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# ASSESSMENT OF FODDER CONSERVATION IN SMALLHOLDER DAIRY FARMING SYSTEMS IN HIGHLANDS AND MIDLANDS OF EASTERN KENYA

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## DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other university.

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## DEDICATION

To the almighty God for the indisputable blessings, guidance, strength and hope during my study. I also dedicate this work to my family (Suge family) and friends for their humble time, understanding and continuous support during the entire study period, may God bless you abundantly.

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## ABBREVIATION AND ACRONYMS

| | |
|---|---|
| AEZ | Agro-Ecological Zones |
| $CO_2$ | Carbon dioxide |
| CSA | Climate-Smart Agriculture |
| DM | Dry Matter |
| FAO | Food and Agricultural Organization |
| GDP | Gross Domestic Products |
| GHG | Greenhouse Gases |
| KALRO | Kenya Agricultural and Livestock Research Organization |
| KCSAP | Kenya Climate Smart Agriculture Project |
| K-SALES | Kenya Semi-Arid Livestock Enhancement Support |
| KDB | Kenya Dairy Board |
| MCL | Mixed Crop and Livestock systems |
| MMT | Million Metrix Tons |
| MVR | Multivariate Regression |
| Non-PDs | Non-Positive Deviant Farmers |
| PDs | Positive Deviant Farmers |
| PUL | Peri-Urban Locations |
| SDCP | Smallholder Dairy Commercialization Program |
| SPSS | Statistical Package for Social Scientists |
| UL | Urban Locations |
| USAID KAVES | U.S.AID’s Kenya Agricultural Value Chain Enterprise |
| UTaNRMP | Upper Tana Natural Resource Management Project |

## DEFINITION OF TERMS

**Agro-ecosystem:** Agricultural environment surrounding an organism

**Climate change:** Changes in the state of climate parameters' which can be identified by prolonged changes in mean and variability in weather phenomena

**Climate-Smart Agriculture Practices:** Agricultural practices that are environmentally friendly practices that increase production and resilience to enhance food security

**Crop residue storage:** Crop residue stored to be used as fodder after harvest of food crops such as maize stovers, straws from wheat and rice, bean husk, sweet potato vine

**Forage:** Any feed material improved or natural meant to feed livestock

**Fodder:** Fodder grown as animal pasture which include: hay and silage

**Greenhouse gases:** Atmospheric gases responsible for causing global warming and climate change

**Pastures:** Grasses naturally occurring or planted and used to graze or cut and feed to livestock

**Productivity:** The quantity of output per unit animal or farm

**Standing hay:** Grass or other fodder left standing in the field to dry naturally for grazing or harvest later

**Strategies:** A plan of action or arrangement to achieve projected long-term goals

**Fodder conservation technologies:** Techniques or methods used to preserve fodder for use during feed shortage and dry season periods

**Urban Market:** Urban populated towns with a ready market for farm inputs and output

# GENERAL ABSTRACT

The dairy industry is important for its contribution to the living standard of people, industries, foreign exchange and 4% of the total GDP in Kenya. Productivity of 7.8 liters/cow/day is low and attributed to poor feeding and contribution to high emission of greenhouse gases (GHGs). Fodder scarcity poses a challenge to the achievement of high productivity, while mitigation of fodder scarcity through fodder conservation remains low. Despite common challenges, farms perform differently, in different farm locations with some farms, also called positive deviants (PDs) conserving adequate fodder. In the highlands and midlands of eastern Kenya, information on fodder conservation among smallholder dairy farming systems is limited. The adoption levels and the intensity of fodder conservation technologies including silage and hay, factors affecting the adoption and use of such technologies in (peri-) urban locations and strategies used by PDs in fodder conservation are unknown. Therefore, the study sought to assess fodder conservation technologies among smallholder dairy farming systems in the highlands and midlands of Tharaka-Nithi County, Kenya. Specifically: to determine factors affecting the adoption intensity of fodder conservation. To determine factors of fodder conservation technologies adoption in urban and peri-urban areas. To determine strategies that distinguish PDs from peers (non-PDs) in fodder conservation. A cross-sectional survey was conducted on smallholder dairy farms producing and conserving fodder in Tharaka Nithi County. Multistage sampling procedures were used: purposive sampling of the Sub-counties and locations, random selection of villages and proportional selection of 242 farms through snowball chain referral. The questionnaire was used to collect information, which included: household socio-demographics, husbandry practices, farm characteristics and fodder conservation characteristics. Two towns were chosen purposively to represent urban locations i.e. Chuka (UL, n=68) and peri-urban locations Chogoria (PUL, n=93) in Chuka and Maara Sub-Counties respectively (Total n=161), due to the relatively high number of urban dwellers. Additionally, the PDs (n=24) conserved fodder adequate to last the dry season and had a milk yield of ≥15 kg/cow/day. While non-PDs (n=97) do not qualify for both criterion as farms qualifying for one criteria were discarded. Multiple regression analysis was applied to explain the quantity of fodder conserved. The Multivariate Regression (MVR) model was used to identify and estimate simultaneously the determinants of fodder conservation technologies adoption. Logit regression was used to examine variables that influence the probability of PDs. The study found that most farms were headed by older males who had basic education. Fodder was scarce during the dry season in most farms. Fodder conserved included; silage was conserved in the least number of farms only 26%, but the highest in the quantity of fodder conserved (13 tons); hay was conserved in 40% of the farms, but the quantity conserved was the least (2 tons); crop residue storage was the major conserved fodder by 85% of the farms and the quantity conserved was 5 tons. Quantities of fodder conserved were affected by land size, herd size, duration planned to use conserved fodder, main fodder source during scarcity and the fodder conservation technologies used (silage and hay). Quantities of silage and hay conserved were higher in urban location (UL) than in peri-urban locations (PUL) farms. Crop residue storage was conserved more in non-PD farms, especially in PUL farms. Fodder conserved in UL and PUL was influenced by farm location, land size, herd size, total milk yield per farm, sex, source of fodder during feed scarcity, extension services, period the current stock is expected to last, use of concentrate feeds and breed kept. Access to extension services, milk yield, land size, land under fodder, period to use conserved fodder, total herd size, and different combinations of fodder conservation technologies differ between PDs and non-PDs. PDs in fodder conservation are favored by a high level of education, access to extension services, large land, herd size and high milk yield. The study shows knowledge production resources and technology used as important in fodder conservation. Recommended mitigation measures target more education on fodder conservation technologies as well as increasing the adoption of improved fodder production. Knowledge advancement of farmers and policymakers through education and extension increases milk production. Therefore, policymakers can focus on creating enabling policies that promote the adoption of improved technologies as used by PDs to support fodder production and conservation to improve productivity and inform the direction of future research.

# CHAPTER ONE

# GENERAL INTRODUCTION

## 1.1 Background information

Globally, the dairy industry contributes to the living standard of people through income, food, asset accumulation, employment, industrial development, fodder production, agricultural marketing and other agro-dealer-related sectors (FAO, 2020). Dairy production contributes to 18% of energy and 34% of protein sources required by human beings globally (FAO, 2020). Africa produces 6% of the total global milk, with East Africa having a high potential of producing more milk than the current production if, quality feeds are availed (Lukuyu *et al*., 2019; FAO, 2022).

In Kenya, the dairy industry contributes 4% of the total GDP and 70% of employment in rural, leading to better livelihoods (Bonilla *et al*., 2017; KDB, 2019). Annual national milk production of 5.52 Million metric tons (MMT) in 2021, is below the demand, which is rising due to an increase in population and urbanization (FAO, 2022). Milk consumption on the other hand is high, with an average per capita of 110 liters per year and the demand is increasing rapidly due to the increase in population (KDB, 2019). The gap between supply and demand for milk has been increasing from 55% when it was reported by Auma *et al*., (2019) to 117% in 2017 reported by Tuei, *et al*., (2021). Productivity improvement, i.e. milk yield per cow, currently at 7.8 kg/cow/day is one way of meeting the increasing demand for milk (Perin and Enahoro, 2023). A major constraint to dairy productivity in Kenya is fodder scarcity, especially in the dry season which often lasts 3 to 4 months (Njarui *et al*., 2016; Auma, 2019).

The mixed crop and livestock (MCL) production system dominates the highlands of Kenya where farmers cultivate crops and keep livestock on the same farm (Kimenchu *et al*., 2015; Balehegn *et al*., 2022). The low productivity of dairy cattle contributes to emissions of GHGs, estimated at 12% CO2 equivalent, dependent on feed availability, utilization and animal genotype (FAO, 2017). Feed availability and quality are low in the lean season/dry season, because production is seasonal and mainly rain-fed, especially in dry and drought-prone areas, (FAO, 2020). Therefore, prices of fodder in the dry season are high and unaffordable to most farmers (Migose *et al*., 2018).

Fodder conservation reduces scarcity and seasonality effects while improving the quality, especially in dry and drought-prone areas. Fodder conservation and storage, also ensure that supply and prices are stable in the dry season. Therefore, fodder conservation ensures consistent feeding and fairly constant milk production (IFAD, 2015; Njarui *et al*., 2016; Bonilla *et al*., 2017). Production of fodder for commercial purposes is done by a few smallholder farmers in Kenya (Lugusa, 2015; Ageya & Omondi, 2016; Kirui *et al*., 2018). Fodder conservation technologies generally remain low in adoption estimated at 27% (Lewa & Muinga, 2015; Bonilla *et al*., 2017). Even where technologies are available and adopted, the quality and quantities of conserved fodder are inadequate for the dry season (Balehegn *et al*., 2020). The average quantity of fodder conserved is six tons per farm/season, which could last on average three months of the dry season, in herd size averaged 2 TLU (1-5), though some farms store more or less fodder (Kogo *et al*., 2022).

Technologies for fodder conservation commonly used in Kenya include silage, crop residue storage and hay (Balehegn *et al*., 2022). Silage is good in nutrient retention during conservation and storage relative to hay and crop residue storage methods (Ndambi *et al*., 2020; Radeny *et al*.,2020). Silage can be conserved in polythene tubes or sheets, containers, silos and pits. Hay storage includes; baled (box or machine), straws, chopped, shredded and caked/pellet (Balehegn *et al*., 2022). Crop residue storage either in stovers or straw form is enhanced for feeding through; the inclusion of legumes, fodder trees, concentrates feeds as well as feed additives like urea (Balehegn *et al*., 2022). The inclusions aim to supplement low-nutrient fodder for the cattle to gain much from the poor-quality materials including crop residue storage (FAO, 2017; Migose *et al*., 2018). Constraints to adoption include prolonged and unpredictable drought and change in climate that reduces the available fodder produced that can be conserved and increases scarcity, high costs of mechanization and materials, limited land and labour for fodder production and inadequate knowledge of fodder conservation among farmers (Muyekho *et al*., 2014; Bonilla *et al*., 2018: Migose, 2020). Adopted technologies vary among farmers at different farm locations some farms being more successful than others. Farmer creativity, education and skills, production factors, such as shortage of land and labour, and market are among the factors influencing the variations in fodder conservation.

