate optimum productivity per unit area of land in various agro-ecological zones. ii) Promote fodder commercialization.

With new technologies and techniques used in the forage sub-sector to add value to forages and encourage trade in the forage market, it is important that legislation and regulation is uniform for all and possibly ahead of new developments. Also when it comes to fiscal policies and taxation regimes, e.g. import duties on inputs and machinery, and value added tax on the end product (including the applicable regime of exemption or zero-rating). For example it has been noted by tax experts that there is discrepancy in the relevant Acts on treatment of manufactured feeds versus forages, treating the latter different and less favourable.

Implementation of the Livestock Feed Policy in regard to forages (pastures, fodders, legumes) is very much depending on policies and the regulations of the seed sector. Kenya is one of the few African countries recognized for having well developed legal provisions and regulatory institutions in the seed sector for a number of years, despite the challenges associated with the content and application of the laws, the degree of regulations, and the capacities of associated implementing institutions (Dwijen, 2006, Sikinyi 2010).

Historic perspective of the seed sector

The Kenya Government through the Ministry of Agriculture Livestock, Fisheries and Irrigation, is charged with the responsibility of producing breeders seed through its research centres (KALRO) and supplying it to seed companies, including Kenya Seed Company. A separate body, Kenya Plant Health Inspectorate Services (KEPHIS) is responsible for seed inspection and ensuring that the seed quality is controlled to international standards. KALRO's research centres dealing with pasture and forage research, produce both pasture seeds and vegetative materials for on-farm research and for distribution to farmers. The seed industry in Kenya comprises of the formal and informal seed sector. (Orodho, 2006).

Several factors were responsible for the development of the seed industry in Kenya. These include: i) establishment of Government research centres responsible for production of basic and breeders seed and maintenance of distinctness, uniformity and stability (DUS) of seed; (ii) increased number of varieties available from research centres; (iii) development of a seed certification and seed law enforcement programme by National Seed Quality Control Services (NSQCS) – the predecessor of KEPHIS; (iv.) development of seed cleaning, processing and packaging technology; (iv) a better knowledge of seed quality; and (v) the emergence of the seed grower as a specialist (Sikinyi, 2010).

Currently, Kenya regulates the seed sector through a number of legal instruments, including the Seed and Plant Varieties Act (Seed Act; Cap 326, Commencement 1975; last amended 2012; gazetted January 4, 2013); the Crops Act 2013 (gazetted January 25, 2013); the Plant Protection Act (Cap 324); the Agriculture, Fisheries, and Food Authority Act 2013 (gazetted January 25, 2013), the Pest Control Products Act (Cap 346), and related regulations such as the Seeds and Plant Varieties Regulations (Seeds Regulations), the Seeds and Plant Varieties Regulations (National Performance Trials Regulations), and the Plant Breeder's Rights Regulations, all of which are currently subject to amendment.

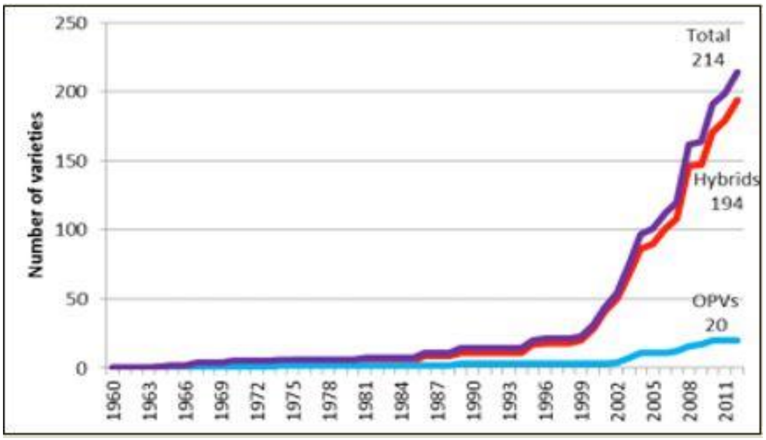
Formal seed sector

The formal seed sector started with the establishment of Kenya Seed Company (KSC) in 1956 in Kitale to produce pasture seed for the colonial settlers. KSC continued to play a predominant role until the industry was partially liberalized in the mid-1980s. Further liberalization of the seed industry was effected in 1996. After this, several companies entered the formal sector largely dealing in seeds of cereals, namely, maize, wheat, barley, oats, triticale and sorghum; oil crops, i.e. rapeseed, sunflower; pulses; pastures; horticultural crops and Irish potatoes.

By 2015 there were 112 registered seed companies, with the latest since 2010 dealing with crops neglected previously due to their low profitability. These include horticultural crops, rice, cotton and pasture seeds, pigeon peas, groundnuts, chickpeas. In spite of this liberalisation, 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).

Figure 6 shows that after liberalisation of the commercial maize seed market in the mid-nineties, the availability of different commercial maize varieties quickly increased within period of 10 years. Currently there are 352 different commercial maize varieties in the market. An increase in availability of different forage varieties can also be achieved if processes and regulations are more favourable for forage seed producers.

Figure 6. Cumulative number of maize varieties released in Kenya between 1960 and 2012 (DTMA, 2015)



The table below shows the crops in the National crop variety list, that are listed because their typical use is as a pasture grass or a forage crop with the purpose to feed animals. Pasture grasses Rhodes, Seteria and Panicum had no new varieties listed in the last 40-60 years. Only the new Brachiaria hybrids were listed as recent as 2016.

Table 13. Pasture grasses and potential forage crops in the National crop variety list

Crop / Pasture grass	Oldest entry on the variety list	Latest addition to the variety list	Number of varieties	Dual Purpose	Percentage of varieties with animal fodder indication
Maize	1965	2018	352	5	1%
Sweet Potato	1998	2015	28	3	11%
Pigeon peas	1981	2018	13	1	8%
Soya	2009	2014	10	2	20%
Sorghum (bicolour)	1970	2018	43	7	16%
Oat	2018	2018	2	1	50%
Rhodes	1960	1976	3		100%
Seteria	1956	1956	2		100%
Panicum	1955	1955	1		100%
Lucerne	2015	2015	5		100%
Brachiaria	2016	2016	3		100%

Maize, pigeon peas, soya, sorghum and oats are grains or grain legumes while sweet potato is an edible root. All are bred for human consumption while in the national crop variety list reference is made to dual purpose, green stems, vines, forage, livestock or animal feed if the crop - or part of the crop - can be used to feed dairy cows.

Worldwide, specific forage varieties of maize and sorghum are used because of different traits and characteristics when grown as feed for livestock. No reference is made to the nutritional value or quality of the crop in relation to its use: animal feed for ruminants. The National crop variety list shows that pasture seeds and forages are not a focus point in the formal seed sector. All forage crop varieties used in the Kenya market must be the conclusion, are reproduced, multiplied and distributed through the informal market. This in stark contrast with the objectives laid down in 1956 when Kenya Seed Company was started to produce certified and improved pasture seed for farmers in Kenya.

Informal seed sector

The informal seed sector has been in operation in Kenya particularly for the small scale farmers. This includes KALRO that is reproducing forages that are not registered on the National crop variety list and are distributed tom farmers for further multiplication, vegetative as well as generative. According to the National Seed Policy document for Kenya, the source and quality of most of the planting materials and seed purchased, multiplied and marketed by the informal seed sector may not be known, yet this is the major source of planting material for the farmers. In this (informal) system, maintenance of distinctness, uniformity and stability (DUS) of seed may be compromised and is therefore not guaranteed. This is not an ideal situation and system to drive sector growth.

Proper functioning (forage) seed systems are essential to agricultural development and food (incl. feed) security. In Kenya – as in most other countries in East and Southern Africa, it can take several years to register new seed varieties. This is often true even when the varieties are already available in neighbouring countries or fellow member states of common trading areas such as EAC, COMESA or ECOWAS (Kuhlmann 2015). Slow (or non) registration contributes to restricting farmers' access to improved seeds, and therefore further limits their ability to increase yields. Some of the species originate from this region and were improved through breeding programmes in other tropical countries (Australia, South America, South Africa), but improved varieties now have difficulties to return to their "motherland".

