Assessment of KMDP Forage Interventions in North Rift, Kenya

The Case of Agricultural Contracting and Baling of Maize Silage



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Annexes

Lists of abbreviations

AFC	Agriculture Finance Corporation
B2B	Business to Business
CAN	Calcium Ammonium Nitrate
CBE	Collection and Bulking Enterprises
CFP	Commercial Forage Producers
DAP	Di-Ammonium Phosphate
DFB	Dairy Farm Benchmarking
DIP	Dairy Investment Plan
DM	Dry Matter
DMI	Dry Matter Intake
DTC	Dairy Training Centre
DTI	Dairy Training Institute
EDFA	Eldoret Dairy Farmers Association
FE	Farm Evaluation
FFB	Forage Farm Benchmarking
FSSC	Feeds Supply and Service Centre
FTE	Full Time Equivalence
KEPHIS	Kenya Plant Health Inspectorate Services
KES	Kenyan Shilling
KMDP	Kenya Market-led Dairy Programme
LCB	Local Capacity Builder
LSF	Large Scale Dairy Farmers
ME	Metabolizable Energy
MFF	Medium-scale dairy Farmers Forum
MoU	Memorandum of Understanding
MSF	Medium Scale dairy Farmers
NDF	Neutral Detergent Fibre
NL	The Netherlands
QC	Quality Control
QA	Quality Assurance
PDTC	Practical Dairy Training Centre
PUM	PUM Netherlands Senior Expert Programme
QBMP	Quality Based Milk Payment
SH	Small Holder
SME	Small and Medium Enterprise
SNV	SNV Netherlands Development Organisation
SPEN	Service Provider Enterprise Network
SR	Status Report
TFM	Total Farm Management
TMR	Total Mixed Ration
ToC	Theory of Change
UA	Uniform Agri
UoE	University of Eldoret
VDM	Visiting Dairy Manager
WUR	Wageningen University and Research

Executive summary

The experience in North Rift Region (Kenya) since 2016 with the "Maize Train", a concept promoted and supported by the Kenya Market-led Dairy Programme (KMDP) of SNV Kenya, has shown that maize silage making is viable in Kenya on-farm, as well as in bales for trading purposes.

Contractors and commercial forage producers successfully turned around the existing poor practices of silage making, where use is made of forage harvesters with a capacity too small for the acreage planted, harvested too early, with too long chopping length, no kernel crushers and long interval between start of making the silage pit and final sealing. These existing practices result in enormous losses during ensiling and feed-out and greatly reduce nutritional value (MJ ME/kg DM) of the silage and dry matter (DM) intake of the cows. Added to this is the risk of poor anaerobic fermentation giving yeast, moulds and Basciluss chances to spoil the silage.

Capacity, technology, speed of work and skills have been crucial to show that it is essential to influence and control the fermentation process in the ensiled crop successfully. Improving the process and logistics of silage making with the assistance of commercial forage producers who invested heavily in technology and capacity able to bring silage making to scale, has improved the quality of maize silage enormously. The combination of harvesting close to the ideal DM content, intense compacting and sealing the silage pit within 12 hours, next to the use of forage harvesters equipped with sharp knives and kernel crushers, are the major reasons that the fermentation process starts-off immediately and respiration losses are kept to a minimum.

The Maize Train concept and baling of maize silage have shown that this is possible and goes with huge benefits for the dairy farmer and crop farmer. At this stage it is important that the early movers (i.e. Nundoroto Farm Company, AG Harvesting, Simam and Tarus) maintain quality of work in each and every step of the process from seed to feed, and that they don't compromise on good practice. For those who are crowding-in, they have to make sure that they reach this level first, even before they can maintain it.
The "Guidelines for High Quality Forage Production and Ensiling" (Annex 3), prepared by KMDP in partnership with the above mentioned companies, and local and international experts, are a useful and important tool and reference for the contractors and the farmers. They explain the "what", "how" and "why" of good silage making.

For farmers who have enough land to grow forage maize, harvest the maize and turn it into a good quality silage pit, this is the cheapest way to provide dairy cows with an energy rich forage - year round - at a price between 0.9-1.7 for 1 MJ ME. Good quality maize silage is the best and economically the most affordable alternative for hay in the total ration. It can as well reduce the amount of dairy meal in the ration, provided the basal ration with maize silage is properly balanced for protein, amongst others. Maize silage being a forage rich in energy will boost milk production and therefore reduce the cost price per litre of milk and raise the margin above feed costs.

The market for baled silages is as of now largely to provide dairy farmers who have shortage of forage due to poor fodder planning and/or small land size and seasonality, with a solution to keep milk production constant all year round. Economies of scale in production of maize and silage, higher tonnage and DM per acre, and more efficient logistics in storage and distribution, can reduce the cost of baling and the farm gate price of baled silage in order to competitively serve a larger segment of dairy farmers year round.

Improving the 3 steps, crop production, harvesting & ensiling and baling further on efficiency and technical and management performance level, will further reduce the ensiling- and baling costs per kg DM. However, also availability and use of maize varieties specifically bred for forage are required These forage maize varieties should target higher nutritional value of maize in the silage pit (i.e. higher ME, lower NDF and higher starch content all per kg DM). This combined will be a major step in further reducing the cost price of high quality maize silage.

Based on indicative calculations for improved maize silage quality presented in Chapter 8 of this report, it is concluded that the Maize Train model, has resulted in great benefits for the farmers that make use of the services provided. Maize silage samples taken recently from the silage pits showed an average ME density of 9.1 M MEJ/kg DM, whilst maize silage of the quality that was found in farms at the beginning of KMDP had estimated densities of 6.0 MJ ME/kg DM or below.

This improvement in energy content of approximately 30% results in significant increases of income for the farmer in terms of enhanced feed value and milk production. Further improvement of the quality of maize silage is possible by optimizing the process and by introduction of forage maize varieties in the Kenyan market.

Improving forage quality to increase milk production generally will contribute to a lower carbon footprint per litre of milk produced. The environmental impact of dairy farming has many contributing factors, of which the emission of enteric methane from cows is a major contributor. Forage with higher ME and optimum NDF is boosting milk yield and consequently lowers the intensity of methane emission (i.e. g methane/liter milk). Feeding high quality maize silage, therefore is an excellent means of lowering methane and CFP emission intensities.

This will be further enhanced if balanced rations are being fed, which can be achieved by use of Rumen8 – a dairy ration calculation software that was introduced and equipped with a Kenyan Feed Library with support from KMDP. Balanced rations allow the dairy cow to increase DM intake and thus increase milk production and productivity.
Improved soil management practices through conservation agriculture, soil analysis and optimum fertilization advice (including liming of soils with low pH and manure management), give higher yields per acre of land, the net effect of which is reduced GHG emission per ton of maize.

The following chapters present the background, rationale and an assessment of the introduction by SNV/KMDP of these innovations in North Rift, viz. the "Maize Train" and baled silages, in terms of impact, strengths and challenges, opportunities for upscaling and replication. The focus of the assessment is on business growth (acreage), technical and operational issues, quality of work and quality of silages, increased value of better silages, benefits for the farmer and response from the market. Chapter 11 consolidates the observations and recommendations of the consultant who was hired to guide the assessment.

1. Introduction

The dairy sector in Kenya is one of the largest in Sub Sahara Africa with total cow milk production estimated at 3.9 billion litres in 2014 (Bulletin World Dairy Situation 2016), and annual consumption per person standing at 115 litres. Dairy is the largest agricultural sub-sector in Kenya in terms of income and employment creation. It contributes 4% of Kenya's GDP and 12% of agricultural GDP, and it is amongst the fastest growing dairy sectors in East and Southern Africa.

The sector is however facing serious inefficiencies in dairy production and farm management. This applies across the board for smallholder farms (SH <20 dairy cows), medium-scale (MSFs 20-50 dairy cows) and large-scale farms (LSFs > dairy 50 cows).

One of the factors that leads to low productivity of dairy cows and high cost per litre of raw milk produced, is the lack of access to good quality, fresh and preserved forages. High cost and seasonality of raw milk production are to a large extent caused by low ability to produce and preserve quality forage. This in turn is due to low skills and knowledge levels, low mechanisation, absence of high quality forage seeds, and small landholdings for the majority of dairy farmers.

The lack of year round availability of good quality forages has been identified as the major bottleneck for enhanced growth and competitiveness of the dairy industry in Kenya, next to low milk quality and safety. This applies equally to SHs, MSFs and LSFs, as also where land for forage production is abundant, forage planning and management is generally poor on large scale farms as well.

The huge demand for forage, especially in the dry season, has led to commercial forage supply chains of mainly low quality hay, and investments in on-farm forage production and preservation for maize silage. Lack of capital to invest in appropriate and innovative farm machinery and low management skills for highly nutritious forage production and preservation have resulted in sub-optimal forage solutions.

Kenya knows different farming systems, viz. free grazing, semi zero grazing combined with pastures and full zero grazing. Dairy farming is commercialised in the high potential agro ecological zones and demand for feeds and forages is high, also because of the high presence of exotic breeds that require better feeds to unlock their genetic potential.

Soils and climate are very suitable for production of quality (preserved) forages and for pastures, depending on available forage seeds, skills, knowledge and technology, which is however abundantly lacking. Hence the forage subsector is underdeveloped, in spite of huge sales volumes of (low quality) hay and straw.

Grass (usually Boma Rhodes or Star grass) and maize - and to some extent Napier grass and forage sorghum - are the main forages that are being preserved by dairy farmers. Both hay and maize silage have room for significant improvements and optimization, if management skills and mechanisation are enhanced (i.e. crop management, cutting stage, preservation, storage) and more suitable forage seed varieties would be available in the market. This includes - but is not limited to - Brachiaria species.

For maize silage this is further explained and highlighted in the following pages. Under KMDP some big steps forward have been made in this regard, in spite of non-availability of forage maize varieties. For grass hay (and grass silage), large improvements can be made in total kg of dry matter harvested per acre, protein content and digestibility, if fertilized properly and harvested at the correct time or cutting stage (with several cuts per year). Grass silage is largely unknown

On the demand side, there is a large market for forages by smallholder dairy entrepreneurs and medium scale dairy farmers. The demand for forages is high due to a commercialising and growing dairy sector in Kenya and the small landholdings of the smallholders who produce 80% of the milk in Kenya. The demand for milk and dairy products is fuelled by population growth and fast urbanisation and development of a more affluent middle class. The predominance of exotic breeds selected for high milk production also necessitates higher quality forages and year round availability of forage in fresh or preserved form.

The many smallholder and medium scale farmers that are engaged in commercial dairy production are usually unable to grow and preserve sufficient quantities on-farm due to lack of land size, skills and/or capital for mechanisation. Also many large scale farmers with abundant land who grow and preserve forage on-farm, lack the skills and machinery to optimize forage production and preservation. This results in many losses in the trajectory from seed-to-feed and – most importantly – it leads to low milk production and productivity of the cows.

One of KMDP's key interventions since its start in July 2012 is to enhance year round availability by dairy farmers (SHs, MSFs and LSFs) of good quality forages. The approach taken had 3 entry point or strategies:

a) Stimulate the farmer to increase on-farm production of quality (preserved) forages
b) Connect farmers to agricultural contracting services (maize train and forage service provider enterprises also known as SPEN)
c) Connect farmers to commercial forage supply models (e.g. baled silages).

This report contains an assessment of part of this work and mainly for North Rift where KMDP engaged with investors in agricultural contracting services also referred to as Maize Train, and in baling of silages.

The Maize Train focuses on MSFs and LSFs, with crowding-in of smaller contractors with one or two row maize harvesters to also serve smallholders. The concept of baling targets also smallholder farmers in the region and elsewhere in Kenya. Production of vacuum baled silages relies on the supply of the raw material (maize or maize silage). Hence, also on professional agricultural contracting services and large scale maize production, to be able to bale for the smallholder sector and for MSFs/LSFs competitively and in sufficient quantity.

Forage interventions under (a) and (b) for smallholder farmers are not part of this report, For SPEN: https://www.cowsoko.com/programs/kmdp/publications see reports 34 and 35 and the video on SPEN that can be downloaded and viewed from the same page.

The following chapters give an assessment of the introduction of professional fully mechanised agricultural contracting services (Maize Train) and the production and sales of baled silages in North Rift. Focus is on impact, strengths and bottlenecks, opportunities for upscaling and replication of these innovations. This includes business growth (acreage), technical and operational challenges, quality of work and quality of silages, increased value of better silages and benefits for the farmer, and response from the market.

Towards the end of the report (in Chapter 9) also attention is paid to a dairy ration formulation tool (Rumen8) that was introduced by KMDP in some of the farms served by Nundoroto and AG Harvesting, as this activity reinforces the two innovations discussed in this report.

In addition KMDP and CIAT piloted different species of Brachiaria in Eldoret and the first outcomes are also included in this report (Chapter 10). This is a forage crop that next to cut-and-carry in smallholder dairy farming systems, also has great potential for larger farms to be used for pastures/grazing or if mowed for silage or hay making.

Chapter 11 consolidates the observations and recommendations of the consultant hired to guide the assessment. The report will be shared widely with all relevant dairy stakeholders in North Rift and other parts in Kenya, in an attempt to further create awareness and instil good practices in maize production and ensiling. For dairy farmers who wish to improve the quality of their silage, for those contractors and investors supported through the KMDP project, and for those who have seen this business opportunity and are crowding-in.

Chapter 12 gives a report on the collaboration between SNV KMDP and PUM Netherlands Senior Experts. This partnership was crucial for the success of KMDP's forage interventions.

The assessment and the structure of this report were guided by a terms of reference that is presented in Annex 1. Frans Ettema a dairy consultant from the Netherlands took lead in the assessment. He was supported by the KMDP team in Eldoret and by Jos Creemers from ProDairy Ltd. Annex 2 gives the schedule of farms visited and persons inter-viewed during the field research that took place in the period 1 – 9 February 2019.

Some chapters in this report (or part thereof) were contributed by Solomon Misoi, dairy consultant in KMDP and based in Eldoret. Important inputs and contributions to the report were also provided by Jos Creemers of ProDairy EA Ltd.

2. Rationale and principles of silage making

a. Rationale of silage making

In Kenya forage production and forage markets are largely determined by seasonality and volume based. Quality of forages (nutritive value) is as yet of secondary concern. Prices of forages traded in the market (mainly hay and Napier grass) shoot up during the dry season to as high as KES 300-350 for a bale of poor quality hay which on average is 13 kilos per bale. Therefore approximately KES 31-36/kg dry matter (at 80% DM content)
The scope to improve hay quality is significant if well managed, fertilised, harvested at the right cutting stage, and especially if improved grass seed varieties become available in the market.

An alternative for haymaking to overcome the dry period, is preservation of forages through silage making, such as the whole maize plant, sorghum and grasses.
Maize silage provides low cost metabolizable energy (ME) for dairy cows which is a key ingredient in the cow's ration. If prepared in sufficient quantity, it not only helps the farmer to counter seasonality and dry spells, but also to feed it all year round.

Whether maize silage is cost effective depends on quality, cost of production (or price in the market if bought externally), vis-a-vis prices of other available feeds and forages in the market. The main target for high quality forage is to make better use of the genetic potential of dairy cows and enhance milk production, to reduce costs per unit of ME fed to the cows and per kg of milk produced, resulting in a higher margin above feed costs.

High quality forages (high in MJ ME/kg DM (dry matter), low NDF and high digestibility) allow high yielding dairy cows to take-in more DM. This results in higher DMI (dry matter intake) out of forages compared to concentrates in the diet (% forage). This is the best way to reduce feeding costs and can prevent metabolic diseases such as rumen acidosis which is due to excess concentrates in the diet.

Maize silage has picked momentum in Kenya, however on most farms including North Rift, there is lack of adequate machinery, skills and knowledge, such that the end-result is poor quality silage due to not following basic rules for successful silage making. Dairy farms in North Rift for example in general have outdated machinery with low capacity, are poorly maintained and calibrated, and hence unable to make good quality silage and to maximize production of maize silage per acre. Speed of work is slow due to low capacity of machines and poor work planning hence the time from harvesting the maize to closing the silage pit or bunker is far too long. It is not unusual to find that the time between harvesting of maize, compacting and covering the silage pit is 1- 2 weeks, causing great losses (heating, moulds, etc.). Maize harvesting for silage making is mainly done by a single row harvester with a capacity of approx. 4 to 5 acres per day. In case of breakdowns the whole process of silage making will be interrupted, sometimes for days.

Medium- and large-scale farmers therefore often face severe challenges in harvesting and ensiling. These single-row harvesters are suitable for small scale farmers for which they are affordable and have the requisite capacity. In the smallholder supply chain in many cases however the maize is manually harvested. After cutting the maize plants are collected and transported to a stationary or PTO-driven maize shredding machine on the farm that cuts the maize stalks singularly. Then the chopped maize is put into a pit that has plastic lining and the compaction is done by a small tractor or more often by rolling drums filled with sand or water over the layers of chopped maize. These silage pits can be as small as containing 10 – 20 tons of silage. With this system not more than 1 or 2 acres per days can be ensiled and usually the maize shredders and the one or two row harvesters do not have a kernel crusher. https://www.youtube.com/watch?v=JilQ7H_0xLM#action=share

Below is a short explanation of the principles and processes that determine good or poor silage. In Annex 3 a more detailed set of guidelines of the "what, how and why" of good maize production and silage making are presented.

b. Harvesting and chopping, speed of work

The principle of good silage making is to preserve fresh forage by anaerobic fermentation. Oxygen is the greatest threat for a good result in the whole chain of silage making. The right stage of harvesting and the use of high capacity machinery are crucial to optimize the entire chain of silage making, regardless the type of forage crop. DM content and chopping length, combined with crushing of the kernels and heavy compaction and coverage of the silage pit within 12 hours, will provide quality forage for the cows. If harvesting 20 acres or more without high capacity mechanisation, it will take several days, sometimes weeks, to finish both the harvest in the fields and the covering of the pit.

c. Compaction and dry matter content

In the pit or bunker the spreading of the maize is done manually (see illustration on page 22) to get the right shape and measurement. As soon as the maize is levelled, a tractor or shovel drives back and forth over the maize for compaction. The compaction is one of the most important parts of the process, as it drives out air. This enhances the anaerobic fermentation process and reduces the heating during feeding out of the silage to the cows. If the silage is chopped in large pieces, it will be more difficult to compact. Important for good compaction and ensiling is the dry matter content at harvesting, which should be 30-35%. If the DM content is too low starch levels are not optimal and together with effluent losses from the wet silage results in low nutritional value. If DM content of the maize is too high at ensiling, it is difficult to achieve adequate compaction. When silage density is low, more oxygen remains in the pit or bale and there is increased air infiltration when the silage is opened for feeding.

d. Storage

To reduce losses in DM and nutrient value the storage of silage is of major importance. Whether the silage is stored in a pit, a silo or in a bale, it always needs a high compaction and airtight cover or wrap. The size of the pit in terms of height and width must be in balance with the number of animals that are being fed daily from it. If feeding-out speed is too slow, heating occurs and there is great loss of feed value and dry matter. Oxidation causes destruction of biochemical compounds and of plant cells and thus of nutrients. The best way to avoid heating and feeding-out losses is to maintain a feeding speed of at least 1.5 meters per week.