Despite common challenges, farmers vary in the adoption of fodder conservation technologies, quantities and types of fodder conserved across different farm locations (rural and urban). Some farmers are more successful in the conservation of fodder than their peers (Migose *et al*., 2018; Ndambi *et al*., 2020). The successful farmers are known as positive deviant farmers (PDs) and the less successful peers are the non-PDs (Migose, 2020). The PDs approach is more informative in understanding the underlying factors and success principles of the few farms in production and use of technologies than the most commonly reported conventional adoption studies (Birhanu *et al*., 2017). The strategies, behaviors and practices of PD farmers are unique in overcoming common challenges; therefore, the strategies make the farmers successful (Birhanu *et al*., 2017; Migose, 2020).

Kenya, through projects such as; the Kenya Climate-Smart Agriculture Project (KCSAP) and County governments, intends to improve production and meet increasing food demand, improve livelihoods and resilience and reduce GHG emissions (KCSAIF, 2018). Tharaka-Nithi County targets an annual increase of two tons of fodder conserved to 55 tons/year by 2022, from the current 50 tons/year. This is achieved by increasing the number of extension services conducted and the acreage used for fodder production from the current 1200 acres to 1800 acres during the same period (GoKb, 2017). However, information on the characteristics of fodder conservation technology among dairy farming systems is scanty. Insufficiency of information limits consistency in fodder conservation for enhanced food security. It also limits appropriate priorities during the formulation of agricultural reforms and policies, aiming to stabilize animal feed supply and stimulate dairy production. Therefore, the objective of the current study was to characterize fodder conservation technologies among smallholder dairy farming systems in Tharaka-Nithi County.

## 1.2 Problem statement

High demand for milk with a gap of 117% has never benefited farmers due to low productivity, closely associated with inadequate fodder, up to 60.5% of the dry matter required for feeding, inadequate fodder quality and prolonged fodder scarcity (Tuei, *et al*., 2021). Therefore, the price of fodder in the dry season becomes high and unaffordable to most farmers. Technologies available for farmers to conserve fodder including silage, hay and crop residue storage are not adopted by farmers. Technology adoption remains low mainly due to inadequate factors of production and the high cost of mechanization and materials. Even where the technologies are adopted, information on methods used and quantities conserved are inadequate. So far, there is inadequate knowledge on the variation of fodder conservation among farmers in different farm locations and strategies used by successful farms. The proportions of farms adopting fodder conservation technologies (silage and hay) and factors affecting adoption are unknown. Factors affecting the adoption of those technologies in urban are unknown. Strategies used by PDs are unknown and technologies used in peri (urban) locations are unknown. Because of the inadequacy of knowledge, there is no appropriate prioritization during the formulation of agricultural reforms and policies to stabilize animal feed supply and stimulate dairy production.

## 1.3 Objectives

### 1.3.1 General objective

To evaluate the conservation of fodder in smallholder dairy farming systems in the highlands and midlands of Tharaka-Nithi County.

### 1.3.2 Specific objectives

i. To determine factors affecting the adoption of fodder conservation in smallholder dairy farming systems in the highlands and midlands of Tharaka-Nithi County.
ii. To determine the factors affecting the adoption of fodder conservation technologies in smallholder dairy farms in the peri (urban)s of the highlands and midlands of Tharaka-Nithi County.
iii. To determine the strategies of positive deviant farmers in fodder conservation among smallholder dairy farmers in the highlands and midlands of Tharaka-Nithi County.

## 1.4 Research questions

i. What are the factors affecting the adoption of fodder conservation among smallholder dairy farming systems in the highlands and midlands of Tharaka-Nithi County?

ii. What are the factors affecting the adoption of fodder conservation technologies in the peri (urban) in the highlands and midlands of Tharaka-Nithi County?
iii. What are the strategies that distinguish the positive deviance in fodder conservation among smallholder dairy farmers in the highlands and midlands of Tharaka-Nithi County?

### 1.5 Justification

Milk is important for household food and nutrition security, as well as employment and income generation. In Kenya, the high demand for milk provides room to increase milk production. Fodder conservation is important to increase the quantities of fodder available for dry season feeding, hence reducing dry season fodder scarcity. Adequate feeding of dairy cattle due to the abundance of quality fodder during the dry season increases productivity (milk yield per cow) and reduces GHG emissions because of the low quantity of $CO_2$ per kg milk produced (Perin and Enahoro, 2023; Tulu *et al*., 2023). Quality fodder and concentrate feeds increase productivity and reduce GHG emission intensity by $2.4 \pm 0.1$ to $1.6 \pm 0.1$ kg $CO_2$ eq (33%) per kg milk (Brandt *et al*., 2020). Therefore, variation in technology adoption is driven by the suitability of forage, storage, weather, farmer skills, entrepreneurial characteristics, production resources, farm characteristics, input and output market and associated losses (Lukuyu *et al*., 2019; Ndambi *et al*., 2020). Lack of adequate knowledge on adoption and constraints to fodder conservation technologies among smallholder dairy farmers limits availability of quality fodder, continuous milk production, enhanced food security and reduced GHG emissions.

### 1.6 Significance of the study

The government of Kenya aims to increase dairy productivity to meet food security, improve livelihoods and reduce GHG emissions (KCSAIF, 2018). Knowledge of interventions of fodder production and conservation practices enhances the appropriate use and availability of fodder which ensures consistency in milk production (Maleko *et al*., 2018; Ndambi *et al*., 2020). Policies on fodder production and conservation address different needs among farmers at different locations as per the distribution of production factors (MALFC 2021). A study that characterizes fodder and the influence of farm location, as well as PDs practices enables the development of suitable policies on fodder conservation and milk production (Migose, 2020).

### 1.7 Thesis outline

This thesis comprises six chapters. Chapter one is a general introduction, with background information on the study, a statement of the problem, objectives, research questions, justification and the significance of the study. Chapter two includes a literature review. Chapters three to five present the individual objectives of the study in paper format. Chapter three includes: Determinants of factors affecting the adoption of fodder conservation among smallholder dairy farming systems across the highlands and midlands of Tharaka-Nithi County, Kenya. Chapter four presents: The determinants of fodder conservation technologies among smallholder dairy farms in the peri (urban) highlands and midlands of Tharaka-Nithi County, Kenya. Chapter five presents: The strategies used by positive deviant farmers in fodder conservation among smallholder dairy farmers in Tharaka-Nithi County. Lastly, chapter six presents: a general thesis discussion, conclusion and recommendations.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Dairy production in Kenya

In Kenya, dairy production is dominated by smallholder farmers (1.8 million) who account for up to 80% of dairy milk production and own land size < 20 acres and herd size < 20 cattle (Auma *et al*., 2018). The productivity of dairy cattle is attributed to genetics, health care, production systems influenced by agroecological zones and the degree of management practices, which include feed and feeding (Auma *et al*., 2019). The productivity of dairy cattle is still low between 6-8 liters/cow/day (Migose *et al*., 2018). The high potential productivity of up to 30 liters/cow/day can be attained, which is up to a 300% increase, but only under proper management practices (Lukuyu *et al*., 2019).

Mixed crop and livestock (MCL) production system being the production of dairy cattle integrated with the main crops grown, which are sometimes accompanied by cash crops such as coffee, tea, or pyrethrum (Kimenchu *et al*., 2015; Balehegn *et al*., 2022). The MCL integration system mutually fits and benefits each other, because of the interdependency and recycling of resources, which involve dairy cattle being fed on crop residues while crops use manure (FAO, 2017; Balehegn *et al*., 2022). The interdependency increases production (more food and income) while reducing the use of inorganic inputs in an intensive process to increase production which also reduces GHGs (Brandt *et al*., 2020).

Fodder production and availability rely mainly on rainwater, hence the reason for availability in plenty only during the wet season and shortage in the dry season (Muyekho *et al*., 2014). Seasonal fluctuation in the quantity and quality of feed resource availability leads to low milk productivity (GoK, 2019; Mudavadi *et al*., 2020). Feed scarcity is experienced by 61% of the farms, while 25% experience fodder shortage for up to seven months a year, where natural pastures and crop residues stored are inadequate for use in the dry season (Tuei, *et al*., 2021).

The shortage of fodder is associated with climate change. The change includes; the variation in mean, range, patterns, intensity, amount, duration and time of weather phenomena such as rainfall, wind and temperature, and the impact experienced worldwide (Roberts *et al*., 2019; Kirui, 2022). Climate change effects on fodder production include the change in agroecological systems through frequent and prolonged droughts and floods (KCSAIF, 2018). The reduced forage yield results equally to a reduction in fodder, which then leads to underfed cattle with an average of 52 kg roughage against the recommended 3% body weight DM of approximately 100 kg daily. Consequently, the reduction in fodder then reduces milk yield and increases the risk of losing cattle during prolonged drought (Kimenchu *et al*., 2015; Mudavadi *et al*., 2020).

Climate-smart agriculture (CSA) is agricultural technologies that aim at sustainably increasing productivity, increasing resilience and reducing GHG emissions from livestock (KCSAS, 2017). Intensification of production and conservation of high-value fodder in the western highland of Kenya was found to reduce overall emissions from dairy by 2.5%, while fodder diversity as mitigation measures to improve fodder quality, can reduce emissions per liter of milk produced by up to 30% (Brandt *et al*., 2020). Conserved fodder was also found to; reduce climate change effects, improve productivity and enhance food security and national livelihoods (Brandt *et al*., 2020; Ndambi *et al*., 2020).

### 2.2 Fodder conservation technologies

Globally fodder conservation is done at different levels for different technologies and diversities as promoted in different countries (MALFC 2021). Developed countries have advanced technologies and resource maximization, which include different automated forage harvesters and different models of balers can make; rounded, squared and rectangular-shaped bales (SNVKenya, 2019). Farmers practicing fodder conservation have an extra 3 liters of milk/cow/day than non-conserving farmers and farmers doing feed ration addition to fodder conservation have another extra 3 liters of milk/cow/day (Sakwa *et al.,* 2020; Ndambi *et al*., 2020). In Kenya, 37% of farmers conserve fodder (Lewa & Muinga, 2015). Production and conservation technologies available in Kenya include intercropping of fodder with legumes and diversification of fodder to improve the quality of fodder feed either fresh or conserved (Aranguiz & J., 2019). Silage conservation is faced with challenges which include; expensive materials (silage tubes and polythene sheets) and high labour demand (Istaitih *et al*., 2023). Hay conservation varies with farmer choice based on efficiency of use and cost (manual box balers and machines-driven balers and shredders). Challenges facing hay making like expensive machines force the majority of the farmers to use the affordable traditional and other convenient methods like; rooftop storage and tree storage (Boote *et al*., 2022).

### 2.3 Fodder conservation among smallholder dairy farmers

Crop residues are stored by up to 80% of farmers under MLC systems after grain harvest, the crop type used varies based on the cultivated crop in the region (Table 1). Straw-based crop residues are characterized by low levels of nutrients and minerals elements essential for animal health. However, crop residues have inherently low acceptability, palatability and digestibility due to high fiber content (28-50%) depending on the crop type. This justifies the need for further feed processing and supplementary feeding with concentrates (Kimenchu *et al*., 2015; Yusuf, et la 2022).