In this context it is surprising that importation of bull semen with high genetic potential is encouraged and stimulated in Kenya, yet importation and consequent registration of improved quality forage and pasture seeds on the National crop variety list is not actively encouraged. The only pasture grasses registered in the past 2-3 years are the Brachiaria hybrid varieties Cayman, Cobra and Mulato II. This increases the gap between the genetic potential of dairy breeds and the quality forages that are needed to feed these dairy cows adequately, reduce cost of production and make them a profitable investment for the dairy farmers who buy these cows (or their bull semen).

Greater regional harmonization of seed policy would have major benefits. Mutual recognition of varietal registration and easier movement of seeds between countries, would significantly reduce costs and delay in introduction and registration. Other policy changes would simplify and increase the transparency of procedures related to import/export licenses, certificates of origin, and phytosanitary controls (Kuhlmann 2015). Taken together, these measures would greatly stimulate suppliers' and farmers' investment in seeds, and in other yield-raising inputs such as fertilizers.

The Kenya Climate Smart Agriculture implementation framework 2018-2027 further states that GOK will promote adaptation interventions and appropriate mitigation that leads to reduced GHG emissions intensity from the agriculture sector, without compromising productivity. It will do so by promoting efficiency in livestock production systems, appropriate livestock manure management and formulation of feeds (including forage-based rations) and feed additives that improve efficiency and reduce enteric fermentation.

Section II. Observations and Recommendations

1. Observations

2. Recommendations

3. Epilogue

1. Observations

From the desk study, the field visits, the interviews and the responses to the questionnaire, the consultants identified a number of constraints that have been listed at the end of each of the chapters of the previous Section I: Survey Results. These can be summarized as follows:

- Limited access to - and availability of - improved forage seed/plant material.
- Mismatch between policies of Government departments for “breeding” and “feeding”.
- Seasonality of forage production (highly rain dependent).
- Insufficient quantity and quality of forages and pastures.
- Use of very low digestible forages.
- Low quality forage in the forage market.
- Low feed efficiency/high feeding cost due to low quality forage and unbalanced rations.
- Absence of reliable forage & feed testing facilities.
- Inefficient forage utilisation (Low FE) due to poor quality.
- Inefficient forage preservation (and ineffective).
- Lack of evaluation of feed cost and pricing based on nutritional value, trading standards not based on quality indicators (DM, ME, CP).
- Lack of forage development plan on farm level, but also regional (e.g County) or national.
- Low skills/education level on forage production and preservation.
- Weak relation between agronomy of forages and animal nutrition.
- Low level of mechanisation.
- Limited forage crop options and possibilities for crop rotations.
- Subdivision of land and urban expansion.
- Climate change.
- Weak link between health, food safety and feed safety.

The majority of Kenya`s dairy cattle farms are in the “cool/warm and wet high/medium altitude region” (AEZ: I, II, III, IV) (Annex 2). The zones have a big potential to be self-sufficient in production of forages like pastures and legumes and other forage crops, as needed to maintain a productive dairy system. The cut-and-carry feeding system is predominant, but many farms are under semi-zero grazing systems, with Napier grass as the main or supplementing forage. These regions have the greatest potential for dairy development and include, in some cases, the most densely populated areas within a potential market for dairy products. Arid and semiarid areas on the other hand are low population density areas, characterised by high temperatures, fragile soils and poor vegetation covers.

There is in most areas an acute shortage of supply during the dry season and the available forages during this period is of very poor quality. This leads to poor nutrition, which results in low production and reproductive performance, slow growth rate, loss of body condition, and increased susceptibility to diseases and parasites. So far, all or most efforts made by stakeholders on forage production have focused on volume rather than quality, often because the concern was on maintenance of the animal and stocking rates, especially in the arid and semi-arid regions.

If the target is animal productivity and requisite breeds, forage quality should get more priority and be linked to animal nutrition. For this, many aspects of the forage production process need to be considered, including the use of improved forage varieties, forage management and agricultural practices, forage planning and preservation (seasonality, climate change), mechanisation, feed testing and education/training. All these aspects need to be addressed together instead of individually, meaning to connect plant science (agronomy) and animal science (ruminant nutrition). This plant-animal relationships is depicted in Figure 7 below. The relationship between forages/fodder and the animal, is by evaluating and steering on the quality of forages (in the black circle), not just on volume.

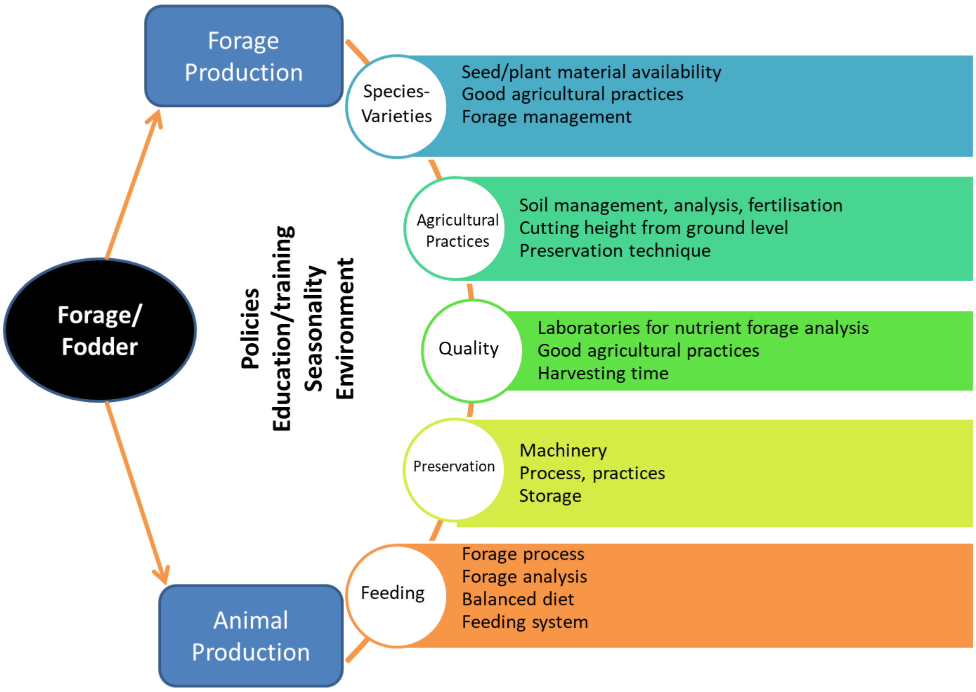


Figure 7. Key aspects that need to be considered to improve the forage sector

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 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. Forage preservation practices, particularly hay and silage making, should be much improved and 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.

In the **medium to long-term**, important points to consider are: 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, introduction and use of appropriate technology and machinery for forage production and preservation, inputs (i.e. planting material, concentrated dairy feed, fertiliser, veterinary drugs, etc.), feed and forage testing facilities, and 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.

2. Recommendations

Innovations need to be fast-tracked to keep improving forages and the forage sub-sector to create positive impact in the dairy production areas. These innovations should:

a) Address different aspects of the chain, from seed to feeding.
b) Intensify sustainable production and maximize profitability of dairy farming to be competitive.
c) Involve all stakeholders.
d) Link plant science (agronomy) and animal science (ruminant nutrition) to increase feed efficiency
e) Need to be environmentally sustainable.
f) Have a strong education and training component together with extension services and monitoring of the new innovations to ensure their success.

In addressing the forage value chain, focus should be on "forage species", including seed and plant material availability, "forage quality including feed safety", "management of seasonality" together with new preservation techniques and mechanisation, "smart agricultural practices", and "rangelands restoration and management" with the aim to intensify environmentally sustainable forage production.

Forage species/cultivars/varieties

Improved or new forages (species/cultivars/varieties) need to be either developed (slow) or imported (fast), and locally tested. Good quality seed and plant material (certified) should be easily accessible to farmers. Emphasis to reduce the fibre content (NDF) in forages through introduction of improved (species/cultivars/varieties) and better agronomic practices can eventually result in increased milk production, lower intensity of enteric methane production and an increased margin above feed cost therefore increasing the competitiveness of the Kenyan dairy sector. Demonstration plots need to be wide spread and easily accessible for farmers while training/extension process should be carried out with main emphasis on best management and good agronomic practices for the new species/cultivars/varieties introduced.