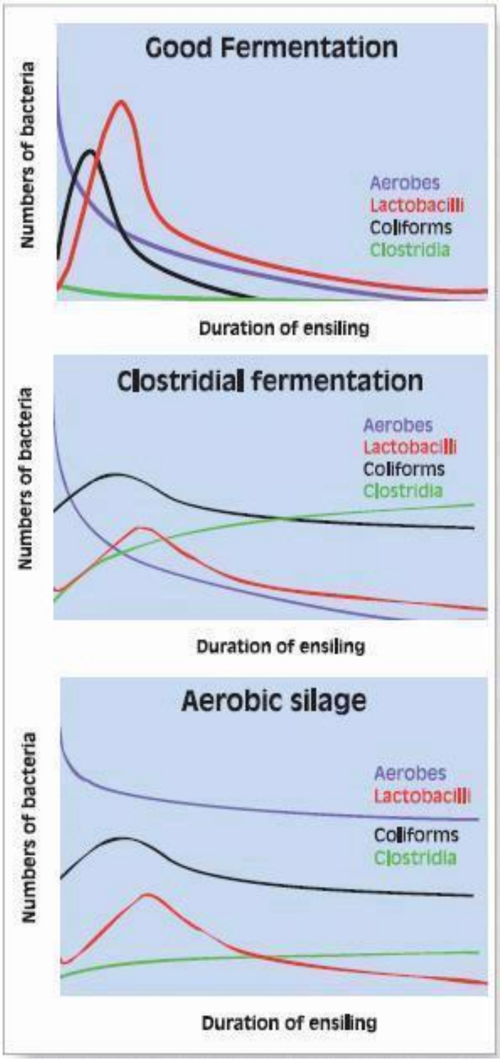
e. Covering

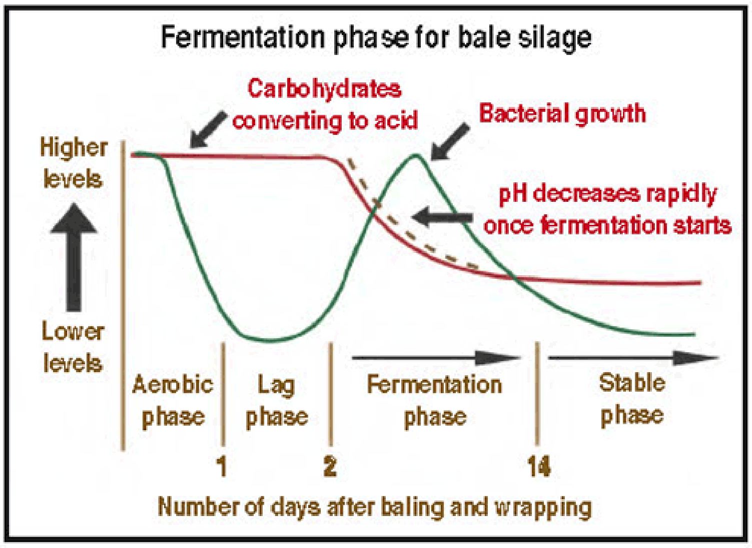
The longer it takes to finish and cover the pit, the higher the risk air will (re-) enter the pit and the heating-up of the chopped maize. This reduces the quality even before the ensiling process starts. Covering needs to be airtight with polyethylene plastic sheets, with extra protection against sun rays that will heat up the silage underneath the polyethylene for preservation and during feeding-out.

f. Quality and nutritional losses

Poorly fermented silage will result in inferior animal feed with low nutritive value but also carry the risk of attack by pathogens (disease causing micro-organisms) such as bacteria and moulds. This leads to reduced feed intake, reduced milk production due to low nutritive value, unpalatability and poor utilisation of crude protein, wastage and moulding. Losses in quality can occur throughout the silage making process. The magnitude of the losses will depend on:

- Physical and chemical properties of the forage at the time of harvest and ensiling.
- The dry matter content of the forage at the time of harvesting.
- The harvesting process and time, including speed and degree of compaction.
- The wilting conditions (in case of ensiling grass).
- The fermentation processes.
- Maintaining anaerobic conditions during storage.
- Management during feeding out.





Source : Magazine Hoard's Dairyman, USA
Article: Baled silage a great option in wet climates

Source: Advanced silage corn management 2004, Chapter 8 Quality of corn silage, E. Charmley

Left figure: explanation

Change in population overtime of 4 bacterial groups in good fermentation (top graph), clostridial fermentation (middle graph) and aerobic fermentation (bottom graph)

Right figure: explanation

Aerobic and anaerobic bacteria are involved in silage fermentation. Aerobic activity occurs while the silo is being filled and at feed out. Good silo management minimizes aerobic activity, thus reducing dry-matter losses. Oxidation of energy-rich sugars produces excess heat, which can damage forage protein. Good silo management also maximizes the anaerobic conversion of water-soluble carbohydrate to silage acids, thus reducing pH to a range that is inhospitable to spoilage organisms (Bill Seglar, 2013).

3. North Rift forage interventions: the cases of Maize Train and baled silages

a. Objectives and approach KMDP (forage interventions)

One of the objectives of KMDP is to assist dairy farmers in increasing their milk production. The project works through teams of local dairy advisors and extensionists supported by international experts. Activities that are organized at the farm level are geared to demonstrate best practices in farm management, among others in forage production and preservation (pasture, grass and maize-silage management).

KMDP partners with PUM Netherlands Senior Experts and other local and international experts and partners, such as ProDairy EA Ltd, Friesian Agro Consulting, Cow Signals/ Vetvice, Wageningen University and Research. These experts and partners helped the programme and the local dairy advisors, with exploring, designing and piloting various models for enhanced access by smallholder, medium and large scale farmers to quality forages through three avenues:

1. Stimulate farmers to establish/preserve on-farm forages.
2. Connect farmers to agricultural contracting services (instead of buying own machines).
3. Connect farmers to commercial forage suppliers and help these investors in piloting innovative models (buy/supply quality forage in the market).

In all three scenarios maize for silage making is the main crop promoted both for all categories of farmers, next to improved pasture management for farms that practice semi-zero grazing. Some pilots with grass silage took place.

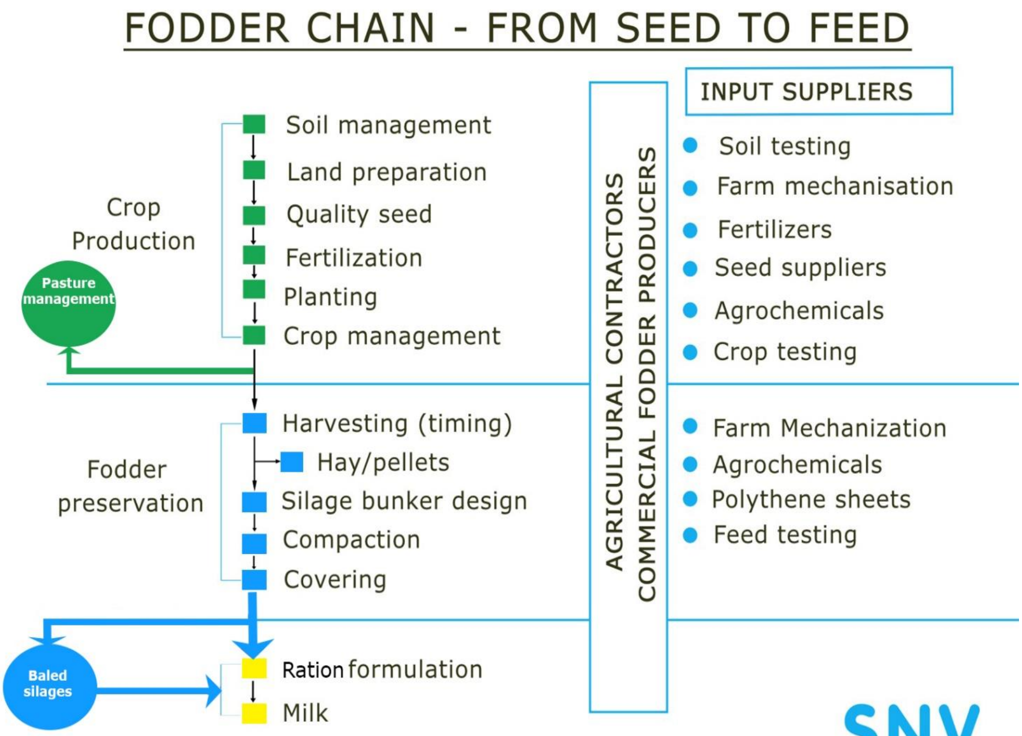
Attempts to promote lucern as a protein rich forage under KMDP-I were not successful mainly because most soils in Kenya's highlands have a pH that is not suitable for lucerne (pH should be above 6.3), the depth to which the roots of lucerne can grow in the soil not deep enough, and also because it is a difficult crop for farmers to manage. In 2018 KMDP started a number of promising pilots with various Brachiaria and Panicum varieties in Meru, Nyeri, Muranga and Uasin Gishu for different scale of farmers. In 2019 (March) two demos of each 5 acres each will be established in Uasin Gishu to trial suitability of Brachiaria for pastures/grazing and mechanised harvesting and ensiling.

b. Maize silage

Making good silage is complex, intense and high-pressure job. All aspects or steps of the operation – from seed to feed - require careful and detailed planning and coordination. This is shown schematically in the figure on the next page (Forage Chain – From Seed to Feed).

At the start of KMDP most farms used single row machines that did low quality work due to low capacity and poor maintenance. The farmers also lacked the technical know-how to make proper silage and the fermentation processes that must start immediately in the chopped and piled material after compacting and coverage is often not well understood.
If the silage bunker or pit is not compacted and/or covered rotting processes start instead of preservation/fermentation processes.

KMDP started promotion of maize silage in North Rift in 2014. Since then a lot has changed. Maize silage was not new to the area, but practised only by few farms in small acreages. Also the good practices from "seed to feed" to assure high quality silage and cost effective processes were lacking.



A market study in North Rift (Nandi, Uasin Gishu, Elgeyo Marakwet -Kitale) carried out in 2018 showed that 5 years after KMDP started operations in North Rift, out of the 250 medium and large-scale dairy farms covered by the study, 175 farms were making silage with on average 21 acres of maize silage per farm in 2018 (total area under maize for silage was 3,625 acres). Out of these 175 farms 120 used the services of a local contractor either for ploughing or for maize harvesting and chopping. The acreage dedicated to maize silage had increased significantly over the last few years, and most farmers indicated that they planned to increase the acreage for forage maize considerably. The study confirms that the concept has been adopted widely and is now part of most commercial dairy farm practices in North Rift with a milk production of 100 litres or more per day.

Promotion of maize silage was amongst others done through advisory work at farm level, field days and demonstrations, study tours and seminars, and through support to investors in silage contracting services and baling of silage. Eldoret Dairy Farmers Association (EDFA) played an important role in mobilizing farmers to be part of this and by exposure to good practices, for example through study tours and trainings to the Netherlands.

From the start of the project, KMDP promoted the agricultural contractor model, where a specialized service provider would handle maize harvesting and ensiling with professional machinery of high capacity. Preferably the model also includes land preparation, seeding, planting and crop management. Interestingly this concept was picked-up first in the small-holder supply chain by training and equipping youth groups to ensile for farmers 1-2 acres manually at a fee. This model called Service Provider Enterprise Network (SPEN) was successfully applied and up-scaled in many dairy cooperatives in Kenya and has been reported upon is separate studies.

To serve medium and large-scale dairy farms in the North Rift, in 2014, SNV/KMDP and Nundoroto Farm Company Ltd (NFC) partnered (KMDP Innovation Fund) to develop the contracting service model based on the so-called maize train concept. The concept involves a service provider (Nundoroto) that has all the equipment for land preparation, seeding, crop protection, maize harvesting, chopping and crushing, transportation to, and compaction and coverage of, the silage pit or bunker.

Nundoroto is equipped with tractors, ploughs, seeders, a self-propelled six-row forage maize harvester, loaders and a shovel for compaction of the silage bunker. Nundoroto's clients are dairy farmers with 20 acres of maize and above in the North Rift. Since the start of its operations, the client-base and acreage harvested and ensiled has expanded fast from 247 acres in 2014 to 1,245 acres in 2018. The growing demand for the services saw Nundoroto partnering with **Simam Farm** where the owner had also bought a 6-row harvester in the Netherlands during a study tour organised by EDFA and KMDP. Simam now owns 2 forage harvesters (see Chapter 4).

During this pilot farmers saw the positive impact on milk production due to improved quality of silage. Reasons for the increase in milk production are attributed to enhanced quality and nutritive value of the maize silage, less wastage and better digestibility due to proper chopping and crushing of the kernels and the right stage of harvesting, followed by immediate compaction and coverage of the silage pit or bunker.

In 2016-17 Dejirene Ltd in Eldoret (Eric de Jong) started collaboration with **Maraba Farm** who owned an old model 6-row harvester and also ventured into the maize train concept. In 2018 De Jong partnered with a Dutch investor (Hans Thijssen) and registered the joint venture AG Harvesting. **AG Harvesting** imported with the help of KMDP's Innovation and Investment Fund equipment for a second full-fledged maize train in Eldoret, which included loaders that can enter the land under all-weather conditions.

In 2018 also the concept of baled silages was introduced in Kenya by **Fodder Innovation Team Ltd** (FIT Ltd). This pilot project is - as is the case with Nundoroto and AG Harvesting – received co-financing and technical support from KMDP. The baler is an Agronic Multibaler imported from the Netherlands and it can package 350-400 kilo bales. This was also facilitated by KMDP's Innovation Fund.

c. Challenges to maintain good agricultural practice and crowding-in

Back to the market study, where it was reported above that the uptake of maize silage and use of agricultural contractors was boosted by KMDP and partners. The contractors supported by KMDP made big steps forward in improving the silage making process with large benefits for their clients.

However a quick scan of their work end 2018, also revealed that the quality of the silages varied due to challenges faced by these contractors, but also because apparently not always there was strict adherence to the good agricultural practices required in each and every step of the process: i.e. the right stage of harvesting, chopping size, kernel crushing, speed of work, pit design and covering of the pit.

Hence, KMDP and partners decided to assess the model of the Maize Train and the business case of baled silages in a more detailed manner, starting with an inventory of the bottlenecks faced by Nundoroto, AG Harvesting in their day-to-day operations and dealing with clients (farmers). Besides, also the FIT pilot was looked into, as well as other initiatives that came up during the past 1-2 years for baling and sales of maize silage (Chapter 6).

The (self-) assessment started in November 2018 and included an inventory of the contractors' clients and acreage done (Chapter 4), (self-) analysis of strength and challenges of the Maize Train by SNV team and the contractors (Chapter 5), and sampling of silage pits and feed testing by Crop Nutrition Laboratory Services in Nairobi and by Eurofins in the Netherlands (Chapter 8). This was guided by the creation of a Forage Committee that brought together KMDP advisors, the contractors and farmers.

Frans Ettema, the consultant and author of the report, joined the Team in Eldoret for farm visits and interviews (1-9 February 2019) and brought all the information gathered by the Team and his own observations together, enriched by interviews with key players.

To raise awareness of the good practices referred to above and to maintain them, early 2019 KMDP prepared a booklet and a poster with "Guidelines for Forage Maize Production and Ensiling". On 6 February 2019 a Field Day was organised by KMDP, Nundoroto, AG Harvesting and FIT Ltd in Eldoret, to promote these guidelines and the need and benefits of conservation agriculture and high quality maize silage.

For the Guidelines click on https://www.cowsoko.com/programs/kmdp/publications and check report 35. They are also attached in Annex 5 of this report.
For the Field Day video see: https://youtu.be/12U7bkc1qrM

4. Contractors and client database

a. Nundoroto Farm Company Ltd (NFC)

Nundoroto Farm Company (NFC) was supported by SNV from 2015 onwards up to date. KMDP co-funded the Nundoroto through its Innovation Fund, provided market linkages to and offered technical support and advisory through local and international experts on all steps in maize production and silage making: soil preparation (conservation agriculture), planting, harvesting, chopping and crushing, pit designs, compaction and coverage.

The company provides services that address the identified challenges of good quality silage making. The machinery the company uses is capable of harvesting 25-40 acres per day and ensiling the same day, with the right chopping size and crushing of the maize kernels. The company has a team of operators who are well trained in all steps from seed-to-feed.

Nundoroto has been serving farmers since 2015 and the client database has been growing with old clients remaining loyal due to quality service they get, and new clients coming into the list each year. Total acreage in 2015 was 247 acre. In 2016 – 680 acre and in 2017 – 740 acre. In 2018 this increased to 1,245 acres, as they were able to use two 6-row-harvesters. Reference is made to Annex 5 for the detailed client base of Nundoroto in 2018.

In 2019 Bles Dairies/De Haan Loonbedrijf – a contractor from the Netherlands - partnered with Nundoroto and became shareholders. In 2019 the new shareholders will invest in more equipment and machinery to expand and enhance the business. They also will provide technical and organisational guidance.

<u>Nundoroto's focus for 2019</u>

- To harvest 1,400 acres of maize silage in 2019 up from the current 1,250 acres using two forage harvesters (Nundoroto and Simam).
- Plans to increase machinery capacity in 2019: forage harvesters and loaders.
- Improve marketing strategies in 2019 on maintaining their client loyalty and client base.
- Shall focus on quality and making follow ups on the current clients instead of focusing on new clients to bring knowledge to the people on board.
- Start producing dairy meal/trading in feed ingredients with the partner from Netherlands.
- To increase volume of contract services with willing farmers to plough their lands and to manage the whole process from crop production to maize silage harvesting.

b. AG Harvesting Kenya Ltd

Agri-Harvesting was established in 2018 as a partnership between Dejirene and the Dutch investor Hans Thijssen, is a new entrant into the silage making business with a late model John Deere 6-row-harvester. It is also benefiting from KMDP-II's Innovation and Investment Fund and started its operations in October 2018 with the arrival of the harvester and loaders.

AG Harvesting's brief is operating an agricultural contracting service to support dairy farmers in maize production, harvesting and ensiling, but with a number of innovations on logistics. This entails modified loaders and wagons that can work under all weather conditions. The machinery can both chop maize and cut grass for making silage.

AG Harvesting also invests in a maintenance and repair service centre in Eldoret for own machinery and machinery of other agricultural contractors. In the short period remaining in 2018 (Oct-Dec 2018) AG Harvesting was able to serve 10 customers and did a total of 435 acres. In spite of late arrival of the machinery these farmers still enjoyed the service and were happy due to the quality of work done. See: https://youtu.be/31jZdrd48EM

AG HARVESTING	FARMER/FARM NAME	ACREAGE
1	Mogotio	50
2	Chemweno Farm	30
3	Kimosop	60
4	Pst.Juma	7
5	Kapkuga Farm	15
6	Philomena	23
7	Sile 1	65
8	Too 1	45
9	Sile 2	45
10	Too 2	30
11	Murgo	35
12	Fred	30
	TOTAL ACREAGE	**435**

AG Harvesting has skilled operators and mechanics, amongst others through 4 months on-the -job training in 2018 by a Dutch expert. AG Harvesting has a strong link and collaboration with FIT Ltd (see chapter 6). FIT contracts maize growers in North Rift to grow maize for baling, whereby AG Harvesting advises on maize growing and also harvests and ensiles the maize for FIT Ltd in bunkers to bale from. The shareholders in AG Harvesting are also share-holders in FIT Ltd.

c. Tarus

Tarus contractor has a 4-row John Deere self-propelled forage harvester that was sourced from the Netherlands through the networks of Dejirene Enterprises (Eric de Jong of AG Harvesting). The machine harvests maize within Eldoret and its environs. This complemented very well with the work of Nundoroto, AG Harvesting and Simam (see below) since they could collaborate in serving all the customers without delay. Tarus was also supported by SNV KMDP to ensure the operators understand the good practices and technicalities of making maize silage. As is the case with Nundoroto and AG Harvesting SNV KMDP Team also supported Tarus with market linkages. The table below shows the clients and the acreages harvested by the contractor.

TARUS	FARMER/FARM NAME	LOCATION	ACREAGE
1	Willens Farm	Kapseret	20
2	Magut Farm	Illula	20
3	Chumo Farm	Illula	30
4	Tarus Farm	Moiben	80
5	D.L Farm	Plateau	50
6	Kibogy Farm	Kaptagat	15
7	Chelimo Farm	Flax	9
8	Beatrice Biwot	Flax	15
9	Chesire Farm	Annex	10
		TOTAL ACREAGE	**249**

d. Simam

Simam has been partnering with Nundoroto contractors since the inception of the maize train concept in 2015. The farmer has one self-propelled 6-row and one self-propelled 4-row forage harvesters (John Deere 5810 and CLAAS). The John Deere harvester is still used in a partner-ship with Nundoroto, but the CLAAS is operated to serve other farms with silage making by the farmer himself. Simam's operators observe the principles and good practices of the maize train concept. Below are the clients served in 2018 by the CLAAS machine and the acreages covered. For 2019 Simam will maintain the partnership with Nundoroto for the other machine and also try to set up a pilot for grass silage.

