NEADAP
Netherlands East African Dairy Partnership

SNV

Working paper for NEADAP APPROACH FOR YEAR-ROUND FODDER AVAILABILITY

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Preface

J. Creemers, P. Chege, D. Kikwai, NEADAP approach for year-round fodder availability

This Working paper is a case study that aims to use the tools, developed by or rolled out by the Netherlands East Africa Dairy Partnership (NEADAP) program. The study is a collaboration between NEADAP, Agriterra, Baringo Agricultural Marketing Cooperative Union (BAMSCOS) and 24 member farmers; it describes 24 mixed crop-livestock farms in Baringo County, Kenya. The farmers are members of the BAMSCOS and they deliver milk to the Union for processing. The farms were visited during the period July - August 2023 by Peris Chege and Damaris Kikwai. The study used tools developed or scaled by NEADAP like the AgroCares Handheld NIRS scanner for soil and feed analyses, the NEADAP Forage Cost Calculator to calculate the cost of forage production, Rumen8 software application version 4.0.3.2 and SNV Tropical Feed Library 3.1, to formulate balanced diets with the available feeds, feed cost to simulate different feeding scenarios. Based on the recommended diets it makes a feed budget, feed plan and fodder crop plan. It gives recommendations for improvements in extension approach and strategies that can lead to increased availability of forage on farms, for better forage production practices and reduction cost of forages in diets of dairy cows. As regards the current situation, it illustrates on the hand of a lactation curve and 5 diets how the feed supply on most of the 24 farms is at times disrupted to support optimum milk production, growth, health and fertility of the dairy herd in Baringo County, Kenya.

The paper further gives directions and recommendations to adopt intensified sustainable forage production and enhance availability of quality forages, to transition an economically and environmentally sustainable dairy sector towards increased productivity and enhanced competitiveness. This Paper is submitted to Netherland East Africa Dairy Partnership (NEADAP).

Netherlands East African Dairy Partnership

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List of Abbreviations and Acronyms

BAMSCOS	Baringo Agricultural Marketing Cooperative Union
BCS	Body Condition Score
CIAT	International Centre for Tropical Agriculture
CH4	Methane
CP	Crude Protein
DM	Dry Matter
DMI	Dry Matter intake
DMY	Dry Matter Yield
EMEI	Enteric Methane Emission Intensity
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO statistical databases
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
Ha	Hectare
ILRI	International Livestock Research Institute
KALRO	Kenya Agriculture and Livestock Research Organization
KDB	Kenya Dairy Board
KEBS	Kenya Bureau of Standards
KEPHIS	Kenya Plant Health Inspectorate Service
KES	Kenyan Shilling
KG	Kilogram
KIT	KIT Royal Tropical Institute
KMDP	Kenya Market-Led Dairy Program
L	Litre
LW	Live Weight
LWC	Live Weight Change
MAFC	Margin Above Feed Cost
ME	Metabolizable Energy
MJ	Mega Joules
MoALFI	Ministry of Agriculture, Livestock, Fisheries and Irrigation
MP	Metabolizable Protein
MT	Metric Tonne
MY	Milk Yield
NIRS	Near Infrared Spectroscopy
NDF	Neutral Detergent Fibre
NEADAP	Netherlands East African Dairy Partnership
NEB	Negative Energy Balance
NGO	Non-Governmental Organisation
PMR	Partly Mixed Ration
PPP	Public Private Partnership
RF	Rumen Fill
SNV	SNV Netherlands Development Organisation
TLU	Tropical Livestock Unit
TMR	Total Mixed Ration
TONNE	Metric unit of mass equivalent to 1,000 kg
WUR	Wageningen University and Research

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Foreword

Livestock plays a vital role in ensuring food security, livelihoods, and incomes in Africa. It contributes 24% of the continent's agricultural GDP (AU-IBAR 2023). The livestock sector in Kenya, particularly beef and dairy cattle, contributes up to 42% of the agricultural GDP (ILRI, 2021) and plays a significant role in the livelihoods, nutrition, and incomes of rural households. However, livestock performance is constrained by lack of good quality and adequate quantity of feed.

Kenya is facing challenges in its feed and fodder sector (AU-IBAR 2023). With a growing population and diverse livestock production systems, Kenya needs to explore ways how to meet the feed demands of its livestock. The availability of feed is a key factor in ensuring the well-being of livestock, and subsequently, food security for the country.

The African Union reports in a press release that Kenya has "a 60 % feed deficit, resulting in a significant shortfall of approximately 2.6 billion bales of feed". Furthermore, it faces a 46% post-harvest loss in livestock feed.

Since livestock sector growth is key in supporting Kenya's GDP, there is a need for compatible growth in support systems, like improved forage production and feeding. A lack of quality and quantity of forages, which form the bulk of ruminant diets, often limit productivity and profitability. Frequent lack of forage affects animal health and productivity and may result in mortality which makes farmers vulnerable against the backdrop of climate change and degradation of landscapes.

Feed resources account for more than 55% of cattle production costs (Odero-Waitituh, 2017). The cultivation of improved forages enables livestock producers to sustainably increase milk and meat production. Permanent grasslands and use of improved forages contribute to reduced environmental footprint. However, for farmers in Baringo County who keep ruminant livestock, one of the most pressing challenges is timely access to quantity, quality, and affordable forages.

There is little information know about the average biomass yield for different forage crops in different AEZs in Kenya. The African Fertilizer and Agribusiness Partnership (AFAP) reported in November 2023, grain maize yields of 8MT per ha with farmers in Kenya who practice precision agriculture. The average yield in Uasin Gishu county was reported to be 5MT per ha, while Kenya's average is 1.7MT per ha. This is respectively 62.5% of a realistically achievable yield in Uasin Gishu and 21.3% grain maize yield in Kenya. In the case of forage maize, the grain yield is related to the biomass yield. Higher grain yield in forage maize production relates to a higher biomass yield and better nutritive value of the ensiled product. In the field the authors of this working paper made similar observations, because of low plant population and soil fertility biomass yield of forage crops were in many cases below 85% of what could realistically be achieved in years with sufficient rainfall. This is one of the reasons the authors found in this study that the cost of on farm forage production is very high, too high in some farms. The AFAP recommended addressing at scale, access to appropriate inputs (e.g. seeds, balanced fertilizer application inc. correction of soil acidity, crop protection and good agricultural practices) this recommendation also applies to improved forage production and need to be extended with best harvesting, conservation, storage and feeding practices.

Background

Building on the working paper “Quick scan of the forage sub-sector in Kenya” (Creemers and Aranguiz, 2019), NEADAP2 project developed tools which can guide farmers in East Africa on strategic and day today decisions namely the Forage Finder and the Forage Cost Calculator. The project further builds on experiences from the SNV Kenya Market-Led Dairy Programme (KMDP), The Inclusive Dairy Enterprise (TIDE) project and continued the roll out of Rumen8 diet formulation software in Ethiopia and Tanzania. It also contributed to further expand the possibilities of the AgroCares Handheld scanner for soil and feed analyses, with the option to test tropical forage crops. The idea came up for an integrated case study with a dairy cooperative in Kenya, in which the tools that are developed or rolled out can be used by farms coaches (extensions staff) to further improve their technical skills in forage production and ruminant nutrition and increase their ability to guide farmers in their day to day on-farm management decisions.

The study refers to the National Feed Inventory which was done by MoALD in collaboration with FAO in 2017 and which identified feed shortages or a feed surplus in all the counties in Kenya. The NEADAP study aims to build on the finding of this study and estimate the feed gap based on an assessment during field visits of 24 individual members farmers of BAMSCOS.

Despite other studies which mention that land size and allocation of land for forage production within households are limited, NEADAP aimed to test a three-way approach in order of priority as listed below, to ensure all year round (quality) fodder availability for dairy farmers.

- Stimulate and support farmers to plant improved forages on their farms because this is likely the cheapest way to produce quality feed for dairy cattle.
- Stimulating owners of neighbouring farms with land that can be utilized for forage production, to grow fodder as a commercial (cash) crop for the neighbouring dairy farmers.
- Planning and organizing fodder production by commercial large scale fodder producers for the members of cooperative thus providing the commercial fodder producers with a guaranteed market and the dairy farmers with a source of quality fodder during periods of scarcity (e.g. drought).

The study considers the economic feasibility of dairy farmers to purchase forages in the forage market for shorter or longer periods of time and the effect this would have on their margin above feed cost.

In May 2023 a meeting was held at the BAMSCOS Headquarters in Eldama Ravine, Baringo County, attended by representatives of BAMSCOS, NEADAP, and Agriterra. The aim of the meeting was to listen to the challenges and needs of BAMSCOS Cooperative Union and discuss if BAMSCOS is interested in piloting the approach proposed by the NEADAP project.

Strategies to promote forage crops.

BAMSCOS pointed out that their members are facing a shortage of forage and feed. The cooperative union has, in recent years encouraged farmers to plant forage sorghum (variety Sugargraze), forage pearl millet (variety Nutrifeed) and Napier grass (variety Pakchong) to reduce the shortage. In the highlands, which is the high potential area for milk production in Baringo, Forage oats, Sugargraze, Nutrifeed, Napier grass (var. Pakchong), forage maize and forage sorghum varieties are promoted as forage crops with the aim to harvest these crops and preserve the biomass as silage for feeding during dry seasons. In the lowland areas the cooperative union has been promoting the cultivation of Rhodes grass (farmers are requested to dedicate at least an acre of land). In addition, seeds of Sugargraze are available through the cooperative union and farmers are encouraged, depending on the size of their farms to plant 0.5-5 acres on their farms. The target is to cover 250 acres of improved forage crops (Sugargraze, Nutrifeed, Maize) for silage making to improve availability of fodder on the farms during the dry season. Next to these 30 acres of land are leased and set aside for hay production from

Rhodes grass. The Rhodes grass is harvested two times a year with a yield of 300-400 bales/acre per year. To support this strategy the union links these farmers, who produce the Rhodes grass hay, with forage seed suppliers. The suppliers of the forage seed, in return, share sales data with the board of BAMSCOS.

Cost of forage production and strategies to increase availability.

At the level of the cooperative union there is no information available on the cost of forage production at the level of individual farmers. BAMSCOS encourages farmers to adopt forage crops that are known for quantity and quality with bias to the protein content of the forage. They point out that farmers are mostly concerned about the biomass yield/acre. According to BAMSCOS, the decision to produce/cultivate forage by farmers is driven by availability and ownership of land within households and not on the feed needs of the herd. There are a few farms that produce surplus forage, especially maize grown for silage. Some of these farmers market the excess through the primary cooperatives or cooperative union.

Contract farming of forage crops, by the cooperative union, was experimented with in the recent past – about 2021 to 2022 – but stopped due to erratic weather patterns and consequently the risk of crop failure. The financial risk for the cooperative union and the forage producer was at that time to high.

The primary cooperatives have been buying baled silage for their members payable by check-off system, however the experience is that the cost of the maize silage is higher than the milk income the farmers receive in their account with the cooperative. The conclusion of the Union is that the silage does not lead to an increase in actual milk supply during the dry season and just covers the maintenance requirement of the cows.
Occasionally the cooperative union or the primary cooperatives take feed samples for testing at the KALRO lab in Naivasha.

Extension and training strategy

The approach which the cooperative union has used is to train farmers to produce their own forage and set-up demonstration farms within the area covered by the primary cooperatives. Five primary cooperatives have forage demo plots and farmers are trained on the importance and benefits of on-farm forage production. The preservation technique making use of fermentation processes commonly referred to as "silage making" is not widespread among the active members. The practice has recently been introduced and is not yet a yearly routine amongst farmers. The problem encountered is that the extension staff are too few and cannot manage all the farmers in the area. The ratio of farmers to the extension officer is 1000: 1 or more and the primary cooperative (PC) cannot hire more extension staff, the Union supports the PC's who are not financially strong enough with 3 extension officers. The situation has resulted in member farmers not having the capacity and skills to adopt the latest technology, agronomic practices and development of the dairy sector in Baringo is therefore not up to par with farmers in other milk producing areas.

Feed security strategy

BAMSCOS estimates that currently 10-15% of the member farmers are feed secure and that by the end of this year 20-25% of their members can be feed secure all year round. The aim of the cooperative union is to increase this to 40-45% to guarantee above minimum milk supply to the processing plant. The cooperative union confirm that member farmers, in general, have land available which can be set aside for forage production.

Methodology

The approach of this case study on all year-round forage availability for dairy farmers in Baringo is a combination of a questionnaire, interviews and field visits and the use of tools developed and/or rolled out under the NEADAP projects:

i. Introduction meeting between, NEADAP, Marco Streng, Damaris Kikwai, Agriterra, Wilfried Chepkwony, BAMSCOS representatives and ProDairy EA, Jos Creemers and Peris Chege.
ii. Preparation of a questionnaire and list of records/data that need to be collected from the farmers. The tools are a) AgroCares NIRS scanner for soil and feed testing, b) forage cost calculator, c) key data for Rumen8, feed planner and budget.
iii. Damaris, Peris together with Sharon Bundotich of BAMSCOS to identify farmers in the highland and the lowland areas of Baringo County.
iv. Field visits to the farms (interviews and data collection),
v. Data screening: sorting, analysis and validation,
vi. Report writing.

Chapter 1. Baringo Agricultural Marketing Services Cooperative Society (BAMSCOS)

1.1 History and organisation structure of BAMSCOS

The Baringo Agricultural Marketing Services Cooperative Society (BAMSCOS) was established in 2012. BAMSCOS has 22 primary cooperatives as their members, 17,000 member farmers of which 13,000 members are active (2023), its core business is collecting and bulking milk from farmers. In 2017 the cooperative society started implementing the extension strategy, followed in 2019 by the intensification of the extension services project that included review of the extension strategy. Agriterra supported BAMSCOS in implementation of the strategy by helping them to create more jobs for extension staff all this in close cooperation with the local government (Agriterra 2021). There are currently, May 2023, 16 extension officers training farmers who are members of these primary cooperatives (PC) but not all primary cooperatives have extension officers. The cooperative union intends to start processing milk under their own label and is in the process of finalizing a milk processing facility which is to be handed over to the cooperative union once all the processing equipment is installed and tested (Meeting notes 2023).

1.2 Growth and realization of goals

The goals of BAMSCOS are to Operationalize BAMSCOS' milk processing plant in 2024 and to increase the average milk deliveries to the union by more than 20% per year until 2024 (Agriterra 2021). For BAMSCOS growth and realization of these ambitious goals and long-term plan of adding value to their members, milk produce, on farm milk production and delivery of adequate volumes of quality milk by her members is key. While investing in milk handling facilities BAMSCOS and its members face challenges in realizing stable delivery of milk particularly in the dry season. Members usually suffer a lot during the dry months and total milk production fluctuates to a low of sometimes 6000 litres per day as compared to the targeted processing capacity of more than 100,000 litres per day by 2024. Fodder production - and thus feed availability – varies much and depends largely on rainfall.

This poses a serious concern and risks for both farmer- members and BAMSCOS as dairy cooperative. Increasing overall and stable milk production throughout the year is thus a key ambition for farmers -improving both household income and nutrition - and the dairy cooperative, creating a sustainable business. To realize this farmer members, need to adapt their farming practices and modernize their dairy system fitting the local context.

1.3 The farmer extension model of BAMSCOS

Government extension services are hardly reaching the field and other service providers like BAMSCOS need to fill this gap and advise their members. An important challenge BAMSCOS faces in this is to organize their extension to reach many farmers while keeping costs at manageable levels.

The extension system of BAMSCOS before improvements in the period 2019-2021 contributed to relatively low levels of extension advice adoption. It became evident that extension needs were not the same for all farmers. As a response, BAMSCOS undertook a simple survey on farmer needs and categorized the farmers in terms of their production system, production level per cow and interest shown in new technologies (see figure 1 below). BAMSCOS used this for targeting farmers and choosing extension approaches.

BAMSCOS' farmer categorization
A. Intensive dairy farmers, practicing zero grazing, average production 15 liters per day per cow, keeping records and using many innovations. Approach: Individual farm visits and phone calls for one-to-one extension, exchange visits and Farmer Field Schools.
B. Farmers with semi-intensive production systems and an average production of 10 liters per day per cow. This category includes those with cows grazing on natural pastures but supplementing lactating animals and willingness to change. Extension approach: Group training with lead farmers, exchange visits, field days, mobile phone messages.
C. Other farmers with a demonstrated interest in learning and adopting new technologies. Extension approach: Group trainings, exchange visits, field days, exhibitions.

Figure 1. Farmer categorization by BAMSCOS

Source: Veldhuizen, L. et all, 2021.

To support the extension efforts BAMSCOS also set up a demonstration field which purpose is to showcase to the members modern ways of establishing maintaining and conserving fodder as well as acting as a training center for its members. In this way members are motivated to replicate such practices on their own farms to address the perennial milk fluctuations

BAMSCOS realizes they need to focus more on inclusion of women in extension services as they are often not invited for trainings while they perform a lot of the activities in dairy farming. Including women in the target group by extension staff is expected to be more effective as compared to providing the same services to mostly men. BAMSCOS thus needs a well-trained pool of experienced lead farmers and extension staff ready to take on board and induce systematically new lead-farmers (especially women) to reach out in a pyramid system to at least 10% of the members in one year and realize with them the required increase in milk production.

The training program will contribute to enhancing food and nutrition security as efficient extension is expected to contribute to overcome: 1.) inefficient production, 2.) post-harvest losses, 3.) lack of food safety, 4.) inclusion of youth and women.

1.4 Financial sustainability of the farmer extension model

BAMSCOS can reach close to 4,000 farmers with an annual budget for extension of around €20,000. This covers salaries (65%), as well as staff mobility and the costs of extension activities. The key question is how to reach more farmers without substantially increasing the budget. One option is increasing the role of lead-farmers. To cover extension costs, a levy of 50 KES cents is applied on milk delivered by farmers to BAMSCOS while the main processor buying the milk adds another 50 cents (KES) per liter. Donor funds are used to complement the levy. This is a weakness in the farmer extension model because apart from the levy on milk supplied by farmers, accessibility to, for example donor funds is not assured over time. Joint bulking of inputs is being considered as one option to create additional sources of funds. Within the farmer extension model a pool of 32 lead -farmers (14 women) is established to act as local extension to support farmers that cannot be reached (yet) by extension officer staff from the cooperatives. The extension team in 2023 at union level stands at 16 4 (2 women) and 12 (4 women) at primary cooperative level. These efforts have resulted in a more systematic and business steered extension services design which BAMSCOS is now implementing.

1.5 Quality of farmer extension services

Ultimately, stronger extension, with appropriate technical knowledge and skills, should lead to increase of adoption of good agronomic and herd management practices resulting in better performance of dairy farmers and to higher volumes of milk intake by the primary cooperatives. This became clear from some data shared by farmers who participated in the extension activities around fodder crops production suggest that they reduced production costs up to 47%. Similarly, increases in milk production from 3,5 to around 4,5 kg of milk per cow per day are being reported (Veldhuizen, L., 2021). However, post education training and coaching of a young, recently graduated extension team, along regular monitoring and evaluation is needed to support these young extension officers in becoming more effective in conveying credible messages on best agronomic practices and herd management skills to the farmers.