Conservation technologies common to smallholder farms include hay at 33% of the farms. Silage is used in 14% of the farms while 9% of the farms use traditional and chemical additives to preserve fodder (Lewa & Muinga, 2015; Kogo *et al*., 2022). Loose or unbaled hay are stacked in a store, under a tree, or hunged in a tree branch, while baled hay are stored under open or roofed wooden storage rack structures. A previous study indicates that the majority of farmers in Tharaka Nithi County conserve crop residues and in particular maize stalks (stovers), as illustrated in Table 1 (Musalia *et al*., 2016).

Table 1. Different crops conserved by farmers in Tharaka Nithi County

| Fodder type | Fodder conserved | Farmers conserving (%) |
|---|---|---|
| Grasses | Natural grasses | 4 |
| | Napier grass | 1 |
| Crop residues | Maize stalks | 80 |
| | Millets straws | 3 |
| | Other crop residues | 16 |
| Fodder trees | Shrubs, trees & other herbage | 12 |

*Source. Musalia et al. (2016)*

### 2.4 Fodder conservation technologies in rural and urban locations

Adoption of fodder conservation technologies vary between rural and urban locations because of several factors including production factors. Land and labour for fodder production are more available and relatively cheaper in rural than in urban locations. Hence rural farmers produce more fodder and are more likely to have abundant fodder during the rainy season and conserve fodder for use in the dry season (Migose *et al*., 2018). Rural farmers are likely to have more commercial fodder producers than urban farmers because of the availability of land in rural than urban. Urban farmers, on the other hand, are more likely to buy and conserve fodder. Farmers in rural are expected to conserve adequate fodder to sustain high milk productivity than farmers in urban. However, rural farmers have challenges with access to good quality markets such as the ones available in urban locations, which leads to low output prices and minimal returns to the farm (Migose *et al*., 2018; Ndambi *et al*., 2020).

## 2.5 Fodder conservation technologies of successful dairy farmers

Levels and intensity of adoption of fodder conservation technologies varies pending on the behaviors and attitudes of farmers. Therefore, some farmers have devised working strategies to overcome common challenges and become successful in fodder conservation. Quantities of quality fodder conserved last the dry season, hence, seasonal fluctuation in cow productivity is minimal and is relatively high (above average) (Henderson *et al*., 2016). Such farmers who show positive deviance and are thus referred to as positive deviants (PDs) among peers (non-PDs). Despite conservation technologies being adopted, quantities conserved can be inadequate to last through the dry season due to; large herds, small land for fodder production, labour, skills and farmers' financial state (Lukuyu *et al.,* 2019; Yusuf *et al*., 2022). Farmers adopt fodder conservation technologies differently and feed management practices such as good storage facilities that do not result in loss of feed quality and further feed processing and preparation. These include; trashing, fermentation, feed ration and feed supplementation (addition of legumes, minerals and concentrates). Farmers could derive the positive deviance from better milk yield, access to extension services, subsidies or grants sourced from being members of dairy cooperatives or groups, affiliated to development projects, non-governmental organizations (NGOs), or by just being strategically located in areas with better access to input and output markets (Ndambi *et al*., 2020; Migose, 2020; Yusuf, *et al*., 2022).

## 2.6 Constraints to fodder conservation and adoption of fodder conservation technologies

Several factors have been associated with fodder conservation in Kenya. Production factors are one of the factors such as limited access to land for fodder production leads to inadequate fodder production, hence, no excess fodder to be conserved for dry season use. Feed shortage associated with climate change and prolonged droughts contribute to limited access to fodder for conservation and adoption of fodder conservation technologies including adoption of modern technologies (Muyekho *et al*., 2014; Auma *et al*., 2018). Fodder storage structures that ensure quality and quantity feeds are rated the second challenge after inadequate skills in fodder production and conservation (Lukuyu *et al*., 2019). Traditional methods for storage of fodder include hanging loose hay and crop residues in tree branches or racks under roofed or non-roofed stores (Lewa & Muinga, 2015; Musalia *et al*., 2016). Inadequate machinery such as tractors, balers, mowers and forage harvesters are used to mechanize fodder operations such as planting, harvesting and hay baling or compacting during silage making (Bonilla *et al*., 2018; KCSAIF, 2018; GoK, 2019). The machines are time-saving, less laborious and cost effective. Other constraints to fodder conservation are related to lack of access to adequate weather information, capital, seed availability, market information as well as social aspects such as sex, age and membership in dairy cooperative groups (Kimenchu *et al*., 2015; Auma *et al*., 2018; Ndambi *et al*., 2020).

## 2.7 Conceptual framework

Inadequate feed is the cause of low productivity in dairy farms, while fodder conservation is one way to stabilize feed availability for high milk productivity (KCSAIF, 2018; Mudavadi *et al*., 2020). The study conceptualizes, that there are fodder production and conservation technologies that will improve the availability of quality feeds in a year. Types and quantities of fodder produced and conserved (dependent variable) differ with the type of conservation technologies adopted, which can be silage, hay, haylage, or crop residue storage. Storage varies in methods, form of fodder, mean and quantities conserved as well as the daily feed given to the animal. The variations in usage of fodder conservation technologies are based on production factors, farm characteristics, input/output market, yield and herd size, as well as other individual farmer skills and creativity among different farms at various farm locations, with some being PDs, i.e, Farms successful in the adoption of fodder conservation better than peers. The variation also includes types of fodder which is in either mono-cropping or intercropping. In between the variables are the external interventions' including government policies and reforms. The schematic representation of how the factors influence fodder conservation among farmers is shown below (Fig.1) The independent variables will have a direct effect either a negative or positive influence on the dependent variable (fodder conservation).

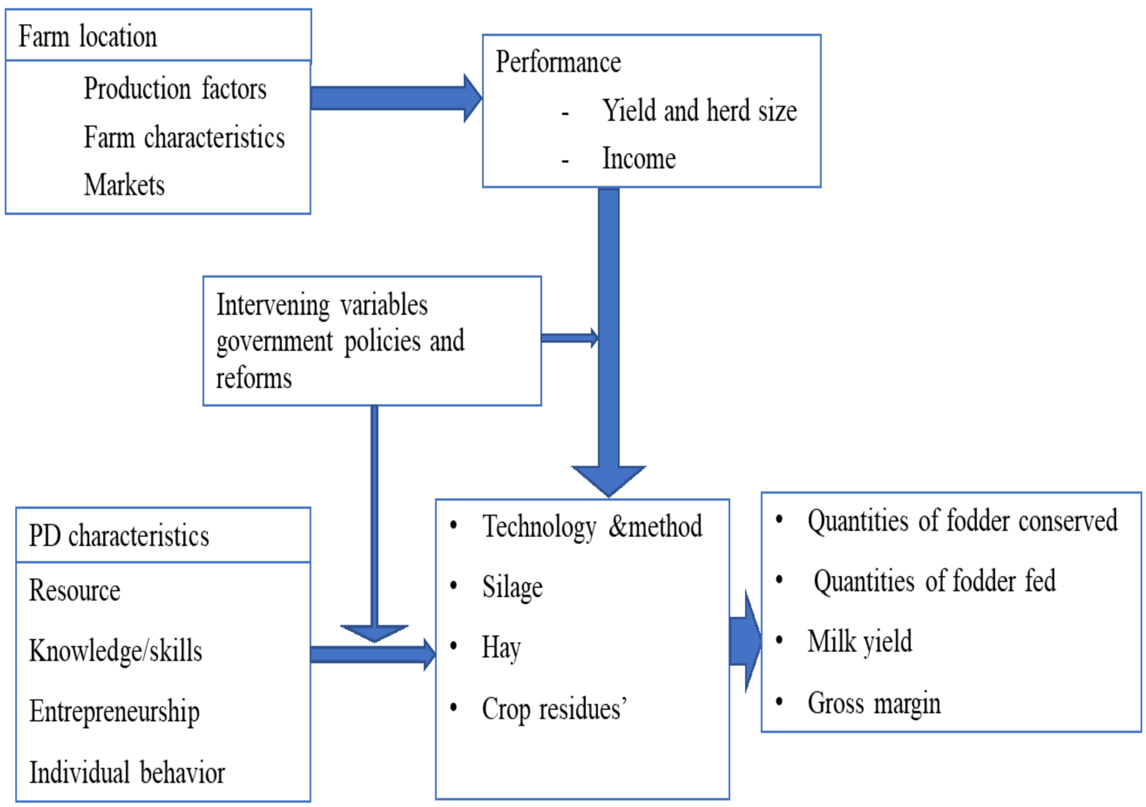


Figure 1. A schematic representation of independent variables of fodder conservation

# CHAPTER THREE

# DETERMINANTS OF FODDER CONSERVATION IN SMALLHOLDER DAIRY FARMING SYSTEMS IN THE HIGHLANDS AND MIDLANDS OF EASTERN KENYA

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**Abstract**

In Kenya, dairy contributes about 70% of rural livelihood. Productivity of dairy cattle, however, is low due to scarcity of fodder which fluctuates with seasons, yet adoption of fodder conservation technologies is low. In the highlands of Kenya, information on fodder conservation in smallholder dairy farming systems is limited. The objective of this study, therefore, was to determine factors affecting the adoption of fodder conservation technologies in smallholder dairy farming systems in the highlands and midlands of Kenya. A cross-sectional survey was conducted on 242 dairy farms that produce and conserve fodder in Tharaka Nithi County. A semi-structured questionnaire was administered to collect information on household demographics, socioeconomic, farm characteristics, husbandry practices and fodder conservation technologies. Data were analyzed using multiple regression to identify determinants of fodder conservation adoption. The study found that more than half of the farms were headed by older (>50 years) males with primary and secondary education. Zero-grazing was the main grazing system, with small land sizes (0.95 ha) and herd sizes of 4.3 Tropical Livestock Unit (TLU, 1TLU = 250kg) and milk yield was low (8.4 kg/cow/day). Crop residue storage (85%) was the most used fodder while silage (26%) was the least used though with the highest quantity of fodder conserved (silage; 13 tons, crop residue storage; 5 tons and hay; 2 tons). Fodder was mostly scarce during the dry season (64%). Quantities of fodder conserved were affected by land size, herd size, duration planned to use conserved fodder, main fodder source during scarcity and the fodder conservation technologies used. Land on food crops contributes to fodder conserved through crop residue storage, which in turn lowers the fodder conserved when used only during scarcity. Large herd size, long duration of using the conserved fodder and use of hay-silage combination enhance fodder conservation. However, the use of conserved fodder should shift to focus all year and improve the quantity of fodder conserved. Silage and hay were the most influential to the quantity of fodder conserved. Therefore, fodder conserved largely depends on technology adoption which is an important step towards improving productivity, limited by

inadequate knowledge of silage making and access to machinery for hay baling and silage making. Therefore, to enhance fodder conservation and the achievement of government objectives, there is a need to lower production costs, capacity building and government tax relief, especially concerning fodder production and conservation which will reduce the breakeven point and attract more people to invest.