In the short-term, forage species currently used, such as Napier grass, Rhodes grass, Kikuyu grass, maize, sorghum, natural (native) grassland, and others need to become available or improved with focus on quality (nutritive value and digestibility). This includes agronomic practices like intercropping, fertilisation, crop rotation to improve DM yield, nutrient yield followed by optimal animal performance but also harvest and post-harvest practices (e.g. cutting interval, stage at harvesting). Training in good agricultural vocational skills for farmers to put them into practice is key combined with good (visual) examples on e.g. model farms.

Table 14. 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

The identification of better dual purpose food/feed varieties already in the market is required, especially for cereal, pulses and oil crops. The point to be made here, is to strive for varieties where the crop residues or by-products have better nutritive value and digestibility then so far and – hence – a higher impact on livestock performance. The looming protein shortage in the nearby future will also require increased acreages of high yielding protein crops. An increase of the acreage of leguminous crops combines well with conservation agriculture through intercropping or crop rotation. Dual purpose or forage varieties for maize, sorghum, oats, and others cereal crops are required in the market, to boost production and productivity of dairy cows and other ruminants. To make maximum use of these forage crops and forage production to stay competitive with food production specific management skills and knowledge is required.

Also extensive farming systems like silvopastoral management and other forms of agroforestry require detailed knowledge and skills in order to work within the complexity of these systems. An understanding of hierarchical relationships within ecosystems, and recognition that defined ecosystem-boundaries exist primarily for managerial convenience, are essential to this concept (Jose S., Dollinger J., 2019).

Table 15. Potential innovations for cereal crops

	Corn Silage: High chopped corn silage is a practice that is used in many countries with the idea of harvesting a more nutrient-concentrated and digestible forage. (Barber D., 2018)		**White sorghum silage:** Silage using only the head of the plant. To preserve high energy concentrate product and increase starch digestibility. The rest of the plant can be fed fresh after being chopped. (Barber D., 2018)		**Forage sorghum silage:** is a very interesting alternative for surplus forage. Also when the forage for any circumstances has passed the ideal stage to be grazed. Cutting height and cutting stage. (Barber D., 2018)		**Oat-Vetch:** The mix of oats/vetch improves nutrient yield and soil conservation. Varieties, seed rates and harvest time need to be chosen according to agro-ecological and soil conditions and production targets But before piping stage to encourage re-growth (africa-rising.net)	
	Normal (10cm)	**High Cut (40 cm)**	**Silage WP**	Headlage	**Grazing**	**Silage**	**Oats**	**Oats/Vetch**
t DM/ha	18.50	17.00	12-18	5-7	9-18	8-16	10-15	10-15
DM (%)	40.4	41.4						
ME (MJ ME/kg DM)	10.8	11.3	9.46	11.3	9.1	7.8	10	10.1
CP (%DM)	8.9	8.9	12.2	13.2	11	7.5	12	15
Starch (%DM)	38.7	41.7	20.5	47.5	0	12.3		
NDF (%DM)	37.2	32.2	48.5	25.0	52.7	56.2	50	40

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. The introduction of high quality seeds of energy or protein rich forage crops, already available in other countries with similar climate conditions, will make it more attractive for commercial forage seed suppliers.

Collaboration between regional, national and international institutions working on forage and pasture grass development is needed, but this should be linked to animal scientists specialized in ruminant nutrition. New species/cultivars/varieties with high potential nutrient content, especially energy and protein need to be introduced and tested on their suitability for different AEZs and feasible animal production target (milk/growth/weight gain). New (forage) maize and sorghum silage varieties, specifically those with the best performance in energy production should be introduced, and high protein species like *Desmodium,* lablab, lupins, lucerne*, Sesbania,* should be selected and distribution systems set in place and knowledge on best practices and use disseminated.

The added advantage of these species is that, depending on AEZ and soil conditions, they could fit very well in a crop rotation plan. To facilitate increased access by farmers to seeds, plant material, forage shrubs and trees, the following activities could be carried out: on-farm micro nurseries, forage seed production, plant parts for propagation, and nurseries of multi-purpose shrubs/trees (fruit, wood, fuel, and forage trees).

Feed safety

A variety of products and strategies are available to mitigate the prevalence and the effects of aflatoxin in dairy cattle. With increased emphasis being placed on prevention, practices to curb mycotoxins incl. aflatoxin intake by animals begin with choices made in the field, including the selection of seed (hybrids), effective tillage (crop residues), crop rotation, harvest practices and storage. Farmers should be aware of the weather conditions during the growing season that favour the growth and development of moulds and thus the production of mycotoxins.

Storage and processing of grain- and finished feed but also of hay and dried forages should be carried out in a clean, dry space where there is adequate ventilation as well as protection from rainfall and microbial contamination. Silage on the other hand needs to be excluded from oxygen within 12 hours to stimulate the anaerobic fermentation process while feed out needs to cover 1.5 – 2 meters per week to avoid heating and mould growth in the silage bunker. Reference is also made in regard to mycotoxins in animal feeds to the Proposed Dairy Industry Regulations (2018) of Kenya Dairy Board.

Table 16. Strategies to reduce mycotoxin levels in forages

Practices to reduce mycotoxin risk in forages
Crop rotation
Soil testing and fertilisation to nutritional level of crop
Varieties selection
Field crop residue management (land preparation)
Harvesting time according to weather conditions
Mechanisation, to improve preservation process (faster, more efficient)
Preservation process adjusted to the conditions (weather conditions, field conditions, crop conditions)
Preserve crop only if fermentation process can be successful. (e.g. do not remove seed heads, keep distance short)
Use of right inoculant (Inoculant to reduce fungal growth)
Storage and storage management (monitoring moisture, temperature, damage)
Awareness
Standards

Management of seasonality

An increase in the availability of quality forages throughout the year is needed, to reduce the fluctuations 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 (see Table 17).

Table 17. Tools for seasonality control

Target	Innovation	Bottleneck
Improved species/cultivars/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	

At County level feed or forage inventories should be made for the high potential dairy Counties, in line with the National Feed Inventory and Feed Balance Assessment (GoK and FAO, 2019) that was carried out for 23 ASAL Counties. As is suggested for ASALs, this could be coupled to Counties or dairy cooperatives institutionalising a strategic forage reserve, preferably in partnership with commercial forage producers.

Commercial production of forages should be further promoted to increase the forage offer in the market, not only in terms of volumes but also as regards quality of forages and pastures. Ideally forages are grown on-farm, but a large section of dairy farmers have insufficient land, labour and/or capital to produce and preserve their own forages.
Demand for forages will further increase in the near future, not only in the high potential dairy Counties but also in ASAL. 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, availability at scale of appropriate certified forage seeds for new forage species/cultivars/varieties, 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, to facilitate access to the latest and best (scaled) machinery, technology, increased capacity and preservation methods. Improvement of the current forage preservation (hay, silage) practices using farm-level techniques requires training/education as well as access to better and new machinery. This includes higher capacity forage choppers/harvesters with kernel crushers and intensive mechanical conditioning of forages under favourable conditions, multibalers, precision choppers, etc. Grass silage can be promoted and alternative preservation methods such as haylage, dehydration, pelletization, compaction, treatment of crop residues and other technologies need to be considered. This involves installation of static plants for dehydration and/or compaction or pelleting, to reduce volume could also be considered.
It is important to optimise the forage supply chains through good production and preservation practices, appropriate farm machinery and logistics with a high capacity and use of high yielding forage seeds varieties. This increases production per acre and nutritive value in the dry matter. Investments in innovation, knowledge and skills for forage production are crucial.

Farm level

In the process of upscaling and increasing interest for silage, it needs to be understood by forage producers and dairy farmers that fresh chopped maize needs to be ensiled close to the field where the crop is harvested. The silage pit should be compacted and closed as fast as possible, or the bales compacted and sealed to avoid respiration losses. Maize from which the cob has been removed will not make a good quality maize silage, due to loss of sugar and starch resulting in poor fermentation and nutritive value; on feed out it will easily heat up and is susceptible to moulds.

To manage seasonality on farm level, it is most advisable to make feeding plans (with the requisite budget) that covers the whole year with some allowance for unpredictable rainfall and prolonged droughts. This will enhance drought resilience at farm level. Such feeding plans will depend on the agro-ecological zone. Storage capacity and preservation methods need to be improved and implemented.
Seasonality management can also be enhanced by improved water management: e.g. drip irrigation, rainwater and runoff water harvesting including water ponds, earth dams, plastic-lined water ponds, water pans in rangelands, and solar/wind water pumps.