Chapter 2. Baringo County Profile

2.1 Location, size and population

Baringo County is one of the largest counties in Kenya situated in the Rift Valley Region of the Republic of Kenya and borders Turkana and Samburu Counties to the North, Laikipia to the East, Nakuru and Kericho to the South, Uasin Gishu to the Southwest and Elgeyo-Marakwet, and West Pokot to the West. It is located between longitudes 35 30' and 36 30' East and between latitudes 0 10' South and 140'. The Equator cuts across the county at the southern part. Baringo covers an area of 11,075 sq. km of which approximately 221 sq. km is covered by surface water from Lake Baringo, Lake Bogoria and Lake Kamnarok. About 80% of the County is arid and semi-arid areas. The population is mainly concentrated in the highlands and urban centres. The arid parts of the larger Tiaty, part of Baringo North, Marigat and Mogotio are sparsely populated. The population of Baringo County is 666,773 (336,322 male and 330,428 female) with youth forming about half of the population. Projection indicates that the population will increase to 794,793 by 2027 (KNBS, 2019). Baringo county population density stands at 66 people per sq. km.

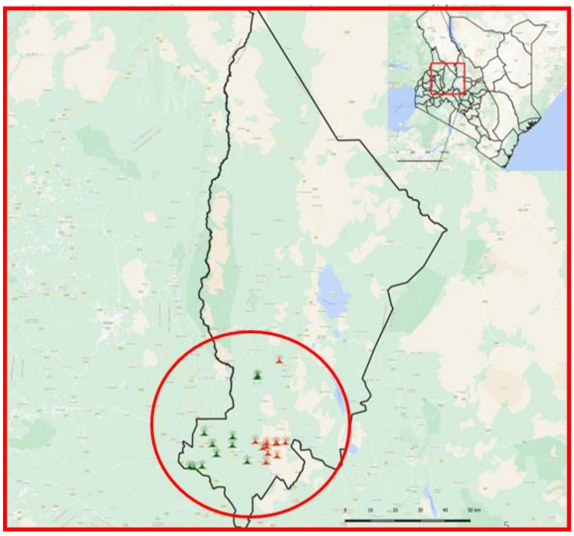

Figure 2. Map of Baringo county the farmers are located in the circled area.

2.2 County climate

Rainfall varies from 1,000mm to 1,500mm in the highlands and on average 600mm per annum in the lowlands. Due to their varied altitudes, the sub-counties receive different levels of rainfall. Koibatek sub-county receives the highest amount of rainfall. The lowland sub-counties of Mogotio, Tiaty East, Tiaty west and Baringo North receive relatively low amounts. The temperatures range from a minimum of 10°C to a maximum of 35°C in different parts of the county. The average wind speed is 2m/s and the humidity is low. The climate of Baringo varies from humid highlands to arid lowlands while some regions are between these extremes. Drought condition occurs frequently in the county causing livestock deaths and loss of potential grazing land. This is due to unreliable, low rainfall patterns.

Baringo County is divided into three major ecological zones: Highlands, Mid- and Lowlands. The Highlands are in the modified tropical zones with soils that are generally well drained and fertile. This zone has high-potential areas for agricultural and improved livestock development. Large-scale farming of cereals and horticultural crops is practised in the south-west of the Kerio Valley where there is also potential for forage crop production. The

Lowland is a semi-arid area with complex soils and essentially a rangeland with scattered and isolated pockets of dry subsistence agriculture and small-scale irrigation in Marigat, Kolowa, and Barwessa.

2.3 County feed balance

Based on the feed and fodder inventory report for Kenya (MoALD-FAO, 2017) the total livestock fodder requirement in terms of dry matter for Baringo county was 1,132,106 tonnes, but the potential dry mater production was approximately 921,797 tonnes. However, actual availability of feed in 2017 was less by 59.4% standing at 459,071 tonnes. The county scored adversely in terms of DM, CP and ME as follows: DM = 59%, CP = 63% and ME = 76.2 % respectively. That means that the supply of feed (dry matter, metabolizable energy and protein) was below the effective feed demand for ruminants in the county.

Table 1. Feed Balance as dry matter (DM), crude protein (CP) and metabolizable energy (ME)

Potential feed availability as DM	**Actual feed availability as DM**	**Livestock (DM) requirement**	**Feed balance as DM based on potential feed availability**	**Feed balance as DM based on actual feed availability and use**
(tonnes)	**(tonnes)**	**(tonnes)**	**(%)**	**(%)**
921,797	*459,071*	*1,132,106*	*-18.6*	*-59.4*
Potential feed availability as CP	**Actual feed availability as CP**	**Livestock CP requirement**	**Feed balance as CP based on potential feed availability**	**Feed balance as CP based on actual feed availability and use**
(kg)	***(kg)***	***(kg)***	***(%)***	***(%)***
104,105,719	*46,587,791*	*125,408,798.9*	*-17*	*-63*
Potential feed availability as ME	**Actual feed availability as ME**	**Livestock ME requirement**	**Feed balance as ME based on potential feed availability**	**Feed balance as ME based on actual feed availability and use**
(MJ)	***(MJ)***	***(MJ)***	***(%)***	***(%)***
7,009,856,286.20	*3,470,401,219.10*	*1,457,263,772.00*	*-51.9*	*-76.2*

Table 2 from the feed and fodder inventory report for Kenya (MALFI-FAO, 2017) shows that cultivated forages contribute only a relatively small percentage of the actual feed availability and use in Baringo. Roughages, low quality crop residues are commonly used for feeding 12.7-29.7% and grazing provides most of the feed available and used in Baringo.

Table 2. Contribution of roughages, grazing biomass and cultivated fodders to actual feed availability and use (contributions as dry matter (DM), crude protein (CP) and metabolizable energy (ME) were different and hence range is given)

County	**Contribution**			
	Grazing biomass	**Roughages**	**Cultivated fodders**	**Concentrates**
	(%)	***(%)***	***(%)***	***(%)***
Baringo	*54.9-78.6*	*12.7-29.7*	*10.6-13.1*	*0.04-0.1*

2.4 Livestock farming systems Baringo County

The main livestock species in the county are cattle, sheep and goats. The primary livestock in the County includes the East African Zebu Cattle in the lowlands and exotic cattle in the highlands. Communities have continued to diversify into high quality breeds for dairy due to shrinking land sizes and increased demand for beef and dairy milk. Thus, exotic dairy breeds and crosses with East African Zebu or Boran are progressively becoming popular.

The dairy value chain is growing faster under intensive and semi-intensive production systems. Exotic dairy breeds reared include Holstein Friesian, Ayrshire, Jerseys and their crosses in the dairy rich sub-counties in the high lands: Eldama Ravine, Baringo Central. In the low-lands, Mogotio, Baringo South, Baringo North and Taity, livestock keeping is the main economic activity with cattle, goats, sheep and camels being the major livestock kept. The table below shows the livestock population in Baringo County as per the county's CIDP 2023.

Table 3. Livestock population in Baringo county in 2022

Livestock Farming	County Statistics 2022
Dairy Cattle	145,594
Beef Cattle	375,843
Goats	943,950
Sheep	354,132
Camel	13,451
Donkey	4,778
Poultry	1,042,327
Source: CIDP, 2023	

Arable land covers 109,500ha, representing 9.9% of the total land area in the county. The average farm size is 2.5ha. Landholding in the county varies from one sub-county to another. For example, in the southern part of the county, in Koibatek Sub-County, a landholding averages 2.5ha and is demarcated with title deeds. In the northern sub-Counties, Tiaty, Baringo North and Baringo south, land is still communal and managed by the community.

Use of agricultural inputs varies with seasons and between households in the county. Inputs include seed, fertiliser (at planting and top dressing), pesticides, herbicides, and irrigation water. More inputs are used in the March-April May (MAM) season than in the October-November-December (OND) season. In the MAM season the inputs mostly used are seeds (97%), fertiliser for planting (66%) and fertiliser for topdressing (43%). More male-headed households use inputs compared to youth- and female-headed households.

2.5 Forage species used by dairy farmers in Baringo County

Forage is a major component in the diets of ruminants. The high digestible and nutritive value of forages helps to reduce feed costs and enables ruminants to exploit their genetic potential. Livestock production in the lowlands is characterized by low productivity, due to constraints related to low or erratic rainfall in large parts of the county and the low quality of feeds.

In the highlands and medium altitude areas there is a wide range of forage species used in Baringo, depending on the agro-ecological zones, soil fertility and feeding systems. In intensive farming system under zero grazing, semi zero grazing, Napier grass (*Cenchrus purpureum*) is used, especially in medium and low altitude areas, where some of the dairy production is concentrated under mixed systems. Star grass (*Cynodon dactylon*) and Kikuyu grass (*Cenchrus clandestinum*) grow, depending on location, naturally and are used for grazing. Rhodes grass (*Chloris guyana*) is mainly used for hay making and mostly targeted for commercial purposes. The use of forage legumes is not widely adopted, naturally occurring Desmodium *ssp.* being the most common. Cow peas (*Vigna unguiculata*), lucerne (*Medicago sativa*), Dolichos lablab (*Lablab purpureus*) and Lupin (*Lupinus albus*) are demonstrated by KALRO and CIAT demonstrates Sun Hemp (*Crotalaria juncea*) and *Desmodium ssp.* in plots in some parts of the county. Maize (*Zea Mays*) and forage Sorghum (*Sorghum drummondii*) silage are also used, but the technology is not widespread in the county. Maize for forage has potential in the higher altitudes, as demonstrated on the demonstration farm of Mumberes cooperative, and Sorghum in the relatively dry areas.

Under the Livestock Development and Management program in Baringo with respect to pasture and fodder development the county reported that in 2022, 18,300 kgs of pasture seed was distributed against a target of 14,500 kgs. Depending on the seed rate applied this is the equivalent of 1830 – 9150 acres of pasture establishment.

A common forage used in the highland of Baringo is Napier grass which under the prevailing management practices can offer circa 6-8 MJME/kg DM and 8-12% CP, and low-quality hay with an estimated ME of 6.5 MJ/kg DM and 4-6% CP. This type of low-quality forage does not cover the nutrient requirements of the exotic dairy cows as found in the intensive farming systems in Baringo. These forages have a low energy density and high fibre content. The high fibre content in these forages and the low digestibility limits the feed intake capacity before these feeds can cover the nutrients requirement of these exotic dairy breeds or their crosses.

Possibly due to lack of knowledge and skills, the team noted that dairy farmers fed cows on overgrown Napier and Rhodes grass further hindering the nutritive values needed for improved milk, and growth. This practise is also contributing to high greenhouse gas emissions in the form of methane. Although the adoption of Rhodes grass variety Boma is rising in Baringo county, this is an "outdated improved variety" (first registered in Kenya in the early 1970's) and focus should go beyond Boma Rhodes grass to other more recently developed and released species or varieties e.g. Brachiaria and Panicum. These – if well managed - perform better in terms of nutritional profiles (DM, ME, CP, NDF). It should be noted that agronomic practices and stage of harvest influence nutritional quality significantly.

Rhodes grass (*Chloris ga*yana) is preferred by farmers, compared to other grasses due to: (i) its potential for hay making, (ii) seed production - seeds easily and in large quantities, and (iii) higher yields compared to other pasture grasses. In the cereal growing areas of Baringo farmers are used to growing wheat which has similar agronomical practices and ecological requirements and can be used as a cover crop thus reducing the cost of land preparation for Rhodes grass. Further advantages include (iv) farmers can do their own seed reproduction, suitability of small-scale production and use of simple tools to harvest e.g baling box, slashers and/or bush cutters, (v) the crop is easy to eradicate unlike other grasses such as Couch grass and Star grass which is important in a crop rotation system.

Although the adoption of Rhodes grass for hay has been on an upward trend, there are challenges that have been observed regarding the overall performance of Rhodes grass as an "improved variety" and its ability to support farmers to improve milk and animal growth. Such challenges include low germination rates due to seed quality, absence of more recently improved varieties such as Katambora, Tolgar and Endura in Kenya since the introduction of Boma and Elmba Rhodes grass in the nineteen seventies, and the low nutritive values for ME and CP of the available Rhodes grass varieties when made into hay. The grass also requires knowledge, skills and expertise to get quality forage for ruminants which is lacking among the dairy farming community. Farmers should therefore be supported and encouraged to grow grass with more potential in terms of yield (per acre tonnage) and nutritional value for their dairy herd.

Chapter 3. NEADAP approach and methodology of the study

In Chapter 2 we cited the MoALD-FAO, 2017 study which concluded that there is a negative balance of 76% as ME based on actual feed availability and use which can be reduced be reduced to 52% as ME if the potential in the county is utilized. Energy is the driver of milk production and contributes to about 70% of cost in the diet while protein contributes to about 25% of the cost in the diet of the dairy cow. In Chapter 1 BAMSCOS mentioned that Fodder production - and thus feed availability – varies much and depends largely on rainfall and the variation in feed availability poses a serious concern to the livelihood of the farmer members and the sustainability of BAMSCOS' business, rendering the service of milk collection and processing in the future.

More and better fodder all year round and balanced feeding is the core pathway to more milk, increasing household income, reducing land use, improving resilience, reducing GHG-emissions and is therefore the main component in realising climate smart agriculture (CSA). The NEADAP focus is on improving dry season dairy cattle productivity. To help overcome the land scarcity challenge, NEADAP approach is to combine:

1.) stimulating and supporting farmers to plant high yielding forages on part of their land,
2.) stimulating non-dairy farms in the area to grow fodder as a commercial crop, and
3.) fodder production, organized by the cooperative, and where necessary sourced from outside.

The 'NEADAP approach for year-round fodder availability framework', which approaches the forage supply chain for intensified environmentally sustainable dairy farming from seed to feed starting with a healthy fertile soil, availability good quality improved forage seeds and good agronomic practices, right stage of harvesting and conservation techniques and supply of a sufficient and balanced diet, can become the overarching framework in realising year-round availability of good quality fodder which leads to sustainable and profitable dairy farms, embedded in the mixed farming systems in Baringo county and other areas in Kenya and East Africa.

Other similar initiatives are tried or implemented by KCC in Nakuru (Africa Milk project), Pearl Dairies in Mbarara, Uganda, ASAS Dairies in Iringa, Tanzania and the Cash-Cow concept rolled out by Perfometer.

The remaining 'forage gap' after pathway 1 has been adopted (total forage requirement minus forage production on the own farm (pathway 1) and minus forage produced by non-dairy farmers (pathway 2)) forage needs to be sourced from outside (pathway 3). The arguments behind this 3-way approach are:
a) The extra income and jobs generated through fodder production remain as much as possible within the community; it can give youth groups the possibility to start Agri-businesses such as demonstrated in earlier dairy development projects (e.g. SPEN).
b) The benefits of forage in the farming system are as much as possible realized within the own farming system. These benefits are, next to improved feeding and manure management, crop rotation, continuous soil cover (crop), inter- and multi cropping, plant diversity, use of catch crops, build-up of organic matter in the soil and nutrient recycling, thus improving soil health.

Key is that the perspectives, ambitions and capabilities of the farmer members of BAMSCOS are taken as the starting point - improving their earning capacity and the sustainability of their farms are the focal points on the horizon. In the end, the farmers decide how to feed the dairy herd, which forages to grow (grass, legumes or maize/sorghum), how and when to conserve (hay or silage) these, and what, when and how to buy supplementary feeds.

3.1 Farmer questionnaire

As part of the study the NEADAP team developed a questionnaire and selected 24 farms in the catchment area of BAMSCOS together with Sharon Bundotich secretary of the Cooperative Society. Selected where 14 mixed farms in the highland (>1905 masl) and 10 mixed farms in the lowland (< 1806 masl). The altitude of the locations of the 24 farms ranged from 1578 – 2668 masl (see Annex 1). In the highland the farmers received >900 mm rain and the predominant soil type was clay – clay-loam and in the lowland the farmers received <800 mm rain and the soil type ranged from clay to sandy-loam. All the farmers where older than 35 years of age and 18 of the interviewed farmers where men and 6 women.

The questionnaire, (see annex 18) covered questions for the farmers such as:

a) Basic information about the respondent
b) Land area and land use
c) Soil and manure management
d) Herd characteristics
e) Type of forages grown and cost of forage crop production
f) Feed and forage assessment
g) Gender roles and labour allocation on the farm
h) Financing of farm activities and investments.
i) Growth limitations

During the visit, next to the questionnaire the consultants made a farm walk together with the farmers to assess the current situation and collect specific field and herd information (soil & feed samples, feed and herd assessment (type and quality of feed, live weight, body condition score, rumen fill etc.). The tools that are used for the study are AgroCares handheld scanner for soil and (some) feed analyses, the NEADAP cost of forage production calculator, 'Farm Walk', Rumen8 a software application for diet formulation, Feed plan and budget and the NEADAP forage finder.

The field visits took place within the period 24th July 2023 and 24th August 2023. A total of 24 farms were visited but only on 23 farms soil samples were taken. Annex 1 shows the farmer code we will use further in this working paper, visiting date, location, farmer name, and altitude. On farm F2 no sample was taken and on farm F12 (see Annex 1 and Annex 2) two samples were taken making a total of 24 soil samples. The soil samples were taken at a depth of up to 15 cm. The soil samples were analyzed with the AgroCares handheld scanner using NIRS (Near Infra-Red Spectrometry) technology. The samples were analyzed for soil moisture, soil acidity (pH), soil organic carbon, total Nitrogen, Phosphor, Potassium, Clay content, Cation Exchange Capacity. The scanner generated analyses reports and recommendation are used in this working paper.

Chapter 4. Soil health and fertility

In this Chapter the results of scanning the soils samples with the AgroCares handheld NIRS scanner are discussed. The test results are shared in annex 1 – 9.

4.1 Soil acidity (pH)

Annex 3 Table 1: Causes, effects and corrective measures for low pH.

Soil pH overall average from Table 1 is 5.8, which is lower than the recommended range (6.0-7.2).

For soils with a low pH, adequate lime should be used preferably after recommendations by soil experts since the crop to be grown influences the demand of nutrients and soil pH which is ideal for optimum growth.

Annex 3 Table 2: Causes, effects and corrective measures for neutral pH.

Soil pH average is 6.5 which is within the recommended range (6.0-7.2).

Despite pH being within the recommended range, adequate lime application is advisable to maintain a neutral soil pH.

4.2 Soil organic carbon

Soil organic carbon content recommended range is 17-50 g/kg. The farms with less that 17g/kg were 8 with an overall average of 13.6g/kg which is not adequate. Soil organic carbon (SOC) is the measurable component of soil organic matter. Soil organic carbon is found in the topsoil mostly between 0-10cm layer of soil. Organic carbon content is related to the amount of organic matter in the soil (decaying plant matter, soil organisms, microbes and organic compounds). Manure added to the soil influences organic carbon content in soil, considerable amount used in soil keeps organic carbon content within the recommended range. Inorganic carbon sources are for example carbonate minerals.