SIMAM	FARMER/ FARM NAME	LOCATION	ACREAGE
1	Martin/Leketon Farm	Cheplasgei	45
2	Rose Kiplombe farm	Kiplombe	20
3	Laban Tanui farm	Jua Kali	5
4	Tarus Gloria	Ngeria	30
5	Kogos	Ngeria	11
6	Turbo farm	Turbo	30
7	Simam farm	Burnt Forest	70
		TOTAL ACREAGE	**211**

e. Contractors' fee and cost price for the farmer

The fee charged by the contractors mentioned above for harvesting, chopping and ensiling is approx. KES 14-15,000 per acre. This means that the higher the tonnage or production per acre of maize, the lower the cost price per ton of maize silage.

For the farmer who has to plough, plant and manage his own maize, and pays the contractor for harvesting, chopping and ensiling including covering, the cost price per kilogram of fresh maize silage is between KES 3-5 depending on the tonnage he is able to produce per acre.

This should ideally be worked back to a price per kg of Dry Matter (DM), as harvesting in early or late stage can give a difference of up to 5% in DM yield (ideally at 33% DM). This will eventually determine the price of the silage as all the nutrients are in the DM.

Table 1: Effect on cost price of maize silage by production per acre and DM content

	Maize silage at harvest		Maize ensiled		Maize ensiled	
15,000 Kes/acre	Fresh	Fresh	33% DM	33% DM	28% DM	28% DM
Yield in tonnes	Cost/ton	Cost/kg	Cost ton DM	Cost/kg DM	Cost ton DM	Cost/kg DM
10	1,500	1.5	4,545	4.5	5,357	5.4
12	1,250	1.3	3,788	3.8	4,464	4.5
14	1,071	1.1	3,247	3.2	3,827	3.8
16	938	0.9	2,841	2.8	3,348	3.3

Table 1. illustrates the effect on cost price of silage making by the contractor that results from the total tonnage of maize that the farmer harvests per acre, and its dry matter content (% of DM) at time of harvesting. The costs are exclusive the production cost related to growing of the maize.

In the scenario of 10 tons per acre with a DM of 28% the cost price comes to KES 5.4 per kg of DM (at a contractor fee of say KES 15,000 per acre). In the scenario 16 tons per acre with DM of 33% the cost price per kg DM is KES 2.8. The conclusion is that it is beneficial to aim for high DM yield per acre.

Pictures speak: the Maize Train in action

5. Strength and challenges of the Maize Train model

Contribution from Solomon Misoi (Dairy Consultant KMDP project, Eldoret Office)

Maize Train as it is called by the contractors and SNV/KMDP, started back in 2015. There was only one contractor then with a self-propelled forage harvester (Nundoroto), that started out on a partnership basis with a farmer (Simam) who owned the forage harvester. 4 years down the line there are now five professional 6-row forage harvesters (three with rotating Kemper heads and two with fixed row-heads) and also two 4-row self-propelled forage harvesters, in the North Rift region. Reportedly all the machines were imported by individual farmers who registered contracting companies within the last 3 years.

The business of maize silage harvesting has been growing over the past 3-4 years where in the first year the lone machine that was available, then managed to harvest 247 acres of maize for silage. In the year 2018, the machines of the above mentioned contractors combined did over 2,500 acres of maize for silage in the North Rif and some of it in the neighbouring Counties. This enormous progress was due to a number of strengths of the concept that are summarized below. However this has happened with an equal share of challenges in the process from 'seed to feed', which are a result of different factors. After describing the strengths of the concept, below some of the most conspicuous challenges in the business of silage making as reported by KMDP and the various contractors in the North Rift, are presented.

a. Strengths

The strength and success of the concept of maize train is clearly derived from the desire and willingness of the contractors to follow good agricultural practices, and to comply with the principles of good maize silage production as discussed in Chapter 2 above.

<u>Quality</u>

The most often mentioned positive point of the Maize Train is the quality improvement of the silage. The quality improves, because the chopping length is good (1 cm) and the machines have kernel crushers that allow maize to be harvested at a later stage when it contains higher starch levels. The crushing is important, because it makes the starch in the maize grain available and digestible for the cows. In combination with the speed of harvesting, ensiling and good compaction and coverage, the nutritional value of the maize silage is high and losses are minimised. This results in increased milk production and reduced costs per litre of milk produced. Notwithstanding the big improvement in quality, it is likely that more can be achieved if forage varieties of maize are used instead of the current grain varieties available in Kenya. The ME content of the maize silages sampled at farms where a maize train was used lies 10-15% below the ME content of the silages of forage maize in Western Europe.

<u>Capacity</u>

Since preservation of forage crops through silage making is an anaerobic process, air (oxygen) is the biggest threat for high quality silage. Machine capacity is needed to harvest the crop at the right stage and to finish the pit or bunker within one day (preferably within 12 hours), including compacting and air tight covering. The high machine capacity of the maize train in silage making is therefore one of the most meaningful improvements in the process.

<u>Compaction</u>

Compaction is crucial for quality silage. Thorough compaction keeps out oxygen from the pit and improves the (anaerobic) preservation process. Also during feeding out of the pit effective compaction prevents oxygen entering the silage that would otherwise result in heating, rotting and moulding and create losses. Utilization of a shovel – which exerts a higher weight per square cm compared to the commonly used tractor - also showed that better compaction can be achieved. Smaller chopping length (see above) eases compaction. The shovel also increases the speed of covering the maize silage bunker as the shovel can be used to cover the plastic coverage with a layer of soil. This is required for weight and also to prevent the sun to heat up the top layers of the bunker or the pit.

Logistics
As the maize train comes along with tractors and a number of tipping trailers, the transport of the chopped maize from the fields to the pit is (within a reasonable distance), equal to the capacity of the harvester. Therefore, the maize train can harvest continuously with high capacity and efficient use of machines and labour, without having to wait for the loader tipper to return from the site of the silage bunker. With loader tippers and other adjustments to the machinery, enabling the maize train to get into wet fields after rain, AG Harvesting has brought another innovation into the practice.

b. Challenges

b.1 Mechanical

Breakdowns, wear and tear
This according to contractors is the main bottleneck in the silage making process. Major mechanical problems include machinery breakdown (including breakdown because of uneven fields, bad roads), wear and tear of essential parts and breakages. Machinery breakdowns impact negatively on the process of silage making, because of major delays and stoppage for long periods of time. Most times the farmers had moved on or the maize had dried by the time the machine was repaired.

Lack of spare parts locally
This is a main cause of delays because the self-propelled harvesters are new to the Kenyan markets and thus their parts are not available locally. In case of any breakage, the contractors are forced to import the parts. In case the parts can be sent by air through courier services, this usually only takes a few days. (NB: if these circumstances occur during harvesting, make sure the maize already in the bunker is sealed until ensiling can continue).

b.2 Human resource (knowledge and skills)

In relation to machinery
Big forage harvesters are still new to Kenyan machine operators since it is new technology in Kenya. This affects the ability of the operators/mechanics to operate, maintain and repair breakages, in addition to a general lack of awareness of the importance of routine maintenance and servicing of the machines.

In relation to silage making process
Machine operators also have limited know-how about silage making. The operators who are starting out most times don’t have basic understanding of silage making process, hence if not well trained and diligent their operations compromise on the quality of silage. There is tendency to just drive the machines paying less attention to technical issues such as proper opening of the fields, not maintaining the dimensions of the pit, poor compactions of edges and even tendency to give limited attention to layer-by-layer compaction.

b.3 Work culture

Time management
It has been a challenge to manage people and to inculcate the sense of responsibility in as far as time-management is concerned. This has often caused delays, working below optimal, losses and sometimes losing customers.

Sense of ownership

Given the mode of remuneration, workers sometimes don't have personal drive and motivation to go the extra mile, because the pay is constant whether less or more work is done. Also there could be no recognition of good work hence tendency to do bare minimum because there is no sense of ownership in the works of the company. This however varies from contractor to contractor.

Customer relations issues

There have been instances of disagreements between the operators and farmers due to various causes, such as when to harvest the maize, where to locate the silos, whether to use own compaction or farmer's tractor etc. These issues indicate that what the language spoken by the management of contracting companies is often different from what the operators face in the field, thus communication breakdown.

b.4 Logistical

In the farm

There are numerous logistical challenges that impede movement of machines in the farms. These include presence of tree stumps, stones and rocky areas, hills and valleys, swampy spots, farm shape, standing trees, many unexpected barbed wire fences etc. These factors impede movements and thus cause waste of time and delays.

During transportation of silage to the silage pit or bunker

Some farms do not have proper access roads to their maize fields, thus causing waste of time to create roads to the farm. In other instances the maize fields are very far from the dairy where the silage bunker or pit is to be made. This causes delays since the harvester is idling in the field waiting for the loader to be back.

Moving from farm to farm

There are challenges of moving machines from one farm to the other because at times the distances are big as farms are scattered. Sometimes the machines have to cross Counties to get to a farm. According to the contractors, driving on the roads with potholes is the major cause of machine breakdowns. This has also had a negative impact on the state of the machines because they are not meant for driving long distances on the roads connection one farm the other.

b.5 Planning and organisation

In the agricultural contracting business work planning is crucial and this involves planning at various levels and for different purposes (see below). Planning and organisation bottlenecks exist within most contractors.

Seasonal work planning: maintenance/repair, ploughing/spraying, harvesting and ensiling.

Planning for increased ploughing and harvesting windows taking into account differences per agricultural zones/Counties (ideally also using early and late maturing seed varieties)

Logistical planning: timely ordering of spare parts, fertilizers, seeds (by contractor or client)

Logistical planning: reduce movements from farm-to-farm.

Human resource planning: staff needs according to seasonal activities/peaks.

b.6 Weather

Rainfall

Frequent changes in weather conditions from dry to wet, sometimes render the maize fields inaccessible because the machines get stuck in the mud. This causes wastages of fuel, time and destruction of the soil structures. In some instances, machines break down due to poor roads and muddy farms that have a lot of potholes and are bumpy due to too heavy rainfall.

Temperature

Maize matures fast during the dry season causing some customers to change their minds on whether to make silage or grain from the maize. Heat at times causes drying of the leaves causing lignification even before the maize crop is mature enough for harvesting as silage.

b.7 Financial

To the farmer

Farmers complain of high prices and lack of finances. If payment upfront is not agreed and adhered too, this may cause huge delays in payment for the contractor and affects his cash flow negatively. This endangers the entire operations if not minimized. In some extreme instances farmers may take up to one year before settling the debt of the previous season.

To the contractor

Sometimes major breakdowns occur demanding for very significant sums of money for repair services and/or new parts. If insufficient cash flow and savings, this may cause not only delay of fixing the machine but also delay in sourcing of funds to finance the spare parts and the services that go with it. Financing of agricultural equipment and cash flow financing is problematic in Kenya, which hampers scaling up of the business.

b.8 Farmer/Client

Attitude

Some farmers are not good communicators and can harass the contractors with demands that are beyond the contractor. It takes too long to negotiate and to communicate with a farmer who has bad attitude and poor communication, thus causing delay in doing the actual work. Some farmers book machines and on arrival the contractor finds that they already harvested the silage themselves or with a different contractor.

Poor planning

Farmers at times demand instant services having no regard to planning and lack patience to wait for their turn. Poor planning shows in booking the machines too late, delaying payment of the services, not preparing the site for the silage pit or bunker, not knowing how many acres of maize to harvest for silage, etc.

Forcing contractor to do as he likes

Farmers have their own (old) ways of doing things, while contractors want things to be done differently and professionally. At the end of the day this push and pull costs the contractor's time, which could have been spent in another farm. And moreover it puts the quality of work and the silage at risk.

Knowledge gap

Farmers often do not understand the reasons behind certain good practices, such as minimum tillage/conservation agriculture, fertilization, seeding space, cutting height (less stubble in the pit or bunker, less NDF and higher digestibility), chopping length (better ensiling, compaction and digestion by the cow), speed of ensiling and compaction (anaerobic process), bunker design etc.

b.9 Management of silage pit or bunker

Poor covering

Farmers are advised that the bunker or pit is covered with sufficient soils or soil bags to prevent heating up by the sun and keep the top layers well compacted. This is sometimes disputed as good practice, or not followed-up in case the contractor agreed that this is the work of the farmer. Lack of soil coverage leaves the plastic exposed to birds, animals and the sun and can lead to holes, which will allow air into the bunker.

Poor covering plastics

Farmers are used to 2-meter wide strips of plastic from local hardware shops, which however are not originally meant for silage. These plastics cause losses through rotting as they are not airtight and in some spots allow air into the silo.

Poor feeding from the pit

Farmers or farm workers tend to remove the silage from the pit in corners or leaving lots of loose silage at the face of the pit, causes irregular feeding speed of the silage in the bunker and heating up and rotting. Leaving the open end or the face of the silage bunker not being removed in a straight line and with plastic cover to close the face, causes spoilage of silage and destroys the quality that otherwise was good to the point of feeding.

Locating silage bunker/pit on the farm

Some farmers have their silage pits far from the cows and they only scoop silage from the pit once a week and transport it to the cow barn. Here it is kept in bags or in the open for a week which greatly reduces the quality of the silage. Meanwhile in the bunker by the time the next weekly scooping takes place, moulds and rot will have formed at the open end of the pit.

Low feeding speed

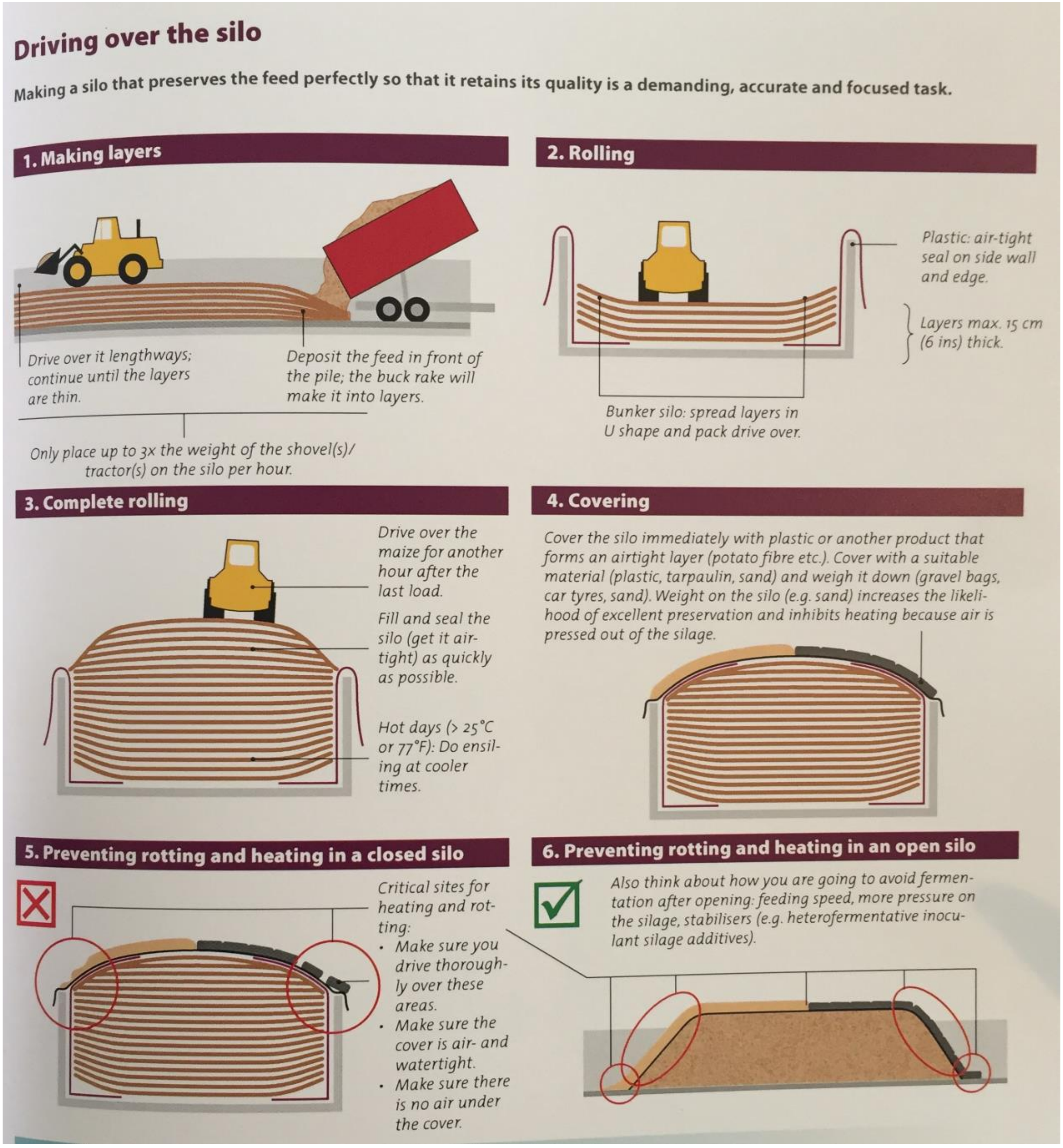
Some pits are fed too slowly that it gives time for moulding and rotting of silage. Weekly 1.5 meters must be fed to the cows and in a straight horizontal line moving the entire face of the pit/bunker 1.5 meter backwards.

b.10 Regulatory environment

This involves importation and duties or levies unrightfully charged for agricultural inputs like nets and plastic film for baling and also for the plastics covering the silage bunker. The policies and regulations in place for registration of new forage seed varieties in Kenya are very cumbersome, time and money consuming, and are the main reason that Kenya is not benefitting from availability of high yielding energy and protein rich forage seed varieties. Varieties that are out there in the market in other countries with similar agro-ecology as Kenya, and in some instances originate from East Africa and were improved elsewhere.

Illustration: How to make a good silage pit/bunker

Source: Feeding signals, Jan Hulsen, Dries Aerden, Jack Rodenburg page 33, from Cow Signals series, Vetvice, Roodbont Publishers



6. Baling of maize silage

Baling silage is a new technology for the Kenyan forage market, introduced by FIT Ltd with the support of KMDP. As compared to hay in the commercial forage market (overpriced and of low quality), baling of maize silage gives opportunities to provide quality forage, transportable over long distance, without losses of dry matter and nutritive value. The bales have a long shelf life if not opened or damaged can be stored for long (up to one year), this gives high flexibility in terms of availability and sales throughout the year, with likely the highest margins in the dry season.

The basic principle of silage baling is to vacuum package the chopped maize directly fresh from the field or to bale from a silage bunker. The baling machine provides high compaction, such that no oxygen can enter the bale and conservation will start immediately (in case of baling fresh product) or will not be interrupted (in case of baling from a silage bunker). Grass can be baled as pre-wilted material. The aerobic losses in baled silages are very low. If baling fresh material, time between harvesting and airtight covering is very short and from a quality perspective the best option to make silage. To minimize losses during transportation of silage over long distance, wrapped bales are the best option.

For feed planning and feed stock management bales are easy to count. Knowing the weight and the DM content of the bale, feeding and ration formulation will benefit from this way of silage making. To make optimal use of these advantages of baled silage, it is necessary to put relevant information on a label on the bale, such as total kgs and dry matter content and preferably also nutritive values. For silage baling by FIT Ltd see the video in the following link:
https://www.youtube.com/watch?v=ytgsuMtqhTQ#action=share

a. Forage Innovation Team (FIT Ltd)

Forage Innovation Team Ltd (FIT Ltd) with brand name Feed & Forage, offers professional forage baling contracting and sales services to ensure enhanced access for small, medium and large-scale dairy farmers to quality feeds, for constant milk production and increased productivity. FIT Ltd offers baling and consultancy services for farmers who wish to grow their own maize and have it baled. In addition to that, FIT grows its own maize - or buys maize from farmers - and bales it to sell in the market. FIT gives advice and service from 'seed to feed' through ProDairy EA Ltd, to ensure highest quality maize production and silage. FIT's operations manager is Mr Eric de Jong who is also operations manager of AG Harvesting, and shareholder in both companies.