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 (AEZ and soil conditions), all contribute to more climate resilient farming systems. Herd management, herd record keeping systems,

and the calving/mating season need to be considered, especially in rangeland areas where irrigation or water management innovations could be more difficult to apply.
All these measures can help stabilise the market throughout the year and improve the capacity to feed the animals and maintain their productivity all year around.

Smart agricultural practices

In summary, numerous interventions, technologies and modalities can be used to improve the forage situation in Kenya. Some require new technology and considerable investments. Smart agricultural practices related to forage, start with the selection of the right forage species/cultivars/varieties that are well-adjusted to the farming system and local conditions (soil, water, climate), and need to be reflected in animal production. Many of these practices are based on reinventing and reorienting current practices, rather than heavy investments, and are shown in Table 18 below.

Table 18. 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
	Total diet ration balancing	Feed efficiency Maximise profits
Machinery	Direct drillers	Yield-quality (grasslands)
	Conditioners	Quality
	Precision choppers	Quality
	Multibalers	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

Rangeland restoration and management

Over-sowing or re-seeding natural grasslands/rangelands with grasses, legumes, shrubs and trees to restore degraded areas, to 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 conservation, water conservation and forage production in those areas.
A right balance between feed supply (carrying-capacity) and animal demand (requirement for livestock and wildlife) needs to be considered in these natural grasslands and rangelands, which include most of the country (>80%). Natural occurring (native) species in these areas need to be prioritised for soil restoration, but improved species adapted to the conditions should also be considered for improved productivity of rangelands systems and commercial forage production.

Over-sowing and re-seeding techniques need to be developed for each agro-ecological (zone) or landscape. Some techniques that can be used are air seeding (plane), bomb seeding, pellet seeding, coated seed (hydrogel, antibirds and insecticides). To increase the efficiency of these techniques, high instant stocking rates after seeding is recommended to increase seed-soil contact. Some less effective practices could involve seeding through the animals grazing pasture when the grasses are in the seeding period, and moving animals from these pastures to other areas for reseeding through their droppings. The animal’s movement to reseeding areas needs to be made on a daily basis.

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.

The temporal exclusion of grazing animals applied at the beginning of the wet season, allows an increase of rhizomes biomass production in natural pastures with a long history of overgrazing. This response occurs due to the predominance of tropical grasses with creeping growth habit, which also have a high above-ground/below-ground biomass ratio. In this sense, at the beginning of the wet season, deferment could be recommended as a sustainable practice to restore overgrazed grasslands. 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.

Productive grade dairy farms can be developed but under special design and with high investment. Pasture resources can be developed in several ways including (i) an improved distribution of water points and a reduction of overgrazing; (ii) increased primary production through land use intensification in a sustainable manner, (iii) reseeding of denuded rangeland, (iv) grassland conservation; and (v) by balancing stocking based on carrying capacity of the natural grassland.

The improvement of rangelands and communal pastures is complex and requires political, social, economic and cultural agreements and acceptance, next to significant financial and management resources. This is further complicated when there is different land- and water-use and interaction e.g. between pastoralists and wildlife conservancies or national parks, wildlife migration routes, and/or expanding large scale commercial farming. Hence, strategies for sustainable rangeland management and rehabilitation need to take a multi-disciplinary and landscape approach.

Knowledge and skills, management capacity

Great emphasis must be placed on the development of knowledge and skills needed to successfully introduce and manage good 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 environment. 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 is missing in Kenyan agricultural education and training programmes. This should be introduced and implemented vigorously at relevant Universities and training institutes in Kenya. Further to this dissemination of knowledge to the farmer, how to plant and take care of newly introduced forage crops, how to preserve and incorporate the new forage crops in a ration for dairy cows is essential to successfully transform the forage subsector to remain profitable and competitive in the future.

Feed testing

Steps can be made in this respect, even in the absence of accredited laboratories for adequate forage analysis with calibration sets or regression lines for tropical forages. In maize forage for example quality of the silage can be assessed through observation of e.g. physiological state, size of chopped maize, presence of whole kernels, moulds, smell, temperature of silages) and of the practices used such as fertilisation, planting, stage of harvesting, stem/leave ratio, stubble height, use of a kernel crusher, speed of work, compaction and coverage. The same applies to hay where the grass is not fertilized and harvested when it is overgrown, long after flowering (CP reduces and NDF increases).

It is better however to facilitate the sector with accredited and professional feed testing facilities (stationary or in future handhelds) that have access to NIR regression lines for tropical forages. These NIRs 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. Application of feeding standards by dairy advisors and farmers, requires information on the nutritive value of available feed ingredients, the amount of feed intake, and the requirements of the animals.

Table 19. Potential innovation for feed and forage analysis laboratory

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

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, the involvement of 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 forage production on GHG emission but it is safe to say that feed efficiency (FE), 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. When there is an increase in cows' feed efficiency a smaller amount of nutrients is excreted.
Thus, feed efficiency impacts economic efficiency and environmental aspects, more specifically at the level of enteric methane emission per litre of milk or per kg of meat (methane intensity). It needs to be mentioned here that we are aware that next to animal products (milk, meat, draught) ruminants also play an important role in the social activities of Kenyan livelihoods but more research is needed to determine the impact on reduction of intensity of methane emission.

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 or sustainable application. 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. Epilogue

Most of the stakeholders interviewed have identified forage quality and scarcity as the main factors to enhance growth and competitiveness of dairy (and beef) sector. Over the past years, many farmers and other stakeholders (e.g. agricultural contractors, dairy cooperatives, dairy advisors, government officials and researchers) have increased awareness regarding the value and importance of forages in the ruminants ration, either fresh or preserved (dried/ensiled).

Also new investors in commercial forage production are now targeting practices and products with higher nutritional value, even though this is still in some cases a pilot stage. To take advantage of this growing awareness and understanding of the need for year round availability of quality forages. These can be summarized in the following steps and direction and recommended to all Kenyan stakeholders.

- Fast track access to new (better) certified forage species/cultivars/varieties through facilitating and stimulating private seed companies to import and register suitable seeds, hand in hand with local research.
- Promote and make use of new species/cultivars that have recently been introduced, such as *Brachiaria* and *Panicum*, and campaign for best management practices from land preparation, seeding to feeding.
- Improve agronomic practices, and efficient use as ruminant forage of currently and commonly used species such as Napier grass and Boma Rhodes grass
- Promote and improve preservation practices and methods – those currently used and new ones – and facilitate access to new technology.
- Recognise investors in commercial forages and agricultural forage contractors as entrepreneurs; create enabling environment for investments to expand commercial forage production and mechanisation.
- 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 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 and connect forage production and animal nutrition in student education and farmer training & extension programmes.
- Link forage and animal production sectors to create a dynamic cooperation and "growing together approach".
- Encourage and implement for good practices from seed to feed focused on optimum productivity, maximum and safe quality and sustainability of agro-ecosystems (conservation agriculture, reduction of GHG-emission intensity).
- Rehabilitate and conserve rangelands.
- Improve soil and water management and use, focused on future generations.
- Intervene in the forage market and set up strategic feed reserves in areas prone to drought and climate shocks.

In summary, non-availability of quality forage is a serious issue for all sizes of dairy farms. Also for those medium and large scale farmers that have sufficient land to grow their own forages. As expected, the magnitude of this problem varies from farmer to farmer, but it is clearly the industry's main constraint in order to reduce cost of production and utilize the available genetic potential. If the target is to intensify sustainable production of dairy cows, forage quality should get more priority and be linked to ruminant nutrition.

For this, many aspects of the forage production process need to be considered, including the use of improved forage species and varieties, forage management and agronomic practices, forage planning and preservation (seasonality, climate change), mechanisation, feed testing and education/training. All these aspects need to be addressed together instead of individually.

These steps address different aspects of the forage chain. To be successful in turning round the story of forages in Kenya and consequently dairy farming, this requires strong dedication of and coordination between stakeholders, for the proper execution of various innovations, training and follow up. To improve and accelerate adoption and implementation, these recommendations and related initiatives to enhance the forage sub-sector, Kenya Government must provide a conducive enabling environment. Below in Table 20 some key themes are suggested for reorientation or reforms.