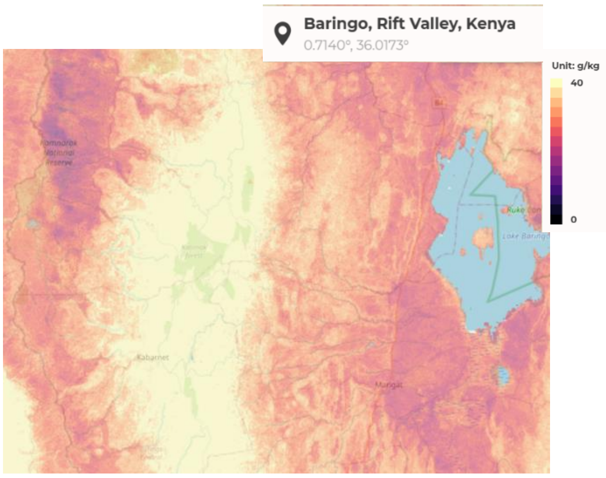

Figure 1. Map of Baringo showing the soil organic carbon content

4.3 Total Nitrogen content

The total nitrogen content overall average was 0.9-1g/kg for 4 farms in the lowlands only. The rest of the farms had a total nitrogen content in the high range (above recommendation 2g/kg). Nitrogen content is commonly in

ammonium and nitrate form, in the soil it can also be found in nitrite and nitrous oxide forms in less quantities. Plants only use nitrogen found in the two forms mentioned first.
Organic nitrogen (soil organic matter, crop residues & manure) and inorganic nitrogen (ammonium found in inorganic fertilizers). High nitrogen in soil causes plants to become overly succulent. Nitrogen among the 3 macro nutrients, (N,P,K) is the fastest to be depleted in soils hence the need to continually supply soil with recommended quantities with regards to crops grown or to be grown in the coming season. To reduce nitrogen leaching from soils practice better nitrogen management by reducing nitrogen supply to soil and encouraging uptake by crops (e.g. cover cropping) and controlling drainage.

4.4 Soil carbon to nitrogen ratio (C:N)

The carbon to nitrogen ratio of soils has an impact on the soil health, microbial activity, and organic matter content. The optimum carbon to nitrogen ratio in the soil is 24:1, that is 24 parts carbon and 1 part nitrogen. This ratio directly affects residue decomposition and nitrogen cycling. Microorganisms in the soil have a carbon nitrogen ratio of 8:1, this is the ratio they must maintain in their bodies. They require 16 parts of carbon for energy and 8 parts of carbon for maintenance, hence the ratio of 24:1 carbon to nitrogen ratio recommendation for soils. The higher the carbon content is regarding the optimum (24:1) the longer the crops residues, and other organic matter takes to decompose because the microbes need extra nitrogen.

High carbon content forces microbes to find nitrogen, this causes immobilization in the soil. Establishing a cover crop (e.g used as green manure) helps balance the C:N ratio of soils because it adds some nitrogen to the soil which aids the microorganisms to breakdown the high carbon (crop residue) from previous harvest found on the soil surface. The cover crop acts as a green manure. Intercropping with legumes has the same impact. All crops have a different C:N ratio and thus influence C:N ratio in the soil, , legumes have lower carbon to nitrogen ratio, thereby allowing decomposition to take place rather quickly and excess nitrogen becomes available in the soil for other growing plants. Soils with low C:N ratio have poor water holding capacity and soils with high carbon make good use of manure and produce forages with higher nutrient density.

4.5 Phosphor (Phosphor Mehlich-3)

Phosphor (P) overall average is 17.9 mg/kg (the range is between 5.2 – 47.5mg/kg). Samples that range between 20 – 40 mg/kg have adequate phosphor in the soil. Samples higher than 40 mg/kg are in phosphor. High pH (above 6.5) in combination with excess phosphor causes zinc and iron deficiencies. To lower phosphor content in the soil reduce phosphor applied to soils, if using synthetic fertilizers use fertilizers low in phosphor). 2 samples lack P, with levels below 20 mg/kg. For these samples adequate phosphor needs to be applied through synthetic fertilizers.

4.6 Potassium (Exchange potassium)

Potassium (K) overall average is high at 5.9 mmol+/kg for the soil tested, recommended range is 1.5<>3.0 mmol+/kg. High potassium content is naturally present in tropical soils in this region.
High potassium does not have immediate effect on crop however, when extremely high in the soil it can cause clay particles to disperse and clog pores spaces causing water not to infiltrate in the soil as normal. High potassium soils are also characterized by high pH. To correct high Potassium levels in the soil, it is important to dissolve soluble potassium. One should loosen the soil thoroughly, increasing soil moisture penetration which

increases potassium availability/movement to plant roots. For soils high in potassium reduce supply to soil either through manure or fertilizer application.

4.7 Clay content mineral parts

Clay content mineral part overall average is within normal range of 45% for the soil samples tested.

4.8 Cation exchange capacity (CEC)

Cation exchange capacity overall average is 157 mmol+/kg (this is within the recommended range) for the soil tested. CEC refers to the property of soil that describes its capacity to supply nutrient cations (calcium, magnesium and potassium) to the soil solution for plant uptake.
A high CEC (>200 mmol+/kg) refers to the total number of cations a soil can hold, the higher the CEC the higher the negative charge and the more the cations that can be held. High CEC is a reflection of the soil potential fertility and these soils are less likely to lose important nutrients like potassium, magnesium and other cations. Soils with high clay and/or organic matter content have a high CEC. Sandy, low organic matter soils have a low CEC. Soil CEC is relatively constant, so no need for repeated analyses.

4.9 Commercial fertilizers in Kenya

The table 4 below shows some inorganic fertilizers in the market in Kenya which AgroCares uses in the analysis report for soil correction.

Table 4. Commercial fertilizers, common names

Commercial fertilisers N:P:K (:S) composition	Abbreviation of fertilizer	Common or Brand name
46:0:0	U	Urea or use 2X recommended kg of CAN
26:0:0	CAN	Calcium Ammonium Nitrate (CAN)
40:0:0 14%S	AS	Ammonium Suphate/Kynoplus S
12:0:0 25%CaO	CN	Calcium Nitrate (CN)
26:0:0 13%S	ASN 13%S	Ammonium sulphate (ASN)
15.5:0:0 26%CaO	ASN 26%Cao	Ammonium sulphate (ASN)
24:0:0 6%S	ASN 6%	Ammonium sulphate (ASN)/ Yara Bela Sulfan/Kynoplus S
18:38:0 2.3%CaO 0.2% MgO 5% S	KN	Kynoch Nafaka
0:46:0 15% CaO	TSP	Triple superphosphate
0:18:0 11% CaO	SSP	Single superphosphate
17:17:17	NPK	NPK

4.10 Soil correction plan

In annex 7 table 1 and annex 8 table 1 an overview is given of the recommended fertilizer use per farm based on the forage crop the farmer was currently cultivation. It needs to be pointed out that the soil correction plans for forage sorghum and forage maize are based on grain varieties of the crops because the choices in the AgroCares -App do not have the option to choose a forage variety of these crops. The difference is that with forage crops most biomass is removed from the field, and thus less crop residue can be incorporated back into the soil. This requires the farmers to be attentive and regularly, at least every 1-2 years take a soil sample for analyses and follow the recommended soil correction plan to maintain soil heath and fertility.

The cost of the blanket fertilizer estimates in the cost of forage production calculations by the authors, ranges for organic and inorganic fertilizer use, between KES 11,000 – 30,000 per acre, over all in this study the average cost for the soil correction plan is KES 10,380 per acre for annual forage crop and KES 13,151 per acre for multi cut forage crops The cost for the soil correction plan ranges of all the 24 samples between KES 3,445 per acre – KES 27,156 per acre for annual forage crops and KES 3,910 – KES 35,153 for multi cut forage crops. Between the highlands and the lowlands there is not very much difference. In the highland the range is between KES 5,715 KES/acre and in the lowland the range is between KES 3,445 and KES 35,153 per acre.

Between the farms the differences for soil correction are high and that can be an indication that maintaining soil health and fertility pays of in the long term, making use of natural resources which are available on farm such as animal manure, incorporation crop residues and (vermi-) compost making to reduce nutrient losses and close the nutrient cycle where needed. Soils which are well taken care of in term of nutrient supply to produce crops have minimum nutrient requirements year by year while soils that are degraded may require expensive correction measurements with organic and inorganic fertilizers to maximize the yield of forage crops, incl. tropical pastures. In multi cropping and intercropping systems part of the nutrient requirements can be met by nitrogen fixing and or deep rooting cover and "partner" crops.

In most of the soil test laboratories and on the soil-test reports, forage crops are not yet well represented, often the choice for a fertilizer recommendation is limited to Rhodes grass and Lucerne as typical forage crops. It is recommended that in the follow up of NEADAP 2 this short coming is addressed and the soil laboratories are encouraged to include in their soil correction plans, a wider variety of tropical grasses such as Napier grass, Guinea grass, Brachiaria Hybrid grasses, fodder legumes such as Lucerne, Desmodium, Sunhemp, Lablab bean and cowpea, and (bi)annual forage crops like maize, sorghum, pearl millet, oats and triticale.

Chapter 5. Assessment of feeds and feed analyses

During the farmers visits NEADAP tools that are developed and scaled during the NEADAP 2 project were used in this Chapter the results of the AgroCares handheld NIRS scanner are discussed, feeds that could not be analysed with the NIRS scanners where sent to CropNuts Laboratory for analyses while forages where assessed visually in comparison to the feed qualities in the SNV Tropical Feed Library the results are shared in annex 10 and annex 11 and the tables 6 to 8 in this Chapter.

5.1 Raw materials and concentrates

The single source and compound concentrates found on the farms where rapeseed (canola) meal, soyabean meal, sunflower seed meal, wheat bran, maize germ and brewers spent sorghum grain. From 9 compound concentrates of different companies' samples were taken and presented to Crop Nuts laboratory for analyses (Annex 10). Some of the compound concentrates were, according to the labels of different qualities such as suggested by the reading on the labels like "Maziwa extra", "High Yield". The analyses reports for the single source concentrates are shared in annex 11. For the comparison and validation of the single source concentrates the SNV Tropical Feed Library 3.1 is used.

Rapeseed meal

- Rapeseed meal: The quality of rapeseed meal is comparable with the values in the Rumen8 feed library on crude protein. Fibre content is 79 g/kg DM, fat is 20 g/kg DM lower and metabolizable energy (ME) is 1.3 MJ/kg DM lower than the value in the Rumen8 feed library Strach is 38 g/ kg DM higher than in the values in the feed library.

Soyabean meal

- Soyabean meal: The quality of soyabean meal is compares best with soyabean meal with fat content below 40 g/kg DM in the values in the Rumen8 feed library on crude protein (CP) and fibre (NDF) and Sugar content. Fat, and starch are respectively 18 and 32 g/kg DM lower and metabolizable energy is 1.5 MJ/kg DM lower.

Sunflower seed meal

- Sunflower seed meal compares best with Sunflower seed meal non dehulled in the Rumen8 feed library, crude protein is 40 g/kg DM and fibre (NDF) is 50 g/kg DM lower. Fat content 45 g/ is higher and Starch, Sugar and metabolizable energy are of the same magnitude.

Wheat bran

- Wheat bran and wheat pollard was sampled on 4 farms, the analyses of all 4 gave the best match with Wheat bran in the Rumen8 feed library. There is some variation within the different sample analyses of Wheat bran but on average the values are close to the values in the Rumen8 feed library, the fibre content (NDF) 66 g/kg DM and metabolizable energy 0.9 MJ/kg DM lower.

Maize germ meal

- Maize germ meal compares best with maize germ meal with > 40 g fat/kg DM. The fat content is 77 g/kg DM, the Starch is 15 g/kg DM and metabolizable energy is 1,7 MJ/kg DM higher, the fibre content is 58 g/kg D lower than in the Rumen8 feed library.

Brewers' sorghum grain

- Brewers Sorghum grain has a lower dry matter content of 49 g/kg. Crude protein (CP) is 55g/kg DM, fat is 24 g/kg DM, Starch 50 g/kg DM and metabolizable energy 0.4 MJ/kg DM lower. The fibre content NDF is 87 g/kg DM higher.

5.2 Forage crops used as fodder

Maize silage

- Maize silage was sampled at F10 the demonstration farm of Mumberes cooperative. The sample is on dry matter basis best compared with maize silage below 30% DM but Starch, metabolizable energy (ME) and lower NDF content justify a comparison with maize silage between 30<>35% in the Rumen8 feed library. The kernels are filling with Starch and the cutting height (stubble) is right, but the low dry matter content can be an indication there is still enough moisture in the stem.

Forage sorghum fresh chop

- Forage sorghum as fresh cut and as silage was not sampled and an assessment of the quality was made visually. Guided by the Rumen8 feed library and Feedipedia. See the 4 qualities of forage sorghum found on the farms in table 6. Forage sorghum, on most farm, was left to overgrow and harvested at flowering/seeding stage. Plant population was low and the plots, compared to the number of animals on the farm generally small.

Table 5. Forage sorghum green chop and silage assessed during the farm visits in Baringo

Date 01.11.2023	Dry Matter	Metabolisable Energy (DM)	Crude Protein (DM)	Neutral Detergent Fibre (DM)
Feed ingredients in dairy cow diet	**(g/kg)**	**(MJ/kg DM)**	**(g/kg DM)**	**(g/kg DM)**
Sorghum fresh < 30% DM	280	8.9	87	650
Sorghum silage < 30% DM (on farm)	280	8.7	87	650
Sorghum fresh 30% <> 35% DM	360	9.1	67	579
Sorghum silage 30% <> 35% DM	360	9.1	67	579

Rhodes grass

- Rhodes grass mainly used as hay was not sampled and assessment of the quality was made visually. Guided by the Rumen8 feed library and Feedipedia. See the 2 qualities of Rhodes grass hay found on the farms in table 7. Rhodes grass, on most farm, is left to overgrow and harvested at or beyond flowering/seeding stage. Plant population was low and the plots, compared to the number of animals on the farm generally small.

Table 6. Rhodes grass hay assessed during the farm visits in Baringo

Date 01.11.2023	Dry Matter	Metabolisable Energy (DM)	Crude Protein (DM)	Neutral Detergent Fibre (DM)
Feed ingredients in dairy cow diet	**(g/kg)**	**(MJ/kg DM)**	**(g/kg DM)**	**(g/kg DM)**
Rhodes grass hay high quality	885	8	101	736
Rhodes grass hay low quality	888	6.4	48	772

Napier grass

- Napier grass is used as green chop in cut and carry systems the grass was not sampled, and assessment of the quality was made visually on the farms. Guided by the Rumen8 feed library and Feedipedia. See the 5 qualities of Napier grass hay found on the farms in table 8. Napier grass is gut at vegetative stage or at overgrown stage “late vegetative” or “flowering/seeding” stage. In the highlands growth of Napier grass is slow due to the low day temperatures.

Table 7. Napier grass assessed during the farm visits in Baringo

Date 01.11.2023	Dry Matter	Metabolisable Energy (DM)	Crude Protein (DM)	Neutral Detergent Fibre (DM)
Feed ingredients in dairy cow diet	**(g/kg)**	**(MJ/kg DM)**	**(g/kg DM)**	**(g/kg DM)**
Napier grass early vegetative (60 cm)	120	9.0	153	611
Napier grass vegetative (120 cm)	184	8.1	106	681
Napier grass late vegetative (120<>200 cm)	265	7.5	90	690
Napier grass flowering/seeding (>200 cm)	351	6.5	42	764
Napier grass silage (on farm)	301	7.1	90	690

Chapter 6. Cost of forage production

To assist the farmer with the cost of forage production, in the case he did not have the figures readily available, we made use of the forage cost calculator which is under development for the NEADAP by Damaris Kikwai. The tool can be used by the farmer or the farm coach and takes the farmers step by step but systematically through the activities and expenses of establishing, maintaining, and harvesting forage crops. In summary the expenses can be categorized as listed below

a. Land lease,
b. Land Preparation costs; ploughing, harrowing, bush clearing, etc.
c. Planting cost; seed or splits cost, fertilizers, manure or compost, manure, etc.
d. Crop management cost; Top dressing, fungicides application, weeding, irrigating, etc.
e. Harvesting costs; cutting, testing, post-harvest cost etc.
f. Conservation costs; bailing, bailing materials, ensiling material, conservation services, etc.

The yield, if not known by the farmer, was taken as a calculated estimate by collecting either of the data listed below.

i. Number of hay bales/are, average weight in kilograms per bale, number of cuttings per year,
ii. Stage of harvesting.
iii. The amount of silage per acre.
iv. A calculated estimate was made by calculating the volume of a silage pit height(m), width(m) and length(m) and compaction density (kg/m3) to estimate the yield/acre.
iv. Total weight of fresh grass per cutting and number of cutting per year.
v. A calculated estimate was made by counting and/or measuring the plant population in 25m2, height of the plant (m) and weight of the fresh cut, to estimate the expected production of forage per acre,

These expenses and the yield of the forage crop were recorded and later analysed to calculate the cost per kilogram of forage produced per acre of land.

The forage crops, most common found on the farms are Rhodes grass, Napier grass, Maize, and Sorghum. Rhodes grass and Sorghum mostly in the lowlands, while Napier grass and Maize, where primarily used for silage production in the highlands. There were other forage crops grown by the farmers but information the farmer could provide and/or the plot size or the growth stages was insufficient or not adequate to draw conclusions. Therefore, we do not include these forage crops in our analysis. These forage crops included amongst other oats, desmodium, brachiaria, and lucerne.

6.1 Rhodes grass hay

Ten farms located in the lowlands cultivated Rhodes grass, ranging from 1 to 12 acres, averaging 5 acres per farm. The total expenses to grow an acre of Rhodes grass varied between KES 13,200 and KES 50,250 with an average of KES 28,617. The yield ranged between 1,080 kg of hay/acre and 7,950 kg of hay/acre with an average of 3,493 kg hay/acre. The average cost to produce 1 kg of Rhodes grass hay was KES 13.0 but the cost of production varied enormously between the farms ranging from KES 2.38 and 26.26 per kg (see Tabel 1 Annex 12) . In comparison to average production cost calculated by the authors (see Tabel 2 Annex 12) which computed to KES 10.5 per kg hay. The quality of the Rhodes grass on the farms the authors describe as poor, most of the hay was harvested at flowering and seeding stage with a low leave to stem ratio in the material. We estimated the hay on all farms having a low a high fibre (NDF content), low protein (CP) content and low digestibility hence metabolizable energy (ME) content. The cost, calculated by the authors, is based on good agronomic practices and the yield may be higher than assumed bringing the cost per kg hay down. One farm (F14) has a higher cost of production as compared to the analyses of the authors cost (KES 50,250 versus KES 47,125 per acre). The yield on farm (F15) was higher, 530 – 15kg bales, than then the yield calculated with by the authors 300 – 15 kg bales per acre.