FIT Ltd – which is a consortium of six shareholders 3 Kenyan, 2 Dutch and 1 from Luxembourg - is assisted by KMDP with a grant from the Innovation & Investment Fund. KMDP also provides market information and linkages with potential suppliers/growers of maize for harvesting and baling, and also linkages to potential buyers. The latter includes medium scale farmers and also smallholders through dairy cooperatives in North Rift, Eastern and Central Kenya. 2018 was the first operational year for FIT. Initial results are promising. 12,500 bales have been produced during the period March 2018 – March 2019 (of which 6,000 or 50% in Q1-2019). See also the table on the next page. Break-even is at 10,000 bales per year.

In December 2018 FIT has been awarded additional funding from KMDP's Innovation Fund in order to address some of the unforeseen logistical issues and responses from the market, to make the pilot more robust and hence better prepared and equipped for upscaling.

FIT's focus 2019

- To have a yard for storage and distribution in Nairobi.
- To have in place telescope loaders and QC/QA testing equipment.
- To produce 20,000 bales.
- Plan to harvest 2,000 acres for maize silage baling in 2019 through contracting of outgrowers.
- Buy a lorry.

DATE	FARM	CLIENT	BALES DONE
MARCH 2018	MOLEM -1	DEJIRENE	1,000
MARCH - JUNE 2018	MOLEM -2	DEJIRENE	527
MARCH - JUNE 2018	CHEMUSIAN FARM	FIT	1,886
AUGUST 2018	REHOBOTH FARM-	RUTH MUNYAO	562
JULY 2018	SUSWA DAIRIES-ELDORET	CHARLES BOIT	169
OCTOBER 2018	CHEPLASKEI FARM-DANIEL TOO	FIT	595
NOVEMBER 2018	KAPTOLI FARM	KIMOSOP	1,818
JAN – MARCH 2019	MT ELGON, OTHERS	MT ELGON	6,000
	TOTAL BALES PRODUCED PERIOD MARCH 2018 – MARCH 2019		**12,557**
	TOTAL BALES SOLD PERIOD MARCH 2018 – MARCH 2019		Circa 6,500

b. Other investors in baling of silages/haylage

With the support of SNV KMDP-II (technical, market studies and financial support), FIT Ltd was the first company in Kenya that imported and piloted professional and high capacity machinery to bale maize silage. A small pilot at **Gogar Farm** earlier received support by KMDP-I, however the technology used is not scalable.

Since the concept was introduced in Kenya, other investors have replicated but with different machinery, technology and even different forages. These are:

Leketeton Farm near Eldoret is about to start a forage baling business with a machine of Turkish brand: a Celikel Perpetua2 baler filling bags of approximately 50 kg.

Another **Farm** near Eldoret baling and wrapping with an Orkel machine making bales varying from 900 – 1,000 kgs. They are selling at KES 10,000 per bale. In case of a 1,000 kg bale, this is KES 10 per kg.

AusQuest Farm (Stuart Barden) near Athi River (30 kms from Nairobi) is piloting sorghum as a grass crop for silage. After mowing with a disc mower the crop is on the field for wilting up to 50% DM and then bales with a Krone single purpose baler. A separate machine is picking the bales for wrapping. Depending on DM content the bale weight is approx. 400-500 kgs.

Grove Feeds (Mr. Johnson) in Kitale is baling maize silage, sorghum and sunflower in 70 to 100 kg bales (depending on DM content). The baling machine is from China and is modified to fit to local supply of spare parts. Capacity of the operation is 12 – 15 tonnes per day.

c. Practices observed in various baling systems

The quality of the silage in the bale is primarily depending on the quality of the raw material: chopped fresh maize from the field that is baled directly or ensiled maize that is being scooped from a bunker for baling. If this raw material is not harvested at the correct time and chopped well (harvesting stage/DM content, the whole plant, 30 cm stubble, low in crude ash, proper chopping length, use of kernel crusher), has moulds or was not preserved well in the bunker, the bale will be of low quality.

FIT Ltd has so far been able to assure raw material for its bales of reasonable to good quality. It has bought several bunkers (Chemusian) that were ensiled well by third parties and it has partnered with AH Harvesting. The latter assures FIT of professional high quality services and harvests and ensiles or bales fresh maize for FIT according the good agricultural practice.

During the first year of their business FIT has encountered a number of challenges around quality and logistics that it has adequately addressed or is in the process of doing. For example increasing and measuring DM content, improving logistics, testing of their product in the field and in the bale, contracting maize growers, marketing and developing a system of labeling. The first year of learning brought out many issues that the investors were not -or only partly - aware off, especially related to quality, market and pricing. SNV KMDP, PUM and ProDairy EA Ltd play an important role in advisory and linking FIT to the market (both maize suppliers and buyers of bales), organizing field days and demos.

The pilot of FIT Ltd showed that bales can be made from fresh chopped maize and from the silage pit or bunker. There is no significant difference in quality between maize in a bunker or in a bale, only that losses in the bale will be slightly less due to 100% vacuum packing/wrapping compaction, causing less side losses and effluent losses. Provided that the process of silage making is executed in the right way (i.e. stage of harvest, capacity, compaction and storage) and as described earlier.

If a farmer has enough land to grow his/her own maize on the farm and ensile in sufficient quantities and with the right machinery and practices, the cost of making a silage bunker is much lower than making silage bales (currently less than half). Many farmers however have to buy forage because of lack of land to grow forage, poor planning or drought, hence this is in principle where the market is for baled silages.

Baling fresh chopped silage from the field, versus baling from the silage bunker, has an advantage as the latter will give an additional loss of circa 5% in DM, energy and protein due to short exposure to oxygen and repacking/compressing.
If baling and wrapping takes place in a stationary position (not in the field), loading the bunker of the baler with a front-end loader mounted on a tractor or a shovel, adds a risk of damaging the bunker of the baler and – if the impact is high - the entire baler. Also scooping out the maize with the front-end loader and make short turns gives high wear and tear on the front axle of the tractor. In the FIT situation as observed by the expert, it would be useful to consider filling the bunker of the baler by a conveyor belt and scooping the fresh chopped or ensiled maize on the conveyor belt using manual labour.

Silage bales are wrapped with 6 to 8 layers of stretch foil that makes them vulnerable to damage during handling, transport and storage. All efforts made in the baling for high quality are negated if the cover gets damaged. Holes should be repaired immediately with tape.
When the bale comes out of the baler the ground must be flat and smooth without any hard or sharp obstacles (maize stubbles, stones!). Handling the bale from the machine to the storage, or in case of direct transport to the trailer, can only be executed by a hydraulic clamp mounted on a tractor or by a telescopic loader.

Rolling bales manually over the ground at the site of production, storage or the farm, increases the risk of holes in the plastic. The location where silage bales are stored needs daily close observation and tape must be available for immediate repair of holes if any.
The bales should be stored in lines with 50-100 cms in between for ventilation and close observance. Rodents and birds do not like ventilated areas. Preferably the bales should be covered with protective sheeting.

In the Kenyan market the weight of the bales or bags vary from 50 kg to 1,000 kg depending on the machinery and technology used. Bale weight also depends on DM content of the crop/silage: the higher the DM content the less water and the lighter the bale. A lighter bale therefore can have the same total kilos of DM (DM weight) as a heavier bale if the DM content of the silage is higher. The nutritional components are all in the DM. The issue of size and weight of the bale is also important with regard to bale density, bale handling and logistics and the amount of foil per kg silage. The larger the bale the higher the compaction and the less packaging materials (foil) is required. So in principle quality increases and costs go down (less plastic used per kg).

-The Turkish Celikel Perpetua-2 baler bought by Leketeton farm, produces bales/bags of 50–80 kg
-The Agronic baler of FIT produces bales varying from 3-400 kg per bale and 85-90 cm high.
-The Krone trailed easycut disc mower machine of AusQuest Farm produces bales up to 4-500 kg.
-The farm in Eldoret operating the Orkel MP200 baler makes bales of 800-1000 kgs.
-Grove Feeds in Kitale produces small round bales of 80-100 kgs.

The weight of the bales, varying from 50 kg to 1,000 kg determines to some extent the market segment for each supplier. Regardless the weight and size the feed-out period for all bales is 3 to 5 days after opening. Bales less than 100 kg are particularly suitable for smallholders with 3-4 lactating cows. These bales are easier to transport and handle. Larger bales of 350 kg and above are more suitable for farms with say 5-10 lactating cows or more.

d. Business case and market for baled silage

Below is a calculation of the indicative cost price for the commercial forage producer of baled silages and his sales price. The data are derived from baling 350-400 kg maize silage under current average cost/sales prices used in the market. The prices below are exclusive of overhead costs and costs for marketing and sales.

<u>Cost price of input, processing and packaging</u>:

- Buying maize as a standing crop at KES 3.70/kg (good maize crop, 33% DM, minimum yield 15 tons acre on level and easy accessible land for large scale equipment).
- Cost of harvesting KES 15,000/acre = KES 1.00/kg fresh
- Cost of baling KES 1,000 / bale = KES 2.86/kg fresh (bale is 350 kg/33% DM)
- Total cost of one kg baled maize silage = 3.70 + 1.00 + 2.86 = KES 7.56/kg fresh
- At 33% DM this is **KES 23.00/kg DM**

<u>Sales price not including transport</u>:

- Maize silage bales (350 kg, 33% DM=117/kg DM) offered at KES 4,300/bale at production site
- This entails a price of KES 12.3/kg fresh
- At 33% DM this is **KES 37.00/kg DM**

Gross Margin **KES 14.00/kg DM**

The business case for baled silages is currently mainly in baled maize silage, but grass silage and sorghum silage are also thinkable solutions and business opportunities in the dairy sector with many smallholders that have to buy forages, relatively high milk prices and exotic breeds. Besides, bales with a mixture of grass and maize silage are an option.

The market potential for baled maize silages – provided of high quality - is in the following use and application on the dairy farm:

1) A highly nutritious component in the diet of dairy cows on dairy farms that cannot produce forage on-farm and are thus relying on forage inputs from the market.
2) An (additional) component to optimize the ration for dairy cows with a high milk production particularly in early lactation.
3) A highly nutritious component in the diet of dairy cows that are fed on a diet too high in concentrates and/or compounded feeds and are therefore at risk of rumen acidosis.
4) A product that can cover shortage of forage due to drought and/or failures in feed planning.
5) A product that, when conserved properly and in plenty, can be a valuable and reliable component in a year-round diet for dairy cows.
6) Use maize silage in the year-round diet of the dairy cow to increase days-in-milk and the total lactation production per cow.
7) It is an excellent product to include in the diet for rearing of weaned calves (as from 4 months) and young stock rearing.

As mentioned above the market for baled maize silage is further segmented by (a) size and weight of the bales: smaller bales are easier to transport and to handle and need less cows to finish in 3-5 days after opening, (b) distance from production to consumption and the logistics around it that influence price, (c) production in tonnage of maize per acre also affecting the cost price, quality, nutritional value and DM % that influence the value, (d) milk price and (e) competition with other available feeds and forages in the market.

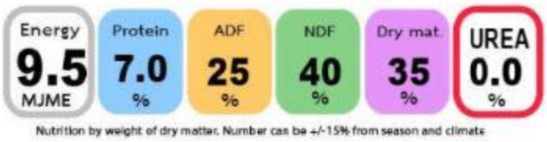
Since maize silage in Kenya is becoming more and more a major component in the ration for dairy cows, this market is expected to continue to develop rapidly. Soon farmers recognize that persistent and continuous quality forage supply has an immense impact on milk production, animal health and fertility. This is however more obvious with silage in a bunker from maize produced by a dairy farmer on own or leased land and ensiled by a contractor, than is the case with baled silages. The reason being that the price difference is high and the cost per kilo more than double and therefore less competitive to include in the diet of the dairy cow.

The current price charged in the market by the suppliers of baled silages varies from KES 13-16 per kg delivered at the farm. This is approximately KES 42-48 per kg of DM. This price is prohibitive for baled maize silages to become a *mainstream* forage solution in the current market, except for those farmers that have high producing cows (exotic breeds) and where this farmer has seasonal shortages of own silage and wishes to maintain high milk production without changing the ration. Or in case all or most forages have to be bought anyway, at a high price and when they are of poor quality. Milk price is also a factor to buy or not to buy baled silages. For example, dairy farms in peri-urban or in dry areas with a low production of milk, often fetch high prices for their milk especially if sold directly to consumers, caterers or institutions.

Most important for market development is the question what position the baled silage will have in the farmers strategy for feed planning and feed stock management. For some farmers baled silage is just to cover the months of drought. For these farmers silage is a seasonal product and baled silage becomes an "emergency" product in competition with the hay market.
For the supplier of baled silages it is difficult to make a planning for this irregular demand. Price calculations will be set "opportunistic" based on shortage and imperfect markets, and not based on quality and nutritive value of maize silage or hay.

Yet this market is considerable in Kenya, but for providing a structural mainstream forage solution in a mature and well-functioning market, cost price of baled silages must go down – without compromising quality - and this can be achieved through various interventions:

1) Increased production/tonnage of maize crop per acre and harvesting at higher DM (33-35%), so as to reduce the cost price of the raw material per kg of DM and per MJ ME.
2) Connected to this, economies of scale in maize production and working with professional outgrowers.
3) More efficient logistics and direct deliveries from production site to the farmer.
4) Availability of forage maize varieties to "replace" current commercial grain maize varieties in the market. Currently, this has to go through a tedious registration process of national performance trials and depends on international seed companies to initiate and request.
5) Providing farmers with correct information on bale weight, DM content/kgs in the bale and nutritional values (labelling the bales)
6) Offering clients ration formulation services (e.g. Rumen8) to optimize margin over feed costs



Example of a label, source: Facebook umami silage

The best strategy for market development for baled silages seems to seek a combination of year round and seasonal clients.

1) As for the first category: target commercial "smallholding" farmers (dairy as a core business on small plots) with high milk production (150-200 litres or more per day) and 8-10 lactating cows or more, who buy most of their forages and want to have silage as a permanent component in the ration, year round for their (early) lactating cows and young stock.
2) As for the second segment, MSFs and LSFs who want to complement own maize silage made on-farm with baled silage to overcome quality issues or shortages, or to feed only to specific groups of cows (early lactation, young stock).

For the second segment, silage is the basic component in the ration for the lactating cows. In this market segment it is easier to predict the demand for silage over a longer period of time and make accurate calculations of the market-price/value of silage for the farmer.

This calculation should preferably be done looking at the total ration of the cow and price and nutritional value of other feeds and forages in the market vis-à-vis that of maize silage. In addition the milk price paid to the farmer is a variable to consider when determining if maize silage is economically viable for the farmer and at what price. An accurate cost-benefit comparison with alternative forages/feeds in the market (e.g. hay) and use of ration formulation software like Rumen8 (see Chapter 9) can be an important tool for the suppliers of baled silages for market positioning and development.

7. Maize varieties for grain and silage

Maize grain hybrid maize varieties are bred for grain and do not make ideal silage. All maize varieties used in Kenya are originally bred for grain production and not suitable for highest quality maize silage. Feed analyses confirm that between grain maize and forage maize there are significant differences in terms of starch, NDF (fibre), DM content at ideal point of harvesting and digestibility.

Globally it is confirmed that forage maize has generally lower NDF, higher digestibility and higher starch content than what we see in Kenya with maize grown for grain (NB: in Kenya referred to as "commercial maize"). The table below confirms this for all important parameters and shows the nutritional value analyses of seven samples of maize silage from North Rift, with reference to the mean of Dutch maize silage 2018, analysed by Eurofins Agro based in Wageningen in the Netherlands. The exception is DM as the maize for the samples was harvested exceptionally late. This too is a disadvantage, as it is doubtful if maize silage with a DM content over 38% preserves well.

Table 2. Results in DM in gram/kg (unless stated differently)

Sample number	395341	395342	395344	395346	395347	395348	395423	Mean Kenyan maize silage of 7 samples	Mean Dutch maize silage 2018
DM	378	313	276	354	383	418	479	372	355
pH	5.5	5.8	6.2	6.2	4.8	4.5	4.5	5.3	3.9
Crude Ash	46	53	58	47	42	43	46	48	34
Dig.OM% (%OM)	65.4	66.5	60.8	69.9	69.1	72.5	72.2	68.1	76.1
NH3-fraction (% CP)	4	8	5	7	9	7	3	6	8
Crude Protein	60	54	67	62	40	56	67	58	65
Soluble CP (%CP)	33	28	53	25	41	48	47	39	58
Starch	277	321	284	317	246	288	320	293	357
Bypass Starch %	38	37	26	45	31	35	23	33	25
NDF	542	480	551	477	521	444	389	486	370
ADF	270	248	263	240	279	247	229	253	204
ME (MJ)	10.0	9.5	8.6	10.2	10.2	10.8	11.1	10.1	11.4

a. Breeding maize for forage (silage)

Globally, about 8% of total acreage under maize is grown for maize silage. In this application, ideal harvest occurs when the crop has reached 65% moisture (35% dry matter) and 50% kernel milk line. During this harvest window, the whole plant is cut low to the ground and is chopped into small pieces before being compacted into a silo or bunker, ensiled (sometimes mixed into a TMR), and fed to dairy cows for a season or more. Given this process, an ideal silage hybrid must satisfy an entirely different set of parameters than a grain hybrid.

It must have a high total plant yield of digestible starch and fibre, a long harvest window in which the plant dries to the appropriate moisture content and remains there for an extended period, adequate sugars to promote fermentation, and a relatively short storage period to save on space and reduce dry matter losses. Ultimately, a corn silage hybrid must produce a robust, reliable, digestible crop that will promote rumination and readily produce high quality milk when mixed into a TMR and fed to a lactating cow.

b. Neutral Detergent Fibre

A successful grain hybrid is bred to withstand the elements until late season harvest, which requires the stalk to be stiff and solid. In addition, its ear (cob) must be positioned high on the plant to ensure successful harvesting by the combine harvester. Both requirements increase NDF in the harvested crop and reduce fibre digestibility. The ear (cob) is the heaviest part of the plant, so the below ear portion of the stalk must be heavily lignified in order to support it. By raising the ear position and selecting for stiff stalks, grain hybrids produce a high proportion of indigestible fibre, as compared to forage maize. It can be difficult to harvest a grain hybrid for silage when its stalk is at the appropriate moisture level. It can pass from too wet to too dry rapidly which reduces silage quality and feed efficiency. Excessively wet or dry silages often result in inadequate fermentation and unstable silage products.

Ideally NDF content in maize silage is between 370-420 gr/kg DM. The average of the 7 Kenyan samples is 486 gr/kg DM against an average of 370 in the Netherlands (a difference of 116 gr/kg DM or 31%). Of a larger sampling set of 53 samples the average NDF content was 511 gr/kg (difference 141 gr/kg DM) High NDF and ADF (+49 gr/kg DM or + 24% in Kenyan compared to Dutch samples) in the cows diet has a negative influence on amount of DM intake and digestibility of the organic matter (OM) which under Kenyan conditions is 8% (absolute) lower than maize silage in the Netherlands. Higher NDF-ADF contents in combination with lower starch content gives a lower ME/kg DM. In the table above 1.3 MJ ME/kg DM less or 11%. The dairy cow requires approximately 5.2 MJ ME/kg DM to produce a litre of milk. Increasing ME in maize silage can lead to an increase of milk production with about 13% (11.4/10.1 MJ/kg DM).

c. Starch

As a maize grain hybrid reaches silage maturity, its kernels dry rapidly and get very hard. This rapid drying creates a very narrow harvest window for maize silage, which is further complicated by the extended stay-green characteristic of the grain hybrid's stalk. Often, when the kernels reach a moisture content that is appropriate for silage (dough ripe), the plants are far too green and still have a high moisture content, such that it is too early to put in the bunker. If the plant is harvested once the plant reaches silage-appropriate moisture levels, the kernels have likely become too hard and too dry. While the kernels may have a high starch content, they remain whole if a kernel crusher is not available, or the kernel fractures only into large pieces during rumination. In this form, much of the starch is unavailable in the rumen for bacterial growth or as by-pass starch for digestion in the intestines with the ultimate goal to contribute to increased milk production. In order to soften these large hard chunks of starch, a minimum storage period of six months in the silage pit is recommended. This long storage period increases storage space requirements and dry matter losses and does not guarantee ideal starch quality by the time it is fed. The ripe kernel can be crushed more intensively so as to make the starch available for the cow, but this increases costs and it can damage effective NDF (fibre).