Table 20. Policies and strategies to enhance the forage sub-sector

Topic	Strategy
Seed and plant material	Developing appropriate legislation to forage seed variety release and certifications Maintaining a commitment to develop, register and release new high yielding varieties Ensuring that the technical procedures are flexible and appropriate to forage varieties Ensuring that the seed quality standard is realistic in terms of species characteristics Facilities for processing and storage Supporting forage seed production activities Stimulating involvement of the private sectors Identification of distribution channels Providing credit facilities to seed producers/traders Suitable institutional arrangement 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
Feed/Forage	Recognize forage producers like feed processors Possibility to apply VAR system for forage producers Develop and legislate Animal Feed Resource Strategy Encourage and assist establishment of forage/feed processing plants Supporting business development services Develop feed & fodder quality control system (standards) Encourage and provide incentive for feed processers in the livestock development potential areas
Land	Revising of the land policy to incorporate the forage production/grazing areas Integrated land, water, soil resources development strategy Silvo-pastoralism/Agro-forestry expansion, Encourage forage bank establishment in potential feed deficit areas Improve pasture use through appropriate grazing land management system, Natural resources governance
Livestock	Animal breeding strategy Impose livestock tax and assign quota for stock control Stratification of livestock production system,
Knowledge	Restructuring extension services Rural training centers Intermediate degree for specially topics related with forage/animal production Facilitate access to social media and mobile apps to be used like teaching tool in rural areas
Research	Encouraging research on imported and indigenous plant materials Conducting research, training and extension in forage seed production Exchange of germplasm materials and beyond Reinforcing the extension efforts and accessibility of new forage varieties Coordinating research, training and extension Unified forage and animal production research
Finance	Promote rural financial institutions Adjust taxes system to forage/seed producers and service providers Promote rural insurance system
General	Improve roads Access to wireless telephone → information Rural electrification and /or solar power Support established of cooperatives and farms associations

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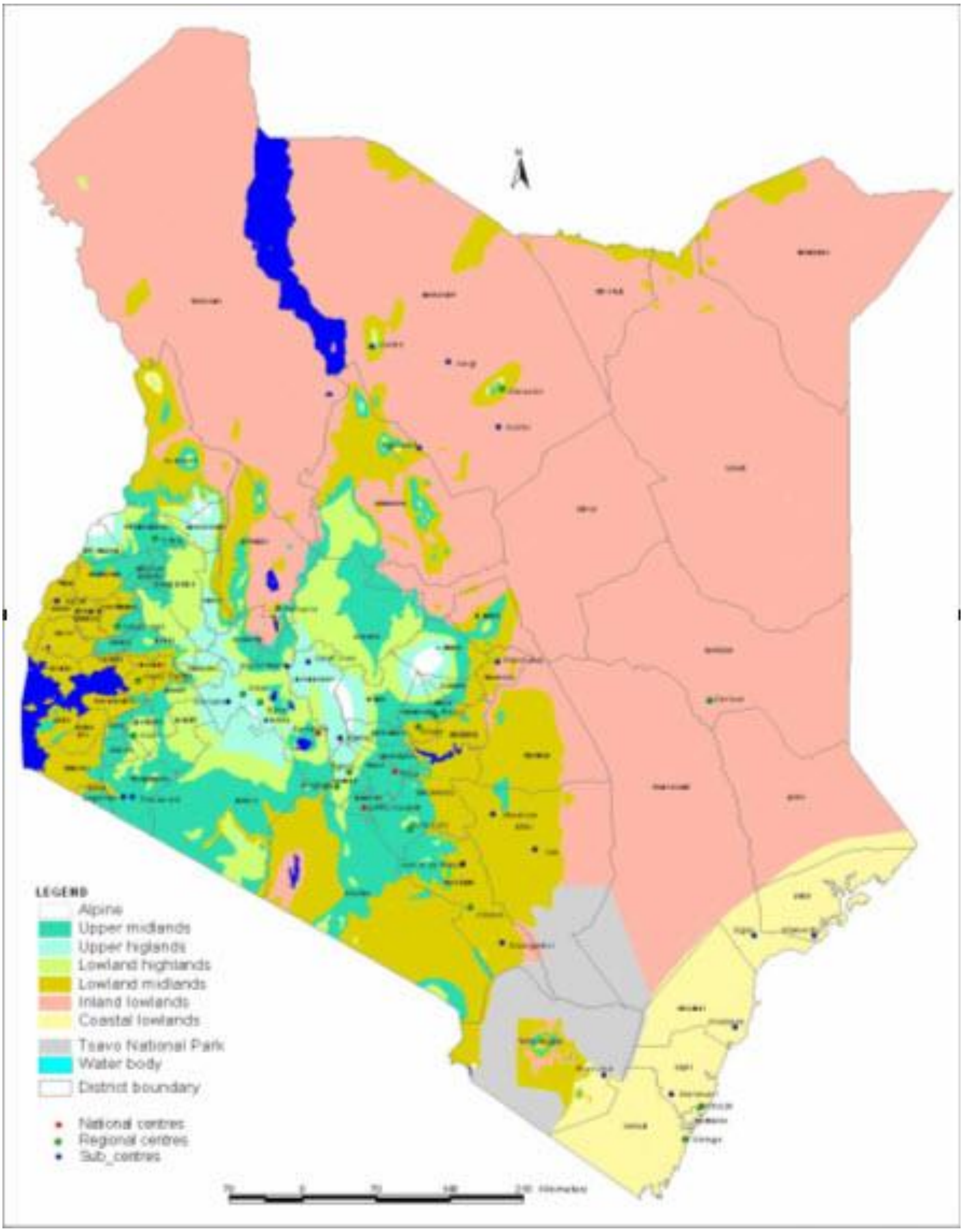
Annexes

Annex 1. List of key resource persons

Respondents to the online Questionnaire	
Name	**Organization**
1. Jane Leakey	Leldet Seed
2. Oscar Ingasia Ayuya	3R Kenya University of Nairobi
3. Dr. Nathaniel Makoni	ABS TCM
4. Dr. Hink Perdok	PUM Netherlands Senior Experts
5. Prof. Charles Gachuiri	University of Nairobi
6. Stuart Barden	AusQuest Farm
7. Humphrey Kiruaye	Pannar/Pioneer Seed
8. David Maina	Performeter Agribusiness
9. Dr. Ben Lukuyu (Uganda)	ILRI
10. Peter Francombe	Kenya Highlands Seed
11. Maina Kariuki	Brazagro
12. Joyce Mutua	AALE Ltd.
13. David Tum Tum	Simlaw Seeds
14. K.S. Subramanian	Advanta Seeds
15. Josephine Karui	Comfort Feeds
16. Frans Ettema	Landfort Consultants
17. Uwe Ohmstedt	CIAT
18. Dr. Piers Simpkin	FAO
19. Fabian Ayoro	SeedCo
20. Francis Ndungu	Pannar/Pioneer Seed
21. Paul Mambo	SNV
22. Solomon Misoi	SNV
23. Dr. Stanley Mutua	MALFI
24. Hamish Grant	Gogar Farm
25. Noah Chemirmir	Hay Producers Association
26. Dominic Menjo	Prime Minister’s Office
27. Frankline Biwott	Bayer
28. Nettie de Pater	Crop Nutrition
29. Angela Ngugi	Morendat Farm
30. Mr. Rao	RTI - Research Triangle International
31. Peter Gildemacher	KIT - Royal Institute of the Tropics
32. Hosea Sirma	Kenya Seed
33. Jaco Kellerman(SA)	Barenbrug SA
34. Stephen Mailu	KALRO-Lanet
35. Paul Sirari	Delamere Farms

Persons interviewed	
Name	**Organization**
1. Stuart Barden	AusQuest Farm
2. Dr Nathaniel Makoni	ABS TCM
1. Dr Stanley Mutua	MALFI
2. Janey Leaky	Leldet Seed Company
5-7. Dr John Muia, Dr William Ayako Dr Judy Kiragu	KALRO Naivasha
8/9. Dr Joseph Mureithi, Dr Elkana Nyambati	KALRO Nairobi
10. Dr David Miano	KALRO Kakamega
11/12. An Notenbaert, Solomon Mwendia	CIAT
13/14. Uwe Ohmstedt, Michael Peters	CIAT
15/16. Chris Jones, Svenja Marquardt	ILRI
17. Simon M. Maina	KEPHIS
18. Paul Sirari	Delamere
19. Frans Ettema	Landfort Consultants
20. Dr Hink Perdok	PUM
21/22. Eric de Jong, Johan Fieten	Agri Assis, AG Harvesting, FIT Ltd
23. Humphrey Lilan	Nundoroto Farm Company
24. Nigel Croft Adams	Laikipia Nature Conservancy
25. Martin Kiptoo Korir	Leketeton Farm