6.2 Forage maize silage

Six farms produced maize for forage and made maize silage, the acreage ranged from 0.5 to 8 acres with an average of 4.3 acres. The total expenses to grow an acre of forage maize varied. The total expenses to grow an acre of forage maize varied between KES 14,765 and KES 60,460 with an average of KES 29,081. The yield ranged between 1,060 kg of maize silage/acre and 15,000 kg of maize silage/acre with an average of 8,015 kg forage maize/acre. The average cost to produce 1kilogram of maize silage was KES 17.1, if we do not include the failed crop of farmer F24 then the variation is smaller for the farms where it was possible to estimate the yield ranging between KES 1.4 and KES 4.0 per acre. The cost of producing maize silage incl. losses calculated by the authors (see annex 12 table 4) is KES84,700/acre with a targeted yield of 15,000 kg/acre bringing the average cost to KES 5.9/kg. The authors assumed a self-propelled forage harvester with kernel processing allows the maize crop to be harvested at ripe stage enabling good fermentation with minimal losses. Most of the maize silage found on the farms was harvested at milk towards milk-dough stage, with an estimated dry matter content of less than 30%. The farms did not have, or could hire, the necessary machinery to effectively process maize at the ripe stage of the kernel targeting dry matter between 30-37%. Farmer F10 was the exception with a well fermented maize silage. A sample was taken for analysis and although the dry matter content was low 27.4%, metabolizable energy (ME), neutral detergent fiber (NDF) and Starch were good respectively 10.6 MJ/kg DM, 456 g/kg DM and 276 g/kg DM (See table 2 Annex 11). A higher dry matter percentage can be realized by leaving a taller stubble height when harvesting.

6.3 Napier grass

Seven farms cultivated Napier grass, averaging 0.8 acres per farm, the acreage ranging from 0.3 to 2 acres. The total expenses to grow Napier grass varied between KES 2,667 and KES 44,000 with an average of KES 22,372. The reported yield ranged between 5,400 – 34,560 kg Napier grass/acre with an average of 22,373 kg Napier grass/acre. The average cost to produce 1 kilogram of Napier grass was KES 1.64, if we do not include the result of farmer F9 who had very low cost of production and the highest yield per acre Then the prices vary from KES 0.9 to 3.3 / kg Napier grass (Annex 12 table 5). The average cost of, well fertilized, Napier grass production according to the calculated estimate by the authors is 2.3 KES/kg (Annex 12 table 6) . However, a significant concern is the stage of harvesting, only one farmer, F10, harvested Napier grass in a young vegetative to vegetative stage. The other farmers harvested Napier grass beyond the vegetative stage, this will have a negative effect on potential feed intake and quality of the forage supplied to the cows. Additionally, the farmers using Napier grass to make silage did not compact the clamp enough. The team further noted that the plots of Napier grass were not regularly kept free of weeds, which made it difficult to determine the real cost of production and assess the quality of the forage supplied to the cows.

6.4 Forage Sorghum

Four farms planted forage sorghum and one farm planted forage pearl millet because forage pearl millet was only planted on one farm, we include it in the farms which are planting forage sorghum because the crops appeared not to be much different in plant population, height and development. The average acreage for this crop of the farms was 1.8 acres, the acreage ranging from 0.5 to 3.5 acres. The total expenses to grow the forage sorghum ranged from KES 13,000 – KES 48,119 per acre with an average of 32,974. The reported yield ranged between 954 – 3,200 kg forage Sorghum/acre with an average of 1,784 kg forage Sorghum/acre. The average cost for 1 kilogram of both forage sorghum was KES 22.50, cost varied between KES 13.6 and KES 37.2 (Annex 12 table 7). These values are considerably higher than the calculated estimate by the authors which comes to KES 4.9 per kg sorghum silage (Annex 12 table 8). Because of the late (delayed) stage at which the forage sorghum and millet was harvested for ensiling the team assessed the silage of low nutritional quality. All these farmers harvested the forage Sorghum after the flowering stage a few waited until the crops reached the seeding stage. Likely resulting in a poorly fermented crop with high fiber (NDF) content and low in metabolizable energy. Delayed harvesting, at flowering/seeding stage, further negatively impacts regrowth and affects uniform re-growth and yield of subsequent cuts from the same field.

Chapter 7. Herd characteristics

7.1 Herd profile

Animal data were gathered from 22 farms listed in Annex 1. The cattle breeds that were used on the farms were mainly (17 farms) crossbred cows 5 farms had cows of the Holstein Friesian breed. All 5 farms with Holstein Friesian breed cows are in the highland (see Annex 14 table1)

The total number of cows in the herds varied, ranging from 4 to 20 animals, including bulls and youngstock, with an average of 9 cows per farm. Each farm, on average, had 5 lactating cows (Annex 14 table 1). The herd profile with average number of animals per animal category is shown in table 9 below.

Table 8. Herd profile in highland and lowland farms

<table>
<tr><th rowspan="2">Animal category</th><th rowspan="2">Production or age group</th><th colspan="2">High land</th><th colspan="2">Low land</th></tr>
<tr><th>(n=101)</th><th>%</th><th>(n=100)</th><th>%</th></tr>
<tr><td rowspan="5">Lactating cows</td><td>Early</td><td>1.4</td><td rowspan="3">51%</td><td>0.8</td><td rowspan="3">56%</td></tr>
<tr><td>Mid</td><td>0.7</td><td>1.4</td></tr>
<tr><td>Late</td><td>0.6</td><td>0.6</td></tr>
<tr><td>>305 days in milk</td><td>1.4</td><td rowspan="2">49%</td><td>1.0</td><td rowspan="2">44%</td></tr>
<tr><td>Dry period</td><td>1.1</td><td>1.2</td></tr>
<tr><td rowspan="5">Female Youngstock (Heifers)</td><td>In-calf</td><td>0.6</td><td rowspan="5">34%</td><td>0.8</td><td rowspan="5">43%</td></tr>
<tr><td>1-2 yrs.</td><td>0.9</td><td>0.8</td></tr>
<tr><td>0.5-1 year</td><td>0.9</td><td>0.8</td></tr>
<tr><td>3-6 months</td><td>0.3</td><td>0.6</td></tr>
<tr><td>< 3 months</td><td>0.5</td><td>0.8</td></tr>
<tr><td rowspan="3">Bulls</td><td>>1 yr</td><td>0.3</td><td rowspan="3">10%</td><td>0.0</td><td rowspan="3">2%</td></tr>
<tr><td>3-12 months</td><td>0.4</td><td>0.2</td></tr>
<tr><td>< 3 months</td><td>0.1</td><td>0.0</td></tr>
<tr><td colspan="2">Total # per farm</td><td>9.3</td><td></td><td>9.0</td><td></td></tr>
</table>

In the highland 49% of the lactating herd is dry or more than 305 days in milk in the low land this is 44%. The target is to have 75-85% of the lactating herd in the first 305 days of the lactating period. The female youngstock, bulls and dry cows all need to be fed but no immediate income is generated. This is 56% of the total herd in the highlands and in the lowlands, this is 58% meaning that respectively 44% and 42% must recover the feed cost of the whole herd through the milk they produce.

7.2 Live weight

Depending on the herd size the cows in the herds where weight or their weight estimated. The weight of the milking cows ranged between from 220 to 496 kg per animals (see annex 14 table 2). The bulls on the farm ranged in weight between 43 and 236 kg and female youngstock ranged in weight between 51 and 447 kg the last being an in-calf heifer.

7.3 Body condition score

The body condition score (BCS) is scored on a scale of 1-5 (Pen state, 20XX) and in the lactating herd ranged between 1.75 and 3, the BCS of 3 being an exception most animals being score below 2.5 BCS. The BCS was overall, in the highland and in the lowland too low ranging from 1.9 in early lactation increasing until 2.2 in the dry period.

7.4 Rumen fill

The rumen fill is scored on a scale of 1-5 and in the lactating, herd ranged between 2 and 3.5. Rumen fill score 1 the cow has eaten little or nothing which could be due to sudden illness or insufficient or unpalatable feed, score

2. If seen later in lactation, this is a sign of insufficient feed intake or a too high rate of passage. Score 3 this is the right score for milking cows with a good feed intake and when the feed remains in the rumen for the optimal time. Score 4 this is the correct score for cows nearing the end of lactation and for dry cows. Score 5 This is the correct score for dry cows.

The live weight, BCS and rumen fill leave the impression that the dairy cows are not supplied with an adequate amount of feed which does not meet the nutritional requirements of the cows. During the farm visits it was noted that the diets were not balanced due to minimal supplementation with a concentrate, averaging not maximum 1.5 kg of supplement per cow per day and in some cases no supplementation at all. Rumen fill of the cows observed in the field were lowest in the afternoon scoring below a rumen fill score below 2.

7.5 Milk yield

Milk production on the farms varies between 5 and 12 kg per cow per day however, it is worth noting that two farms, F16 and F10, performed better with milk yield of respectively 14.5 kg and 23 kg per cow per day. Better feeds where available and feeding practices where observed. The cows on these farms had an average live weight of ±550 kg and appeared to have better rumen fill and body condition score as compared to the other farms.

Located in the highlands, F10 is near Mumberes Dairy Cooperative and used as a demonstration farm of the cooperative. F16 is a neighbouring farm that follows the training and guidance provided by the extension staff of the cooperative closely. Both farms produced a variety of forages and had a stock of well-conserved maize silage, which we assessed of higher quality as compared to maize silage found on most other farms.

With the data (annex 17 tables 1,2,3,4,5) the average cow in the different stages of lactation can be prescribed for the highland (table 10) and the lowland (table 11)

Table 9. Dairy cow profile in the highlands

High land	Animal Category				
Stage of lactation	**Early**	**Mid**	**Late**	**>305 days**	**Dry period**
Days in milk	**1-100**	**101-200**	**201-305**	**306-dry**	**Dry**
Live weight	422	429	408	420	466
Live weight change	-0.44	-0.14	0	+0.12	+0.4
BCS	2.3	2.1	2.2	2.1	2.2
Rumen fill	2.3	2.5	2.5	2.4	2.5
Milk yield/d	13.5	12.8	8.2	5.3	

Table 10 shows in the highland the weight of the average dairy cow develops from ±466 kg at calving to ±408 at the end of mid lactation and then the weight increases again to 466. The cow losing weight over nearly the entire lactation period. This is normally limited to the early lactation period after which cows remain stable and start gradually increasing weight again in the second half of mid lactation. The BCS is targeted to be at 3-3.5 at the end of the dry period and in early lactation between 2.5-3. The BCS on the farms is the whole lactation period below 2.5 which indicates cows do not receive enough energy to sustain and maintain not only milk production body also the maintenance requirements. This hypothesis is confirmed by the rumen fill score which in early lactation can be at around 2-2.5 but should then gradually increase to 3 in mid lactation 4 in late lactation towards the dry period and 5 during the dry period.
We did not get enough data for the cow's milk production in early lactation therefor the authors estimated the milk yield at 15.5 kg/d gradually dropping to 5.3 kg/d before drying off.

For the cows in the lowland the average cow profile, Table 11 shows an average live weight of ±412 kg at calving to ±337 at the end of mid lactation and then the weight increases again to ±380 and then to ±412 at the end of the dry period. The body condition score is 1 BCS point to low over the whole lactation and dry period and rumen fill like in the highland does not meet the full rumen capacity of the cows. The milk yield is about half the production per day compared to the production curve of the cows in the highland and the curve is flatter. The milk yield is 7.6 kg/day in early lactation gradually dropping to 3.9 kg/d before drying off.

Table 10. Dairy cow profile in the lowlands

Low land	Animal Category				
Stage of lactation	**Early**	**Mid**	**Late**	**>305 days**	**Dry period**
Days in milk	**1-100**	**101-200**	**201-305**	**306-dry**	**Dry**
Live Weight	378	337	380	382	412
Live weight change	-0.34	-0.41	0	0	+0.32
BCS	1.8	2.1	2.2	2.2	2.3
Rumen fill	2.0	2.4	2.1	2.5	2.6
Milk yield/day	7.6	5.8	5.8	3.9	

These two-cow profile we will use in the Rumen8 diet formulation software to simulate the current feeding situation and recommend ways of improving the diet and feeding practices on the farms.

Chapter 8. Formulating balanced diets

8.1 Scenario analysis of the current situation in Baringo

In annex 13 the assessment of all forages and feeds on the farms in Baringo is summarised (DM, ME, CP and NDF) and in annex 14 the cost-range of the feeds and forages. The authors calculated the cost of forage production (Annex XX table) medium cost range and listed a low production cost and a high production cost. The same was done for the feeds that are purchased in the market a price range is given expressed in low, medium, or high price) In annex 15 this is combined and the cost of metabolizable energy per MJ is calculated and ranked as per the lowest cost per MJ for farmers to use in the diet of dairy cows. The colour pattern in the table evolving from yellow-orange-red-dark brown shows that for the diet ingredients for which the cost range per MJ is in the yellow/orange it is attractive to use in the dairy cows' diet. The last column predicts the dry matter intake potential of the diet ingredient. This shows that diet ingredients that appear to be cost effective in term of cost per MJ may limit the dry matter intake potential because of the high fibre (NDF) content which slows down the digestion in digestive system. In annex 15 we assumed that low, medium or high quality of a forage can be produced at the same expenses but to harvest a high quality (low in NDF, high digestibility and high CP) forage generally requires a compromise with the highest biomass yield/acre. The same methodology we used for crude protein as can bee seen in Annex 16; the feeds are here ranked as per the lowest cost per kg protein (CP) produced. These are important aspects for farm coaches and farmers to realize because energy and protein in the diet are the drivers of milk production.

The field visit and farm walk aim to get a quick insight in feeding practices, feed qualities, feed availability and feed cost. Unfortunately, the farm visit is limited to one day and historical farm records are not easily accessible of not available making is difficult the replicate the diets used by the farmer. The fact that feeds in stock as fresh cut, hay or silage is limited to a few weeks or even days means that we need to consider sudden differences in feed supply and quality of the feeds supplied. This results in weekly or daily differences in milk yield as can be seen in the figure 4 below. The brown curve shows the realized average milk yield per week per animal and the yellow curve shows the targeted milk yield per cow per week.

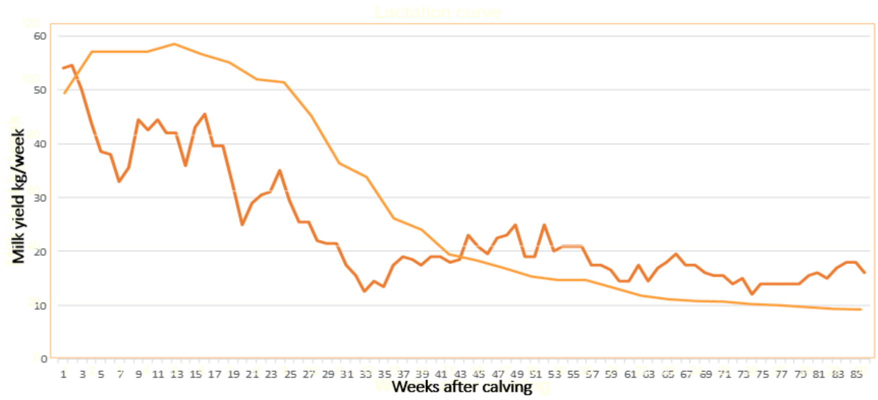

Figure 2. Typical lactation curve of small holder farmers in Kenya

Source Miano, D., 2019

Figure 5 below shows the expected effect of improved feeding realizing a higher average milk production per week/cow and a shorter calving interval. In the scenario represented by the 2 blue lactation curves the animal calved down twice versus the scenario with improved nutrition in the yellow curves where the same animal calved down 4 times in the same period.

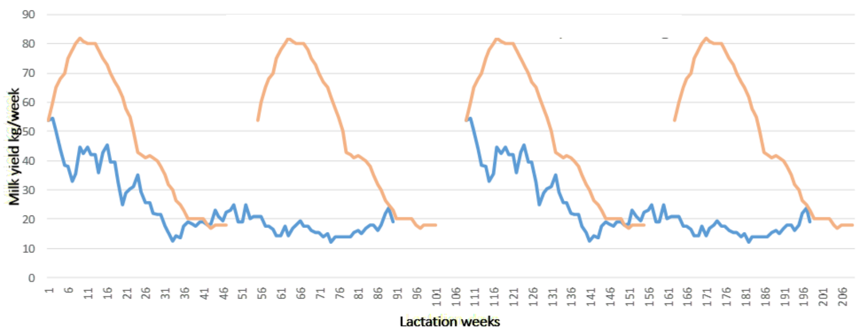

Figure 3. Improved lactation curve through improved feeding

Source Miano, D., 2019

The farms in the highlands had similar challenges and although the feed ingredients they chose from are different and dairy meal is from different millers often the nutrient supply is guided by limiting factor not related to the nutritional requirements of the cow e.g. financial constraints, availability in the market, transport etc. This is often expressed in the amount of concentrate the farmers supply to their cows. Below is an example of a case which explains the situation the authors found on any farms and tries to visualize in figures the cow profile, LW, BCS, RF, LWC and the collapse of the lactation curve in the highland.

In the example the authors describe the situation as they found it across the farms have a dairy crossbred cow, 475 kg LW after calving, 20 days in milk with liveweight change -0.6 kg/d, not pregnant, milk with 3.6% Fat and 2.9% true protein, zero grazing (2.5 km/day), ME meet “requirement 100%, MP may be in excess.

The farmer grows some Napier grass and harvest this at an average height of 120 cm (Napier grass of medium quality Annex14) and has some Rhodes grass hay from the previous season in stock, to maximize the yield it Rhodes hays was harvested when the grass was seeding. On the market he buys some dairy meal and maize germ. Part of the farmland is pasture where the cow can graze for a few hours of the day. The pasture is overgrazed and feed intake from grazing is therefore compromised to 1kg DM per day, but the young grass leaves (early vegetative) are of high nutritional value (high ME, CP, low NDF).

At calving the cow is 475 kg slightly more than the 466 kg in the dry period. The farmer has left the Napier grass plot to grow in preparedness to have grass for the cow when she calves and bought enough concentrates for the cow for the first weeks. The diet the farmers feed to the cow is shown in table 12 as diet 1 and the corresponding result of the diet on meeting nutrient requirements, diet density, milk yield and margin in table 13.

We assume in the example to illustrate the current situation, that after the first 2-4 weeks the farmers restricts supplementation with concentrates to approximately 3 kg dry matter (Diet 2), instead the cow is fed some more Napier grass however, because of the lower nutrient density of the Napier grass, this lowers intake of nutrients which in turn causing milk to drop to 12.5 kg/d.