**Keywords:** Fodder, conservation technologies, dry season, characteristics, determinants

### 3.1 Introduction

Dairy production contributes to 18% of energy and 34% of protein sources globally (FAO, 2020). Approximately 6% of the total global milk output comes from Africa and 68% is from East Africa (FAO, 2020). In Kenya, dairy production contributes to 70% of rural livelihoods through direct and indirect benefits (Bonilla *et al*., 2018). The annual national milk output was 5.52 Million metric tons in 2021, 88% of which were derived from dairy cattle (KDB, 2019; FAO, 2022). The per capita milk consumption is 109 liters per year and the demand is increasing rapidly due to an increase in population (Bonilla *et al*., 2018; Auma *et al*., 2018). Milk supply, therefore, is 55% less than the demand (Auma *et al*., 2019; KDB, 2019). To meet increasing milk demand, the County governments aim to improve the productivity of dairy cattle, i.e. milk yield per cow, (Brandt *et al*., 2020; Migose, 2020). This is through diverse improvement strategies including education and extension service of farmers on general animal husbandry practices and feeding, provision of subsidized inputs, such as distribution of fodder seeds and promoting fodder conservation (KCSAIF, 2018).

The majority of smallholder farms produce and conserve fodder for their use. Production of fodder for commercial purposes is done by a few farms (Lugusa, 2015; Ageya & Omondi, 2016; Kirui *et al*., 2018). Fodder production is rainfed and fluctuates with seasonal rainfall. Fodder availability is low in the dry season. Therefore, the prices of fodder are high and unaffordable (Migose *et al*., 2018; FAO, 2020). Fodder is conserved for use during periods of scarcity to ensure consistent feeding and fairly constant milk production (IFAD, 2015; Njarui *et al*., 2016; Bonilla *et al*., 2018).

Technologies adopted for fodder conservation include hay, haylage and silage-making (Lewa & Muinga, 2015). Crop residues are also stored for use during periods of scarcity. Silage is conserved in polythene tubes, sheets, containers, silos and pits, while hay is mainly baled (Muyekho *et al*., 2014; Balehegn *et al*., 2022). Crop residues are stored mainly mainly as a whole stalk but some farms chop or shred them before storage and are sometimes treated with urea and fermented to improve quality (Bonilla *et al*., 2018; Balehegn *et al*., 2022). Adoption of fodder conservation technologies generally remains low, estimated between 15% and 37% (Lewa & Muinga, 2015; Bonilla *et al*., 2018). Adoption is constrained by factors such as limited land for fodder production, frequent droughts, high costs of mechanization and inadequate knowledge of fodder conservation among farmers (Bonilla *et al*., 2018; Migose, 2020). Even where technologies are available and adopted, the quality and quantities of conserved fodder are inadequate for the dry season because of limited choices of fodder conservation technology (Balehegn *et al*., 2020).

In Tharaka-Nithi County, the government targets to increase fodder conserved by 2 tons per year from the current 50 tons/year to 55 tons/year by 2022. This is expected to be achieved by increasing access to extension service and acreage on fodder production from the current 485.83ha to 728.74ha in the same period (GoKb, 2017). Information on the characteristics of fodder conservation technologies adopted by smallholder dairy farms is scanty. This inadequacy in information limits consistency in fodder conservation and formulation of appropriate policies to reform the fodder sector, stabilize fodder supply for dairy cattle and stimulate production. Therefore, the objective of the present study was: To determine factors affecting the adoption of fodder conservation among smallholder dairy farming systems across the highlands and midlands of Tharaka-Nithi County, Kenya.

## 3.2 Materials and Methods

### 3.2.1 Study area

The study was conducted in Tharaka-Nithi County, Eastern Kenya. The county covers diverse agroecological zones ranging from highland to arid and semi-arid lands (ASALs). The highlands and midlands receive bimodal rainfall, with long rains in April-June and short rains in October-December. The two dry seasons occur between January – February and July-September (Njarui *et al*., 2016; GoK, 2019; NDMA, 2020). Fodder production is rainfed, with production peaking during the rainy seasons and scarcity being severe in the dry seasons. Dairy cattle and fodder production are concentrated in the highlands and mid-highlands (Auma, 2019).

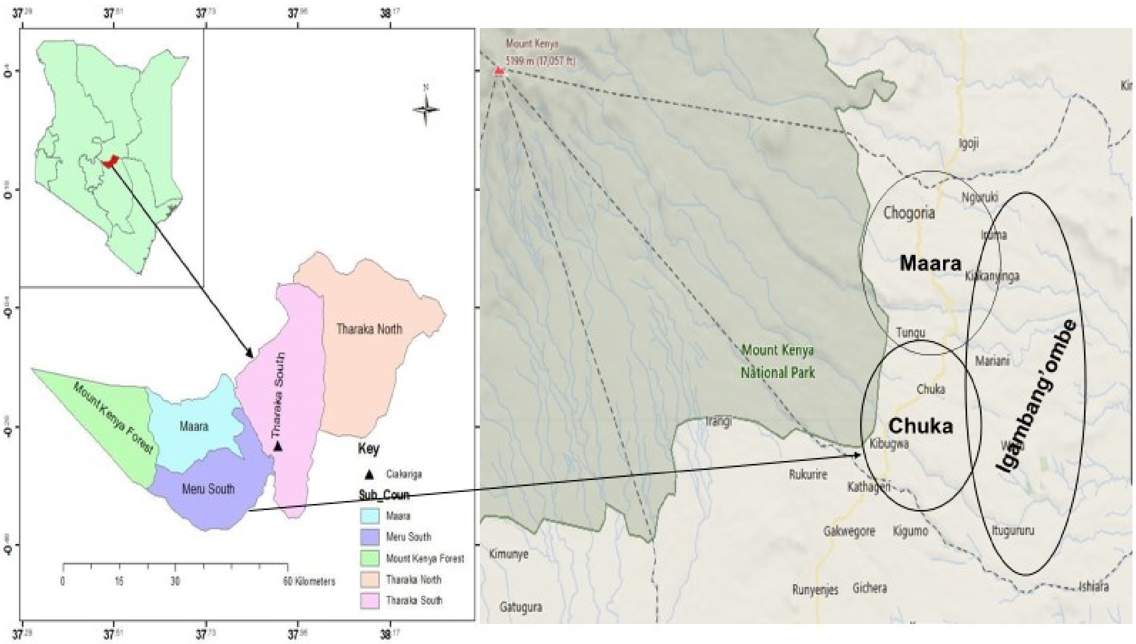


Figure 2. Tharaka-Nithi County and locations of surveyed farms

### 3.2.2 Study design and sampling procedure

A cross-sectional survey was conducted on dairy farms producing and conserving fodders for their use. A multistage cluster sampling was used to select smallholder dairy farms (Rahman, et al., 2022). Two sub-counties (Maara and Chuka-Igambang'ombe) in highlands and midlands with a high proportion of dairy farms were selected (KNBS, 2019) and within each sub-county, at least half of the locations were selected (Figure 2). Snowball chain referral was used to identify farms conserving fodder, which were then randomly selected. In total 242 farms were selected, i.e. 242 dairy farms selected mostly from the coffee zone. A sampling formula by Cochran & Wiley, (1977) for a large population with the desired level of precision and confidence level was used:

$$n = (z/m)^\wedge 2\ p\ q \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(Eq. 3.2.1)}$$

where:

*z* = confidence level at 95%, *m* = margin of error (0.05), *p* = estimated value of the population expected to respond from the unknown population (*P* = 80%), *q* = (1-p), the estimated proportion of target attributes (household) in population and will respond in a given way to a survey question, $q$ = 20%

Therefore, $n = (1.96/0.05)^2\ (0.8)(0.2) = (39.2)^2(0.16) = 246.86 \approx 246$ households

### 3.2.3 Data collection

A semi-structured questionnaire was administered to collect information which included; household demographics, socioeconomic, farm characteristics, husbandry practices and fodder conservation technologies. The respondent was the household head or family member with experience in livestock fodder. Information in the questionnaire was coded in the Open Data Kit (ODK) and administered through a computer-assisted personal face-to-face interview (CAPI) (Delhi, 2018). The ODK was filled by a principal researcher aided by Research Assistants. Data were collected between July and August 2021, after approval by the National Commission for Science, technology and Innovation, under license No: NACOSTI/P/21/11411.

### 3.2.4 Data Analysis

Data were prepared by conversion of variables to universal measurements: Total land size and fodder production land include all land used in the farm either farmer-owned or rented land, 2.5 acres equal 1 hectare (ha). Herd size according to Tropical Livestock Unit (TLU, 1 TLU = 250 kg) (Rothman-Ostrow *et al*., 2020), herd population cow (above 2 year) Av. 400kg, heifers (1-2 years) av. 200kg, after weaning (4-12 months) av. 100kg and calves (under 4 months) av. 50kg. Daily feed intake (kg/cow/day), daily concentrate intake (kg/cow/day). Milk yield per cow per day (kg/cow/day), was done by dividing yield per herd per day (kg/farm/day) by total lactating and dry cow. Quantity of fodder conserved (kg/farm/season). Test for normalities was by scatter plots and QQ plots.

The predictor variables were classified broadly into four groups: demographic characteristics, socioeconomic characteristics, farm characteristics and fodder conservation technologies. Frequencies of categorical variables include; household demographic variables (gender and age), socioeconomic variables (membership to the group, occupation and education level and extension service) and farm characteristics (breed, grazing system, feed type, fodder conservation technologies and fodder scarcity) were analyzed using descriptive statistics. Continuous variables including; land size, herd size, milk yield, daily feeds, quantities of fodder conserved and expected period of using the conserved fodder were analyzed using means and standard deviation.

The predictor variables include both continuous and categorical such as; gender, age, occupation, education level, land size, herd size, extension service, membership to dairy groups or cooperatives, expected duration of using the quantity of fodder conserved (months), and the options of fodder conservation technologies adopted. While the response variable was continuous i.e. total quantity of fodder conserved (kg/farm/season) in different fodder conservation technologies. The variables were tested for normality and linearity using scattered plots. However, all variables were normally distributed and were analyzed quantitatively using descriptive statistics and regression. Multiple regression analysis was applied to assess whether one or more predictor variables explained the response variable (quantity of fodder conserved).

A regression procedure was conducted after creating dummy variables for the predictor variable (conservation technologies), i.e. one variable was made as a reference category before regression analysis for a continuous variable, categorical variable and options of technology adoption independently. Crop residue storage was chosen as a reference category for technology adoption options because it's done in the majority of the farms. Thus, the intercept or the constant in the regression output represented the mean amount of conserved fodder for farmers who used crop residue storage alone as their conservation technology. All analyses were done in the Statistical Package for Social Sciences (SPSS 23 version).