Annex 2. Agro-ecological zones (AEZ) in Kenya
(Source: Kenya Soil Survey 2007)



Annex 3. Influence of forage quality on milk production, margin above feed cost and enteric methane intensity (example Napier grass; based on Rumen8 ration calculation software)

Dairy Cow

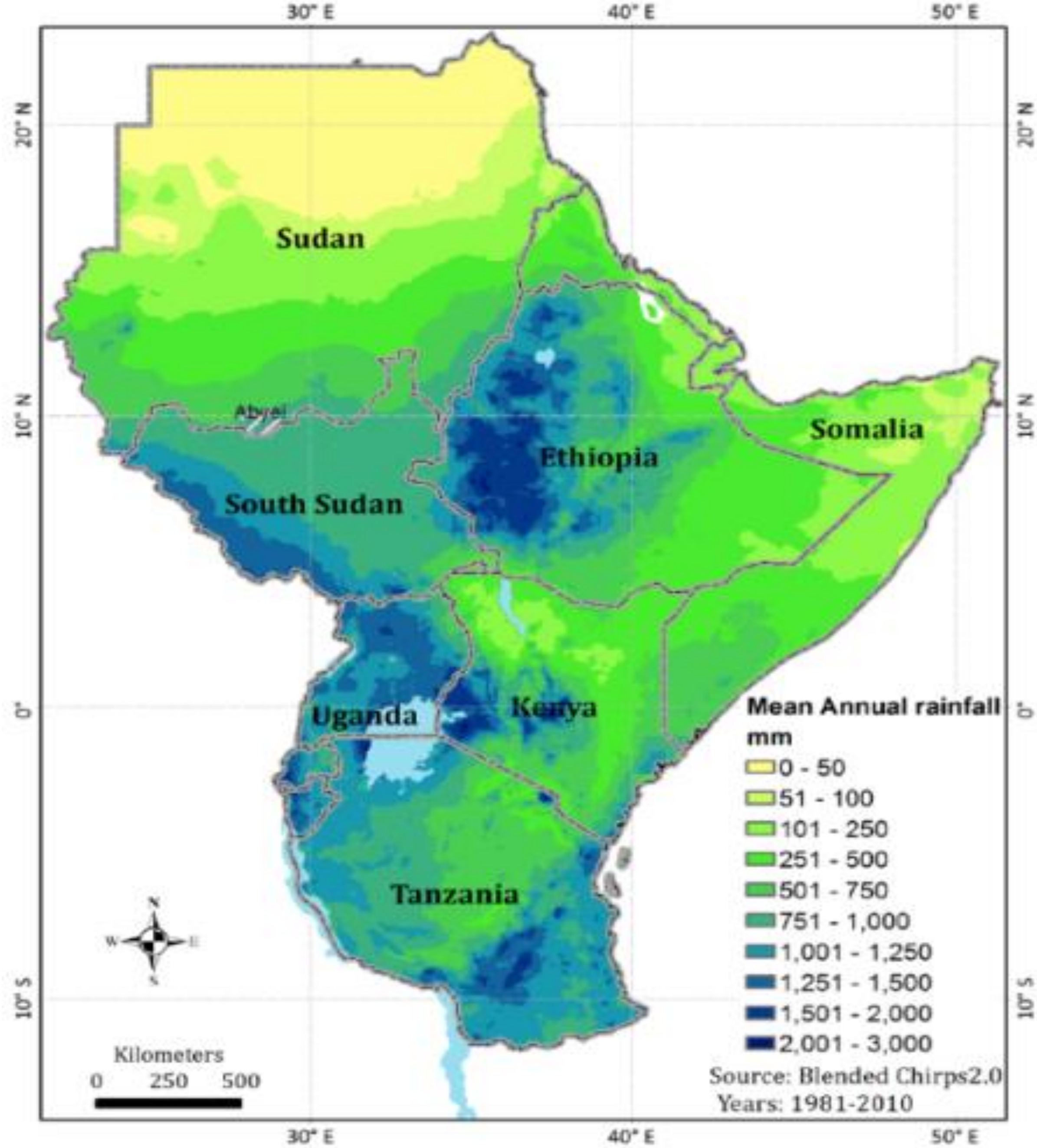
550 kg Body Weight
150 Days in Milk
70 Days Pregnant
365 Calving Interval
DMI = NDF intake at 1.3% of BW
3.7 Milk Fat
3.1 Milk Protein
Stall Fed
35 KES milk price

2	KES / kg Napier	Intensive Napier management regime (10 year cycle / 5 cuts per year / 20,000 kg/acre)
1.6	KES / kg Napier	Semi intensive Napier management regime
1	KES / kg Napier	Extensive Napier management regime (long overgrown Napier grass)

Forage crop & cutting stage	NDF g/kg DM	ME MJ /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	261.9	0
Napier = 120 cm	695	8.1	8.8	10.3	2.7	100	111	128.8	4
Napier < 60 cm low CP	630	9.0	12.5	11.3	6.4	100	132	51.4	115
Napier < 60 cm high CP	611	9.0	15.3	11.7	7.0	100	163	47.3	161

(Source adapted from Perdok, H. 2018)

Annex 4. Mean annual rainfall of East African countries
(Source Blended Chirps 2.0)



Annex 5. Kenya seed and vegetative material suppliers and producers

	Name	Species
Formal (certified) producers and supplies	Western Seed Company	Maize
	Agricultural Development Cooperation (ADC's) 7 large scale farms	Rhodes grass
	Leldet Ltd farm	Rhodes grass, Fodder sorghum (bicolor), Maize, Beans
	Ngongongeri farm	Rhodes grass, Maize
	KALRO- Kitale	Rhodes grass
	Pembeni farm	Rhodes grass, Fodder sorghum
	Kenya Seed Company	Maize, Columbus grass, Rhodes grass, Oats, Sorghum bicolor
Informal producers and suppliers	KALRO Muguga, Kakamega, Embu, Ol Joro Orok, Lanet, Naivasha, Kiboko, Mtwapa, Kisi,Mariakani, Matuga	Napier grass, Rhodes grass, Panicum, Clitoria, Dolichus lablab, Leucaena, Vetch Gliricidia, Mucuna, Siratro, Tree Lucerne, Desmodium, Clover, Sorghum, Sweet potatoes, Lupins, Calliandra, Edible Canna
	Gicheha farm	Guinea grass, Rhodes grass, Lucerne
	Bukura ATI	Napier
	Sang'alo Institute of Science and technology	Napier Clone 13, Bana grass, Napier Uganda hairless, Desmodium
	East college, Embu	Napier, Calliandra, Leucaena, Sesbania, Mulberry
	Karuga ATC, Meru	Setaria grass, Napier grass, Desmodium, Gliricidia, Calliandra, Mulberry, Sesbania, Leucaena, Sweet potatoes
	Kamweti ATC	Napier, Calliandra, Sweet potatoes (Musinya)
	Kenyatta ATC	Napier grass, Rhodes grass, green leaf Desmodium, Calliandra, Sweet potatoes
	Magaba ATC	Rhodes grass, Calliandra, Leucaena
	Mtwapa ATC	Napier grass
	Nomotio Livestock Improvement Centre	Rhodes grass
	Njabini ATC	Napier grass, Guinea grass, Rhodes grass, Setaria grass, Lucerne
	Ol Joro Rok ATC	Napier, Lucerne, Desmodium, Vetch, Sweet potatoes, Forage Sorghum
	Oyani Livestock Improvement Centre	Rhodes grass
	Wambugu ATC	Napier, Rhodes grass, Calliandra, Leucaena, Tithonia
	Ikinyukia CBO	Vetch, Lupin, Barley, Fodder Sorghum
Formal Seed suppliers	Hygrotech Ltd	Lupins, CowCandy
	Continental Seeds	Maize
	Advanta Ltd	Fodder Sorghum
	Coopers K Brand	Lucerne
	Tropical Seeds Ltd	Brachiaria Hybrids
	Amiran Ltd	Brachiaria Hybrids
	Fresco Seed Company	Maize
	Monsanto Dekalb	Maize
	Western Seed Company	Maize,
	Kenya Seed Company	Lucerne, Rhodes grass, Setaria grass, Guinea grass, Columbus grass, Oats, Desmodium, Cowpea