Meanwhile the supply of Napier grass in the farm is reducing and to “safe the Napier grass” the supply of Napier grass is restricted to 4 kg dry matter, instead some hay is now added to the diet (Diet 3), the hay being of lower quality (high NDF, lower ME and CP) then the Napier grass, thus lowering the nutrient intake of the for the cow further causing the milk production to drop to 9.5 kg/day. Further restriction of the Napier grass is needed to 3 kg dry matter, due to delayed growth for example cold weather or dry period and the stock of hay is getting smaller (Diet 4) causing the milk production to drop further to 7.5 kg/d.

The farmer realizes the is not enough feed for the cow and feeds and forages in the market are expensive. The farmer tries to feed some more hay that was bought in the market at the same price he produced it himself. The cow is not losing weight anymore (LWC = 0 g/d) and milk composition in late lactation is 4% fat and 3% protein. The is now fed on diet 5 that can only support 5.2 kg milk/d.

Table 11. Diets which illustrate the current feeding practices affecting cow performance and welfare

	Napier grass medium quality	Hay low quality	Grazing young vegetative grass	Dairy meal	Maize Germ	Total DM intake/day
	kg DM/d	kg DM/d	kg DM/d	kg DM/d	kg DM/d	kg DM/d
Diet 1. All feeds are at available at choice to meet nutrient requirements	5.3		1	3.44	2.36	12.1
Diet 2: restriction of concentrates to approximately 3 kg DM	6.75		1	0.49	2.97	11.21
Diet 3: Restriction of Napier grass to 4 kg DM supplements with hay	4	2.32	1	1.66	1.57	10.55
Diet 4: Further restriction of Napier grass to 3 kg DM,	3	1.69	1	0.48	2.52	8.69
Diet 5: Adds more hay to the diet	3	2.66	1	0.48	2.52	9.66

Table 12. Diet density, dry matter intake, milk yield, requirement level, methane production, margin above feed cost and feed cost of the 5 diets in table 12 above

	Diet density			Dry matter intake		Milk yield	Requirement level			Methane production		Margin		Feed cost
	CP	NDF	ME	DMI*	DMI	MILK	DMI	ME*	MP*	CH4	CH4	MAFC	Feed % Inc.	Feed Cost
On farm produced forages	g/kg DM	g/kg DM	MJ/kg DM	g/kg DM	%LW	L/day	%	%	%	g/day	g/L	KES/d	%	per cow
Diet 1	125	510	10.6	12.1	2.5	15.5	100	100	100	268	17.3	380	45	317
Diet 2	114	551	10.1	11.2	2.4	12.5	100	100	100	273	21.8	333	41	229
Diet 3	105	585	9.5	10.5	2.2	9.5	100	100	100	277	29.2	212	51	216
Diet 4	104	552	10	8.7	1.8	7.5	78	100	100	239	31.9	158	53	179
Diet 5	98	574	9.7	9.7	2.0	5.2	90	100	102	265	51.0	44	82	190

8.2 Scenario analysis of the recommended situation in Baringo

There are several possibilities with the available forages, Napier, forage sorghum, forage maize, and Rhodes grass to optimize forage production (agronomic practices and yield/quality balance at harvesting) and improve the diets of the dairy herd at the farms. In this report we take 2 diets to illustrate which are building on the activities and practices initiated by BAMSCOS and Mumberes cooperative.

Table 13. Recommended dairy cow profile in the highlands

High land	Animal Category			
Stage of lactation	**Early**	**Mid**	**Late**	**Dry period**
Days in milk	**1-100**	**101-200**	**201-305**	**Dry**
Live Weight	475	425	475	475
Live weight change	-0.5	0	0.5	-
BCS	3.5-2.75	3	3.25	3.5
Rumen fill	3	3	3.5	4
Milk yield/day	15.5	13	8.5	-

Table 14. Diets which illustrate the recommended feeding practices affecting cow performance and welfare

	Lactation stage						
	Early	Mid	Late	Dry	Transition	Heifer unmated	Heifer mated
Diet ingredient	**kg DM/d**	**kg DM/d**	**kg DM/d**	**kg DM/d**	**kg DM/d**	**kg DM/d**	**kg DM/d**
Forage sorghum <30%	3.76	2.93	3.69	4.97	5.47	0.72	4.8
Napier grass high quality	4.79	4.22	3.25			2.39	1.66
Maize germ	3.22	3.89	4.24	2.43	1.57	2.15	2.84
Hay				1	1		
Total DM intake	**11.8**	**11.0**	**11.2**	**8.4**	**8.0**	**5.3**	**9.3**

Table 15. Diet density, dry matter intake, milk yield, requirement level, methane production, margin above feed cost and feed cost of the 5 diets in table 15 above

	Diet density			Dry matter intake		Milk yield	Requirement level			Methane production		Margin	
	CP	NDF	ME	DMI*	DMI	MILK	DMI	ME*	MP*	CH4	CH4	MAFC	Feed % Income
Lactation stage	g/kg DM	g/kg DM	MJ/kg DM	g/kg DM	%LW	L/day	%	%	%	g/day	g/L	KES/d	%
Early Lactation 50 d	123	531	10.5	11.6	2.4	15.5	100	100	100	275	17.7	464	33
Mid Lactation 150 d	124	500	10.9	11.0	2.6	13	100	100	100	246	18.9	339	42
Late Lactation 250 d	117	506	11.1	10.8	2.6	8.5	100	100	100	253	29.7	148	61
Dry period 245-day pregn.	92	554	10.3	8.4	1.8	0	100	100	106	170		-149	100
Transition period	89	591	9.6	8	1.7	0	100	100	110	165		-169	100

Table 16. Diet density, dry matter intake, milk yield, requirement level, methane production, margin above feed cost and feed cost of the diet in table XX above female youngstock targeting a growth rate of 0.75 kg/d.

	Diet density			Dry matter intake		Live weight change	Requirement level			Methane production		Feed cost
	CP	NDF	ME	DMI*	DMI	LWC	DMI	ME*	MP*	CH4	CH4	Feed cost/head
Age	g/kg DM	g/kg DM	MJ/kg DM	g/kg DM	%LW	kg/day	%	%	%	g/day	g/kg	KES/d
Heifer unmated	130	476	11.3	5.3	2.1	0.75	100	100	100	128	172	139
Heifer mated	109	526	10.7	9.3	1.9	0.75	100	100	100	182	243	187

Chapter 9. Budget, feed and fodder plan

9.1 Feed plan and budget.

Based on the formulated balanced diet in table 15 we calculated the total forage and feed requirements per animal category in table 18. In this scenario the total dry matter intake always meets the dry matter intake requirement, metabolizable energy and metabolizable protein requirements of the herd. This will result, once the herd in consequently fed at nutrient requirement level that the animals can maintain better body conditions score, are healthier and will likely conceive earlier and quicker during the lactation period.

The dairy cow in the highland requires a dry matter supply from forage of 2646 kg and 1251 kg dry matter from concentrate (in the example maize germ). Over the period of one year the farmer can generate a margin above feed cost of KES 86,480/= per dairy cow while the total dry matter intake for the heifer is 1604 from forage and 881 kg dry matter per year from concentrate, the cost to feed an in-calf heifer are KES 114,910/= for a 2-year period (calving at 24 months). If the farmer would generate 66 KES /= average margin per day over the 2-year period as with the dairy cows, the sales price for the in-calf heifer would need to be KES 48,180/= above the total feed cost bringing the sales price to minimum KES 163,090/= The heifer are fed targeting an mature weight between 500 and 550 kg liveweight, this would increase the feed intake potential of the new generation and this a higher milk yield potential, provided enough feed is available for this medium size dairy cow.

Bulls, if the farmer decides to stay with the animal would require fodder as well, good quality forage can reduce the amount of concentrate needed to rear the bull and at a latter age fatten the bull before slaughtering. Currently the prices per kg carcass weight in Kenyan slaughterhouses are approximately 420 KES while a common liveweight at slaughter is 350-400 kg live weight. This weight could be achieved after 16-18 months. For Assuming a carcass dressing of 50% is achievable after some intensive fattening 90-100 days before slaughter a bull of 350 can fetch KES 73,500 per head. To create some feed security forage supply for the bulls is calculated over a period of 24 months. Concentrates needed for the bulls, incl. the fattening period is not calculated in this report because it targets the dairy herd, forage is calculated for the bulls, because if this is not included, forage produced for the dairy herd would likely be used to sustain the bulls on the farm.

Table 17. Feed plan & budget for a dairy herd in Baringo

FEED PLAN & BUDGET												
Dairy herd	**Animals**	**Period**	**Sorghum Silage**		**Napier grass high quality**		**Rhodes grass hay**		**Maize germ**		**MAFC**	**Total MAFC**
			As is	**DM**	**As is**	**DM**	**KES**	**KES**	**As is**	**DM**	**KES**	**KES**
	#	**Days**	**kg**	**kg**	**Kg**	**kg**	**day**	**year**	**Kg**	**kg**	**day**	**year**
Early lactation	1	100	1343	376	3992	479			355	322	464	46400
Mid lactation	1	100	1046	293	3517	422			428	389	339	33900
Late lactation	1	105	1384	387	2844	341			490	445	148	15540
Dry	1	39	692	194			44	39	104	95	-149	-5811
Transition	1	21	410	115			24	21	36	33	-169	-3549
Per cow/year	**1**	**365**	**4876**	**1365**	**10352**	**1242**	**44**	**39**	**1378**	**1251**	**-**	**86480**
Average/cow/day			**13.4**	**3.74**	**28.4**	**3.40**			**3.8**	**3.43**	**-**	**237**
Unmated heifers	1	450	1157	324	8963	1076			1066	968	-139	-62550
Mated heifers	1	280	4800	1344	3873	465			876	795	-187	-52360
Per heifer/2 years		**730**	**5957**	**1668**	**12836**	**1540**			**1941**	**1763**	**-**	**- 114910**
Per heifer/year		**365**	**2979**	**834**	**6418**	**770**			**971**	**881**	**-**	**-57455**
Average heifer/day			**8.2**	**2.3**	**17.6**	**2.1**			**2.7**	**2.4**	**-**	**-157.4**
Bulls < 1 year	1	365	939	263	7270	872						
Bulls > 1 year	1	365	6257	1752	5049	606						
Per bull/2 years		**730**	**7196**	**2015**	**12319**	**1478**						
Average head/day		**365**	**9.9**	**2.8**	**16.9**	**2.0**						

9.2 One-year feed and fodder plan

Based on the total dry matter from the different forage crops needed per animal in the different production and growth stages we calculated the acreage (m² green columns in table 19) required based on the estimated yield per acre (Annex 12 table 1-8). This gives a total of 3768 m² (0.94 acre) for one lactating cow, one heifer and one bull per year and 34 (70 kg bags) maize germ meal.

Table 18. Feed plan & budget for the dairy herd

ONE YEAR FEED & FODDER CROP PLAN													
Dairy herd	**Animals**	**Period**	**Sorghum fresh chop (28% DM)**			**Napier grass high quality**			**Rhodes grass hay low quality**			**Maize Germ**	
	#	**Days**	**As is (kg)**	**DM (kg)**	**m²**	**As is (kg)**	**DM (kg)**	**m²**	**As is (kg)**	**DM (kg)**	**m²**	**As is (kg)**	**DM (kg)**
Early lactation	1	100	1343	376	172	3992	479	403				355	322
Mid lactation	1	100	1046	293	134	3517	422	355				428	389
Late lactation	1	105	1384	387	178	2844	341	287				490	445
Dry	1	39	692	194	89	0	0	0	44	39	39	104	95
Transition	1	21	410	115	53	0	0	0	24	21	21	36	33
Per cow/year	**1.0**	**365**	**4465**	**1250**	**573**	**10352**	**1242**	**1044**	**44**	**39**	**39**	**1414**	**1284**
Unmated heifers	1	450	1157	324	148	8963	1076	904				1066	968
Mated heifers	1	280	4800	1344	616	3873	465	391				876	795
Per heifer/2 years		**730**	**5957**	**1668**	**764**	**12836**	**1540**	**1294**				**1941**	**1763**
Per heifer/year	**1.0**	**365**	**2979**	**834**	**382**	**6418**	**770**	**647**				**971**	**881**
Bulls < 1 year	1	365	939	263	120	7270	872	733					
Bulls > 1 year	1	365	6257	1752	803	5049	606	509					
Per bull/2 years		**730**	**7196**	**2015**	**923**	**12319**	**1478**	**1242**					
Per head/year	**1.0**	**365**	**3598**	**1007**	**462**	**6159**	**739**	**621**					
Total m²/year					**1417**			**2312**			**39**		

9.3 One-year fodder crop plan

For the entire average herd over the 22 farms , 9.3 animals, 5.3 dairy cows, 3.2 female youngstock and 0.8 male youngstock this would require a reservation of 3.23 acre for forage production in the highland farms. If this acreage could gradually increase to 4 acres the farmers can build a feed stock for emergency, years with forage shortage. In our case it is assumed to happen every 5-6 years in the highlands.

The dairy herd is estimated to produce 80-90% more milk per (from 2000 kg per 305-day lactation to 3743 kg per 305-day lactation this increase in milk yield is likely to be higher if the calving interval of the dairy herd decreases from once every 1.5-2 years to every 1-1.25 years. With cows that are healthier and stronger because they are in a better body condition.

Based on these figures the farmer can generate a total margin above feed cost of (5.3* 86,480/=) KES 458,344 for the dairy herd and (3.2/2 *48,180/=) KES 77.088/= bringing the total margin above feed cost for the dairy herd to KES 535,432 per year.

If the cost of forages in the diet would double (100% increase) for forage Sorghum (2.5 KES/kg -> 5.0 KES/kg) and Napier grass high quality (2.0 KES/kg -> 4.0 KES/kg) and a the price of Rhodes hay would increase with 50% (10 KES/kg -> 15 KES/kg) which is equal to 225 KES/15 kg bale the total margin per cow would reduce with 38.4% from KES 86,480/- to KES 53,285/= This increases the feed cost from 49% based on own forage production to 68% of the milk income in cost of forage production increases either through increase in inputs or inefficiencies, low yields due to weather conditions of poor agronomic practices.

If the farmer had to buy the forage sorghum in the market at fourfold the price (2.5 KES/kg -> 10 KES/kg) and the price of hay would double (10 KES/kg -> 20 KES/kg) which is equal to 300 KES/15 kg bale and assuming the farmer can continue to harvest the same amount of Napier grass at the same cost (2 KES/kg) the total margin per cow would reduce with 43.8% from KES 86,480/= to KES 48,640/=. This equals to feed cost being 71% of the milk income.

Table 19. Fodder crop plan for the herd

FODDER CROP PLAN					
	Dairy herd			**Commercial**	**Total**
	Dairy cows	**Female youngstock**	**Male young stock**	**Sale**	**Acreage per forage crop**
Number of head	5.3	3.2	0.8		**Acre**
Forage sorghum (m²)	3036	1223	369	-	**1.16**
Napier grass (m²)	5533	2071	497	-	**2.03**
Rhodes grass	207	-	-	-	**0.05**
Forage Maize (m²)	-	-	-	-	**0**
Existing grazing land (m²)	-	-	-	-	**0**
Total acreage per animal category (acre)	**2.19**	**0.82**	**0.22**	**0**	**3.23**

Chapter 10. Conclusions and recommendations

- On farm forage production is the cheapest and most preferred option to maximize margin above feed cost for the dairy farmer in the highlands and lowlands of Baringo
- The herd size needs to match the land that can be dedicated to forage production, as a rule of thumb, one acre on green forage (Fresh Napier and forage Sorghum) chop can sustain 1 dairy cow and 2 followers.
- The price of the price per kg dry matter of the same quality should not be more then 20-40% of the medium cost of forage produced on-farm for the farer to keep the feed cost as a percentage of milk income in between 50-60% over the whole lactating period.
- Select dairy cows on their ability to maximize use of quality forage grown on-farm, as a result milk output increases, feed costs are reduced, milk income increases, the feed efficiency increases because of genetic match with the available feeds, resulting in optimized milk production, this leads to reduced inputs needed per liter of milk produced."
- Current practices: forage of low quality is produced at high cost, dairy cows and youngstock are underfed and the "milk curve" cannot be sustained by the cow resulting in low milk production, poor animal health and fertility. The farmer has relative high feed cost with a small or negative margin above feed cost.
- Allocation of enough land for forage production in relation to the size of the herd, followed by good agronomic practices, ensuring enough quality forage (fresh or conserved) able the meet the nutrient requirements of the herd with a balanced diet will ensure a healthy, fertile productive herd with better margin above feed cost.
- The forage availability and feed supply gaps between the current situation and the recommended situation is substantial and because forage is not immediately accessible there is not a "quick fix". Prices of fodder in the forge market are too high to feed the entire herd on forage from the market for longer periods of time.
- To change the situation persistent, disciplined long-term effort is needed which requires a financial investment upfront to resolve the downward spiral of events.

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Annexes

Annex 1. List of farmers, visiting date, location

Legend: Red- data collected are incomplete.