The multiple linear regression model was

$$Yi = 〚\beta\_0 + \beta〛\_1 X\_i1 + \beta\_2 X\_i2 + \beta\_3 X\_i3 \ldots + \beta\_5 X\_i5 + \epsilon\_t \quad \ldots (Eq.\ 3.2.2)$$

where, $i = 1,2,3,4,5$

$Y_i$ ($i^{th}$) Response variable value (Quantity of fodder conserved in kg/farm/season)

Beta = $Y$-intercept (Crop residue storage value)

$\epsilon_{t}$ = Error term. (The error term $\epsilon$ independent and normally distributed)

$X_i$ = ($5^{th}$) Predictor variable

*X1* – Total land (ha)

*X2* – Herd size (TLU)

*X3* – Duration expected to use the conserved fodder

*X4* – Crop residue as a source of fodder during scarcity

*X5* – Conservation technology (silage and hay)

## 3.3 Results

### 3.3.1 Demographic, socioeconomic and farm characteristics

Table 2. Indicates demographic, socioeconomics and farm characteristics variables which include: gender, age, education, occupation and extension service. The proportion of males was high relative to females. The proportion of senior farmers above 50 years of age was more than half compared to the last group (less than a quarter) of junior farmers 35 years and below. Farmers with secondary education and bellow were more than half, with the main occupation being farming and most of the farmers being members of a dairy or cooperative group, using formal milk market majorly. Less than half of the farmers accessed extension services in the last two years, on dairy husbandry, feeds and fodder conservation topics. Zero-grazing was the major grazing system practiced with common breeds being Friesian and Ayrshire including the crossbreeds and other breeds (Jersey and Guernsey). Common feeds used in most farms include; fresh fodder, concentrate feeds and of course conserved fodder. However, fodder was scarce mainly during the dry period, where farmers reported using conserved fodder, concentrate feeds, tree leaves, grass from the forest and some irrigated fodder to grow faster during this period. Fodder sources were majorly on-farm and more than half of the farms purchased fodder in addition. Conserved fodder was used throughout the year and other farmers used it only during scarcity periods (mostly dry periods).

Table 2. Descriptive statistics of demographic, socioeconomic and farm characteristics among farmers (n=232) in Tharaka-Nithi County

| **Category** | **Variable** | **Items groups** | **Respondents (%)** |
|---|---|---|---|
| Demographic | Gender | Male | 61.6 |
| | | Female | 38.4 |
| | Age | 18-35 Years | 14.7 |
| | | 36-49 Years | 31.9 |
| | | Above 50 Years | 53.4 |
| | Education | Non-formal | 2.2 |
| | | Primary | 37.0 |
| | | Secondary | 33.7 |
| | | College | 19.4 |
| | | University | 8.6 |
| Socioeconomic | Group members | No | 18.9 |
| | | Yes | 81.1 |
| | Extension service | No | 59.9 |
| | | Yes | 40.1 |
| | Milk market channel | Formal | 77.1 |
| | | Informal | 25.9 |
| | Main occupation | Business | 9.1 |
| | | Casual Labour | 3.5 |
| | | Farming | 76.9 |
| | | Formal employment | 10.4 |
| Farm | Breeds | Friesian | 53.9 |
| | | Ayrshire | 7.3 |
| | | Friesian & Ayrshire | 35.8 |
| | | other breeds | 3.0 |
| | Grazing system | Semi zero grazing | 1.7 |
| | | Zero-grazing | 98.3 |
| | Main feeds | Concentrates | 82.1 |
| | | Fresh fodder | 93.4 |
| | Fodder scarcity | Wet season | 3.7 |
| | | Dry season | 65.6 |
| | Fodder in Scarcity | Purchase | 68.5 |
| | | On-farm | 98.7 |
| | Period to use conserved fodder | During scarcity only | 15.6 |
| | | Throughout the year | 84.4 |

**Farm Characteristics**

Means for various farm characteristics are presented in Table 3. Total land size (both land on food crops and fodder crops) was small, with the least portion being on fodder crops. Herd size was small with more than half being lactating. Fodder intake was low supplemented with a low concentrate intake, except in a few farms where the quantity was high. Milk yield was low both production per farm and per cow per day. The duration of fodder conservation was moderate, where few farms conserve fodder enough for long periods. The quantity of fodder conserved was low in most of the farms, where only a few farms conserved enough and the majority conserved low quantities. Fodder conserved as silage was the highest while hay was the least in quantity.

Table 3. Mean, Standard Deviation, Minimum and Maximum for farm characteristics in Tharaka-Nithi County

| **Farm characteristics** | **Mean** | **S.Deviation** | **Min** | **Max** |
|---|---|---|---|---|
| Total land size (ha) (n=242) | 0.95 | 0.86 | 0.04 | 4.03 |
| Land on food crops | 0.72 | 0.72 | 0.04 | 3.23 |
| Land on fodder crops | 0.35 | 0.30 | 0.04 | 1.61 |
| Herd size (TLU) (n=242) | 4.32 | 2.95 | 1.60 | 19.30 |
| Lactating | 2.95 | 1.98 | 1.60 | 9.60 |
| Dry cattle | 1.50 | 2.05 | 1.60 | 10.90 |
| Heifer | 0.84 | 0.86 | 0.80 | 4.00 |
| Milk yield (kg/farm/day, n=242)[1] | 18.28 | 19.28 | 0.00 | 132.00 |
| Milk yield (kg/cow/day, n=242)[1] | 8.40 | 5.78 | 0.00 | 30.00 |
| Fodder intake (kg/cow/day) (n=242) | 38.40 | 13.93 | 15.00 | 90.00 |
| Concentrates (kg/cow/day) (n=200) | 4.00 | 2.28 | 1.00 | 12.00 |
| Duration of fodder conservation (months) (n=242) | 3.18 | 3.60 | 0.25 | 24.00 |
| Fodder conserved (tons /year, n=242) | 5.62 | 12.78 | 0.15 | 94.00 |
| Silage | 11.59 | 18.16 | 0.50 | 90.00 |
| Hay | 1.72 | 2.52 | 0.11 | 15.00 |
| Crop residue storage | 4.73 | 14.30 | 0.20 | 80.00 |

1 Farms with zero milk yield include farms with only dry cow

### 3.3.2 Fodders utilized, conserved and conservation technologies used

Fodders utilized in most farms (Appendix 3) included: Napier grass (99%), maize (48%), natural grasses (36%) e.g. Kikuyu grass and Nandi sateria among others, brachiaria (11%), boma rhodes (10%), sorghum (2%) and millet (1%) in small proportion among other fodders. Common legumes utilized included desmodium (8%), lucerne (1%) and soya beans, which few farms conserve. Fodders conserved included: crop residues (>80% being maize stovers), bananas, bean husks/hulls and sweet potato vines. Napier grass (58%), silage maize (30%), boma rhodes (20%), fodder trees (Calliandra, Leucaena, Sesbania, Mulberry and *P. Sepium*, 11%) and natural grasses.

Various fodder conservation technologies were adopted (Figure 3). Crop residue storage, hay and silage were adopted, where some farms adopted multiple technologies in different methods. Silage technology being the least adopted, was in methods that include; silage in a pit lined with polythene sheet, silo, silage tube and container. Hay was majorly conserved in bales and unbaled or loose form, while few farms used standing hay and chopped or shredded. Crop residue storage was majorly stored dry maize stovers or chopped (processed).

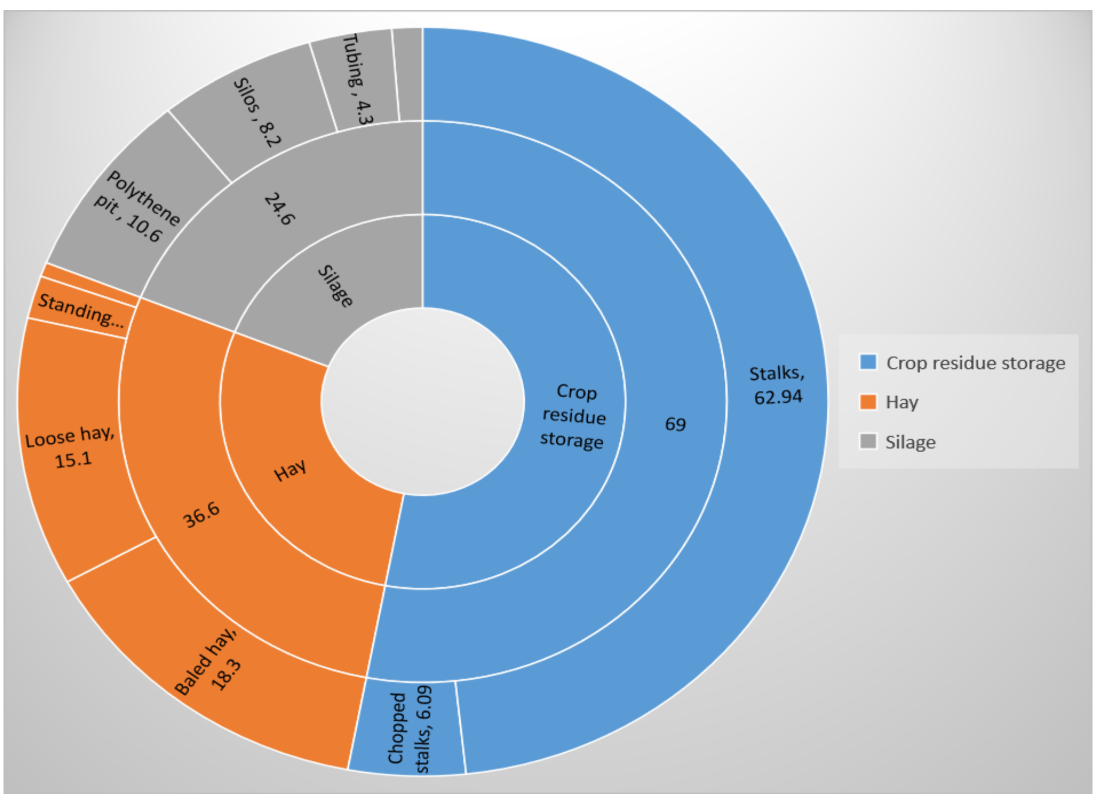


Figure 3. Proportion (%) of farms (n=242) & different fodder conservation technologies

### 3.3.3 Determinants of fodder conservation

Table 4. Presents the predictor variables that explain 54% ($R^2 = 0.54$) of the variations in the quantity of fodder conserved. Five variables were significantly important ($P$ <0.05) i.e.

$Y_i$ = -2481.01 + Land size both of food crops * 4885.64 + herd siz * 566.41 + duration expected to use the conserved fodder * 854.49 + crop residue as a source of fodder during scarcity * -8237.32 + silage and hay fodder conservation technologies * 21047.62 + $\epsilon_t$

Land size on food crops, herd size, duration expected to use the conserved fodder, crop residue as a source of fodder during scarcity as well as combinations of silage and hay fodder conservation technologies. While, four other variables were moderately important ($P$ <0.10) determinants of fodder conserved, which include; land on fodder crops silage, sex, use of silage as a source of fodder during scarcity and the use of purchased fodder as the main source of fodder in the farm. The intercept is the mean quantity (kg) of fodder conserved when the variables on the test are held constant at zero for both continuous and categorical variables. The significant variables have different coefficient values, which determine the amount of increase or decrease expected in the response variable for each unit change in the predictor variable.