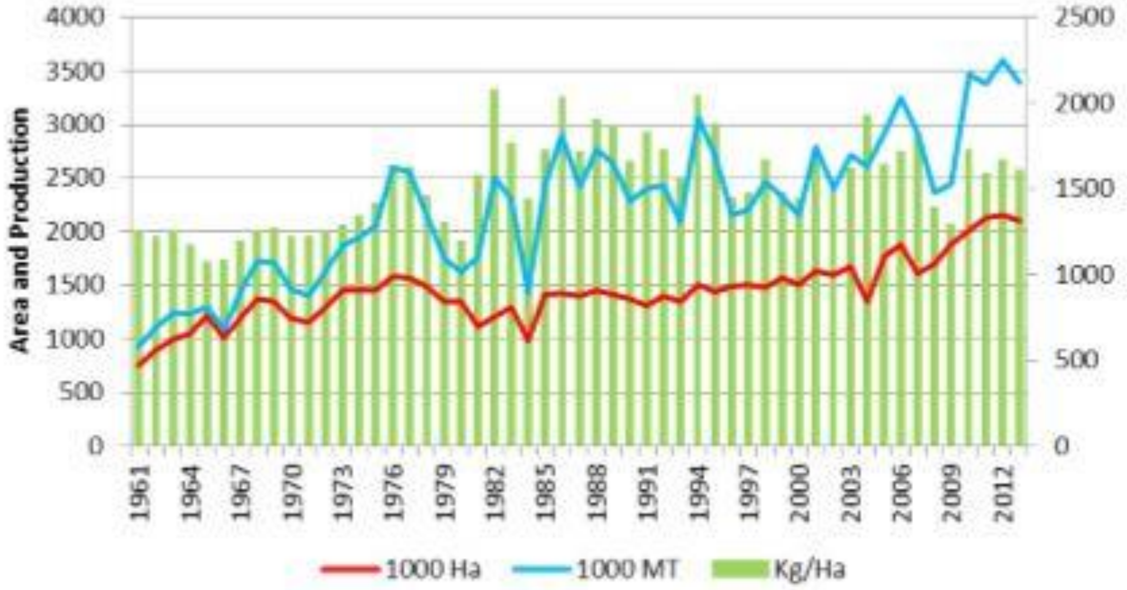
	Simlaw Seeds Company	Lucerne, Rhodes grass, Desmodium, Bermuda grass, Kikuyu grass
	Dupont K Ltd (Pannar Seed, Pioneer HiBred)	Maize, Dual purpose Sorghum, Lucerne
	Advantage Crops Ltd	Brachiaria hybrids
	East African Seed	Lucerne, Sorghum Sudan
	AgriSeedco	Forage Sorghum
Source: SNV 2013 / CIAT 2016 additional information		

Annex 6. Forage species in Kenya

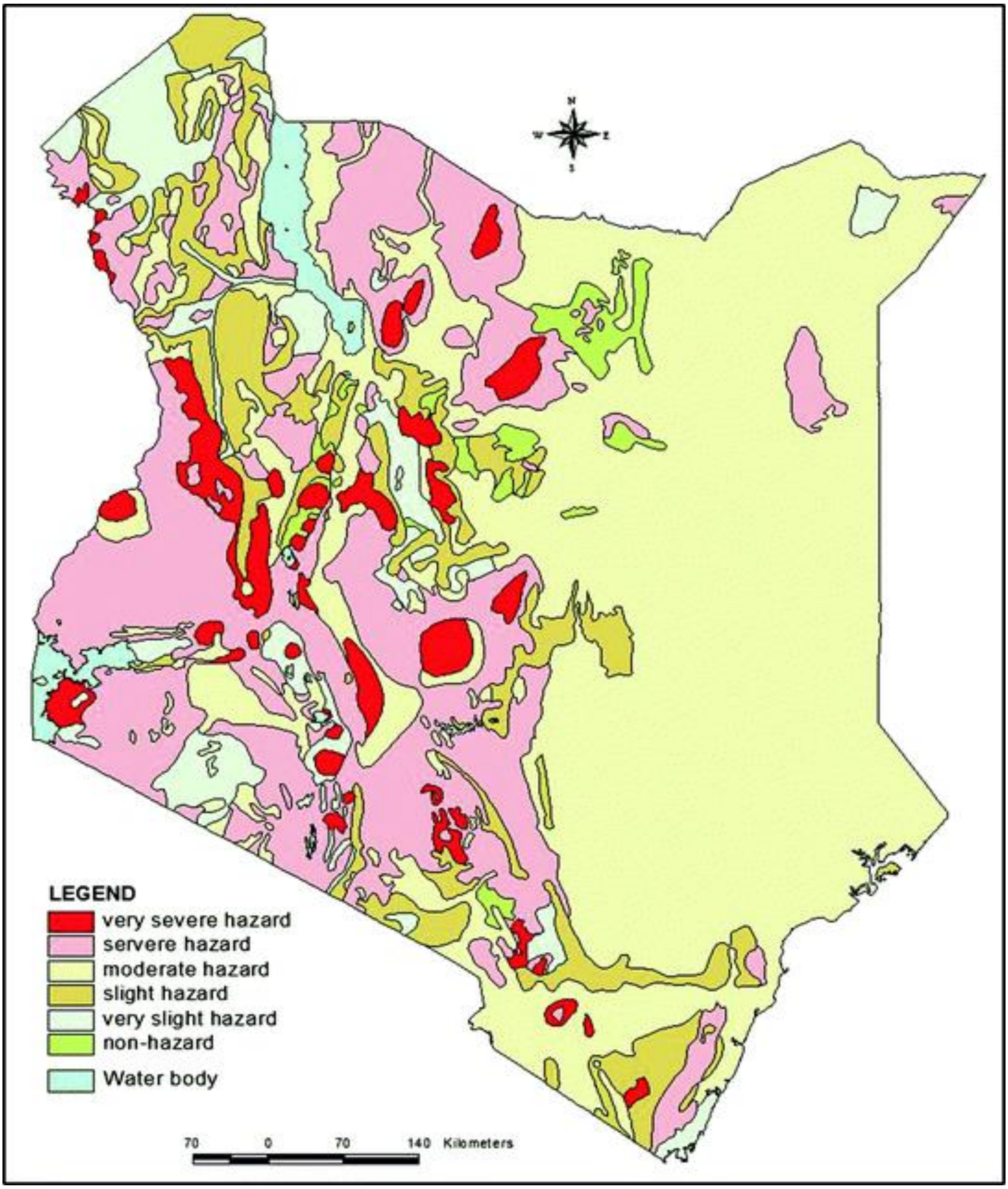
Common name	Scientific name
Acacia	*Acacia spp*
Needle grass	*Aristida adscensionis*
Oats	*Avena sativa*
Fodder beet	*Beta vulgaris*
Beard/Blue grass	*Bothriochloa insculpta*
Congo Signal	*Brachiaria Ruziziensis*
Bracharia varieties	*Brachiaria ssp*
Kale	*Brassica oleracea*
Turnips	*Brassica rapa var. rapa*
Calliandra	*Calliandra calothyrsus*
African Foxtail grass	*Cenchrus celiaris*
Rhodes grass (Katambora, Boma)	*Chloris gayana*
Chicory	*Cichorium intybus*
Butterfly/Blue pea	*Clitoria ternatea*
Sun hemp	*Crotalaria juncea*
Hemp varieties	*Crotolaria spp*
Star grass (Naivasha, Bermuda)	*Cynodon dactylon*
Star grass varieties	*Cynodon spp*
Lucerne tree	*Cytisus proliferus/Chamaecytisus palmensis*
Desmanthus	*Desmanthus*
Silver leaf desmodium	*Desmodium incanum*
Green leaf desmodium	*Desmodium intortum*
Desmodium varieties	*Desmodium ssp*
African Couch grass	*Digitaria abyssinica*
Jarra Digit grass	*Digitaria milanjiana*
Enteropogon	*Enteropogon macrostachyus*
Stink grass	*Eragrostis cilianensis*
Love grass	*Eragrostis superba*
Eustachyus	*Eustachyus paspaloides*
Tall Fescue	*Festuca arundinacea*
Zea Mays	*Forage maize*
Soybean	*Glycine max*
Perennial Soybean	*Glycine wightii*
Black spear grass	*Heteropogon contortus*
Giant Thatching grass	*Hyparrhenia rufa*
Sweet potato vines	*Ipomoea batatas cv Mafuta*
Lab Lab	*Lablab purpureus*
Leptochloa	*Leptochloa obtusifolia*
Leucaena	*Leucaena leucocephala*
Rye grass	*Lolium perenne*
Lupins	*Lupinus albus graecus*
Macrotyloma	*Macrotyloma axillare*