Annex 1, Table 1, List of farmers

	Farmer name	Code	Date of data collection	Field Latitude	Field Longitude	Altitude (masl)	Highland (H) / Lowland (L)	
1	Isaiah Cheraisi	F1	24/07/2023	0.05322	35.84468	1687	Lowland	L
2	John Chesire	F2	25/07/2023	0.08997	35.8769	1616	Lowland	L
3	Cornelius Kiprono	F3	25/07/2023	0.0896	35.87759	1612	Lowland	L
4	Elijah Kaitany	F4	26/07/2023	0.3853	35.88565	1705	Lowland	L
5	Philip Chebon	F5	27/07/2023	0.0731	35.82654	1683	Lowland	L
6	Dominic Kitilit	F6	28/07/2023	0.09027	35.84061	1683	Lowland	L
7	Lameck Chebutuk	F7	29/07/2023	0.12499	35.61564	2573	Highland	H
8	Lenah Cheruiyot	F8	01/08/2023	0.02391	35.77034	1972	Highland	H
9	David Cheruiyot	F9	02/08/2023	0.112625	35.71802	2169	Highland	H
10	Mumberes Farm	F10	03/08/2023	0.00598	35.56384	2668	Highland	H
11	David Kolbech	F11	03/08/2023	0.002405	35.57856	2625	Highland	H
12	Pamela Kosgei	F12	04/08/2023	0.0819	35.71688	2129	Highland	H
13	Everlyne Koech	F13	16/08/2023	0.04889	35.65981	2309	Highland	H
14	Simon Korir	F14	16/08/2023	0.04889	35.65982	2305	Highland	H
15	Sammy Chumba	F15	17/08/2023	0.0845	35.64522	2351	Highland	H
16	Nelson Bett	F16	17/08/2023	0.00691	35.60765	2550	Highland	H
17	Esther Cheruiyot	F17	18/08/2023	0.33235	35.80774	1905	Highland	H
18	Amos Kipkoech	F18	18/08/2023	0.32631	35.80566	1969	Highland	H
19	Samuel Ngetich	F19	21/08/2023	-0.03977	35.86856	1721	Lowland	L
20	Cheruiyot K Kimaiyo	F20	22/08/2023	0.09238	35.90755	2072	Lowland	L
21	Monicah Bartonjo	F21	23/08/2023	0.03982	35.73368	2068	Highland	H
22	Elijah Kurere	F22	23/08/2023	0.09578	35.79945	1806	Lowland	L
23	Daniel Cheruiyot	F23	24/08/2023	0.07898	35.83983	1663	Lowland	L
24	Julia Singa	F24	24/08/2023	0.02137	35.83735	1729	Lowland	L

Annex 2. Complete soil sample analysis overview

Annex 2, Table 1, Complete soil sample analysis per farm

				Low Range	<6,0	<17	<1	<20	<1.5		<20	<75	<10
				Adequate	6<>7.2	17<>50	1<>2	20<>40	1.5<>3.0		20<>40	75<>200	10<>30
				High Range	>7.2	>50	>2	>40	>3.0		>40	>200	>30
	Farm code	**Altitude (m)**	**Highland (H) & Lowland (L)**	**Common Name**	**pH (H2O)**	**Organic carbon content g/kg**	**Total nitrogen content g/kg**	**P (Phosphor Mehlich-3) mg/kg**	**K (exch. Potassium) mmol+/kg**	**Soil Texture**	**Clay content mineral part**	**Cation Exchange Capacity (CEC)**	**Soil Moisture**
1	F14	2305	H	Boma Rhodes	5.4	32.5	2.4	8.5	2.9	Clay	48	73	18
2	F12 (1)	2129	H	Napier	5.5	26.2	2.1	20	3.2	Clay	42	109	28
3	F7	2573	H	Napier	5.7	36.4	3.2	26.5	4.3	Clay	48	119	25
4	F10	2668	H	Napier	5.7	24.7	2.3	6.1	3.7	Clay	57	107	25
5	F16	2550	H	Maize	5.7	37.4	3	8.1	2.8	Clay	60	136	26
6	F11	2625	H	Maize	5.8	25.4	2.5	6.9	4.1	Clay	55	118	26
7	F8	1972	H	Napier	5.9	22.7	2	34.8	5.4	Clay	40	127	21
8	F9	2169	H	Napier	5.9	27.6	2.4	14.2	3.9	Clay	60	136	26
9	F13	2309	H	Maize field	5.9	20.2	1.6	12.5	4.4	Clay	53	97	21
10	F15	2351	H	Napier	6.1	26.8	2.1	18.2	5.3	Clay	55	99	19
11	F6	1683	L	Sorghum	6.2	13.2	1	12.4	5.4	Loam	19	106	7
12	F17	1905	H	Maize & Bean	6.2	29.7	2.4	5.2	5.8	Clay	58	197	22
13	F21	2068	H	Sorghum	6.2	19.7	1.7	11.1	5.8	Clay	58	177	17
14	F1	1687	L	Sorghum	6.3	24.3	1.9	25.8	8.6	Clay	41	263	22
15	F4	1705	L	Brachiaria	6.3	13.2	1.2	24.2	7.3	Clay	42	173	16
16	F18	1969	H	Napier	6.3	25.8	2	12.8	6.2	Clay	57	224	20
17	F22	1806	L	Sorghum	6.3	15.7	1.4	15.9	7.3	Clay	52	124	11
18	F5	1683	L	Sorghum	6.5	15.3	1.2	47.5	10.7	Loam	20	143	6
19	F20	2072	L	Sorghum/Millet	6.5	35.8	2.3	27.5	14.8	Clay loam	38	328	18
20	F19	1721	L	Sorghum/Millet	6.6	11	0.9	16.9	6.3	Sandy Loam	15	100	6
21	F23	1663	L	Boma Rhodes	6.6	13	0.9	6.5	8.2	Clay	52	236	17
22	F24	1729	L	Sorghum	6.6	13.5	1	13.5	7.6	Loam	25	169	12
23	F3	1612	L	Sorghum	6.7	14	1.3	26.4	3.9	Clay loam	40	189	18
24	F12 (2)	2129	H	Napier	6.8	17.2	1.8	27.9	3.2	Clay	42	211	39
				Average	6.2	22.6	1.9	17.9	5.9		45	157	19

Annex 3. Soil analysis with pH less than 6

The table below shows the analyses report of soil samples from 9 farms in the highlands with pH below 6

Legend: Red- less than recommended
Green- on the range of recommended level
Yellow- above the recommended level

Annex 3, Table 1, Soil sample analyses report ranked by soil pH

	Low Range	<6,0	<17	<1	<20	<1.5		<20	<75
	Adequate	6<>7.2	17<>50	1<>2	20<>40	1.5<>3.0		20<>40	75<>200
	High Range	>7.2	>50	>2	>40	>3.0		>40	>200
Farm code	**Common Name**	**pH (H2O)**	**Organic carbon content g/kg**	**Total nitrogen content g/kg**	**P (Phosphor Mehlich-3) mg/kg**	**K (exch. Potassium) mmol+/kg**	**Soil Texture**	**Clay content mineral part**	**Cation Exchange Capacity (CEC)**
F14	Boma Rhodes	5.4	32.5	2.4	8.5	2.9	Clay	48	73
F12	Super Napier	5.5	26.2	2.1	20.0	3.2	Clay	42	109
F7	Napier grass	5.7	36.4	3.2	26.5	4.3	Clay	48	119
F10	Napier grass	5.7	24.7	2.3	6.1	3.7	Clay	57	107
F16	Maize for silage	5.7	37.4	3	8.1	2.8	Clay	60	136
F11	Forage maize	5.8	25.4	2.5	6.9	4.1	Clay	55	118
F8	Napier grass	5.9	22.7	2.0	34.8	5.4	Clay	40	127
F9	Napier grass	5.9	27.6	2.4	14.2	3.9	Clay	60	136
F13	Maize field	5.9	20.2	1.6	12.5	4.4	Clay	53	97
	AVERAGE	5.7	28.1	2.4	15.3	3.9		51.4	113.6

Annex 4. Soil analysis with pH more than 6

Table 1 below shows the soil sample analyses report of 15 farms, 10 from lowlands and 5 from highlands with an average pH 6.5. 8 of 15 soil analyses, all 8-farm situated in the lowlands, showed low organic carbon contents with an average of 13.6g/kg.

Legend: Red- less than recommended
Green- on the range of recommended level
Yellow- above the recommended level

Annex 4, Table 1, Soil sample analyses report ranked by soil pH

	Low Range	<6,0	<17	<1	<20	<1.5		<20	<75
	Adequate	6<>7.2	17<>50	1<>2	20<>40	1.5<>3.0		20<>40	75<>200
	High Range	>7.2	>50	>2	>40	>3.0		>40	>200
Farm code	**Common name of forage crop**	**pH (H2O)**	**Organic carbon content g/kg**	**Total nitrogen content g/kg**	**P (Phosphor Mehlich-3) mg/kg**	**K (exch. Potassium) mmol+/kg**	**Soil Texture**	**Clay content mineral part**	**Cation Exchange Capacity (CEC)**
F15	Super Napier	6.1	26.8	2.1	18.2	5.3	Clay	55	99
F6	Sorghum	6.2	13.2	1.0	12.4	5.4	Loam	19	106
F17	Maize & Bean	6.2	29.7	2.4	5.2	5.8	Clay	58	197
F21	Sorghum	6.2	19.7	1.7	11.1	5.8	Clay	58	177
F1	Sorghum	6.3	24.3	1.9	25.8	8.6	Clay	41	263
F4	Brachiaria	6.3	13.2	1.2	24.2	7.3	Clay	42	173
F18	Napier grass	6.3	25.8	2	12.8	6.2	Clay	57	224
F22	Sorghum	6.3	15.7	1.4	15.9	7.3	Clay	52	124
F5	Sorghum	6.5	15.3	1.2	47.5	10.7	Loam	20	143
F20	Sorghum & Millet	6.5	35.8	2.3	27.5	14.8	Clay loam	38	328
F19	Sorghum & Millet	6.6	11	0.9	16.9	6.3	Sandy Loam	15	100
F23	Boma Rhodes	6.6	13	0.9	6.5	8.2	Clay	52	236
F24	Sorghum	6.6	13.5	1	13.5	7.6	Loam	25	169
F3	Sorghum	6.7	14.0	1.3	26.4	3.9	Clay loam	40	189
F12	Super Napier	6.8	17.2	1.8	27.9	3.2	Clay	42	211
	AVERAGE	6.4	19.2	1.5	19.5	7.1		40.9	182.6

Annex 5. Soil organic carbon / Total Nitrogen ratio

Annex 5, Table 1, Soil organic carbon (SOC) - Total Nitrogen (TN) ratio

Low Range		<17	<1	>25
Adequate		17<>50	1<>2	15<>25
High Range		>50	>2	<15
	Farm code	**Organic carbon content g/kg**	**Total nitrogen content g/kg**	**C:N Ratio**
1	F19	11	0.9	12
2	F23	13	0.9	14
3	F4	13.2	1.2	11
4	F6	13.2	1	13
5	F24	13.5	1	14
6	F3	14	1.3	11
7	F5	15.3	1.2	13
8	F22	15.7	1.4	11
9	F12	17.2	1.8	10
10	F21	19.7	1.7	12
11	F13	20.2	1.6	13
12	F8	22.7	2	11
13	F1	24.3	1.9	13
14	F10	24.7	2.3	11
15	F11	25.4	2.5	10
16	F18	25.8	2	13
17	F12	26.2	2.1	12
18	F15	26.8	2.1	13
19	F9	27.6	2.4	12
20	F17	29.7	2.4	12
21	F14	32.5	2.4	14
22	F20	35.8	2.3	16
23	F7	36.4	3.2	11
24	F16	37.4	3	12
Average		27.0	2.2	12.1

Annex 6. Fertilizer composition

Annex 6, Table 1, Fertilizer composition

RECOMMENDED FERTILISER N:P:K:S	ABBREVIATION OF FERTILIZER	FULL- OR BRAND NAME
46:0:0	U	Urea or use 2X recommended kg of CAN
26:0:0	CAN	Calcium Ammonium Nitrate (CAN)
40:0:0 14%S	AS	Ammonium Sulphate/Kynoplus S
12:0:0 25%CaO	CN	Calcium Nitrate (CN)
26:0:0 13%S	ASN 13%S	Ammonium sulphate (ASN)
15.5:0:0 26%CaO	ASN 26%Cao	Ammonium sulphate (ASN)
24:0:0 6%S	ASN 6%	Ammonium sulphate (ASN)/ Yara Bela Sulfan/Kynoplus S
18:38:0 2.3%CaO 0.2% MgO 5% S	KN	Kynoch Nafaka
0:46:0 15% CaO	TSP	Triple superphosphate
0:18:0 11% CaO	SSP	Single superphosphate
12:52:34% KH_2PO_4	MKP	Mono potassium phosphate
12:11:18%	NPK	Nitrogen (N), phosphorus (P) and potassium (K)

Annex 7. Soil fertility test recommendation

Legend: see Annex 6

Annex 7, Table 1, Soil fertility test recommendation

SOIL FERTILITY TEST RECOMMENDATION								
Farm	**Forage crop**	**Before planting**		**Planting**	**After Planting**			
Farm code	**Common Name**	**Lime kg/acre**	**Compost or Manure kg/acre**	**Planting kg/acre**	**Topdressing (4-6 weeks)**	**1st cut**	**2nd cut**	**3rd cut**
F14	Boma Rhodes	350	540	10kg MKP, 127kg NPK	40kg AS	40kg AS	40kg AS	40kg AS
F12(1)	Napier	350	535	30kg ASN 26%Ca, 15kg KN		15kg U	15kg U	15kg U
F10	Napier	350	560	5kg CAN 26%Ca, 35kg KN		15kg U	15kg U	15kg U
F7	Napier	350	530	30kg ASN 26%Ca, 15kg KN		15kg U	15kg U	15kg U
F16	Maize	350	560	50kg SSP, 30kg KN	10kg AS			
F11	Maize	350	555	50kg SSP, 30kg KN	10kg AS			
F13	Maize	350	545	50kg SSP, 30kg KN	10kg AS			
F8	Napier	350	530	30kg ASN 26%Ca, 15kg KN		15kg U	15kg U	15kg U
F9	Napier	350	565	5kg CAN 26%Ca, 35kg KN		15kg U	15kg U	15kg U
F15	Napier	350	540	5kg CN 26%Ca, 20kg KN		10kg U	10kg U	10kg U
F6	Sorghum	100	1205	130kg CAN, 140kg NPK		40kg U	40kg U	
F21	Sorghum	150	580	10kg SSP, 20kg KN		5kg AS	5kg AS	
F17	Maize/ Bean	150	565	25kg SSP, 40kg KN	10kg U			
F4	Brachiaria	150	1380	30kg ASN 26%Cao, 15kg KN		15kg U	15kg U	15kg U
F22	Sorghum	150	1520	10kg SSP, 20kg KN	5kg AS	5kg AS	5kg AS	
F1	Sorghum	150	550	175kg CAN, 45kg NPK		50kg U	50kg U	
F18	Napier	150	570	5kg CAN, 35kg 'KN		15kg U	15kg U	15kg U
F5	Sorghum	100	1300	205kg CAN,		50kg U	50kg U	
F20	Sorghum /Millet	150	530	15kg CAN		5kg AS	5kg AS	
F19	Sorghum /Millet	100	1005	20kg CN, 25kg KN		10kg U	10kg U	
F23	Boma Rhodes	150	1495	55kg ASN 26%Cao, 45kg KN	40kg AS	40kg AS	40kg AS	40kg AS
F24	Sorghum	100	1205	20kg CN, 25kg KN		10kg U	10kg U	
F3	Sorghum	100	1405	170kg CAN, 45kg NPK		50kg U	50kg U	
F12(2)	Napier	150	550	30kg ASN 26%Ca, 15kg KN		15kg U	15Kg U	15Kg U

Annex 8. Fertilizer prices

Annex 8 Table 1, Market fertilizer prices in Kenya

Brand	Nakuru/Baringo	NPK Ratio	Unit (kg)	Retail Price KES/50 kg bag	Price KES/Kg
FALCON	*DAP*	18:46:00	50	5730	115
	CAN	27%N	50	4040	81
	P.UREA	46% N	50	4670	93
	G.UREA	46% N	50	4670	93
	A.SULPHATE	21% N 24% S	50	3080	62
	NPK 23 23 0	23% N 23% P	50	4890	98
	NPK 17 17 17	17% N 17% P 17% K	50	4890	98
	MOP	60% K20	50	5420	108
	CN		50	5000	100
	TSP	46% P	50	6160	123
Kynoch	*KynoPlus "Top"*		50	5070	101
	KynoPlus "S" (AS)		50	4650	93
	KynoNafaka NPK	18:38:00 + 5%S +2.3 % Ca+ 0.2 % Mg	50	5920	118
	KynoHorti		50	5500	110
	Kynoch Panda Plus		50	6240	125
	Kynoch Panda Power		50	5810	116
	KynoPlus Growmax		50	4650	93
	KynoPlus Chai	25% N 5% P 5% K 5% S 2Ca	50	5500	110
	KynoPlus Expresso		50	5500	110
	KynoPlus Multicrop		50	5180	104
	KynoPlus Kuza		50	5070	101
	KynoMAIZEic		50	5070	101
	Kynoplus Avo Starter		50	5070	101
	Kynoch Polysulphate		50	4650	93
YARA	YaraMila Power	13:24:10+Mg +s+Zn	50	5500	110
	Yara Vera Amidas(Urea)	40N +6S	50	5600	112
	Microp +Planting	11N 28P 4.5K 6CaO Mg +S+Zn	50	5200	104
	Microp +Topdressing	34N 3K 4CaO Mg +S+Zn	50	5000	100
	YaraBela Sulfan (CAN)	24N+6S	25	2150	86

Annex 9. Fertilizer cost of soil correction plan per acre

Annex 9 Table 1 Fertilizer cost of soil correction measures of BAMSCOS farms

Farm code	Total soil correction cost for multicut crops	Total soil correction cost for 1 harvest
#	KES/acre	KES/ acre
F1	8,915	6,125
F3	22,673	19,883
F4	10,725	6,540
F5	6,300	3,510
F6	35,153	25,853
F7	12,300	8,115
F8	12,300	8,115
F9	12,503	8,318
F10	12,500	8,315
F11	13,748	13,748
F12 (1)	12,303	8,118
F12 (2)	10,310	6,125
F13	13,743	13,743
F14	30,876	27,156
F15	9,420	6,630
F16	13,750	13,750
F17	10,183	10,183
F18	10,505	6,320
F19	8,313	6,453
F20	3,910	3,445
F21	6,180	5,715
F22	6,650	6,185
F23	23,448	19,728
F24	8,913	7,053
Min	**3,910**	**3,445**
Max	**35,153**	**27,156**
Avg	**13,151**	**10,380**

Annex 9 Table 2 Fertilizer cost of soil correction measures of BAMSCOS farms in the highlands

Farm code Highland	Total soil correction cost for multicut crops	Total soil correction cost for 1 harvest
#	**KES/acre**	**KES/acre**
F14	30876	27156
F16	13750	13750
F11	13748	13748
F13	13743	13743
F17	10183	10183
F12 (1)	12303	8118
F10	12500	8315
F7	12300	8115
F8	12300	8115
F9	12503	8318
F15	9420	6630
F18	10505	6320
F12 (2)	10310	6125
F21	6180	5715
Avg	**12901**	**10311**
Min	**6180**	**5715**
Max	**30876**	**27156**

Annex 9 Table 2 Fertilizer cost of soil correction measures of BAMSCOS farms in lowland

Farm code Highland	Total soil correction cost for multicut crops	Total soil correction cost for 1 harvest
F23	23448	19728
F4	10725	6540
F6	35153	25853
F22	6650	6185
F5	6300	3510
F24	8913	7053
F3	22673	19883
F1	8915	6125
F20	3910	3445
F19	8313	6453
Avg	**13500**	**10477**
Min	**3910**	**3445**
Max	**35153**	**25853**

Annex 10. Feed analyses of compound concentrate mixes

Annex 10 Table 1 Proximate analyses report of compound concentrate mixes against feed library value in Rumen8 ration formulation software

Farm Code	Description raw material	Dry Matter g/kg	Crude Ash g/kg DM	Crude Protein g/kg DM	Crude Fat g/kg DM	Starch g/kg DM	Sugar g/kg DM	NDF g/kg DM	ME MJ/kg DM
F1	Luuche feeds Std	912	165	107	84	205	22	388	11.6
F4	Eldo vet Nax Feeds Maziwa Extra	926	218	111	101	110	15	462	11.7
F10	Ainabkoi Farmers coop feeds	898	119	144	78	139	27	411	11.6
F17	Faida feeds	909	79	202	65	116	38	384	11.6
F9	Wonder Feeds	908	100	155	101	113	28	424	11.9
F16	Suguna Feeds High Yield	911	118	174	86	101	63	339	11.9
F15	Chefko dairy meal	903	79	167	80	175	35	371	11.9
F10	Menengai Feeds	905	103	130	98	216	37	354	12.4
F20	Kays Dairy meal	915	93	158	82	185	31	383	12.1
	Average	**910**	**119**	**150**	**86**	**151**	**33**	**391**	**11.9**
Library	**Standard dairy meal**	**899**	**109**	**151**	**64**	**224**	**53**	**329**	**11.9**