In comparison with maize silage grown in a temperate climate, starch content in Kenyan maize silage is low, 293 gr/kg DM compared to 357 gr/kg DM (64 gr/kg DM or 18% less) despite the late harvesting stage and use of a kernel crusher. Better maize varieties specifically for forage production will improve the starch content next to better production practices targeting at higher cob yield.

Table 3. Effect of cutting height on dry matter yield (DMY)

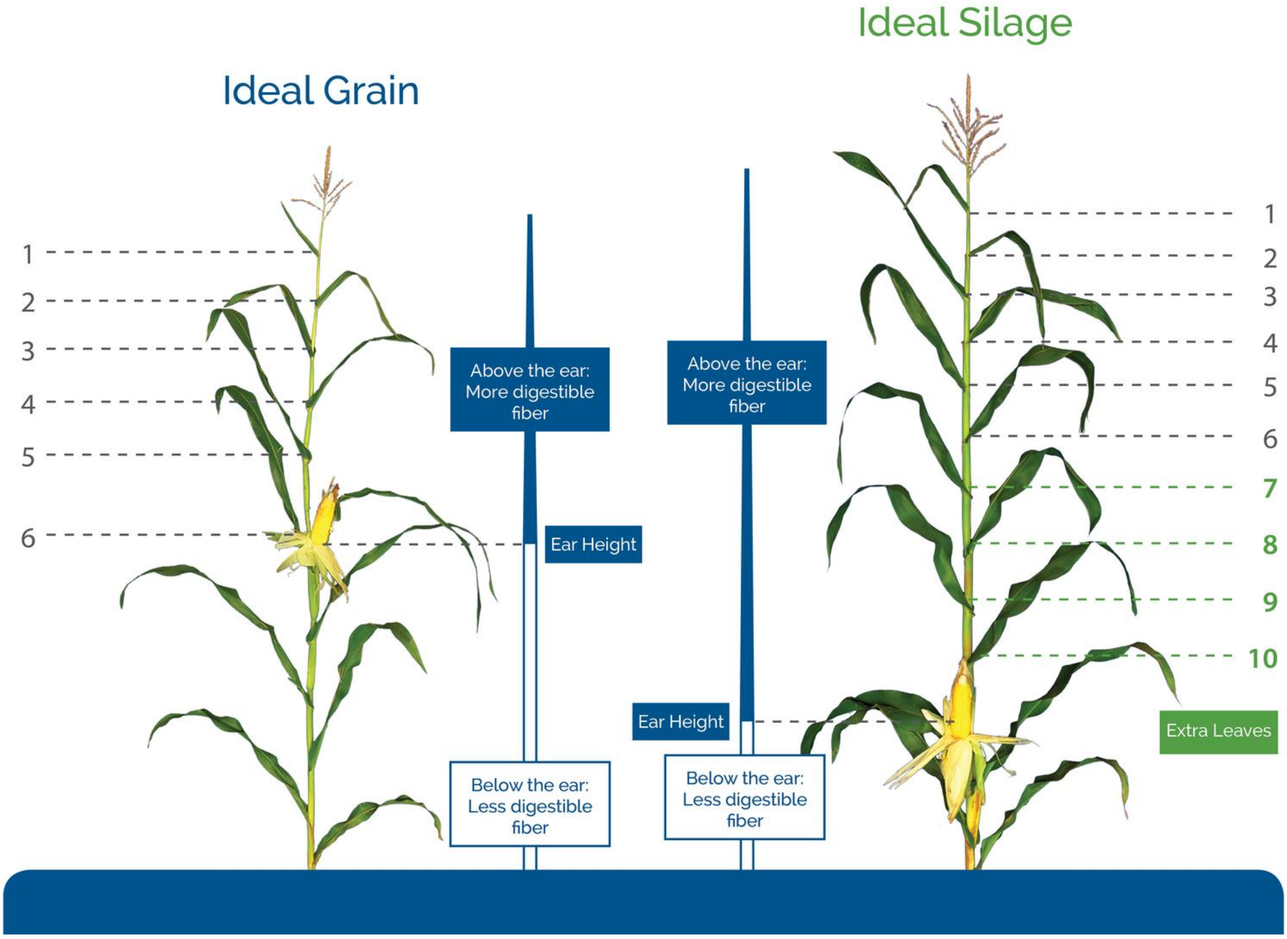
Cutting height (cm)	Silage yield (tonnes DM/acre)	Silage DM (%)	Energy per kilogram dry matter (MJ ME/kg DM)
10	8.98	35.7	10.8
30	8.58	37.2	11.0
60	7.98	39.2	11.2

The table above shows the effect of cutting height on DM yield of maize silage per acre, DM% in the maize silage and ME per kg/DM. Increasing the cutting height from 10 cm to 30 cm increases the DM content by 1.5% because more of the wet stem material was left in the field. The yield decreased by 0.4 ton DM/acre. Increasing the cutting height from 10 cm to 60 cm increases the DM content by 3.43% and decreased the yield by 1 ton DM/acre.

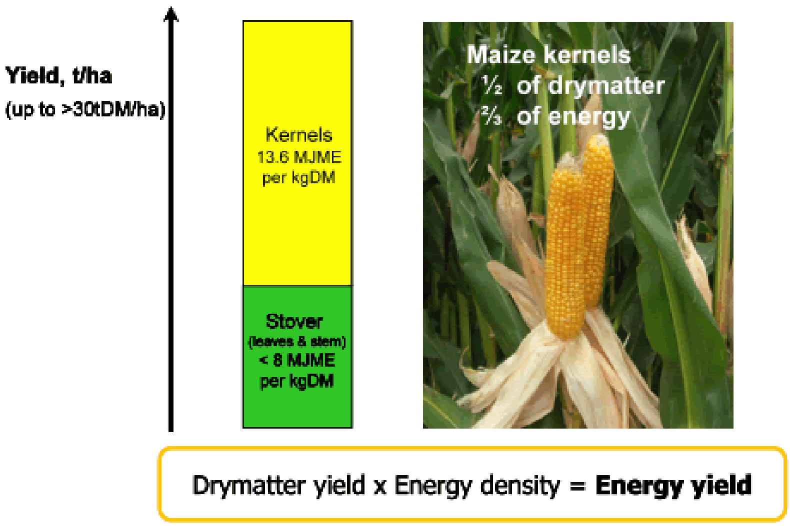
If we assume that the 10 cm silage had an ME content of 10.8 MJ/kg DM and that the ME value of the stalk left behind was 7.5 MJME/kg DM, the last column shows the effect of lifting the cutter bar on the energy density of the maize silage in MJ ME/kg DM.

Table 4. Characteristics of grain and forage maize

Characteristics	Grain type maize	Silage type maize
Yield	High grain yield	High total plant yield of digestible forage
Kernel moisture	As dry as possible at grain harvest time	50% milk line for as long as possible at silage harvesting time
Kernel hardness	As hard as possible to decrease the possibility of breakage and facilitate storage	Soft and easily broken for maximum digestion in the rumen
Kernel size	Small to decrease the possibility of breakage	Large to increase the possibility of breakage
Stalk moisture	Wet to keep plant alive as long as possible to reach higher grain yield	Dries to achieve 65% total plant moisture and stays in that range to extend harvest window
Stalk integrity	As stiff and solid as possible for late season grain harvest	As soft and flexible as possible yet strong enough to remain standing through late harvest
Ear (Cob) height	High position on the plant	Low position on the plant to increase proportion of digestible fibre above the ear (cob)
Ideal at harvest	Wet strong stalk that supports the ears (cobs)of vitreous, hard and dry kernels	Large plant with a soft stalk and moist ear (cob) of large breakable kernels. Stalk and ear (cob) dry simultaneously



The picture above shows that for the ideal silage maize the cob placement is low on the plant and above the cob the stem is soft and flexible, with approx. 10 leaves above the cob.



When MJME/kg DM is <= 10 relatively more stovers (leaves and stems) are part of the DM in the maize silage while not enough energy is coming from the kernels (starch), Source: Pioneer.

8. Benefits of maize silage for the dairy farmer

This chapter shows through a number of calculations and assumptions - based on actual farm gate prices of feeds and forages – the benefits of good quality maize silage and increased tonnage of maize and DM content, on the milk income of the dairy farmer.

a. Comparison of on-farm produced maize silage, baled maize silage and hay

The below cost price calculation for maize silage from the pit, baled silage and hay as component in the dairy cow ration, is based on price/kg DM and MJ ME/kg DM. Prices are farm gate prices.

Key data maize silage production on farm (North Rift 2018)

- Soil preparation & fertilizer KES 30,000/acre
- Harvesting & Ensiling KES 15,000/acre
- Cost price/kg ensiled product KES 3.0 – 5.0/kg fresh *(15,000- 9000 kg fresh/ acre)*
- Cost price/kg DM KES 9.0 – 15.0/kg DM *(DM content 33%)*

Key data baling maize silage by commercial contractor

- Baling price/350 kg bale KES 1,000/bale = KES 2.86/kg
- Baling price/kg DM KES 8.6/kg DM *(DM content 33%)*
- Cost prize baled silage KES 17.6 – 23.6/kg DM

Key data Boma Rhodes Hay in fodder market

- Hay price/13 kg product KES 250 - 350/bale
- Hay price/kg DM KES 24 – 34/kg DM *(DM content 80%)*

Farm gate (f.g.) price comparison of baled silage to hay and dairy meal on DM basis

- Price baled maize silage KES 13-16/kg fresh = KES 42-48/kg DM
- Price hay 1 kg DM (13 kg bale/KES 250/80% DM) = KES 24/kg DM
- Price hay 1 kg DM (13 kg bale/KES 350/80% DM) = KES 34/kg DM
- Price dairy meal 1 kg DM (DM content 90%) = KES 34 - 40/kg DM

Comparison (f.g.) of on-farm made maize silage, baled silage to hay and dairy meal on ME basis

Average nutritive value of maize silage, hay and dairy meal in the market

- Maize silage 9 – 10 MJ ME/kg DM
- Hay 5,5 – 6,5 MJ ME / kg DM
- Dairy meal 10 – 11 MJ ME/kg DM

Maize silage

- Price of 1 MJ ME on-farm ensiled maize silage KES 0.9 – 1.7
- Price of 1 MJ ME of baled maize silage KES 4.2 – 5.3

Boma Rhodes Hay

- Price of 1 MJ ME of hay (13 kg bale/KES 150/80%DM) KES 2.2 – 2.5
- Price of 1 MJ ME of hay (13 kg bale/KES 250/80%DM) KES 3.7 – 4.4
- Price of 1 MJ ME of hay (13 kg bale/KES 350/80% DM) KES 5.2 – 6.2

Dairy Meal

- Price 1 MJ ME of dairy meal KES 3.1 – 4.0

Explanation

1) For farmers who have enough land to grow forage maize, harvest the maize and turn it into a good quality silage pit, this is the cheapest way to provide dairy cows with an energy rich forage - year round - at a price between 0.9-1.7 for 1 MJ ME. Good quality maize silage is the

best and economically affordable alternative for hay in the total ration. It can as well reduce the amount of dairy meal in the ration, provided the ration with maize silage is properly balanced for protein, amongst others. Maize silage being a forage rich in energy will boost milk production and therefore reduce the cost price per kg milk. In practice the advantage of feeding roughage with a high ME content is even larger, because cows consume more of it and milk yield will increase further. This will be done in an economic manner because maintenance costs are diluted by a higher milk yield.

2) To further reduce the cost of 1 MJ ME it is essential to increase maize production per acre through improved soil and crop management. But also availability and use of maize varieties specifically bred for forage. These forage maize varieties should target higher nutritional value of maize in the silage pit (higher ME, lower NDF and higher starch content per kg DM). This combined will be a major step in reducing the cost price per unit of nutrients of maize silage.
3) Improving the 3 steps crop production, harvesting & ensiling and baling further, on efficiency technical and management performance level, will reduce the ensiling- and baling costs per kg DM and per MJ ME.

b. Potential of maize silage in the dairy farm

The following example is illustrative for the potential of growing good quality maize silage in the dairy cow's diet to increase milk production and milk income per acre. Assumptions:

- 1 kg Milk Solids (MS) needs 135 MJ ME fed
- Milk (Kenya) has 11.6% MS/kg milk
- Milk price 35 KES/kg
- The extra nutrients are used for milk production

Table 5. Effect of yield and quality of maize silage on milk yield/acre and milk income

Energy Density	DM Yield 3 ton/acre (at 33% DM = 9 ton fresh maize)				DM Yield 5 ton/acre (at 33% DM = 15 ton of fresh maize)			
MJ ME/kg DM	MJ ME/ acre	MS/ acre	kg milk/ acre	Milk income KES / acre	MJ ME /acre	MS/ acre	kg milk/ acre	Milk income KES / acre
6	18,000	133	1,149	**40,227**	30,000	222	1,916	67,044
7	21,000	156	1,341	46,931	35,000	259	2,235	78,219
8	24,000	178	1,532	53,636	40,000	296	2,554	89,393
9	27,000	200	1,724	60,340	45,000	333	2,873	100,567
10	30,000	222	1,916	67,044	50,000	370	3,193	111,741
11	33,000	244	2,107	**73,749**	55,000	407	3,512	**122,915**

The table above shows that very good quality maize silage (ME density 11) and a good DM yield per acre (5 ton) represents an energy value equal to 3,512 kg of milk (with 11.5 % MS/kg), assuming the silage is being fed in a balanced and optimized ration.

The difference in potential milk income (at KES 35/kg milk) between very low quality silage (ME density 6) and very good quality silage at the same DM Yield 3 ton/acre, is KES 33,522 (73,749 – 40,227). This increases to KES 49,166 for silage with an ME-density of 11 at 5 ton DM /acre (122,915 – 73,749).

Increasing the quality of the maize silage (MJ ME/kg DM) and the DM yield has a big effect on the farmer's income. In this example the difference between ME density 6/kg DM at a yield of 3 ton/acre (40,227) and ME density 11/kg DM at a yield of 5 ton (122,915), represents a value of **KES 82,688/acre**.

A farmer growing 50 acres of maize for silage will in this scenario be able to raise his milk income by 50 x KES 82,688 = KES 4,134,400 or **US $ 41,000** (US $ 1 = KES 100) through production of potentially 118,125 kg extra milk (1 kg milk = KES 35).

This example does not take into account that the cows also need to be fed for maintenance and other energy requirements: all the (extra) ME is used to produce milk. The actual increase in milk production will depend on DM intake (higher with palatable and good quality silage), whether the ration is balanced and the general management of the cows. However it shows the potential of good quality maize silage for milk production.

c. Impact of poor ensiling practices on ME density and cost price/kg DM

In the calculation below (Tables 6 and 7) we show an example of losses incurred through poor ensiling process. Often the maize crop itself is of good quality but through inefficient execution of harvesting, capacity, compaction and airtight sealing of the maize silage pit, nutritional and consequently financial losses can be big.

For this illustrative calculation we use the following assumptions:

- Density in the fresh product 11.5 – 12.0 MJ ME/kg DM (harvested at the right stage)
- Fresh maize 15,000 kg/acre
- Cost price KES 3.00/kg ensiled product
- DM Yield 5,000 kg/acre
- Cost price KES 9.00/kg DM
- Maize silage market price of 1 MJ ME – KES 4.2 – 5.3

Table 6. Cost price of maize silage and potential loss (in %) due to poor ensiling practices

Quality of maize silage	Density in MJ ME/kg DM in the final ensiled product	Price of 1 MJ ME (KES)	Loss in %
Fresh maize	11.5	0.78	
Very high quality silage	11	0.82	4%
Good quality silage	10	0.90	
Average quality silage	9	1.00	22%
Below average quality silage	8	1.13	
Low quality silage	7	1.30	
Very low quality silage	6	1.50	48%

The table above shows that the cost price of 1 MJ ME produced, is increasing when the quality of the silage decreases from 'very high' to 'very low'. If the ensiling process is successful, the ensiling losses in terms of monetary value can be limited to 4-5%. If the ensiling process is not done precise and accurate in accordance with the guidelines, the loss can increase to 50%.

Table 7. Potential economic losses due to poor ensiling practices

Value of ensiled maize silage	MJ ME / acre	KES MJME/acre at 0.9 KES / MJ ME	KES MJME/acre at 1.7 KES / MJ ME
Value of fresh maize in the field (11.5 MJ ME)	57,500	51,750	97,750
Value of very high-quality maize silage (11 MJ ME)	55,000	49,500	93,500
Value of average quality maize silage (9 MJ ME)	45,000	40,500	76,500
Financial loss due to average ensiling process		-9,000	-17,000
Value of very low-quality maize silage (6 MJ ME)	30,000	27,000	51,000
Financial loss due to poor ensiling process		-22,500	-42,500

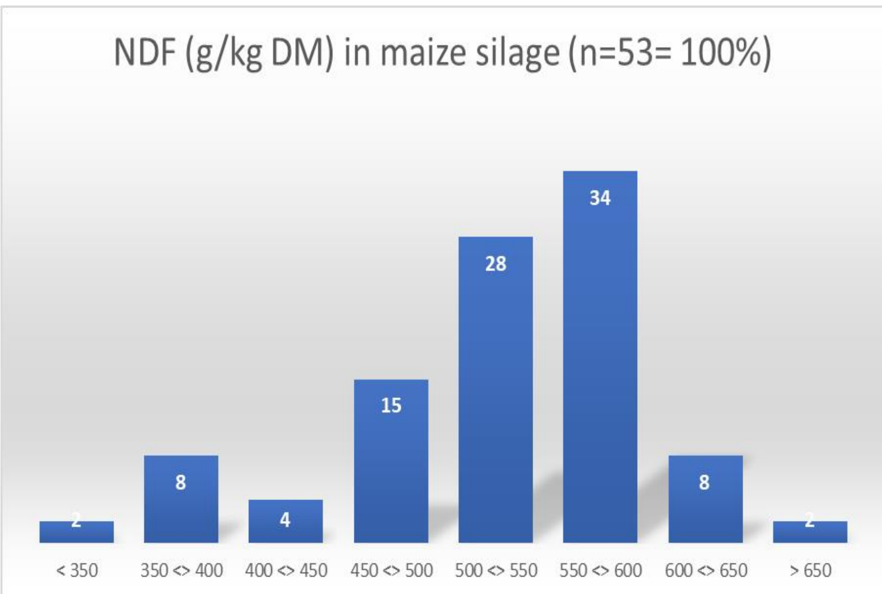
Table 7 shows the loss in value per acre due to poor silage making practices (lower feed value density 11 vs 9 and density 11 versus 6 respectively). Assuming a price of 1 MJ ME on farm produced maize silage KES 0.9-1.7 the loss per acre can vary between KES 9,000 (49,500-40,500) and KES 42,500 (93,500-51,000).
Next to this loss in value due to losses in ME density, also digestibility and DM intake will be reduced due to the lower silage quality. When this very low quality maize silage with a low density in MJ ME/kg DM is used in the diet of the dairy cow, farmers often try to compensate with expensive ingredients in the diet in order to maintain milk production level of the dairy herd.
The farmer then pays a second time for –and adds on to - the losses incurred during ensiling. Buying 1 MJ ME equivalent in the market in form of dairy meal is KES 3.1–4.0, whilst the price of 1 MJ ME for hay is KES 3.7-4.4 (13 kg bale/KES 250/80%DM). See page 34.