Common Name	Scientific Name
Lucerne varieties	*Medicago sativo*
Guinea grass	*Panicum maximum*
Panicum varieties	*Panicum ssp*
Bahia grass	*Paspalum grass*
Kikuyu grass varieties	*Pennisetum clandestinum*
Napier grass	*Pennisetum purpureum*
Tropical kudzu	*Pueraria phaseoloides*
Snout bean	*Rhynchosia spp.*
Sesbania	*Sesbania sesban*
Foxtail Millet	*Setaria italica*
Nandi Setaria Grass (Golden Bristle)	*Setaria sphacelata cv Nandi*
Giant Setaria	*Setaria splendida*
Wood grass	*Sorghastrum nutans*
Columbus grass	*Sorghum almum*
Forage sorghum	*Sorghum drummondii*
Sudan Grass	*Sorghum Sudanese*
Sorghum	*Sorghum vulgare*
Dropseed grass	*Sporobolus fimbriatus*
Velvet /Mucuna beans	*Stizolobium spp*
Stylo	*Stylosanthes guianensis*
Stylo (pencilflower)	*Stylosanthes scabra*
Red oat grass	*Themeda triandra*
Kenyan White clover	*Triflorum semipilosum*
Clover	*Trifolium repens*
Guatemala grass	*Tripsacum laxum*
Triticale	*Triticosecale*
Hydroponics - Wheat grass	*Triticum aestivum*
Vetch	*Vicia sativa*
Maize	*Zea Mays*

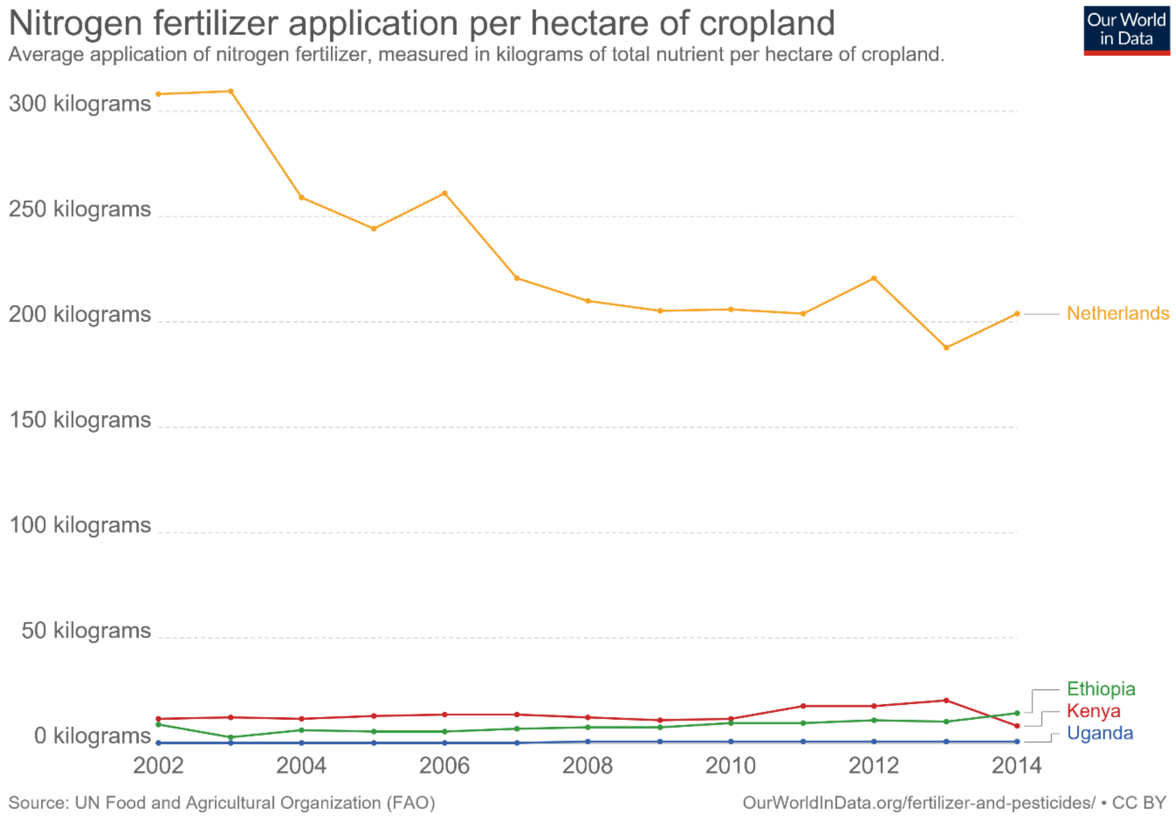
Annex 7. Total area under maize, production and yield per acre from 1961-2013



Annex 8. Kenya land degradation map (Source: Kenya Soil Survey 2007)



Annex 9. Nitrogen fertilizer application per ha of cropland in East Africa



Annex 10. List of participants validation workshop and workshop programme (26 June 2019, Ngong Hills Hotel, Nairobi)

	Kenya	
1.	Anton Jansen	SNV-KMDP
2.	Adolfo Alvarez Aranguiz	WUR-presenter
3.	Jos Creemers	SNV-presenter
4.	Solomon Mwendia	CIAT
5.	Chris Jones	ILRI
6.	Elkana Nyambata	KALRO
7.	Christoph Weber	ILRI
8.	Albert Mulwa	MALFI
9.	Joyce Mutua	AALE (Formerly KAVES)
10.	Nathaniel Makoni	ABS-TCM
11.	David Harvey	Land O'Lakes
12.	William Ayako	KALRO-DRI-Naivasha
13.	David Miano Mwangi	KALRO-Kakamega
14.	John Muia	KALRO-DRI-Naivasha
15.	George Odingo	RTI - KCDMSD
16.	Rita Laker-Ojok	RTI - KCDMSD
17.	K. S. Subramanian	ADVANTA SEEDS
18.	Mustafa Ghulam	CORTEVA
19.	Noah Chemirmir	SOCHON Ltd
20.	Waweru Nyangi	Rift Valley Hay Growers
21.	David Maina	PERFOMETER
22.	Catherine Kilelu	3R KENYA PROJECT
23.	Paul Sirari	DELAMERE Estates Ltd.
24.	Zippy Kerama	PERFOMETER
25.	Frida Njoki	SNV

Workshop objectives
1). Interactively discuss, review and validate the report's findings, insights and good practices.
2). Identify gaps in the current findings that need to be addressed in the final report.
3). Discuss challenges linked to the recommendations of the forage quick scan report

Expected outputs
1). Documentation of proceedings of the Validation Workshop
2). Validation of the forage quick scan report with inputs from the validation workshop
3). Based on the forage quick scan, inputs for a 5-8 page policy or strategy brief.

Key participants
Respondents to the Questionnaire sent for the Forage Quick Scan as listed in Annex 1 of the report.

Programme
9.00 am Welcome, round of introductions, opening
9.15 am Background of the Forage Scan (NEADAP project)
9.30 am Summary of the Forage Quick Scan Report: topics/structure
9.45 am Overview of the outcome of the questionnaire
10.45 am Summary of Forage Quick Scan Observations and Recommendations
11.45 am Summary of comments received in writing, quick inventory of gaps
13.30 pm Group discussions on selected chapters and recommendations
14.30 pm Feedback/presentations per group
16.00 pm Plenary discussion, summary and way forward

NEADAP

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