A unit increase in land on food crops (Ha) increases the fodder conserved relative to the constant, while a unit increase in land on fodder crops reduces the quantity of fodder conserved when all variables are at zero (constant). An increase in total herd size per unit (TLU) increases the quantity of fodder conserved. A unit (month) increase in the period the conserved fodder is expected to be used results to an increase in fodder conserved. While, being a male increase the fodder conserved relative to being a female. Purchased fodder as the main source of fodder reduces the fodder conserved, while the main fodder used during scarcity influences the fodder conserved; the use of silage increases the fodder conserved, as the crop residue storage reduces fodder conserved. The technologies used also determined the fodder conserved; silage and hay combination as a source of fodder results to increase in fodder conserved relative to conservation of only crop residue storage. The use of silage conservation as the only conservation technology increases the fodder conserved relative to the used of crop residue storage. Other variables were not significant and therefore, were not presented in this study.

Table 4. Coefficients (standardized and unstandardized) of variables determining fodder conservation among farmers in Tharaka-Nithi County

| **Variables** | **Unstandardized Coefficients** | | **Standardized Coefficients** | |
|---|---|---|---|---|
| | **B** | **S Error** | **Beta** | **Sig.** |
| **Continuous** | | | | |
| (Constant) | -2481.01 | 1255.86 | | 0.050 |
| Land on food crops | 4885.64 | 1571.46 | 0.275 | **0.002** |
| Land on fodder (Ha) | -5521.45 | 3129.98 | -0.157 | 0.079 |
| Total herd size (TLU) | 566.41 | 165.86 | 0.241 | **0.001** |
| Duration of conserved fodder (months) | 854.49 | 205.46 | 0.276 | **<0.000** |
| **Categorical** | | | | |
| (Constant) | 12042.23 | 3216.58 | | **<0.000** |
| Sex (Male) | 2408.70 | 1434.02 | 0.139 | 0.095 |
| Main source of fodder in scarcity | | | | |
| Crop residue (fodder tree) | -8237.32 | 2654.92 | -0.255 | **0.002** |
| Silage (fodder tree) | 3401.90 | 1728.02 | 0.161 | 0.051 |
| Purchased fodder (fodder tree) | -3200.72 | 1818.33 | -0.145 | 0.081 |
| **Option of technologies adopted** | | | | |
| (Constant) | 4256.38 | 794.96 | | **<0.000** |
| Silage+Hay | 21047.62 | 3126.41 | 0.406 | **<0.000** |
| Silage | 5252.33 | 2944.94 | 0.147 | 0.077 |

AIC: 55.), B - Unstandardized coefficient estimate, Standardized coefficients (Beta) - Odd ratio. Dependent variable: Total quantity of fodder conserved

### 3.4 Discussions

Regression results explained 54% of the variations in fodder conserved. Factors important in predicting the quantity of fodder conserved include: Sex, land size, herd size, duration expected to use the conserved fodder, source of fodder during scarcity, main source of fodder in the farm as well as fodder conservation technologies used (Table 4). However, other factors covered though with less or no impact include; age, education level, extension, membership, market, breed, grazing system and occupation.

The sex of the farmer's head influenced the fodder conserved, where male-led farms were conserving more fodder relative to the female-led farms probably due to male dominants in the control of production resources. Maina *et al.,* (2020) also reported similar results that male-headed household has more access to land ownership, resources and information making it easy to adopt new technologies. Farms led by elder farmers compared to young farmers dominate fodder conservation probably contributing to low adoption of fodder conservation and conservation technologies, the results which were also reported by Migose, (2020) that "old age impaired physical and cognitive ability to adopt dairy improved technologies" and Istaitih *et al.,* (2023) that "young members of the household have a higher willingness to apply new knowledge". Education level was low for majorly of the farmers' heads with average access to extension services, probably explaining low knowledge of technologies and probably low adoption levels. The majority of the farms were members of either dairy groups or cooperatives and the main milk market was the formal channel. The findings which were also reported by Omollo, (2017) that members of cooperatives enjoy services including; economics of scale, extension service, fodder, concentrate feeds and mineral salts, as well as access to market, credits and input subsidies.

The average land size was a significant contributor to fodder conserved even though small (1.04ha), a portion remaining for fodder being too little (36%) most of it being intercropped parts between food crops land as terraces and windbreaks compared to crop production, the reduction could be associated with population increase as well as changing lifestyles, the result which was also reported by other studies (IFAD, 2015; Valbuena *et al.,* 2015; Omollo, 2017; Bonilla *et al.,* 2017). Farms with small farm sizes are among those who buy and conserve fodder for the next season, the results which were also reported by Ndambi *et al.,* (2020).

Total herd size was an important factor in determining the quantity of fodder conserved. The majority of the farmers had a small herd size, except in a few farms with higher numbers reflected by a higher standard deviation. The results within the range (3.1 ± 2.1) reported by Njarui *et al*., (2016). Average milk production (8.4 liters/cow/day) being valued within 7.8-11.8 liters/cow reported by IFAD, (2015). The production level is low compared to the average potential of exotic breeds (15 kg/cow/day) in the Kenya highlands, which gives room for improvement. The study, therefore, associated low investment in dairy farming with low motivation towards challenges of technical knowledge on fodder conservation, breeds, disease and droughts and unreliable markets (IFAD, 2015; Bonilla *et al*., 2018).

Zero-grazing was the main production system combining both conserved and fresh feeds to maximize the available production resources according to Njarui *et al*., (2016). Fresh feeds were dominated by Napier grass, in addition to maize fodder, natural grasses, Boma Rhodes, fodder trees, sorghum and brachiaria, the feeds which were also reported by Musalia *et al*., (2016). Maize, Napier and boma Rhodes were the highly conserved fodder. Napier grass is known to adapt well to less moisture and with the shortest chain in line with the fodder value chain assessment report (Auma *et al*., 2018) and feed study by Maleko, *et al*., (2018).

Dairy farmers conserving fodder feed supplement their feeding using 4 kg/cow/day concentrates compared to the overall mean of 2 kg/cow/day (double) for entire livestock farmers, the quantity fit 1k concentrate/cow for every 2-3 liters of milk above 5 liters (Njarui *et al*., 2016; Lukuyu *et al*., 2019). Farmers conserving more fodder could be more focused on production and eventually end up conserving enough fodder (Migose, 2020; Habermann, 2023). Crop residue stored was over 90% maize stover, among other crops; beans, cowpeas, green gram, pigeon pea, banana and sorghum, because maize was a staple food in Kenya (Lukuyu *et al.,* 2019; Yusuf, *et al.,* 2022).

The common technologies were; silage, hay and crop residue storage (mainly maize stover) Figure 3. Silage was the least adopted technology while crop residue storage was the most adopted, the findings which were also reported by Lukuyu *et al*., (2019). However, silage was the technology conserving the largest quantity of fodder despite being the least adopted. This could result from the expected long duration of silage storage and the economics of scale since most of the silage processing is machine-based

(SNVKenya, 2019). The polythene sheets line pit method was done by the majority probably because it is cost-effective and less capital-intensive compared to permanently cemented silos, the container and tube silage (SNVKenya, 2019). To cut the cost and increase the period expected to be used of the conserved fodder, therefore, members belonging to a group or cooperatives (80%) can organize a cost-sharing program for expensive silage-making machines (Ndambi *et al.,* 2020).

The expected period to use conserved fodder increases with an increase in the quantity of fodder conserved, mitigating fodder scarcity from unpredicted droughts and climate change. Low adoption of fodder conservation is indicated by low quantities of fodder conserved and fluctuating fodder availability and fodder scarcity experienced in most (64%) of the farms, especially during the dry period and only (3%) during the wet period (Pradesh, 2016). The shortage was experienced in the months of August to October and January to March with September and February being the peak (Appendix 2). These tally with the results reported in the previous studies (Musalia *et al*., 2016; Mudavadi *et al*., 2020; Tuei, *et al*., 2021). During this period farmers use: Conserved fodder, concentrate feeds, buy from outside, tree leaves, forest/roadside natural grass and irrigated fodder (Njarui *et al*., 2016). Although the majority (83%) of the farms used conserved fodder throughout the year, they reduced the quantity of fodder fed during the dry season, a problem associated with low production and emaciation (Mudavadi *et al*., 2020).

An increase in the use of silage as the main fodder during scarcity increases the quantity of fodder conserved relative to the use of fodder trees, probably because of the technology used in few farms that conserve enough fodder (Maleko *et al*., 2018b). The use of silage and hay combination as the major feed during scarcity strongly and positively influences (highest Standardized Coefficients) the quantity of fodder conserved. In addition, silage conservation alone had a moderate influence on the quantity of fodder conserved. The results could be because of the expected fodder quality and the highest quantity of fodder predicted to be contributed by the combinations of the technologies and synergized by dry matter in hay probably to bring a good balance. However, two dairy cooperatives were selling silage packed in 50kg silage bags, supplied by a company (Azma Foods) at a wholesale price and mostly consumed during the dry period. Silage commercialization is a new thing for most farmers and has yet to be optimized to sort fodder scarcity, the findings are in agreement with Ndambi *et al*., (2020).

Ironically the use of stored crop residue as the major fodder during periods of fodder scarcity negatively influences the quantity of fodder conserved relative to farms using other options including fodder trees probably because of the reduction in feed stored while expecting crop residue from food crops and a reduction in feed intake during scarcity period. Crop residue storage technology was the highest adopted (69%) either unprocessed (63%) or processed (chopped 4%) and ranked second in quantity (4730kg) conserved in both dry and ensiled form, the same findings were reported in the previous studies (Boote *et al*., 2022; Balehegn *et al*., 2022). Storage could be the most preferred option for being readily available, cheap and easy to use (Balehegn *et al*., 2020). Some farmers are doing very well with it despite being low quality like hay through further preparation; chopping and shredding for storage, ensiling, supplementation and urea treatments, all aiming at improving the quality of the material conserved for a better outcome (Kashongwe *et al*., 2017; Balehegn *et al*., 2022).

Hay was the second most adopted technology, with fluctuating quantities of fodder conserved, a technology farmers prefer to have utilized due to its convenience and ease of storage rather than its nutritional impact (low quality) thus the need to improve its quality (Maleko *et al*., 2017). The bulk of the conserved hay was baled hay, others were conserved as standing hay, chopped and dry straw storage, the results which resemble Omollo, (2017). Despite hay contributing much to the dairy diet up to 80% of the dry matter it has low crude protein and other nutrients and hay quality was among farmers' concerns. The concern from farmers includes the presence of foreign materials in commercial hay fodder and low quality, probably due to late harvesting of fodder to optimize biomass and not considering quality, the results which were also reported by Ndambi *et al*., (2020).