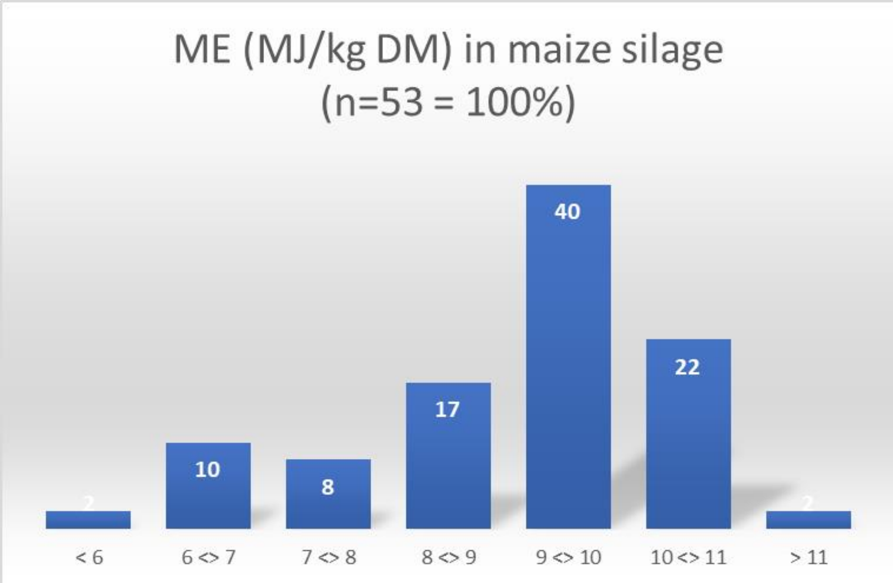
d. Variation in quality of sampled silage pits in North Rift

In November 2018 a total of 53 maize samples were taken and sent for analyses to Crop Nutrition Laboratory Services Ltd in Nairobi. Whereas due to ongoing optimisation by Crop Nutrition of the NIR regression lines for tropical forages the absolute figures are approximate, the two graphs below show the trend in quality of the 53 maize silage pits on 16 different farms in ME density (MJ/kg DM) and NDF (g/kg DM) in the maize samples. In all farms a form of maize train was used and farms were either served by Nundoroto, AG Harvesting, Simam, Maraba, Tarus or had own equipment.

The wide range in ME density (5.5–11.5 MJ ME/kg DM) shows there is room and need for improvement in some farms. This can be done by strictly following the 12 guidelines for making maize silage. It was observed that the samples showing the lowest ME were harvested in August which is very early and results in low DM, high sugar and low starch. In some cases contractors agreed with the farmer that the latter would compact or cover the silage bunker. It is known that at least in one case the bunker was only covered 2 weeks later. Obviously this defeats the whole purpose of the maize train and all investments made before covering.

The graph with NDF (optimum between 370 – 420 g/kg DM, lower NDF will increase DMI of the maize silage) shows that it is advisable with the existing (maize) grain varieties to increase cutting height. This will lower NDF, increase DM and ME in the pit (see Table 3 on page 32 showing the effect of cutting height on MJME/kg DM).





e. Conclusions

1) The total loss of poor quality silage is the cumulative effect of lower nutrient value per kg DM, spoilage and wastage, lower intake of DM by the cow, and reduced digestibility of the nutrients in the silage.

2) The overall negative effect of poor silage cannot be compensated entirely by other ingredients in the cow's ration, and will always result in a lower milk production and higher feed costs. In addition, poor quality silage also has a major negative effect on animal health and fertility, and also on food safety if the silage due to aerobic fermentation is contaminated with moulds and could therefore contain high levels of mycotoxins.

3) The experience in North Rift since 2016 with the "Maize Train" has shown that the concept of silage making (maize, sorghum and grass) is viable in Kenya. Contractors and commercial forage producers successfully turned around the existing practices of silage making, where use is made of forage harvesters with a capacity too small for the acreage and herd size, harvested too early (DM well below 30%) and with too long (> 10 mm) chopping length, no kernel crushers and too long interval between start of the silage pit and final sealing of the pit (2-14 days instead of 12 hours). These existing practices result in enormous respiration losses during ensiling and feed-out. Added to this is the risk of poor anaerobic fermentation because the pH does not drop fast enough giving yeast, moulds and rotting bacteria chances to spoil the silage.

4) Capacity and technology have shown that it is essential to influence and control the fermentation process in the ensiled crop successfully. Improving the process and logistics of silage making with the assistance of commercial forage producers who invested heavily in technology and capacity able to bring silage making to scale, have enormously improved the quality of maize silage available for the cow.
The combination of harvesting close to the ideal DM content (30-35%), intense compacting and sealing the silage pit within 12 hours, next to the use of forage harvesters equipped with sharp knives and kernel crushers, are the major reasons that the fermentation process starts-of immediately and respiration losses are kept to an absolute minimum. Silage that is well-fermented and compacted, will also show less respiration (aerobic) losses and no losses to moulds during feed-out. Provided that the feeding speed is at least 1.5 m per week.

5) Based on the calculations presented in Chapter 8.b with the improved silage quality, we can conclude that the Maize Train Model has resulted in great benefits for the farmers that made use of the services provided. The maize silage samples (53) presented above shows an average ME density of 9.1 MJ/kg DM. Poorly made maize silage of the quality that was found in farms at the beginning of KMDP - showed density levels that are estimated at 6.0 MJ ME/kg DM or below. This improvement results in a potential extra income of KES 20,113 (KES 60,340 – 40,227) to KES 33,523 (KES 100,567-67,044) per acre of maize in milk income depending on the DM Yield per acre (3 ton or 5 ton per acre respectively). See Table 5 on page 35.

6) This means for 2,500 acres done in 2018, a total potential extra income for all the farmers served of between KES 50.3 million (US $ 503,000) and 83.8 million (US $ 838,000). At a sales price of KES 35/kg of milk the total potential of extra milk produced is respectively 1.4 million kg and 2.4 million kg.

7) To reduce variation in quality (and thus in MJ ME and NDF), at this stage it is crucial that the early movers Nundoroto, AG Harvesting, Simam and Tarus, maintain their quality of work and don't compromise on the guidelines for high quality forage production and ensiling. For those who are crowding-in, they have to make sure that they reach at this level first, even before they need to maintain it. Ultimately only sampling every silage pit and silage bales can tell failure and success of ensiling, but with this SNV-KMDP targets have been set and is very well possible to aim for maize silage pits and bales with an ME density > 10.5 MJ ME/kg DM and NDF < 400 g/kg DM).

9. Rumen8 dairy ration calculation software

Rumen8 is a software application to calculate dairy cow rations. It was developed by Dr Martin Staines and Richard Morris in Australia. It operates on Microsoft Windows computers and allows dairy advisors to manage forage based dairy cow diets to increase production and/or reduce feed costs. Rumen8 has been specifically designed to be easy to use, educational and provide visual feedback to the user (www.rumen8.com.au/). It has been continuously improved for over 20 years. While most users are in Australia and New Zealand, some 500 consultants, educators and farmers in 60 other countries across the world are using Rumen8 and their numbers are growing rapidly.

SNV KMDP started to pilot Rumen8 in Kenya in March 2018 with a small team of 3 dairy advisors and 3 students from University of Nairobi and Egerton University, that was headed by Mr Jos Creemers of ProDairy EA Ltd and supported by Dr Hink Perdok from PUM Netherlands Senior Experts. During the first 4 months of the pilot this Team was trained on the use of Rumen8 software and they developed a Kenyan Feed Library with over 250 feeds and forages (of different qualities).

In the period June to December 2018, the software was tested in 25 farms, some smallholder farms but the majority medium and large scale farms. During the process also 5 farms in North Rift were roped in and the Rumen8 Team saw entrance of two KMDP dairy advisors from North Rift and two from Meru. In addition two MSc students from Wageningen University joined the Team to assist with impact measurement (one in 2018 and one in 2019). Testing and impact measurement of the tool in the farms will continue up to May 2019.

Based on feedback and in consultation with the KMDP Rumen8 Team, the developers of Rumen8 made a large number of adjustments to the programme to make it more adapted and suitable for use in tropical countries. The shortcomings of most other diet formulation software is that when used in the tropics, they structurally overestimate voluntary feed intake. Usually software that has been developed for temperate areas, predict DM intake with the NRC model. Rumen8 has next to NRC the option to use NDF intake as a percentage of body weight as a driver of DM intake. In Kenya an NDF intake of 1.3% of body weight is used to suit the tropical conditions.

The tool assists dairy advisors to advise the farmer as regards making optimal forage based rations for his cows, taking into account (amongst other factors) the breed and weight of the cow, the stage of lactation, the farming system under which the cow is kept, the expected and targeted milk production, the optimum ration of available forages and feeds to maximize the margin above feed costs, and to optimize the productivity of the cow. Hence it seeks to increase economic performance of the dairy enterprise.

The use of the Rumen8 tool and the availability of good quality forages in abundance, has proven to be mutually reinforcing. Rumen8 balances diets and those farmers who have access to quality forages and implement the advice, see more effective use of these forages and the better balanced diets lead to reduced feeding costs and increased margins above feed costs.
Equally Rumen8 shows that farms that have used a professional silage service provider and have therefore good quality maize silage, see their margin above feed costs being higher than those who did not have a good stock and quality of silage for their dairy herd.

It is noted by the Rumen8 Team that in farms where Nundoroto and AG Harvesting were used by the owners, excellent results are being achieved when following up the ration that is advised by Rumen8 team for the different cow groups. Those farmers are not only willing to follow up the advice, but they also have the feeds (i.e. good quality maize silage) available to formulate a good diet.

In the same vein, having quality feeds and forages in the farm is one thing, but balancing these in an optimal way to make them more effective for uptake by the cow and low cost milk production is equally important. The Rumen8 tool can therefore also be of great value to forage maize contractors and commercial forage producer as an add-on to - and actually to enhance - their core business.

Finally, by the collaboration between SNV KMDP and the software developers of the Rumen8 ration formulation tool, Rumen8 was enhanced recently with an equation to calculate and predict methane emission per cow per day (methane yield) and per litre of milk (methane intensity). This makes the Rumen8 tool an even more powerful and promising tool for the dairy sector in East Africa and other tropical countries.

10. Forage demonstration plots - KMDP/CIAT collaboration

In 2018 SNV KMDP started collaboration with CIAT (International Center for Tropical Agriculture). CIAT is an organisation that does research on new tropical forage varieties. The collaboration entails demonstration and testing of various brachiaria varieties and other protein rich forage (desmodium, vetch, panicum) in different ecological zones and sizes of farms (SHs, MSDs, LSFs). Various farms were selected across Kenya from Eastern region (Meru: 10) Central region (Nyeri, Muranga: 2) and North Rift region (3). As for brachiaria the following were the selected varieties: 3 hybrids (Mulato II, Cayman and Cobra) and 4 cultivars (Xaraes, Piata, Basilisk and MG4).

In the North Rift the pilots involved 3 MSFs with demo plots of 0.5 acre to test suitability not only for cut & carry, but also for grazing and mowing (mechanised harvesting). These plots will be up scaled in March 2019 at 2 farms each doing 5 acres. The farmers were guided by KMDP – notably Fredrick Muthomi in Meru and Solomon Misoi in Eldoret - on how to prepare the seed beds, how to plant, how to weed and fertilize and even on gapping and sample collection procedures. CIAT monitors the demonstration plots and also takes samples at different growth stages for testing of the nutritive values.

In the first year it has not been possible to test the different varieties for their suitability of silage making. However KMDP and CIAT recommend that this will be done in the next growing season as the practice is successfully applied outside Kenya. This may in the future become a potential forage to commercialise for baling as a wilted grass silage. Brachiaria, if well-managed, is a balanced fodder in terms of energy and crude protein, and therefore a forage with a high nutritional value for dairy cows.

11. Consultant's observations and recommendations

a. Observations

The consultant has been involved in the Kenya Market-led Dairy Programme since December 2013, through PUM Netherlands Senior Expert Programme (see Chapter 12). In this capacity he carried out 16 missions with a focus on forage production, preservation and feeding and visited numerous farms across Kenya, including in the North Rift. The consultant's involvement was as part of a team of three PUM experts, all being involved in the whole chain from seed to feed, including conservation agriculture and pasture management. Together the three experts carried out over 40 missions and exchanged information continuously.

The consultant also contributed to a feasibility study carried out by him and Gjalt de Haan of De Haan Loonbedrijf/The Friesian in August 2014, entitled: "Quick scan of the business opportunities for a commercial fodder production and supply center in Kenya (and Uganda)".

One of the conclusions of this study was that:
"In a maturing dairy sector, the professional production, supply and use of fodder (and feed) is key and this requires specialized knowledge and service providers with adequate machinery and management skills. There is need for the development of a strong commercially driven "service infrastructure" for the dairy value chain. In particular this should be directed towards supporting the establishment and management of best practice mechanised fodder production, preservation, and – in case of commercial fodder supply chains – marketing, logistics and distribution".

Another conclusion was that maize silage that can be found on dairy farms in Kenya was in most cases of very poor quality, and this confirmed the observations by KMDP staff and PUM experts. Most silage pits were in a state of decay, silage not well chopped, kernels not crushed or silage too wet (DM well below 30%), poorly compacted, poorly covered, moulding, and with big losses in the pit and during feeding (selection by the cow).

Considering this situation as encountered by the expert at the start of his engagement in KMDP, and confirmed by de Haan (15 August 2014), the following observations can be made of the current state of affairs and the changes over the past 4-5 years:

1. Maize silage has been adopted in North Rift as a main component in the total ration for dairy cows by commercial dairy farmers.
2. KMDP successfully initiated, promoted and supported the concepts of Maize Train and baling of maize silages, through its Innovation Fund, with technical support, by initiating and facilitating feasibility and market studies, and by providing linkages to the market.
3. The silage pits/bunkers inspected during the field visit (1-9 February 2019) on 4 farms (3 served by Nundoroto and 1 by AG Harvesting) were impressive as regards shape, size, compaction and covering of the pit. For those pits that were open for feed-out, there was a good feeding speed of over 1.50 meter per week. We observed good quality silage with regard to conservation and storage without any heating or moulding.
4. In another farm visited we inspected a silage bunker that was done by another contractor. The pit was open for feeding-out and showed (too) high DM content combined with a low feeding speed. There was some heating and mould in the top layer of the pit.
5. Inspections done in the period October-December 2018 by Solomon Misoi (KMDP), Halbe Klijnstra (PUM) and Jos Creemers (ProDairy EA Ltd) at other clients of Nundoroto and AG Harvesting, confirmed generally the good quality of work and silage (based on organoleptic assessment and milk production). Some incidents occurred where the silage was of lesser quality, for example where the maize was harvested too early and/or the contractor agreed

with the farm manager that the latter would cover the silage pit which was delayed by 2 weeks, obviously leading to big losses and heating up of the silage (an indication of decay).

6. Samples taken in November 2018 of over 50 silage bunkers in North Rift supported these observations, however it also showed a rather wide variation in quality of silages made through the Maize Train concept. It is assumed that where the quality was lower than expected, this was due to not following good practice in all the steps of the maize train, i.e. harvesting time (low DM), cutting height, speed of work (capacity), compaction and coverage of the pit.
7. The pH levels in some of the silage pits were high (5.2) whilst the target is a pH below 4.2. This indicates that the pH during ensiling is not decreasing fast enough. This can be an indication that compaction and coverage (airtight seal) of the pit were not fast enough. A sample of freshly bailed maize silage also had a higher pH level, which in this case could point at a shortage of soluble sugars needed for the fermentation process. Adding additives like lactic acid bacteria or lacto bacillus plantarum could improve this.
8. Nundoroto Farm Company Ltd and AG Harvesting – both financially and technically supported by KMDP – are the leading agricultural contractors in North Rift in terms of equipment, trained staff, knowledge and skills and (generally) good practices, client base and market linkages. Others like Simam Farm and Tarus follow suit. The initiative and response from the market has also resulted in smaller contractors and dairy cooperatives buying 1-2 row harvesters serving smaller farmers and cooperative members.
9. The demand for the services of these professional contractors has grown fast. The business case of the Maize Train is a proven concept and enables farmers year round access to high quality maize silages grown on farm and ensiled on farm. It is a cost effective manner to assure ME for the cow and increases milk production, reduces cost of feeding and cost price of raw milk. In a well-balanced diet or ration it increases margin over feed costs significantly.
10. The challenge for Nundoroto and AG Harvesting is to maintain in all cases - and where necessary to enhance - the level of services provided and the good agricultural practices that are part of it. This implies taking responsibility for the entire process of silage making, including compaction and covering the pit or bunker. Offering a one-stop solution should not be aborted at the point of covering and closing the silage pit. Assisting with diet formulation could be a logical next step to get maximum value out of the maize silage and to maintain contact with the clients.
11. Crowding-in is a sign of upscaling through replication and positive market response. But it goes with a risk as not all contractors may understand how and why - or are unwilling - to apply the good practices. Often the farmer is not knowledgeable of “how” the work should be done and “why”.
12. There is need to raise the awareness and sensitize farmers (i.e. the clients of Nundoroto, AG Harvesting, FIT and their peers) on the needs and benefits of good agricultural practices. Not only the “what and how”, but especially also on the “why”.
13. Crucial is good communication between the contractor and the farm owner/manager. This starts with planning for maize production and ends with planning for harvesting and ensiling, and includes all other steps in the chain or train from planting to feeding. It needs a high level of management from the contractor and excellent communication skills.
14. Part of planning and coordination is strategic management on farm level for crop- and seed selection, selection and preparation of fields to grow the maize, how many acres as per the herd size requirements and the feeding regime, all these are important elements of planning.
15. In general, farmers (clients) are very positive about the quality of the silage made by contractors under the maize train program. Farmers commented that communication and planning can be improved to have the work done at the right stage of harvesting. Mechanical breakdowns are mentioned as a major challenge to adhere to earlier agreed planning.

16. FIT Ltd introduced as a first mover professional baling of maize silage, supported by KMDP. In the Kenyan market with relatively high raw milk prices and demand for milk, large numbers of commercializing smallholders, relatively high genetic base of the dairy cows, lack of quality forages and seasonality, this concept could become a game changer. Provided of course that the price per bale or kg DM in the bale is competitive for the farmer.
17. FIT Ltd has started of the pilot project well and has produced over 12,500 bales in the first one year of which 50% in the last 3 months. Over 6,000 bales have been sold and turn-around time (time in stock) is less than 2 months. Break-even point is at 10,000 bales per year.
18. Currently and largely due to price, the bales are finding a way into the market, especially where farmers who use maize silage in their ration have a seasonal shortage and need to bridge to the next harvest/silage bunker. This market is considerable in Kenya but not reliable or year round, and also may not be sufficient basis for upscaling.
19. The cost price of baled silage can be reduced by introducing economies of scale and improved practices of maize production leading to higher tonnage per acre, and more efficient logistics with direct delivery from the location where maize is grown and baled, to the farmer.
20. Another opportunity to reduce costs for the farmer, is by increasing yield and DM content (this lowers transport costs) and nutritive value. To optimize the latter further and next to strictly following good practice by the contractors, registration and availability of forage maize varieties suitable for the Kenyan conditions is required. Literature shows that maize grown for the grains only (commercial maize) is not ideal for converting into forage/silage from a point of (reduced) nutritional value and digestibility. This is confirmed by samples taken of silage in North Rift that were analysed in the Netherlands (see table 2 above).
21. The business case for silages is currently mainly in maize silage, but grass silage and sorghum silage are also thinkable solutions and business opportunities, both baled and on the farm in silage pits.

b. Overall conclusions on required skills and capacities of agricultural contractors

1. Knowledge and awareness of the importance of quality feed for dairy cows. Among farmers and fodder producers there is not enough knowledge and awareness what quality really means for their business. On many farms even when the silage is visibly moulded and heated, farmers still judge this silage good enough for feeding. To deliver and demand high quality fodder must be top priority for fodder producers and dairy farmers respectively.

2. Management skills to organize the process. The need for high machine capacity at the right stage of harvesting under changing weather conditions, makes silage contracting a difficult business to manage. This is compounded by the fact that the window for harvesting is only 4 months. Planning and operational management of the process needs good communication between contractor, his staff and his clients. Not only at harvesting time. Good planning starts at planting with seed selection, field selection and land preparation and planting.

3. Operational skills to execute the process. The quality of silage making mainly depends on the quality of the execution of all the different steps in the process or chain from seed to feed. Qualified machine operators and mechanics are crucial to keep the train on track.