Farm Code	Price as fed KES/kg	Price of DM Kes/kg of DM	Price of ME KES/MJ
F1	28.5	31.3	2.7
F4	32.9	35.5	3.0
F10	46.0	51.2	4.4
F17	42.0	46.2	4.0
F9	42.1	46.4	3.9
F16	42.9	47.1	4.0
F15	40.0	44.3	3.7
F10	42.0	46.4	3.7
F20	40.0	43.7	3.6
	39.6	**43.6**	**3.7**

Annex 11. Feed analyses single source concentrate ingredients

Annex 11 Table 1 Proximate analyses report of single source concentrate ingredients against feed library value in Rumen8 ration formulation software

Farm Code	**Description of raw material**	**Dry Matter**	**Crude Ash**	**Crude Protein**	**Crude Fat**	**Starch**	**Sugar**	**NDF**	**ADF**	**ADL**	**ME**	**Price**
	Client sample	g/kg	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	MJ/kg DM	KES/kg
F24	Rapeseed CP<380	908	62	379	68	63	94	221	168	77	11.6	
F24	Rapeseed CP>380	910	63	375	69	63	89	222	169	70	11.6	
	Average Rapeseed meal	**909**	**63**	**377**	**69**	**63**	**92**	**222**	**169**	**74**	**11.6**	
Library	**Rapeseed meal fat > 40 g/Kg**	**916**	**72**	**371**	**89**	**25**	**92**	**301**			**12.9**	
F24	Soya	910	67	486	13	0	107	131	84	5	11.9	
Library	**Soyabean meal fat < 40 g/Kg**	**896**	**68**	**481**	**31**	**32**	**100**	**133**			**13.4**	
F24	Sunflower -27%CP	927	57	252	117	33	47	421	316	91	10.5	
F24	Sunflower-31%CP	926	57	255	115	39	55	375	272	74	10.5	
	Sunflower seed meal	**927**	**57**	**254**	**116**	**36**	**51**	**398**	**294**	**83**	**10.5**	
Library	**Sunflower seed meal non dehul**	**907**	**56**	**294**	**71**	**30**	**56**	**448**			**10.1**	
F24	Wheat bran	896	51	163	35	195	63	372	115	30	9.8	
F11	Wheat bran	882	48	150	31	198	62	390	124	33	9.5	38
F24	Wheat bran	899	48	163	36	201	63	366	112	30	10.2	
F12	Wheat bran	877	51	158	44	133	38	428	157		11.2	38
	Wheat bran	**889**	**49**	**159**	**37**	**182**	**56**	**389**	**127**	**31**	**10.2**	**38**
Library	**Wheat bran**	**883**	**56**	**165**	**40**	**198**	**66**	**455**			**11.1**	
F6	Maize germ	908	44	120	135	385	23	268	59		14.6	35
Library	**Maize germ fat > 40 g/Kg**	**894**	**57**	**127**	**58**	**370**	**57**	**326**			**12.9**	
F7	Sorghum brewers' grain	267	43	300	93	7	24	443	344		9.6	18
Library	**Sorghum brewers' grain wet**	**316**	**25**	**355**	**117**	**57**	**10**	**356**			**10.0**	

Annex 11 Table 2 Proximate analyses report of maize silage against feed library value in Rumen8 ration formulation software

		Dry Matter	Crude Ash	Crude Protein	Crude Fat	Starch	Sugar	NDF	ADF	ME	Price
Farm Code	Description raw material	g/kg	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg DM	MJ/kg DM	KES/kg
F10	Mumberes Farm	274	46	81	28	276		456	269	10.6	5
Library	Maize silage DM<30%	262	48	65	26	189	8	486		9.9	

Annex 12. Forage production cost analyses

Annex 12 Table 1 Production cost of Rhodes grass hay on the farms of BAMSCOS members

Rhodes grass hay												
Farm code		F2	F8	F14	F15	F17	F18	F19	F20	F23	F24	**AVG**
Land under forage	acreage	12.0	1.0	1.0	1.0	0.5	3.0	6.0	9.0	10.0	3.0	5
Expenses												
Land lease	KES/acre						1,667		5,000		10,000	5,667
Land Preparation	KES/acre	7,667	7,500	6,000	14,500	7,200	6,600	8,500	5,400	8,000	6,000	7,472
Planting	KES/acre	9,429	2,000	11,400	3,400	6,000	5,000	1,150	11,111	7,150	12,167	6,844
Crop maintenance	KES/acre	1,000	4,850	3,050	3,950		3,975	1,533	3,200		1,283	2,869
Harvesting	KES/acre	6,996	15,750	16,800	1,200		9,600	4,033	13,303	6,940	6,000	8,966
Conservation	KES/acre	250		13,000					400			5,380
Total cost	KES/acre	**25,342**	**30,100**	**50,250**	**23,050**	**13,200**	**26,842**	**15,217**	**38,414**	**22,090**	**35,450**	**28,617**
Yield												
Total bales/acre	Bales/acre	72	300	265	530		268	320	133	62	75	238
no. of cuttings/year		1	2	4	2	2	2	2	1	2	1	2
Weight/bale	kg/bale	15	15	14	15		12	10	13	10	18	14
Yield/acre/year	kg/acre	1,080	4,500	3,710	7,950	2,652	2,274	6,400	1,729	1,235	1,350	3,493
Production cost		**23.5**	**6.7**	**13.5**	**2.9**	**5.0**	**11.8**	**2.4**	**22.2**	**17.9**	**26.3**	**13.2**

Annex 12 Table 2 Production cost analysis of Rhodes grass hay on the farm as estimated by ProDairy team

Margins Analysis of Rhodes Grass (Hay) Production- 'on farm'						
Product	Description	Number	Unit price	Year 1	Total	Average 4 years
Establishment cost						
Land lease	Annual lease	1	-	-	-	-
Planting material	Seed (kg)	8	1,000	8,000	8,000	
Chissel Ploughing	Acre	1	3,500	3,500	3,500	
Harrowing	Acre	1	2,500	2,500	2,500	
Spring tine cultivator	Acre	1	2,500	2,500	2,500	
Fertilizer	NPK (50kg)	1	5,250	5,250	5,250	
Manure	FYM/Compost (10MT/ha)	4	1,000	4,000	4,000	
Planting/Broadcasting	Acre	1	2,500	2,500	2,500	
Spraying	Acre	1	2,000	2,000	2,000	
Herbicides (2,4 D Amine)	Acre	1	2,000	2,000	2,000	
Sub-total				32,250	32,250	8,063
Fertilzer application	Acre	1	2,000	2,000	8,000	2,000
Maintenance	N Fertilizer (50kg)	3	4,750	9,500	52,250	13,063
Harvesting/conservation	Mechanized harvesting/baling	1	80	12,000	96,000	24,000
Sub-total				23,500	156,250	39,063
Total cost				**55,750**	**188,500**	**47,125**
Total output	Yield kg Hay			2250	18,000	4,500
	Bales (15kg)			150	1,200	300
Unit cost	Per bale					157
	Per kg		10.5			10.5
	Per kg DM (DM=85%)					12.3
Unit price hay producer	Per bale			300		300
	Per kg		20.0	20.00		20.00
Total revenue				45,000	360,000	90,000
Gross margins				-10,750	171,500	42,875
Total recurrent cost				23,500		
Grand total cost			0.7	55,750		
Gross revenue				45,000		
Total gross margin				-10,750	171,500	42,875
Source: ProDairy 2023						

Annex 12 Table 3 Production cost of forage maize on farms of BAMSCOS members

Forage maize								
Farm Code		F1	F4	F10	F16	F23	F24	**AVG**
Land under forage maize	acre	5	8	5	5	2	0.5	4.3
Expenses								
Land lease	KES/acre	3,000		10,000				6,500
Land preparation	KES/acre	7,040	4,275	3,500	2,250	9,500	6,000	5,428
Planting	KES/acre	1,860	2,500	14,460	5,500	6,700	8,000	6,503
Crop maintenance	KES/acre	2,865		4,300		7,200	3,833	4,550
Harvesting	KES/acre			15,000	1,000	3,000	15,000	8,500
Conservation	KES/acre		2,500	13,200	9,000	500	12,500	7,540
TOTAL COST	KES/acre	**14,765**	**9,275**	**60,460**	**17,750**	**26,900**	**45,333**	**29,081**
Yield								
Harvesting stage				Dough	Milky	Stover	Dough	
Estimated Yield	kg		3,000	15,000	13,000		1,060	8,015
Cost/kg silage			**3.1**	**4.0**	**1.4**		**42.8**	**17.08**

Annex 12 Table 4 Production cost of forage maize on farms as estimated by ProDairy team.

Margins analysis of forage maize production per acre				
Product	Description	Number	Unit price	Year
Establishment cost				
Land lease	Annual lease	1	10,000	0
Planting material	Seed (kg)	12.5	800	10,000
Chissel Ploughing	Acre	1	3,500	3,500
Harrowing	Acre	1	2,500	2,500
Seed bed preparation Spring tine cultivator	Acre	1	2,500	2,500
Fertilizer	NPK (50kg)	2	5,250	10,500
Manure	FYM/Compost (10MT/ha)	10	1,000	10,000
Planting	Acre	1	2,500	2,500
Spraying	Acre	2	4,000	4,000
Herbicides	Acre	1	2,000	2,000
Pesticides / Fungicides	Acre	1	1,000	1,000
Fertilizer @ knee height	N (50kg)	1	4,750	4,750
Fertilizer @ tassling	N (50kg)	1	4,750	4,750
Fertilizer application	Acre	2	1,000	2,000
Sub-total				60,000
Harvesting	Mechanized harvesting	1	20,500	20,500
Additive	%	3		
Plastic Cover	ton	0.28	15,000	4,200
Sub-total				24,700
Total cost				84,700
Total output	kg			15,000
Losses	Storage loss	3%		450
	Feeding loss	2%		300
Total output after losses	kg			14250
Ensiled Cost per Unit	Per kg			5.94
	Per kg DM (DM=33.0%)			18.01
Grand total cost				84,700
Source: ProDairy 2023				

Annex 12 Table 5 Production cost of Napier grass on farms of BAMSCOS members

Napier grass									
Farm code		F6	F7	F8	F9	F10	F11	F12	**AVG**
Land under Napier grass	acre	0.25	0.5	1	1.5	0.25	0.25	2	0.8
Expenses									
Land Preparation	KES/acre	3,600	6,000	4,000	1,333	7,200	4,000	3,900	4,290
Planting	KES/acre	8,400	12,200	2,000	1,333	9,600	6,400	12,500	7,490
Crop maintenance	KES/acre	6,000	4,400	4,750		4,800		4,860	4,962
Harvesting	KES/acre		2,752	12,000			33,600	800	12,288
Conservation	KES/acre							177	177
TOTAL COST	**KES/acre**	**18,000**	**25,352**	**22,750**	**2,667**	**21,600**	**44,000**	**22,237**	**22,372**
Yield									
Cutting stage		LV*	LV*	LV*	LV*	LV*	LV*	LV*	
Yield/cut/acre	kg/acre	1,800					8,000		4,900
Cuttings/year	# cut/year	3	3	3	4		3		3
Yield/acre	kg/acre/year	5,400	29,280	6,960	34,560		24,000		20,040
Total yield/acre/year	kg/year					17,792		25,600	21,696
cutting height	meters			1.50		0.60	0.90	1.20	1.05
cost/kg fresh		**3.3**	**0.9**	**3.3**	**0.1**	**1.2**	**1.8**	**0.9**	**1.6**

Annex 12 Table 6 Production cost of Napier grass on farms as estimated by ProDairy team

Napier Grass Production and Margins Analysis cutting interval 8 weeks							
Product	Description	Unit	Number	Unit cost	Year 1	Average 5 Years	Average 10 Years
Establishment Cost:							
Planting material	Cuttings	Cuttings	2000	3	6,000		
Chissel Ploughing	Acre	Acre	1	3,500	3,500		
Harrowing	Acre	Acre	1	2,500	2,500		
Fertilizer	NPK (50kg) 23:23:23	Bags	1	5,250	5,250		
Manure	FYM/Compost (4 MT/acre) 3 kg N per tonne	Acre	4	1,000	4,000		
Labor	Planting	Man days	5	500	2,500		
	Weeding	Man days	8	500	4,000		
Sub-total					27,750	5,550	2,775
Maintenance Cost:							
Fertilizer application	CAN (50kg) 27:0:0	Bags	3	4,750	14,250	14,250	14,250
Labor	Weeding after every cutting	Man days	24	500	12,000	12,000	12,000
	Fertilizer application	Man days	6	500	3,000	3,000	3,000
	Harvesting and transport	Man days	40	500	20,000	20,000	20,000
Sub-total					49,250	49,250	49,250
Total cost					**77,000**	**54,800**	**52,025**
Unit cost	Per kg fresh cut			3.35	3.35	2.30	2.19
	Per kg DM (DM=20.0%)		200	g DM /kg	16.74	11.51	10.93
Output (yield/acre)	kg DM		4,600	1.49	23,000	23,800	23,800
Source: ProDairy 2023							

Annex 12 Table 7 Production cost of forage Sorghum on farms of BAMSCOS members

Forage Sorghum / Pearl Millet							
Farm code		F1	F3	F20	F24	F20	**AVG**
Land under forage- sorghum or millet	acre	3.5	0.5	2.25	0.5	2	1.8
Expenses							
Land Lease	KES/acre					1,500	1,500
Land Preparation	KES/acre	7,040	3,000	6,900	6,000	5,400	5,668
Planting	KES/acre	10,371	800	5,466	7,800	5,733	6,034
Crop maintenance	KES/acre	771		12,977	3,833	12,577	7,540
Harvesting	KES/acre		3,000	1,666	8,000	1,666	3,583
Conservation	KES/acre	950	6,200	21,110	12,500	21,110	12,374
TOTAL COST	KES/acre	**19,132**	**13,000**	**48,119**	**38,133**	**46,486**	**32,974**
Yield							
Harvesting stage			Flowering	seeding	Seeding	Seeding	
Yield/cut/acre	kg		954	1,957	1,024	3,200	1,784
cuttings/year	Number			1	1		1
Cost/Kg silage			**13.6**	**24.6**	**37.2**	**14.5**	**22.5**

Annex 12 Table 8 Production cost of forage Sorghum on farm as estimated by ProDairy team

Margins Analysis of forage Sorghum production per acre				
Product	Description	Number	Unit price	Year 1
Establishment cost				
Land lease	Annual lease	1	10,000	0
Planting material	Seed (kg)	5	1,250	6,250
Chissel Ploughing	Acre	1	3,500	3,500
Harrowing	Acre	1	2,500	2,500
Seed bed preparation Spring tine cultivator	Acre	1	2,500	2,500
Fertilizer	NPK (50kg)	1,5	5,250	7,875
Manure	FYM/Compost (10MT/ha)	10	1,000	10,000
Planting	Acre	1	2,500	2,500
Spraying	Acre	2	4,000	4,000
Herbicides	Acre	1	2,000	2,000
Pesticides / Fungicides	Acre	1	1,000	1,000
Fertilizer 1st topdressing	NPK (50kg)	1.5	4,750	7,125
Fertilizer 2nd topdressing	NPK (50kg)	1.5	4,750	7,125
Fertilizer 3rd topdressing	NPK (50kg)	1.5	4,750	7,125
Fertilizer application	Acre	3	1,000	3,000
Sub-total				66,500
Harvesting	Mechanized harvesting	3	20,000	60,000
Additive	%	3		
Plastic Cover	m2	150	10	1,500
Sub-total				61,500
Total cost				128,000
Total output	kg			30,000
Losses	Storage loss	3%		900
	Feeding loss	10%		3000
Total output after losses	kg			26100
Ensiled Cost per Unit	Per kg			4.90
	Per kg DM (DM=30.0%)			16.35
Total recurrent cost				0
Total gross margin				
Source: ProDairy 2023				

Annex 13. Summary of assessment of forages and feeds available with BAMSCOS farmers

Annex 13 table 1, Assessment of forages and feeds available with BAMSCOS farmers.

Alphabetical Ranking	**Date 01.11.2023**	**Dry Matter**	**Metabolisable Energy (DM)**	**Crude Protein (DM)**	**Neutral Detergent Fibre (DM)**
	Feed ingredients in dairy cow diet	**(g/kg)**	**(MJ/kg DM)**	**(g/kg DM)**	**(g/kg DM)**
1	Brewers spent grain	267	9.6	300	443
2	Dairy meal 1 (ME 11.9)	910	11.9	150	391
3	Dairy meal 2 (ME 12.9)	910	12.9	170	276
4	Lucerne hay high quality (market)	866	9.5	193	434
5	Maize germ	908	14.6	120	268
6	Maize silage < 30% DM	270	9.6	81	538
7	Maize silage < 30% DM	274	10.6	81	456
8	Maize silage 30% <> 35% DM (market)	330	10.7	80	430
9	Napier grass high quality	120	9	153	611
10	Napier grass medium quality	184	8.1	106	681
11	Napier grass low quality	265	7.5	90	690
12	Napier grass silage	301	7.1	90	690
13	Rapeseed meal (Canola)	909	11.6	377	222
14	Rhodes grass hay high quality	885	8	101	736
15	Rhodes grass hay low quality	888	6.4	48	772
16	Sorghum fresh < 30% DM	280	8.9	87	650
17	Sorghum fresh 30% <> 35% DM	360	9.1	67	579
18	Sorghum silage < 30% DM (on farm)	280	8.7	87	650
19	Sorghum fresh 30% <> 35% DM	360	9.1	67	579
20	Soyabean meal	910	11.9	486	131
21	Sunflower seed meal low quality	927	10.5	254	398
22	Wheat bran	889	10.2	159	389

Annex 14 Summary of cost of forages production and feed cost with BAMSCOS farmers

Annex 14 table 1, Prices of raw materials and concentrates, calculated cost range of forage production, because of variation in expenses, yield and losses by the authors and data collected from the farmers.