### 3.5 Conclusion and Recommendation

Land on food crops was important in contributing to fodder conserved through crop residue storage, lowering the total fodder conserved when used only during scarcity. Large land size, herd size, long duration of using the conserved fodder and use of hay-silage technologies combined enhance fodder conservation. Farmers, therefore, are adviced to strengthen the availability of production resources (land and herd size), adding more chances of more fodder conservation. However, the use of conserved fodder only during scarcity should shift to focus all year use and improve the quantity of fodder conserved. Silage and hay technologies were the most influential to the fodder conserved. This means farmers using silage and hay technology impact the conserved fodder. Therefore, fodder conserved largely depends on technology adoption which is an important step towards improving productivity. The technology option of fodder conservation will hasten productivity improvement and the achievement of government objectives. Therefore, to enhance fodder conservation government could need to subsidies mechanization costs, sensitization grants and means to lower expensive production resources and inputs. There is a need for capacity building and government tax relief, especially concerning fodder production and conservation to lower the breakeven point and attract more people to invest.

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# CHAPTER FOUR

# DETERMINANTS OF FODDER CONSERVATION TECHNOLOGIES IN SMALLHOLDER DAIRY FARMING SYSTEMS IN (PERI-) URBAN HIGHLANDS OF EASTERN KENYA

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**Abstract**

Mitigation of fodder scarcity through fodder conservation remains low in Kenya, especially in urban locations (UL) due to limited production resources. Information scanty on the use of fodder conservation technologie in the urban highlands. In this study, we investigated the determinants of fodder conservation technologies among smallholder dairy farming systems in the peri (urban) highlands and midlands of Tharaka-Nithi County, Kenya. A cross-sectional survey was conducted among smallholder dairy farms (n=161) in ULin Chuka Sub-County (n=68) and peri-urban locations (PUL) in Mara Sub-County (n=93) in Tharaka Nithi County. Information collected includes; socio-demographics, farm characteristics and fodder conservation characteristics. Chi-square and T-test were used to determine the relationship between the categorical and continuous variables respectively. Logistic regression models were used to explain the determinants of the fodder conserved. Farms in UL, therefore, had more male-headed farms, more university-educated, self-employed, informal milk markets, heifers and high milk prices, conserved silage more using silos and buy less fodder during dry season relative to PUL farms. The quantity of fodder conserved in the three fodder conservation technologies was influenced by different variables either positively or negatively; Silage conservation being influenced significantly and positively by; farm location, land size, total milk yield per farm, sex and extension services, but negatively influenced by conserved fodder as the main option of fodder source during feed scarcity. Hay conservation being influenced significantly and positively by; total land size, herd size and period the current stock were expected to last and keeping of the Ayrshire breed, but negatively influenced by the use of concentrate feeds. While crop residue storage being influenced significantly and positively by; the period current stock were expected to last and the keeping of other breed, but negatively influenced by the use of fodder trees as the source of fodder during scarcity. The study, therefore, concludes that the utilization of silage increases with an increase in knowledge and urban development. The findings provide information for planning urban farming policies and frameworks on agricultural practices, food and nutrition security, especially with the challenges of climate change and feed scarcity.

**Keywords:** Crop residue storage, hay, silage, highlands and midlands, socio-economic factors, dry season, fodder scarcity

### 4.1 Introduction

Dairy production sustains the livelihoods of 1.8 million households regarding food and income and contributes about 4% of the Gross Domestic Product in Kenya. The annual total national milk production was 5.52 Million metric tons in 2021 (FAO, 2022). The high production of milk is triggered by the increasing demand due to the increase in population, urbanization and high per capita consumption of about 110 liters of which 74% come from dairy cattle (KDB 2019; FAO, 2023). Dairy cattle production mainly involves mixed crop-livestock (MCL) production systems using exotic breeds and crossbreeds (Bonilla *et al.,* 2018). Dairy farms in the highlands use stall feeding due to reduced land size, as a result of a growing population and rural-urban migration (GOKa 2017). Feed quality and quantity limitations, especially protein and energy deficiency contribute to low productivity i.e. about seven liters/cow/day, of the exotic breeds, against a potential of up to 30 liters in Kenyan conditions (Mudavadi *et al.,* 2020; Migose, 2020). Feed limitation is aggravated by rainfed fodder production and increasing climate change effects such as drought.

Dry season fodder scarcities because of low adoption of fodder conservation technologies that provide quality fodders, common because and availability is, therefore, seasonal with abundance during rainy seasons and scarcity during dry seasons, especially under erratic rainfall and changing climatic conditions (Ndambi *et al.,* 2020; Radeny *et al.,*2020). Adoption of various fodder conservation technologies (hay and silage) are recommended for use to mitigate scarcities during dry season, however, the adoption remains low with about 37% of farms adopting the technologies (Lewa & Muinga, 2015). Besides, the quantities conserved are often inadequate to last the dry season while some fodder conservation technologies also result in conserved fodders of low quality due to technological and or financial or resource challenges among others (Bonilla *et al.,* 2018).

Dairy production is increasing in urban locations (UL) and peri-urban locations (PUL) because of large and reliable informal milk markets with favorable prices for milk, which are expected to trigger high conservation of quality fodder. Urban areas have developed access roads and electricity, which are expected to ease access and reduce costs of other inputs such as concentrate feeds and services like veterinary care and artificial insemination (Migose *et al.,* 2018; Aranguiz & J., 2019). Limited resources, specifically land and labour, for fodder production are expected to trigger relatively high fodder conservation (Aranguiz & J., 2019; Desta, 2022). Silage and hay fodder conservation technologies are promoted to enhance access to feeds during dry seasons in the urban and peri-urban highlands of Kenya (Auma *et al*., 2018; Balehegn *et al.,* 2022). Urban and peri-urban farms in the highlands of Kenya, therefore, are expected to conserve fodder in large quantities compared to farms in the midlands and rural areas, which have relatively larger access to land for pasture production and or grazing (Aranguiz & J., 2019; Ngetleh *et al.,* 2023). Silage is often stored in-ground pits, silos, polythene tubing and plastic or metallic containers while bales and loose straws are the preferred method for hay storage (Balehegn *et al.,* 2020). Storage of crop residues (straws, stovers and husk or hulls) in relatively large quantities after harvesting of the main crops (wheat, rice, maize and legumes) is a common practice among smallholder farms in MCL systems. Crop residues, however, are of low quality, sometimes chopped or shredded and stored in sacks or fortified with maize germ, molasses and ensiled to enhance quality (Aranguiz & J., 2019; Balehegn *et al.,* 2020). The rate and intensity of adoption of such technologies depend on several factors: access to technology, knowledge and skills, resource availability and returns on investment (Ngetleh *et al.,* 2023).

Farmers get new technologies, through extension and other trainings which are provided by the government, research institutions, development agencies and dairy cooperatives or groups (Istaitih *et al.,* 2023). Membership in dairy cooperatives or groups improves service provision to farmers which includes; access to credit, inputs and output market and extension services in topics including methods and technologies for fodder conservation. Therefore, members of dairy cooperatives are expected to adopt fodder conservation technologies and conserve more fodder than non-members (Aranguiz & J., 2019; Balehegn *et al.,* 2022). Government and development agencies, in addition, conduct training for farmers and sometimes support the acquisition of new technologies such as silage tubes and box balers (KCSAIF, 2018). Resource endowment facilitates the adoption of farm technologies and resourced-endowed farmers are likely to conserve hay or silage in large quantities (Birhanu *et al.,*2017; Bonilla *et al.,* 2018).

The level of development in a markets (dairy inputs and milk) with limiting production resources such as land and labour in UL influence the adoption of dairy technologies including fodder conservation technologies in peri-urban and rural locations (Migose *et al.,* 2018; Istaitih *et al.,* 2023). The UL areas with good quality markets for inputs and milk are expected to trigger higher adoption of silage and hay than peri-urban locations. Information is scanty on the levels and intensity as well as the determinants of the adoption of fodder conservation technologies in UL and PUL in the highlands and midlands of Kenya. The objective of the present study, therefore, was: To determine the use of fodder conservation technologies among smallholder dairy farms in the peri (urban) highlands of Tharaka-Nithi County, Kenya.

## 4.2 Materials and Methods

### 4.2.1 Study Area

A cross-sectional survey was conducted in Tharaka Nithi County, Kenya. The county has five sub-counties: Tharaka North, Tharaka South, Igambang'ombe, Maara and Chuka. Chuka Sub-county has a population density of 90,520 while Maara Sub-county has a population density of 114,734 (KNBS, 2019). However, Chuka town had a high urban population of 19,574 also called urban location (UL) compared to Chogoria town with 6,842 urban population also called peri-urban location (PUL) in Tharaka Nithi County (GoKb 2017; KNBS, 2019).

The sub-counties fall in diverse agro-ecological zones; Igamban'gombe, Maara and Chuka are in the highlands and midlands while Tharaka North and Tharaka South are on the lowland and the arid and semi-arid zones. The highland and midland zones receive moderate and reliable annual bimodal rainfall (up to 2200 mm). Long rains fall between April, May and June followed by a cold and dry season in July, August and part of September. Short rains fall between October, November and December and are followed by hot and dry seasons in January, February and March. The temperature ranges between $14^0$C and $30^0$C. These climatic conditions favor dairy farming in MCL production systems using exotic cattle breeds and crossbreeds (GOKb 2017). Intensive and semi-intensive systems are used and fodder production is rainfed, mainly, Napier grass (*Pennisetum purpureum*) fed fresh or wilted (Radeny *et al.,*2020). Excess fodders are conserved for dry season use but hay and silage conservation are relatively low (Kogo *et al.,* 2022). Farmers also purchase hay and silage for conservation and use throughout the year or during the dry season.

Markets or urban centers (towns) develop along the Meru-Nairobi highway within the County. Public institutions, such as Chuka University and Hospital, Chogoria College and Chogoria Hospital contribute to urban development and further attract non-farming populations within these centers. The infrastructure in urban and peri-urban is fairly developed with the availability of local amenities, such as piped water, electricity and tarmac. Dairy farming is common in UL and PUL with quality markets for milk, concentrate feeds as well as veterinary inputs and services (Migose *et al.,* 2018). The population increases and grows the demand for food providing room to increase dairy production (Boote *et al.,* 2022). Production resources (land and labor) for fodder production are limited in urban and hence fodder scarcity in urban remains a concern.

### 4.2.2 Sampling

A multistage random sampling procedure was used to select smallholder dairy farms. Farms that had at least one lactating or dry cow and conserved fodder were considered and those that had more than 5 lactating cows were omitted. Chuka and Maara Sub-Counties were chosen purposively to represent urban and (peri)-urban locations respectively due to the relatively high number of urban dwellers. Farms were stratified within villages and wards (Table 5). Within each sub-county, 6-8 wards that were within the (peri) urban were selected and within each ward, 1 to 15 villages were randomly picked. Within each village, snowball chain referral was used to select between 1 to 8 farms. Chogoria and Ganga wards had 12 villages while Karingani had 15 villages, the rest had 1-2 villages per ward. A total of 161 farms were selected; 68 around Chuka town and 93 around Chogoria town).