4. Machine capacity in the operation. The right stage of harvesting of the maize crop is crucial and the time frame very short. Dough ripe stage is best for silage making as it provides the optimum combination of metabolizable energy (ME), high yield (ton of DM/acre) and the best circumstances for preservation. A high machine capacity combined with clear standard operational procedures (SOPs) for the implementation of the work is necessary to deliver high quality work in time.

c. Overall conclusions on technical feasibility, economic and environmental impact

1. The experience in North Rift since 2015 with the “maize train” has shown that the concept of silage making (maize, sorghum and grass) is viable in Kenya on-farm, as well as in bales for trading purposes. Contractors and commercial forage producers successfully turned around the existing practices of silage making, where use is made of forage harvesters with a capacity too small for the acreage and herd size, harvested too early (wet) and with too long chopping length, no kernel crushers and too long interval between start of the silage pit and final sealing of the pit (2-14 days instead of < 12 hours). These existing practices result in enormous respiration losses during ensiling and feed-out. Added to this is the risk of poor anaerobic fermentation because the pH does not drop fast enough giving yeast, moulds and rotting bacteria chances to spoil the silage. The end result being that DM intake will be lower and feed losses higher. A good maize crop will only then be good quality forage, if the fermentation process was successful with an absolute minimum in DM and nutritive losses.

2. The Maize Train concept and baling of maize silage have shown that this is possible and goes with huge benefits for the farmer. To reduce variation in quality (DM, MJ ME/kg DM and NDF in the DM), at this stage it is crucial that the early movers Nundoroto, AG Harvesting, Simam and Tarus, maintain their quality of work and don’t compromise on the guidelines for high quality forage production and ensiling. For those who are crowding-in, they have to make sure that they reach at this level first, even before they can maintain it.

3. Ultimately only sampling every silage pit and silage bales can tell failure and success of ensiling, but with this SNV/KMDP targets have been met and it is very well possible to aim for maize silage pits and bales with an ME density > 10.5 MJME/kg DM and NDF < 400 g/kg DM). Eventually, trading in fodder and price setting on the basis of nutritive value will be the best system that is fair to producers and buyers of the fodder.

4. Capacity and technology have been crucial to show that it is essential to influence and control the fermentation process in the ensiled crop successfully. Improving the process and logistics of silage making with the assistance of commercial forage producers who invested heavily in technology and capacity able to bring silage making to scale, has improved the quality of maize silage available for the cow enormously.
The combination of harvesting close to the ideal DM content, intense compacting and sealing the silage pit within 12 hours, next to the use of forage harvesters equipped with sharp knives and kernel crushers, are the major reasons that the fermentation process starts-off immediately and respiration losses are kept to an absolute minimum. Silage that is well fermented and compacted, will also show less respiration (aerobic) losses and no losses to molds during feed-out. Provided that the feeding speed is at least 1.5 m per week.

5. For farmers who have enough land to grow forage maize, harvest the maize and turn it into a good quality silage pit, this is the cheapest way to provide dairy cows with an energy rich forage - year round - at a price between 0.9-1.7 for 1 MJ ME. Good quality maize silage is the best and economically most attractive alternative for hay in the total ration. It can as well reduce the amount of dairy meal in the ration, provided the ration with maize silage is properly balanced for protein, amongst others. Maize silage being a forage rich in energy will boost milk production and therefore reduce the cost price per kg milk.

6. To further reduce the cost of 1 MJ ME it is essential to increase maize production per acre through improved soil and crop management. But also availability and use of maize varieties specifically bred for forage. These forage maize varieties should target higher nutritional value of maize in the silage pit (higher ME, lower NDF and higher starch content per kg DM). This combined will be a major step in reducing the cost price of maize silage.

7. Further improving the three steps, crop production, harvesting & ensiling and baling, in terms of efficiency and technical and management performance level will further reduce the ensiling- and baling costs per kg DM.

8. Based on the calculations presented in Chapter 8.b with the improved silage quality, we can conclude that the Maize Train has resulted in great benefits for the farmers, who made use of the services provided. The maize silage samples (53) showed an average ME density of 9.1 MJ/kg DM. Poorly made maize silage as it was found at the start of KMDP has estimated density levels at or below 6.0 MJ ME/kg DM.

9. This improvement results in a potential extra income of KES 20,113 (KES 60,340 – 40,227) to KES 33,523 (KES 100,567-67,044) per acre of maize in milk income depending on the DM Yield per acre (3 tonnes or 5 tonnes per acre respectively). This means for 2,500 acres done in 2018, a total potential extra income for all the farmers served of between KES 50.3 million (US $ 503,000) and 83.8 million (US $ 838,000). At a sales price of KES 35/kg of milk the total potential of extra milk produced is 1.4 million kg and 2.4 million kg respectively.

10. Improving forage quality to increase milk production will contribute to reduced carbon foot-print per litre of milk because milk yield increases. The environmental impact of dairy farming has many contributing factors and the enteric emission of methane from cows is a major concern and contributor. Forage with higher ME and optimum NDF is boosting milk yield and consequently lowers the intensity of methane emission (i.e. methane/liter milk). Feeding high quality maize silage, therefore is an excellent means of lowering methane and CFP emission intensities.

11. To raise margin above feed costs it is crucial to feed balanced rations, which can be achieved by use of Rumen8 that was introduced and Kenyanised with support of KMDP. This allows the dairy cow to increase DM intake and thus increase milk production and productivity with further reduction of methane emissions per liter of milk produced.
    Next to this, farmers need to be more critical on the high number of non-producing animals on the farm – both from an economic and environmental perspective. It is important that heifers calve down at an early age (24-27 months), high fertility of the animals are maintained, and good record keeping and reproduction management are applied. This helps to further reduce GHG per litre of milk produced.

12. Improved soil management practices through conservation agriculture, soil analysis and optimum fertilization advice (including liming of soils with low pH and manure manage-ment), give higher yields per acre of land, the net effect of which is reduced GHG emission per ton of maize.

d. Recommendations

<u>Farm and contractors' level</u>

1. Increasing crop production per acre with regard to DM and energy is the shortest route to lower the cost price for silage making, next to harvesting at the most ideal DM content of 30-35%
2. Focus on quality in the execution of all steps in the silage making process is the shortest route to reduce the losses.
3. Stock planning for feed and forage on farm level needs high priority.
4. Be aware of the economic and financial value of the silage in stock.
5. Take samples and analyze the nutrient value of your silage.
6. Take samples and analyze the nutrient condition of your fields and follow fertilization advice.
7. Communicate and make an agreement with the farmer placing the contractor in the lead of managing the silage making process.

8. For the contractor, the airtight covering of the pit/bunker with a strong plastic sheet and at least 6 inches of soil on top, is part of the job of silage making and his responsibility.
9. Make transparent/clear agreements (on paper) about price and planning.
10. For commercial forage suppliers apply a system of quality control and assurance (QC/QA) on the content of the bales. Be transparent with regard to weight, DM % and nutrients and put this information on the bale.
11. Commercial fodder producers should work out strategies to reduce the cost of baled maize silages, the shortest way being economies of scale in maize production and higher tonnage per acre, more efficient logistics.
12. Contractors and commercial fodder producers are encouraged to pilot other crops to ensile like grasses (incl. Brachiaria), to balance a maize-silage based ration for protein.
13. Engage with dairy advisors to assist with on-farm ration formulation software (Rumen8) to optimize the ration for nutrients and cost price purposes.

Sector level:

14. International and local seed companies must be sensitized and facilitated to bring in new and suitable forage varieties such as forage maize, forage sorghum, lucerne, and grasses including Brachiaria and Panicum - appropriate for Kenya's different agro-ecological zones. Focus not only on DM yield/ha, but also on quality (high in ME and CP, low in NDF).
15. To rely entirely on local research will not be adequate to address the needs of the market. Bringing in high-yielding certified forage seed varieties that are suitable for Kenyan conditions, is the only way to fast-track availability of such forages. Local research can be carried out parallel and in partnership with international seed companies and plant breeders.
16. Improve access to finance for contractors, commercial forage producers and farmers to acquire appropriate farm machineries.
17. Provide practical skills based training and University curriculum to improve skills and knowledge on forage production and forage crop management and dairy cow nutrition.
18. Provide training for machine operators and mechanics.
19. Focus on developing awareness, demand and information on quality based rather than volume based feed and forage markets.
20. Enforce labelling of feeds and forages - or otherwise providing information - indicating weight, DM content and nutritive value of products sold in the market.
21. Develop and maintain a Kenyan or East African Feed Library with nutritive values for feeds and forages grown on the farm or being sold in the market, based on actual sampling and testing of forages.
22. Facilitate and invest in professional and accredited feed laboratories based on calibrated NIR with regression lines for tropical forages. This will give farmers, feed manufacturers and commercial forage producers reliable results of feed samples.
23. Make better use of available information on agro-ecological zones and weather data in relation to forage crop selection and production planning.



12. PUM Netherlands Senior Experts Programme

The PUM Netherlands Senior Expert Programme (PUM) has been very instrumental - if not crucial - in propelling KMDP's forage interventions. PUM is an organisation financed by the Minister for Development Cooperation of the Netherlands, that makes available retired experts for advisory in developing country (see: https://www.pum.nl/).

The partnership between SNV and PUM (Netherlands Senior Experts) started with an Inception Mission by Mr Johan Koeslag in September 2013. This mission laid the foundation of a very fruitful and intense collaboration between KMDP and PUM throughout KMDP-I and II. A Memorandum of Understanding was developed and signed including annual strategic and operational workplans. Subsequent missions of PUM experts for technical advice, were of major importance to support the KMDP interventions in the Feed & Forage agenda. PUM experts also played an important role in linking KMDP and its clients to the private sector in the Netherlands.

In KMDP-I a total number of 32 PUM Missions took place by three experts. The first mission was in November 2013. In KMDP-II up to March 2019 20 PUM missions took place by again three experts (of which 2 were new experts). The PUM experts supported not only KMDP activities in North Rift but also in other parts of Kenya (Central and Meru). For an overview of all PUM mission in KMDP-I and II reference is made to annex 5.

These (2-weeks) missions were executed by PUM experts to train and support KMDP clients and LCBs on forage crop management (CM), soil preparation (SP), Total Farm Management (TFM), Cow Signals (CS), ration formulation (RF), calf rearing (CR), record keeping (RC), fertility (F), breeding (B), animal health (AH), housing and cow comfort (CHC) and forage production (FP) and silage making (SM).

Training and knowledge transfer by PUM experts has raised awareness of farmers, consultants and forage producers to a critical level, where Kenyan farmers/investors see the value of purchasing and paying on commercial terms machinery, technology, inputs and services, and management advice by Dutch input and service providers.

As for the KMDP forage interventions in North Rift, PUM experts played an import role in facilitating the business models or cases of Maize Train and baled silages. They offered important technical advice to the investors, linked them to suppliers in the Netherlands and also coached Dutch interns that were part of KMDP North Rift Team to support the forage agenda and the investors. This was done together with Mr Wytze Heida of The Friesian Agro Consulting from the Netherlands, who was hired by KMDP in 2015/16 and based in Eldoret to support the KMDP Team in North Rift.

The recommendations made in the 'Status Report Medium scale Farmers and Commercial Forage Producers Agenda (2016 and beyond)", were to bring more focus to the programme, to deepen the support as regards demonstrating good practice and farm economics, and to invest even more in developing a sustainable local delivery mechanism. This was operationalised by the Rumen8 pilot that brought many interventions together and now forms the linking-pin between advisory on good practices forage production, feeding, and farm economics and recording.

Jaap de Vrij (KMDP-I) focused strongly on soil preparation and conservation agriculture, with much attention to ploughing, machine calibration and operation, and crop management, including weed control and fertilisation. Jaap was working in all regions supported by KMDP.

Halbe Klijnstra (KMDP-I & II) was working in the North Rift on total farm management, including feed management, calf rearing, record keeping, maize silage and grassland/pasture management.

Halbe also gave much advice to Dejirene Ltd (Eric de Jong) and was instrumental in shaping De Jong's ideas around agricultural contracting and baling.

The missions of Tseard van de Kooi (KMDP-II) were all in Meru County. His training focused on total farm management, feeding, calf rearing and fertility/genetics. Tseard was also involved as an adviser in the development of the Meru Union Breeding Strategy and he played an important role in facilitating linkages between Meru Union and CRV. With Frans Ettema, he also much facilitated a trade mission of Meru Union to the Netherlands and an exchange visit of the Kenya Dairy Board. Tseard also supported the introduction and piloting of brachiaria varieties in Meru.

Frans Ettema (KMDP-I & II) supported Perfometer Agri Business Consultants and KMDP to implement the KMDP project in Central Kenya. Focus was on developing Perfometer's capacity in dairy advisory in total farm management. He developed with Perfometer the Dairy Farm Benchmarking tool and training courses for Farm Managers. Frans was also instrumental in supporting more strategic issues in KMDP – both for KMDP clients (Eldoret Dairy Farmers Association - EDFA) and KMDP management. He was co-author of the feasibility study for a Commercial Forage Production and Service Centre, and he prepared or contributed to several other reports of KMDP.

Since 2018 Hink Perdok joined the KMDP project being an expert on dairy nutrition and ration formulation. He introduced Rumen8 (R8) to the KMDP team in Kenya and is the linking-pin between the Rumen8 Team and the software developers in Australia. He also networks for KMDP/Rumen8 in Kenya (CIAT, ILRI, Department of Livestock, and KALRO) and in the Netherlands with several parties, amongst others to facilitate B2B linkages in feed testing and collaboration with WUR Livestock Research. Hink was also instrumental in obtaining a €16,000 grant from Victam Foundation in The Netherlands that was used to co-fund with SNV adaptation of the Rumen8 software for use in the tropics.

All trainings, farm visits, demonstrations and field days by PUM experts have a dual purpose. Focus was not just on farmers but also, and sometimes even more, on dairy service infrastructure, capacity building local consultants/extension workers and organisations (cooperatives, processors, input suppliers and service providers). Development of diagnostic tools, training and instructional materials, SOPs, power point presentations and other reference documents were also part of PUM experts' deliverables. PUM experts usually offered a help-desk function between missions and maintained continuous contact and communication with the teams they supported in Kenya.

In addition, all experts were involved in networking in the Netherlands for B2B opportunities with stakeholders in Kenya. They participated in a number of farmer exchange visits/study tours of Kenyan farmers to the Netherlands. In Kenya Frans Ettema represented PUM at several Dairy Trade Fairs and Exhibitions such as the prestigious ESADA/AfDA Dairy Exhibition and the Eldoret Agri Business Fair.

The PUM experts also facilitated 4 PUM Business Links (BL) in 2014, 2015, 2016 and 2018, where KMDP dairy consultants were given the opportunity for one week induction, training and networking in the Netherlands dairy sector. The programme for the Business Links was to link the participants to Dutch business companies and to have practical training on farm management in the context of the KMDP project. The latter was realized by placing 1-2 Kenyan dairy consultants two days in a Dutch dairy farm to experience the daily operations on the farm.
A Farmers Exchange Programme was executed in 2017 for a group of Kenyan dairy farmers. The main objective for this farmers exchange programme was - next to training - to be connected to a Dutch dairy farm family and learn about farm planning, feeding, cow housing, cow comfort and operational farm data.

Annexes

Annex 1. Terms of Reference (November 2018)

SNV Kenya/KMDP and PUM have collaborated for over 5 years in the forage and feed agenda, and several private sector initiatives developed as a result in agricultural contracting and baling of maize silages. Not only Nundoroto, AG Harvesting and FIT (all three supported through the KMDP Innovation Fund), but also we see replication by other investors.

In addition in North Rift advisory work started with introduction of the Rumen8 ration formulation tool. After a slow start, uptake of advice and implementation has been encouraging over the past few months in a number of farms in North Rift and this also seems to be linked much to availability of quality maize silage at these farms that were receiving the services from Nundoroto Farm Company (NFC) and AG Harvesting (AGH). We wish to document the impact of these interventions and their interrelations.

The SNV Team in Eldoret with support from Mr Jos Creemers ProDairy Ltd collected data for the purpose of such documentation which includes amongst others:

a) Inventory of clients, acreage, tonnage of maize harvested and ensiled by NFC and AGH
   Same for FIT in terms of maize silage bales
b) Compliance to good agricultural practices (GAP) and inventory of bottlenecks for NFC, AGH and FIT (e.g. quality issues)
c) Replication/crowding in of other investors in agric. contracting and commercial forage production
   Sampling of maize silages on nutritive values
d). Pilot Rumen8 on 5 farms in North Rift/Nakuru area

This information or raw data needs to be analysed, consolidated and documented in a report with observations and recommendations for enhanced efficient operations of above mentioned companies, improved quality and good agricultural practices, and impact measurement (response from the market and effect on economic performance of farms served).

In addition, farms visits will be planned during the field visits of the expert, for him to assess quality of silages, impact on milk production and interview the farm owner/manager. Meetings will be held with key staff of SNV, ProDairy EA Ltd, BDEA Ltd, FIT, NFC, AGH and other investors in agricultural contracting and baling.

The report could have the following structure, but this is only a proposal and will be fine-tuned before the mission:

Chapter 1.) Common practices currently used from seed to feed by farmers and contractors
Chapter 2.) Challenges and bottlenecks for farmers and contractors
Chapter 3.) Sample of Maize Silage
Chapter 4.) Recommended Practices (Do's and Don'ts)
Chapter 5.) Way forward

The report will be a joint collaboration and effort of Frans with the Team in Eldoret, with support from Jos Creemers and inputs from Dr Hink Perdok.

It includes a learning component, not only because of the messages in the report itself, but also in terms of data analysis, translation of findings to practical action and presentation of findings.

The report furthermore will highlight the contribution of PUM missions and experts as regards the achievements of KMDP and local partners and LCBs in this important forage agenda.

Annex 2. Schedule of Field Work in Kenya (1-9 February 2019)

Day	Mission Activity	Remarks
1 February	Arrival at Nairobi Travel to Eldoret	Briefing with Anton Jansen and Jos Creemers Brief talk with Martin Korir
2 February	Kick off meeting at Kenmosa Visit to Ag Harvesting Talk with Dirk Harting	KMDP team (Mr. Joseph Langat, Kosgei, Solomon Misoi and Tijs van Balen) Talk with Eric de Jong, CEO Ag Harvest Managing Director Bles Dairies EA
3 February	No programme	Informal visit and talk with Dirk Harting
4 February	Preparation field day (Wed 06/02) Visit to Illulla farm	KMDP team Client of Ag Harvesting for silage making Pilot farm for Rumen8
5 February	Visit to Sprout Farm Visit to Small Farm Visit to Lesmat Farm	Client of Nundoroto for silage making Client of Nundoroto for silage making Client of Nundoroto for silage making *All 3 farms are pilot farms for R8*
6 February	Visit and participation in the field day programme at Nundoroto Farm	KMDP team. Talk with the Humphrey Lilande, MD of Nundoroto Contacting Business. Hans Thijssen, partner in AG Harvesting Johan Fieten, partner in FIT. Several farmers from North Rift and Meru
7 February:	Visit to North Rift Dairy Farm (Tarus Farm. Visit to Simam Farm. Visit the bailing activity by FIT on Too farm site	Client of Agri Harvesting for silage making. Talk to Simam about among others, plans for 2019 and options for grass silage Talk with Daniel Too
8 February	Visit to Chuma Farm. Visit to Leketeton farm Debriefing at Kenmosa Travel to Nairobi	Together with Jos Creemers, Kosgei and Misoi KMDP team, (Joseph Langat, Solomon Misoi, Kosgei, Tijs v Balen) and Jos Creemers
9 February	Debriefing Travel to Amsterdam	Anton Jansen

Annex 3. Guidelines for Forage Maize Production and Ensiling

KMDP with input from the partnering contractors developed a booklet and a poster containing Guidelines for Forage Maize Production and Ensiling. These Guidelines are copied below and can be downloaded from: https://www.cowsoko.com/programs/kmdp/publications Report nr 35
The Guidelines were presented at a Field Day in Eldoret on 6 February 2019. For the videos see:
https://youtu.be/12U7bkc1qrM
https://www.youtube.com/watch?v=ytgsuMtqhTQ#action=share

1. PREPARATION / PLANNING		
What	*How*	*Why*
a. Maize silage	To plan and prepare more acreage for maize silage not only to overcome seasonality in milk production, but more to be a constant component in animal nutrition.	Maize silage provides low cost metabolizable energy (ME) for dairy cows and is a key ingredient in the cow's daily feed ration. If prepared in enough quantity, it also helps the farmer to counter seasonality in milk production. Whether maize silage is cost effective depends on quality, cost of production (and price in the market if bought externally), vis-a-vis other available feed and forages in the market.
b. Target high quality forage	Invest in land preparation, focus on right stage of harvesting and for high capacity make use of contractors.	To make better use of the (genetic) potential of the dairy cow and enhance milk production. To reduce the cost per unit of ME fed to the cows and per litre of milk produced. To make feed management more flexible
c. Minimize cost of production	Focussing on higher yield per acre reduces cost of production per kg of DM.	To seek to maximize efficiency and quality in each step of the silage making process (from seed to feed). Consider costs of hiring specialized contractors versus buying and operating own farm machinery. Is it more lucrative to outsource?
d. Feed planning	Use of a feed planning tool	To balance feed requirements based on number of cows and expected milk production with acreage under forage production and/or purchased forages.
2. LAND CULTIVATION		
What	*How*	*Why*
a. Field selection	Select suitable fields for forage production	To make field characteristics: a) soil type, b) soil fertility, c) accessibility, d) suitability for mechanization.
b. Ploughing	Plough with a mould board plough or a fixed chisel tine cultivator with levelling harrow attached. Avoid disc ploughs!!	Completely turns the soil, breaks hard pan, increases soil aeration, reduces soil erosion, levels the field.
c. Seed bed preparation	Cultivate to a fine tilth and level by cross cultivating.	To encourage uniform growth of plants, maximum exposure to sun, increase germination rates, easy machine operations, etc.
3. SEED SELECTION		
What	*How*	*Why*
a. Seed variety	Select forage maize variety or hybrid suitable for forage production i.e. with low NDF, stay green, cob stem ratio of 50:50 (on DM basis) and high in starch, and gradually maturing.	Good variety means good quality feeds (high energy/kg dry matter and high digestibility/kg organic matter), optimum crop yields, suitable varieties that can stay green even after ripening. Because there are no forage maize varieties available in Kenya (only for grain) we have to look for those available varieties with characteristics that come closest to forage maize (see "How")
b. Seed size	The size of the seed should suit the planter to be used.	This will ensure that the machine drops the correct number of seeds, resulting in the desired plant population per acre or hectare
4. PLANTING		
What	*How*	*Why*
a. State of implement	Check the settings of the planter. Fertilizer placement should be 5 cm beside and below the seed. There should be no blockage.	To prevent scorching of the seeds, to ensure seeds are able to drop through the perforated plate, to ensure the correct seed rate is obtained.
b. Seed rates	Determine the correct seed rate to get the desired plant population.	To avoid plant competition and ensure maximum yield per acre or hectare.
c. Fertilization	Analyse the soil: supplement the required amounts of nutrients at planting and top dressing as per the soil analysis.	To ensure that the amount of fertilizer supplied meets the deficit and to avoid waste of fertilizer and money in case of oversupply.