Ranking alphabetical	**Date 15.08.2023**	**Cost range KES/kg as purchased /produced (farm gate price) by authors**			**Cost range KES/kg as purchased /produced by Bamscos members**		
	Feed ingredients in dairy cow diet	**Low**	**Med**	**High**	**Min.**	**Avg.**	**Max.**
1	Brewers spent Sorghum grain	10.0	14.0	18.0		18.0	
2	Dairy meal	30	40	50	29	40	46
3	Dairy meal HY	30	40	50	29	40	46
4	Lucerne hay high quality	30	35	40			
5	Maize germ	30	35	40		35	
6	Maize silage < 30% DM	4.0	6.0	8.0		5.0	
7	Maize silage < 30% DM	4.0	6.0	8			
8	Maize silage 30% <> 35% DM (market)	8.0	13	18			
9	Napier grass high quality	1.0	2.0	3.0	1.0	1.6	3.3
10	Napier grass medium quality	1.0	2.0	3.0	1.0	1.6	3.3
11	Napier grass low quality	1.0	2.0	3.0	1.0	1.6	3.3
12	Napier grass silage	1.5	2.5	3.5			
13	Rapeseed meal (Canola)	65	70	75			
14	Rhodes grass hay high quality	5.0	10.0	15.0	3.0	13.2	26.3
15	Rhodes grass hay low quality	5.0	10.0	15.0	3.0	13.2	26.3
16	Sorghum fresh < 30% DM	1.0	2.5	4.0			
17	Sorghum fresh 30% <> 35% DM	1.0	2.5	4.0			
18	Sorghum silage < 30% DM	3.5	5.0	6.5	13.6	22.5	37.2
19	Sorghum silage 30% <> 35% DM	3.5	5.0	6.5	13.6	22.5	37.2
20	Sunflower seed meal low quality	30	45	60			
21	Wheat bran	30	35	40		38	

Annex 15. Analyses of cost forages and feeds per MJ Energy (ME) and potential dry matter intake

Annex 15 table 1, Ranking of feeds as per cost of MJ in diets of dairy cows based on medium cost with range to low and high cost and dry mater intake potential of the feed.

Ranking on Medium Cost KES/MJ of ME	**Date 15.08.2023**	**Energy (ME) on DM basis**	**Dry Matter**	**Energy (ME) on "As Fed" basis**	**Cost range KES/kg as purchased /produced (farm gate price)**			**Cost range of ME KES/MJ of ME**			**DM Intake prediction (based on NDF)**
	Feed ingredients in dairy cow diet	**(MJ/kg DM)**	**(g/kg)**	**(MJ/kg)**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**% of LW**
1	Sorghum fresh 30% <> 35% DM	9.1	360	3.3	1.0	2.5	4.0	0.31	0.76	1.22	2.2
2	Sorghum fresh < 30% DM	8.9	280	2.5	1.0	2.5	4.0	0.40	1.00	1.61	2.0
3	Napier grass low quality	7.5	265	2.0	1.0	2.0	3.0	0.50	1.01	1.51	1.9
4	Napier grass silage	7.1	301	2.1	1.5	2.5	3.5	0.70	1.17	1.64	1.9
5	Napier grass medium quality	8.1	184	1.5	1.0	2.0	3.0	0.67	1.34	2.01	1.9
6	Rhodes grass hay high quality	8	885	7.1	5.0	10.0	15.0	0.71	1.41	2.12	1.8
7	Sorghum silage 30% <> 35% DM	9.1	360	3.3	3.5	5.0	6.5	1.07	1.53	1.98	2.2
8	Rhodes grass hay low quality	6.4	888	5.7	5.0	10.0	15.0	0.88	1.76	2.64	1.7
9	Napier grass high quality	9	120	1.1	1.0	2.0	3.0	0.93	1.85	2.78	2.1
10	Sorghum silage < 30% DM	8.7	280	2.4	3.5	5.0	6.5	1.44	2.05	2.67	2.0
11	Maize silage < 30% DM	10.6	274	2.9	4.0	6.0	8	1.38	2.07	2.75	2.9
12	Maize silage < 30% DM	9.6	270	2.6	4.0	6.0	8.0	1.54	2.31	3.09	2.4
13	Maize germ	14.6	908	13.3	30	35	40	2.26	2.64	3.02	4.9
14	Dairy meal HY	12.9	910	11.7	30	40	50	2.56	3.41	4.26	4.2
15	Maize silage 30% <> 35% DM (market)	10.7	330	3.5	8.0	13	18	2.27	3.68	5.10	3.0
16	Dairy meal	11.9	910	10.8	30	40	50	2.77	3.69	4.62	3.3
17	Wheat bran	10.2	889	9.1	30	35	40	3.31	3.86	4.41	3.3
18	Lucerne hay high quality	9.5	866	8.2	30	35	40	3.65	4.25	4.86	3.0
19	Sunflower seed meal low quality	10.5	927	9.7	30	45	60	3.08	4.62	6.16	3.3
20	Brewers spent Sorghum grain	9.6	267	2.6	10.0	14.0	18.0	3.90	5.46	7.02	2.9
21	Rapeseed meal (Canola)	11.6	909	10.5	65	70	75	6.16	6.64	7.11	5.9

*The colour scheme shows the darker the colour the less interesting it is to use the feed as a protein source in the diet for dairy cows

Annex 16. Analyses of cost forages and feeds per kg protein (CP) and potential dry matter intake

Annex 16 table 1, Ranking of feeds per kg protein in diets of dairy cows based on medium cost with range to low and high cost and dry mater intake potential of the feed.

*The colour scheme shows the darker the colour the less interesting it is to use the feed as a protein source in the diet for dairy cows

Ranking on Medium Cost KES/kg CP	**Date 15.08.2023**	**Crude Protein on DM basis**	**Dry Matter**	**Crude Protein on 'As Fed' basis**	**Cost range KES/kg as purchased /produced (farm gate price)**			**Cost range of CP KES/kg CP**			**DM Intake prediction (based on NDF)**
	Feed ingredients in dairy cow diet	**(g/kg DM)**	**(g/kg)**	**(g/kg)**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**% of LW**
1	Napier grass low quality	90	265	23.9	1.0	2.0	3.0	42	84	126	1.9
2	Napier grass silage	90	301	27.1	1.5	2.5	3.5	55	92	129	1.9
3	Napier grass medium quality	106	184	19.5	1.0	2.0	3.0	51	103	154	1.9
4	Sorghum fresh < 30% DM	87	280	24.4	1.0	2.5	4.0	41	103	164	2.0
5	Sorghum fresh 30% <> 35% DM	67	360	24.1	1.0	2.5	4.0	41	104	166	2.2
6	Napier grass high quality	153	120	18.4	1.0	2.0	3.0	54	109	163	2.1
7	Rhodes grass hay high quality	101	885	89.4	5.0	10.0	15.0	56	112	168	1.8
8	Brewers spent Sorghum grain	300	267	80.1	10.0	14.0	18.0	125	175	225	2.9
9	Sunflower seed meal low quality	254	927	235.5	30	45	60	127	191	255	3.3
10	Rapeseed meal (Canola)	377	909	342.7	65	70	75	190	204	219	5.9
11	Sorghum silage < 30% DM	87	280	24.4	3.5	5.0	6.5	144	205	267	2.0
12	Sorghum silage 30% <> 35% DM	67	360	24.1	3.5	5.0	6.5	145	207	269	2.2
13	Lucerne hay high quality	193	866	167.1	30	35	40	179	209	239	3.0
14	Rhodes grass hay low quality	48	888	42.6	5.0	10.0	15.0	117	235	352	1.7
15	Wheat bran	159	889	141.4	30	35	40	212	248	283	3.3
16	Dairy meal HY	170	910	154.7	30	40	50	194	259	323	4.2
17	Maize silage < 30% DM	81	274	22.2	4.0	6.0	8	180	270	360	2.9
18	Maize silage < 30% DM	81	270	21.9	4.0	6.0	8.0	183	274	366	2.4
19	Dairy meal	150	910	136.5	30	40	50	220	293	366	3.3
20	Maize germ	120	908	109.0	30	35	40	275	321	367	4.9
21	Maize silage 30% <> 35% DM (market)	80	330	26.4	8.0	13	18	303	492	682	3.0

Annex 17. Herd characteristics

Annex 17 table 1, Herd profile

	Animal Category		Lactating cows							Female Youngstock (Heifers)						Bulls				Total Herd		
Farm codes	Highland(H), Lowland (L)	Breed Cross (C) Friesian (H/F)	Total milking cows and dry cows	Cows in milk	Early lac	Mid lac	Late lac	>305 days	Dry cows	Total Heifers	In-calf	1-2 yrs	0.5-1 year	3-6 months	< 3 months	Total Bulls	< 3 months	3-12 months	>1 yr	Total cattle	Total cattle in High lands	Total cattle in Low lands
F1	L	C	8	7	1	0	1	5	1	5	1	2	0	1	1	5	0	2	3	18		18
F3	L	C	4	4	3	0	0	1	0	3	0	1	0	0	2	2	1	0	1	9		9
F4	L	C	12	7	2	1	1	3	5	8	1	1	4	1	1	0	0	0	0	20		20
F5	L	C	3	3	0	0	2	1	0	6	1	3	2	0	0	2	0	2	0	11		11
F6	L	C	5	5	1	1	0	3	0	0	2	0	0	1	1	2	0	0	2	11		11
F19	L	C	5	4	0	2	0	2	1	2	0	1	1	0	0	0	0	0	0	7		7
F20	L	C	5	5	3	2	0	0	0	2	0	0	2	0	0	0	0	0	0	7		7
F22	L	C	8	4	2	0	0	2	4	1	0	1	0	0	0	0	0	0	0	9		9
F23	L	C	3	3	1	0	2	0	0	1	1	0	0	0	0	0	0	0	0	4		4
F24	L	C	2	2	1	0	0	1	0	0	0	0	0	0	0	2	0	2	0	4		4
F8	H	C	9	9	2	0	2	5	0	2	0	0	0	1	1	7	0	4	3	18	18	
F9	H	C	3	1	1	0	0	0	2	2	0	1	0	0	1	0	0	0	0	5	5	
F12	H	C	4	4	0	1	0	3	0	2	0	0	1	1	0	0	0	0	0	6	6	
F13	H	C	5	3	1	0	2	0	2	3	0	0	2	1	0	2	0	1	1	10	10	
F14	H	C	4	3	1	0	0	2	1	0	0	0	0	0	0	1	1	0	0	5	5	
F17	H	C	2	2	1	1	0	0	0	1	0	0	0	0	1	1	0	1	0	4	4	
F18	H	C	3	3	3	0	0	0	0	4	1	1	0	0	2	1	1	0	0	8	8	
F7	H	H/F	7	4	2	2	0	0	3	3	0	0	0	1	2	0	0	0	0	10	10	
F10	H	H/F	3	2	0	2	0	0	1	3	1	0	1	0	1	6	0	0	0	6	6	
F11	H	H/F	6	6	0	1	2	3	0	3	1	1	0	1	0	1	0	1	0	10	10	
F15	H	H/F	4	3	1	0	0	2	1	3	0	2	1	0	0	0	0	0	0	7	7	
F16	H	H/F	5	4	1	2	1	0	1	7	2	1	2	1	1	0	0	0	0	12	12	
AVG	All	C&H/F	5.0	4.0	1.2	0.7	0.6	1.5	1.0	2.8	0.5	0.7	0.7	0.4	0.6	1.5	0.1	0.6	2.0	10.7		
AVG	H	C&H/F	4.6	4.1	1.4	0.7	0.6	1.4	1.1	2.8	0.6	0.9	0.9	0.3	0.5	0.9	0.1	0.4	0.3		9.3	
AVG	H	H/F	5.0	3.8	0.8	1.4	0.6	1.0	1.2	3.8	0.8	0.8	0.8	0.6	0.8	1.4	0.0	0.2	0.0		9.0	
AVG	H	C	4.3	3.6	1.3	0.3	0.6	1.4	0.7	2.0	0.1	0.3	0.4	0.4	0.7	1.7	0.3	0.9	0.6		8.0	
AVG	L	C	5.0	3.8	0.8	1.4	0.6	1.0	1.2	3.8	0.8	0.8	0.8	0.6	0.8	1.4	0.0	0.2	0.0			9.0

Annex 17 table 2, Liveweight of cattle

	Animal Category		Lactating cows						Female Youngstock (Heifers)					Bulls		
Farm codes	Highland (H), Lowland (L)	Breed Cross (C) Friesian (H/F)	Average weight for lactating cows	Early lac	Mid lac	Late lac	>305 days	Dry cows	In-calf	1-2 yrs	0.5-1 year	3-6 months	< 3 months	< 3 months	3-12 months	>1 yr
F1	L	C	**423**	420		417	389	466				222	53		127	236
F3	L	C	**341**	303			378			296			46	48		
F4	L	C	**408**	439	425	370	384	422	250	333	95	51				
F5	L	C	**390**			322	458		358	290	113				142	
F6	L	C	**407**	408	335		478		357			98	49			190
F19	L	C	**307**		242		272	408		303	162					
F20	L	C	**328**	310	345						168					
F22	L	C	**357**	393			327	350		215						
F23	L	C	**429**	447		410			358							
F24	L	C	**338**	303			373								190	
F8	H	C	**413**	456		391	393									225
F9	H	C	**386**	414				357								
F12	H	C	**421**		378		463				143	95				
F13	H	C	**232**	220		243					110	65			70	
F14	H	C	**329**	314			303	370						45		
F17	H	C	**382**	438	325								59		100	
F18	H	C	**390**	390					348	246			47	43		
F7	H	H/F	**464**	495	432							178	49			
F10	H	H/F	**436**		446			426	457		170		75			
F11	H	H/F	**485**		480	485	490		447	320		128			138	
F15	H	H/F	**437**	364			452	496		278	123					
F16	H	H/F	**602**	705	512	512		680	530	248	135	113	40			
AVG	All		**396**	401	392	394	397	442	388	281	135	119	52	45	128	217
AVG	H	C&H/F	**415**	422	429	408	420	466	446	273	136	116	54	44	103	225
AVG	H	H/F	**485**	521	468	499	471	534	478	282	143	140	55		138	
AVG	H	C	**364**	372	352	317	386	364	348	246	127	80	53	44	85	225
AVG	L	C	**373**	378	337	380	382	412	331	287	135	124	49	48	153	213
MIN			232	220	242	243	272	350	250	215	95	51	40	43	70	190
MAX			602	705	512	512	490	680	530	333	170	222	75	48	190	236

Annex 17 table 3, Body condition score (BCS) of cattle

	Animal Category		Lactating cows				
Farm codes	Highland(H), Lowland (L)	Breed Cross (C) Friesian (H/F)	Early lactation	Mid lactation	Late lactation	>305 days in lactation	Dry cows
F1	L	C		2		2	2
F3	L	C		2			2.5
F4	L	C		2.5	2.25	2.5	2.5
F5	L	C				2	2
F6	L	C		2.5	2.5		2.75
F19	L	C		2			
F20	L	C		2	2		
F22	L	C		2			2
F23	L	C	1.75		2		
F24	L	C		2			2
F8	H	C		1.75		1.75	1.75
F9	H	C	2				3
F12	H	C			1.75	1.75	1.75
F13	H	C		1.75		1.75	
F14	H	C		1.75		1.75	
F17	H	C		2	2		
F18	H	C			1.75		1.75
F7	H	H/F		2	2		
F10	H	H/F	2.5		2.5		
F11	H	H/F			2.5	2.5	2.5
F15	H	H/F		2.5			2.5
F16	H	H/F		3	3	3	
AVG	**All**		**2.1**	**2.1**	**2.2**	**2.1**	**2.2**
AVG	**H**	**C&H/F**	**2.3**	**2.1**	**2.2**	**2.1**	**2.2**
AVG	**H**	**H/F**	**2.5**	**2.5**	**2.5**	**2.8**	**2.5**
AVG	**H**	**C**	**2.0**	**1.8**	**1.8**	**1.8**	**2.1**
AVG	**L**	**C**	**1.8**	**2.1**	**2.2**	**2.2**	**2.3**
MIN			1.75	1.75	1.75	1.75	1.75
MAX			2.5	3.0	3.0	3.0	3.0

Annex 17 table 4, Rumen fill of cattle

	Animal Category		Lactating cows				
Farm codes	Highland(H), Lowland (L)	Breed Cross (C) Friesian (H/F)	Early lactation	Mid lactation	Late lactation	>305 days in lactation	Dry cows
F1	L	C		2.5		2.5	2.5
F3	L	C		2			2.5
F4	L	C		2	2	2	2
F5	L	C				3	3
F6	L	C		2.5	2.5		2.5
F19	L	C		3			
F20	L	C		2	2		
F22	L	C		2.5			2.5
F23	L	C	2		2		
F24	L	C		3			3
F8	H	C		3		3	3
F9	H	C	2				3
F12	H	C			2	2	2
F13	H	C		2		2	
F14	H	C		2		2	
F17	H	C		3.5	3.5		
F18	H	C			3		3
F7	H	H/F		3	3		
F10	H	H/F	3		3		
F11	H	H/F			2	2	2
F15	H	H/F		2			2
F16	H	H/F		3	2.75	2.75	
AVG	**All**		**2.3**	**2.5**	**2.5**	**2.4**	**2.5**
AVG	**H**	**C&H/F**	**2.5**	**2.6**	**2.8**	**2.3**	**2.5**
AVG	**H**	**H/F**	**3.0**	**2.7**	**2.7**	**2.4**	**2.0**
AVG	**H**	**C**	**2.0**	**2.6**	**2.8**	**2.3**	**2.8**
AVG	**L**	**C**	**2.0**	**2.4**	**2.1**	**2.5**	**2.6**
MIN			2.0	2.0	2.0	2.0	2.0
MAX			3.0	3.5	3.5	3.0	3.0

Annex 17 table 5, Milk production

	Animal Category		Lactating cows				
Farm codes	**Highland(H), Lowland (L)**	**Breed Cross (C) Friesian (H/F)**	**Early lactation**	**Mid lactation**	**Late lactation**	**>305 days in lactation**	**Dry cows**
F1	L	C	10	6.5	5	4	-
F3	L	C	6	-	-	4	-
F4	L	C	-	-	-	-	-
F5	L	C	-	-	7	4	-
F6	L	C	-	-	7	4	-
F19	L	C	-	2	-	0.5	-
F20	L	C	6	9	-	-	-
F22	L	C	5	-	4	-	-
F23	L	C	-	-	-	-	-
F24	L	C	11	-	-	7	-
F8	H	C	8	-	4	3	-
F9	H	C	11	-	-	-	-
F12	H	C	-	10	8	4	-
F13	H	C	-	10	8	4	-
F14	H	C	9			0.5	-
F17	H	C	11	10			-
F18	H	C	12				-
F7	H	H/F	-	-	-	-	-
F10	H	H/F	-	23			-
F11	H	H/F	-	10	8	4	-
F15	H	H/F	-	-	-	-	-
F16	H	H/F	-	14	13	16	-
AVG	**All**		**8.9**	**10.5**	**7.1**	**4.6**	
AVG	**H**	**C&H/F**	**10.2**	**12.8**	**8.2**	**5.3**	
AVG	**H**	**H/F**		**15.7**	**10.5**	**10.0**	
AVG	**H**	**C**	**10.2**	**10.0**	**6.7**	**2.9**	
AVG	**L**	**C**	**7.6**	**5.8**	**5.8**	**3.9**	
MIN			5.0	2.0	4.0	0.5	
MAX			12.0	23.0	13.0	16.0	