5. CROP PROTECTION		
What	How	Why
a. Weed control	Use appropriate herbicide in the recom-mended concentration; apply correctly and under right conditions	To maximum yields, to avoid silage contamination by weeds, and to make harvesting of the crop by machine easier.
b. Pest control	Use appropriate pesticide in the recommended concentration. Apply correctly and under the right conditions.	To avoid losses through pest attack. To maximize production per acre.

6. HARVESTING		
What	How	Why
a. Stage of harvesting	Aim at a DM level of the whole crop of 30-35% and a starch level of at least 30%. The most accurate method of deciding when to harvest is to deter-mine the dry matter on samples of the whole maize plant. DM can be deter-mined with a probe, by NIRS or in an oven. The kernel should be at dough ripe stage.	If machines with a well-functioning kernel crusher are available it is advised to ensile at a high DM content of 32-35% to maximize starch and ME levels. The energy in maize silage mainly comes from the starch in the cob and the energy level of the total crop increases as the plant matures. This happens in spite of an increase in the NDF content of the stem and a consequently lower energy content of the stem. Longer stubble length improves digestibility and energy content, as the stubble is high in NDF.
b. Machine to be used (kernel crushers) and servicing	The machine should have a kernel crusher. The machine needs proper preventive maintenance and servicing during harvesting (e.g. calibration and sharpening of knives).	The kernel crusher allows for harvesting at a higher DM and starch content (dough ripe stage) and silage with higher energy content per kg DM. Chaff cutters usually do not have a kernel crusher which forces the user to harvest at milk ripe stage. At this stage the total crop has not reached its maximum energy (i.e. starch) content, as sugars in the kernels have not yet converted into starch, the DM of the silage is too low, and nutrients will be lost through effluent wastage.
c. Additives	Adding inoculants based on lactic acid bacteria.	Even if good silage preservation is expected certain inoculants can improve silage quality reduce losses and raises animal production. Additives will never compensate poor crop production or silage management!
d. Location of silo or trench	Determine how far the clamp/pit is from the barn, how well-drained the location is, how safe from any other traffic and from birds, rodents and wild animals.	The clamp/pit should be on a dry well-drained area to avoid dampness, rainwater stagnation and animals from entering the pit. When the crop has been harvested too early, there should be space for the effluent to drain-off.
e. Weather	Check the weather if appropriate for machines to enter the field and right for harvesting.	Monitor weather pattern and forecast so as to bring machines at best conditions. This will avoid machines to get stuck and delays in the process, and contamination of silage with mud. It maintains silage quality.

7. CHOPPING AND KERNEL CRUSHING		
What	How	Why
a. Chopping length	The machine used should be able to chop the crop into pieces of 8-12 mm.	This will reduce losses, enables easier compaction, increases voluntary feed intake per cow and avoids selective feeding.
b. Kernel crushing	The machine used should be able to crush the grains into at least 3 parts each.	This will ensure that the starch in the grains is faster available for bacteria that produce acids, thus preserving the silage. Moreover, the cows will better digest crushed kernels and whole grains will not be seen in the dung.

8. TRANSPORTATION		
What	How	Why
a. Distance of field to pit	The distance should be as short as possible.	Unless more trucks or trailers are used, the shorter the distance, the faster the filling of the pit and the better the quality of the silage. A pit/clamp should always be filled, compacted and closed within 12 hours.
b. Truck or tractor	Should be selected depending on distance, access and state of roads.	The machine used should transport fast and efficiently to shorten time between chopping, compaction and covering. Plan in a way that the trench can be closed within 12 hours after filling starts.
c. Accessibility and field conditions	The field and farm should be accessible to the forage harvester but also to trailers and trucks when loaded.	The farm should have good accesses roads, the maize fields should be accessible to the machines. Large (e.g. 6 rows) self-propelled maize choppers need more space than smaller machines. The fields should be level and free from stones, tree stumps and other obstacles that can cause damage to the harvesters and the loaders.

9. COMPACTION		
What	How	Why
a. Machine / equipment	The silage should be compacted using the heaviest machine available: a tractor or a shovel.	This is to remove as much oxygen as possible from the pit to create the necessary (anaerobic) conditions for conserving the chopped maize. Good compaction is necessary to prevent the silage from heating during the ensiling process and feeding out.
b. Pit dimensions	The dimensions should be designed to give appropriate feeding speed of 1.5 to 2 meters per week. Narrow and long is better than short and wide. Ensure sufficient height of the trench.	The dimensions should tally with the number of cows to ensure good feeding speed of 1.5 to 2 meters a week and hence to minimize losses by heating and moulds.
c. Shaping of the pit	The sides should be as upright as possible. Avoid flat “chapati shaped” edges.	The sides should be slightly less than 45 degrees to minimize the surface area exposed to air/oxygen and to ensure firm edges.
d. Layering and spreading	Spread and compact each layer the moment it is tipped, i.e. keep a shovel or tractor on the pit during the ensiling process.	Each layer should be compacted to obtain properly and homogeneously compacted silage. Continuous compaction will eliminate air more effectively.
10. COVERING		
What	How	Why
a. Sealing	Seal silage pits or clamps immediately when that particular pit has been filled.	Ideally within 12 hours from the start of making the pit/clamp.
b. Choice of plastic	The polythene should be preferably one continuous sheet, without any holes, of good gauge (>500) specially produced for silage making. Many farmers use a second, heavier gauge sheet to protect the vulnerable polyethylene sheet.	The airtight plastic prevents oxygen from entering the pit. The one sheet plastic is best because there are no uncovered edges that can allow penetration of air into the silo. The economic value of well-preserved silage is high, and it can be cost-effective to invest in a heavy-duty outer sheet.
c. Covering	Dig a trench around the pit, place plastic, tighten the plastic with soil around the pit, and gently place soil up to 15 cm (6 inches) thick on the top and sides of the pit. Do not puncture the polythene; repair holes before covering with soil.	Soil or sand bags keep the polythene sheet tighter to the silage and continue exerting pressure on the silage pit. Tires are not preferred as they do not keep out the heat and sometimes wires stick out of old tires that can damage the polyethylene sheet.
d. Fencing	Fence-off the area to keep away animals from walking on the pit.	If cows are moved or grazed and there is access to the silage pit/ clamp, they can walk on the silage bunker and the hooves can make holes in the plastic. Fencing keeps the livestock away.
e. Inspection	Fence-off the area to keep away animals from walking on the pit.	If cows are moved or grazed and there is access to the silage pit/ clamp, they can walk on the silage bunker and the hooves can make holes in the plastic. Fencing keeps the livestock away.
e. Inspection	Weekly walk around the silage pit/ clamp/bales.	Inspect the silage pit/clamp/bales at least once a week. This to ensure equal and sufficient soil cover (it may have washed off with heavy rain) and to repair holes in the polythene made by rodents, birds or wildlife.
11. MANAGEMENT & FEEDING-OUT OF SILAGE		
What	How	Why
a. Feeding speed	The feeding speed should be 1.5 - 2 meters per week based on the feed planning tool.	To prevent heating, moulding and rotting at the face of the silo.
b. Ease of removing	Make sure the silage can be removed easily and is accessible.	If silage removal takes great effort, staff will attempt to remove less than necessary. Make sure to remove corners every day and keep the face of the silage clamp straight and tight.
c. Removal of silage	Remove all loose materials from the open side (face) of the pit and feed immediately.	Loose materials in front or on the bottom of the silage pit or clamp cause moulds and rotting bacteria to grow. From here moulding and rotting will spread to the good parts of the clamp.
d. Cleanliness around	Clean the open silage face from all rotten and loose materials daily.	This removes moulding and rotting materials hence preventing contamination of good feed.

e. No cover on open silage face	Do not cover the open pit or clamp with polythene but keep the face open.	A loose cover will not avoid air coming in, but it may protect against rain. However during warm days the cover in front creates a microclimate suitable for multiplication of moulds and bacteria in the silage.
f. Feeding space	Provide enough feeding space at the feeding rack in the cow barn. A minimum of 65 cm per cow is recommended to ensure a high feed intake.	To avoid competition at the feeding trough or feeding barrier, to give each animal the opportunity to eat the same diet and to ensure enough space for all animals to eat at the same time.
g. Avoid losses during feeding.	Cows should not trample or foul the silage. Feed regularly and not in excess, only what animals can eat between two successive feeding. Keep feed-out areas, feed troughs and feed alleys clean to prevent contamination of fresh batches.	High feed quality will reduce wastage. Good feeding facility will reduce losses (waste and left overs).
12. WHOLE SILAGE MAKING PROCESS / EVALUATION		
What	*How*	*Why*
a. Field operations	Record keeping of all field activities (plot number, date, activity, cost, result).	To determine whether all operations were done at the right time, speed and compaction. What could have been done better, how can it be improved?
b. Inventory of all pits/ clamps/bales	Calculate total tonnage of silage stored.	When the total stock of maize silage and other feeds is known a feeding plan for the dairy herd can be made for the coming year.
c. Sample each silage pit for analyses of nutritive value	Use feed analysis to monitor silage quality and for ration calculation/formulation.	To have insight in the quality and nutritive value of the silage, and the effect of good/bad silage practices. To determine which other feeds are required to balance the ration for the different cow groups. To monitor if the production of the cows is in line with the analysed quality of the silage.
d. Storage losses	Monitor/observe losses in the storage area pit/clamp/bale.	To explain and avoid in future the cause of the losses, and/or to ask your nutritionist for advice on how to reduce losses.
e. Feed-out losses	Estimate feed-out losses.	To ask yourself how the feed-out losses can be reduced.
f. Silage cost per kg intake	Monitor/re-calculate silage costs.	Assess possibilities to reduce cost per kg of silage. To calculate the costs per kg silage DM for comparison between silages with a different DM content.
g. Evaluate the silage making process with the contractor	Make calculations, pictures and exchange experiences.	To improve the results for all actors involved in the silage making and feeding process.

Annex 4. Clients and acreage of Nundoroto Farm Company in 2018

NUNDOROTO CONTRACTORS	NAME /FARM NAME	LOCATION	ACRES
	TRANS-NZOIA KITALE		
1	ENDAKANO FARM	KIMININI	10
2	SPROUT DAIRIES	KIMININI	30
3	KOSGEI TANUI	SCKHENDU	7
4	ALFRED SOITA	MUTHONI	8
5	DANIEL MWANGI	SURNGAI	6
6	WESLEY KORIR	BIRBIRIET	13
7	SAMWA FARM	KWANZA	10
8	LESMAT FARM	MAILI SABA	70
9	ESTER MUSUNDI	KIUNGANI	6
10	ENOCK KIBET	LEGACY	6
11	JEREMIAH NGETICH	LEGACY	5
12	SIRWO FARM	MAILI NANE	24
13	ST ANTONY BOYS	KITALE TOWN	4
14	DR KORIR	MAILI NANE	7
15	DR SANGULA	MAILI SABA	7
16	WAIJOHI	MAKUTANO (MWAITA)	6
17	SMALL DAIRIES	MOIS BRIDGE	22
18	ROSTOW FARM	WAITALUK	10
19	EMJAY FARM	SCKHENDU	50
20	TOM NYAIRO	MATUNDA	36
21	MARY TONJE	KIMININI	8
22	WESTERN SEED		200
	UASIN GISHU ELDORET		
23	PLATEAU COUNTRY DAIRY	PLATEAU	25
24	DL FARM	KUINET	44
25	ELDORET POLYTHECNIC	LANGAS	24
26	NICHOLAS KOSITAY	ZIWA	20
27	KIGEN JOHNSTONE	CHEPKANGA	21
28	MOI UNIVERSITY	KESSES	50
29	DL FARM (ASAI)	PLATEAU	45
30	SIMAM	BAYETTE	35
31	MOGOTIO	BARINGO	120
32	NAROK	NAROK	97
33	MOLO (MAU FLORA)	NAKURU	150
34	BEN CHUMO	TALKET	30
35	MARGARET KIBOGY	KAPTARGAT	15
36	BEATRICE BIWOTT	FLAX	15
37	DANIEL CHELIMO	FLAX	9
	TOTAL ACREAGE		**1,245**

Annex 5. PUM mission and business links (KMDP I/II: Sept 2013 – March 2019)

Start date	End date	PUM expert	Topics
Sept 2013	Sept 2013	Johan Koeslag	Inception Mission
24-11-2013	12-12-2013	Frans Ettema	Assessment for trainings farms
24-11-2013	12-12-2013	Jaap de Vrij	Assessment for trainings farms
12-01-2014	31-01-2014	Halbe Klijnstra	TFM, CR, PM
23-02-2014	15-03-2014	Jaap de Vrij	CM, FP
14-04-2014	03-05-2014	Frans Ettema	TFM, FM, CS
07-05-2014	05-06-2014	Halbe Klijnstra	TFM, CR
20-07-2014	08-08-2014	Jaap de Vrij	CM, FP, SP
19-08-2014	30-08-2014	Frans Ettema	TFM, SM, FM
02-09-2014	23-09-2014	Frans Ettema	TFM, CS, RF, CR, CHC, SM
12-10-2014	26-10-2014	Jaap de Vrij	CM, FP, SP
25-10-2014	14-11-2014	Halbe Klijnstra	TFM, CR, RC, PM
25-01-2015	09-02-2015	Frans Ettema	TFM, CS, RF, CR, CHC, SM
08-03-2015	22-03-2015	Jaap de Vrij	CM, FP, SP
11-04-2015	26-04-2015	Halbe Klijnstra	TFM, Pm, CR, RC
12-04-2015	19-04-2015	Jaap de Vrij	CM, FP, SP
03-05-2015	17-05-2015	Jaap de Vrij	CM, FP, SP
07-06-2015	21-06-2015	Frans Ettema	TFM, SM, CS
19-07-2015	05-08-2015	Jaap de Vrij	CM, FP, SP
26-08-2015	12-09-2015	Halbe Klijnstra	PM, TFM, CS, RC
13-09-2015	30-09-2015	Frans Ettema	TFM, SM, CHC, RC
28-10-2015	15-11-2015	Jaap de Vrij	CM, FP, SP
01-11-2015	15-11-2015	Halbe Klijnstra	PM, TFM, CS, CR, RC
06-12-2015	21-12-2015	Frans Ettema	TFM, FM, CS
17-03-2016	03-04-2016	Frans Ettema	TFM, SM, CR,
17-03-2016	01-04-2016	Halbe Klijnstra	TFM, PM, CR, CS
03-04-2016	24-04-2016	Jaap de Vrij	SP, FP, SP
14-05-2016	29-05-2016	Halbe Klijnstra	TFM, PM, CR, CS
17-07-2016	31-07-2016	Frans Ettema	TFM, FP, CS,
24-07-2016	12-08-2016	Jaap de Vrij	CM, FP, SP
04-09-2016	18-09-2016	Halbe Klijnstra	TFM, PM, CR, RC
18-09-2016	09-10-2016	Frans Ettema	TFM, CHC, CS,
03-10-2016	22-10-2016	Jaap de Vrij	CM, FP, SP
02-11-2016	10-11-2016	Arend Jan Nell	KMDP seminar
06-11-2016	11-11-2016	Frans Ettema	KMDP seminar
06-11-2016	12-11-2016	Halbe Klijnstra	KMDP seminar
06-11-2016	12-11-2016	Jaap de Vrij	KMDP seminar
01-03-2017	18-03-2017	Frans Ettema	TFM, CR, CS, Milking
19-03-2017	04-04-2017	Tseard van der Kooi	TFM, F, B, CR
02-04-2017	16-04-2017	Halbe Klijnstra	TFM, PM, CS, RC
10-06-2017	25-06-2017	Frans Ettema	TFM, CS, CR, Milking
30-06-2017	23-07-2017	Halbe Klijnstra	TFM, PM, CR, CS
08-07-2017	23-07-2017	Tseard van der Kooi	F, B, CS, TFM
11-11-2017	25-11-2017	Tseard van der Kooi	F, B, CS, CR, TFM
15-01-2018	28-01-2018	Halbe Klijnstra	TFM, PS, FM, CR
03-03-2018	17-03-2018	Hink Perdok	RF/R8, CS

		11-93-2018	24-03-2018	Tseard van der Kooi	F, B, TFM, CR	
		30-04-2018	13-05-2018	Halbe Klijnstra	TFM, PM, CS	
		27-05-2018	03-06-2018	Frans Ettema	TFM, CS, Milking	
		07-07-2018	21-07-2018	Tseard van der Kooi	F, B, CR, TFM	
		14-07-2018	28-07-2018	Hink Perdok	FM/R8	
		15-12-2018	27-10-2018	Halbe Klijnstra	TFM, CR, PM, CS	
		03-11-2018	17-11-2018	Tseard van der Kooi	F, B, CR, CS	
		10-11- 2018	24-11-2018	Hink Perdok	FM/R8	
		31-01-2019	09-02-2019	Frans Ettema	FP, SM, Feed & Forage assessment	
		09-02-2019	24-02-2019	Hink Perdok	FM/R8, CS	
		17-03-2019	08-04-2019	Tseard van der Kooi	TFM, F, B, SM, CR	
		19-08-2014	30-08-2014	D Maina / S Koech	PUM BL on TFM and Farm data	
		12-04-2015	19-04-2015	S Misoi / K Mutoro	PUM BL Machinery &Contracting	
		13-08-2016	22-08-2016	P Mambo / A Gitau	PUM BL on TFM, CR and CS	
		23-05-2018	03-06-2018	8 Junior Consultants	PUM BL on TFM, CR and F&F	
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