Table 5. Farms selected for the study in UL and PUL

| **Wards in Chuka** | **Sampled farms** | **Wards in Maara** | **Sampled farms** |
|---|---|---|---|
| Karingani | 39 | Chogoria | 43 |
| Mitheru | 15 | Kanga | 35 |
| Mugwe | 14 | Mitheru | 5 |
| | | Mwimbi | 3 |
| | | Muthambi | 7 |
| **Total** | **68** | | **93** |

### 4.2.3 Data Collection

Semi-structured questionnaires in Kobo collect were used to collect data. Data were collected on demographic and socioeconomic characteristics (sex, age, education level, the main occupation of the household head, extension access and membership to a dairy cooperatives or groups, milk marketing); farm characteristics (such as land size, herd size, breeds, feed intake, concentrate supply and milk yield) and fodder conservation (fodder type, fodder conservation technologies, methods of technology application and quantity of fodder conserved). Farmers were asked to recall information on milk production and feed usage during the data collection period, including the expected duration of conserved fodder and experiences with fodder scarcity. Practices during the dry season and fodder scarcity. Data were collected between July and August 2021, which was a dry season and expected to have limited availability of quality forage at farmlands and an abundance of conserved fodder. Approval to collect data was granted under license No. NACOSTI/P/21/11411.

### 4.2.4 Data Analysis

Data were categorized into Urban Locations (UL) and Peri-urban Locations (PUL) for comparison, differentiating between farms situated in urban and peri-urban respectively (Table 6). Data were initially converted into universal standards: herd size according to Tropical Livestock Unit, i.e. 1 TLU = 250 kg (Rothman-Ostrow *et al.,*2020), where lactating, dry cows and bulls (above 2 years) 400 kg, heifers (1-2 years) 200 kg, after weaning (4-12 months) 100 kg and calves (under 4 months) 50 kg. The land size was 2.5 acres equivalent to 1 hectare (ha). Land on fodder and food crops included land within and outside the urban location (owned or rented). Milk yield per farm (kg/farm/day) and per cow (kg/cow/day) were calculated by dividing milk yield per herd per day by the total number of lactating and dry cows. The price of milk was in Kenya Shilling (KES/kg). Quantities of fodder conserved were calculated as the total amount available (stored) for use during the season (tons/farm/season). Fodder supply (kg/cow/day) was calculated as the total feed given per herd per day divided by the herd size, while concentrate intake was quantity given by the number of lactating cows (kg/cow/day). Variables were created for the various analyses. Shapiro-Wilk was used to test for normality of residuals and linearity of variables while the distribution of variables was tested using scatter plots and Q-Q plots before analysis.

Table 6. Variables fitted in the regression model to explain the determinant of fodder cultivation and fodder conservation technologies

| **Variable** | **Variable** | **Levels** | **Measurement /response levels** |
|---|---|---|---|
| Age | Numeric | N/a | Age of household head (years) |
| Sex | Categorical | 2 | Sex of household head (1=Female, 2=Male) |
| Education | Categorical | 4 | Education of household head (1=Primary, 2=Secondary, 3= College, 4 = University) |
| Occupation | Categorical | 4 | Main occupation of household head (1=Casual, 2=Farming, 3=Formal employment, 4=Self-employed) |
| Extension service | Categorical | 2 | Attending at least one education session on fodder conservation by the (1=Yes, 0=No) |
| Land size | Numeric | N/a | Land on crops and fodder (ha) |
| Herd size (TLU) | Numeric | N/a | Number of cows, lactating, dry, heifers and weaners and calves in TLU |
| Breed | Categorical | 3 | Breed of cattle kept (1 = Friesian, 2 = Ayrshire, 3 = Friesian and Ayrshire, 4 = Other breeds[1]) |
| Fodder supply | Numeric | | Feed intake (kg/cow/day) |
| Concentrate feeds | Numeric | | Concentrate feeds (kg/cow/day) |
| Milk yield (cow) | Numeric | | kg/cow/day |
| Milk yield (farm) | Numeric | | kg/farm/day |
| Fodder scarcity | Categorical | 2 | Experienced feed scarcity (1=Yes, 0=No) |
| Fodder source during scarcity | Categorical | 3 | Fodder source during scarcity 1= Buy, 2 = fodder tree and 3 = conserved fodder |
| Period to use conserved fodder | Categorical | 2 | Period of use of conserved fodder (1= during dry period, 2 = all year) |
| Fodder duration | Numeric | N/a | Period expected to use conserved fodder (Month) |
| Membership | Categorical | 2 | Membership to dairy cooperative or group (1=Yes, 0=No) |
| Milk market | Categorical | 2 | Milk marketing channel (1= Informal, 2= Formal) |
| Milk price | Numeric | N/a | Price of milk/liter in Kenya shillings (KES) |

[1] Jersey, Guernsey and crossbreed between exotic breeds or between exotic and Zebu.

Chi-square and Fisher's exact tests were used to compare the categorical variables (education, gender, dairy group membership, occupation, extension service, cattle breed, fodder scarcity, fodder availability, milk market and farm location) at $P \leq 0.05$). An independent t-test was used to compare means between UL and PUL for continuous variables (age, total land, land on fodder, herd size, fodder supply, concentrate intake, milk yield and fodder duration). The proportion of farms adopting different fodder conservation technologies was used to determine the adoption levels. The intensity of adoption was determined based on the quantities of fodder conserved using the three different technologies: silage, hay and crop residue storage.

Adoption of technology is a binary variable (1 if adopted or 0 otherwise), however, due to technology constraints and benefits which include the difference in the quality of the conserved fodder, inadequate access to extension services and limited production resources among others, farmer's adoption of one technology therefore, could be conditional to the adoption of the other technologies either as substitute or complementary. This means a farmer chooses either one or multiple fodder conservation technologies, hence different choices and adoption intensity of the technologies.

Unlike the univariate logit and probit model which is based on one technology without factoring in the adoption interdependence of the technologies. The multivariate Regression (MVR) model was used to identify and estimate simultaneously the determinants of smallholder farmers' adoption of fodder conservation technologies, where the interdependence between the technologies in the study is assumed. The adoption of fodder conservation technologies is a latent variable determined by observed characteristics and random error components distributed as a multivariate normal distribution with zero mean and unitary variance. The model assumes data linearity, normality of the residuals and homoscedasticity. All statistical analysis was performed using Stata software Release 15.

In a multivariate regression with multiple dependent variables, each dependent variable has its regression equation. In this case, we have three dependent variables *Y1, Y2 & Y3* (silage, hay & crop residue storage) and p independent variables *X1, X2…Xp*. Each dependent variable (*Yi*) can be predicted with an equation that involves all the independent variables (age, sex, education, occupation, …).

The multivariate regression model can be represented as:

$$Y = X\beta + \varepsilon \text{……………………………………………….}(Eq\ 4.2.1)$$

where:

- $Y$ is the n×k matrix of dependent variables (with n observations and k outcomes),
- $X$ is the $n\times(p+1)$ matrix of independent variables (with $p$ predictors plus an intercept),
- $B$ is the $(p+1)\times k$ matrix of regression coefficients (each column corresponds to a different dependent variable),
- $E$ is the n×k matrix of errors (one for each observation-outcome pair).

**Expanded Equation**

For each dependent variable $Y_j$ (where $j=1,2$ & $3$), the regression equation looks like this:

$$Y_j = \beta_{0j} + \beta_{1j}X_1 + \beta_{2j}X_2 + \cdots + \beta_{11j}X_{11} + \varepsilon j \text{ ………………………..... } (Eq\ 4.2.2)$$

where:

- $\beta_{0j}$ is the intercept for the *j-th* dependent variable,
- $\beta_{ij}$ (for $i=1,2\ldots,p$) represents the effect of $Xi$ on $Y_j$,
- $\varepsilon j$ is the error term for $Y_j$.

## 4.3 Results

### 4.3.1 Farmer characteristics

Farmers (household heads) were younger in UL than in PUL (Table). Sex, occupation of the household heads and milk market differ between UL and PUL. Males head most dairy farms in both UL and PUL, however, males dominate UL compared to more females in PUL. A larger proportion of farms in urban locations (UL) market their milk through informal channels compared to the most common formal channels used in peri-urban locations (PUL). The education level of the household head, access to extension services, breeds of cattle kept and membership in dairy cooperatives did not differ between UL and PUL.

Table 7. Mean ± SD and proportions (%) of farmers having different characteristics and conserving fodder in urban (UL) and Peri-urban (PUL) of Tharaka Nithi County

| **Variable** | **Categories** | **UL (n=68)** | **PUL (n=93)** | |
|---|---|---|---|---|
| ***Continuous*** | | ***Mean (SD)*** | ***Mean (SD)*** | ***T-test*** |
| Age (Year) | None | 49.63 ± 13.7 | 53.8 ± 13.8 | 0.061* |
| ***Categorical*** | | ***(%)*** | ***(%)*** | $X^2$ |
| Sex | Female | 29.4 | 45.2 | 0.043** |
| | Male | 70.6 | 54.8 | |
| Education | Primary | 41.2 | 43.0 | 0.050* |
| | Secondary | 29.4 | 36.6 | |
| | College | 16.2 | 18.3 | |
| | University | 13.2 | 2.2 | |
| Occupation | Casual labor | 2.9 | 5.4 | 0.047** |
| | Farming | 73.5 | 81.7 | |
| | Formal employment | 10.3 | 10.8 | |
| | Self-employed | 13.2 | 2.2 | |
| Membership[1] | Yes | 77.9 | 87.1 | 0.125 |
| | No | 22.1 | 12.9 | |
| Milk market | Formal milk market | 59.1 | 93.8 | <0.001*** |
| | Informal market | 40.9 | 6.2 | |

*** $P < 0.01$, ** < 0.05 and * < 0.1. [1] Membership to dairy groups or cooperatives

### 4.3.2 Farm Characteristics

Total land (ha), land on food crops and fodder crops did not differ between UL and PUL (Table 8). Total herd size and number of heifers were larger in UL than in PUL while the number of lactating cows did not differ between UL and PUL. Fodder supply, concentrate intake and milk yield per farm and per cow did not differ between UL and PUL. Milk price (KES) was higher in UL than in PUL.

Table 8. Means ± SD for selected variables that describe farm characteristics in urban (UL) and Peri-urban (PUL) of Tharaka Nithi County

| **Variable** | **UL (n=68)** | **PUL (n=93)** | **T. Test** | **P-value** |
|---|---|---|---|---|
| Total land (ha) | 0.6 ± 0.5 | 0.7 ± 0.5 | -0.144 | 0.707 |
| Land on food crop | 0.4 ± 0.5 | 0.4 ± 0.4 | 0.068 | 0.722 |
| Land on fodder crop | 0.3 ± 0.3 | 0.3 ± 0.3 | 0.593 | 0.313 |
| Total herd size (TLU[1]) | 7.1 ± 4.9 | 5.5 ± 3.8 | 2.266 | 0.065* |
| Lactating cow | 3.1 ± 2.5 | 2.9 ± 1.9 | 0.552 | 0.632 |
| Heifer | 0.9 ± 0.9 | 0.6 ± 0.7 | 2.893 | 0.004** |
| Fodder supply (kg/cow/day) | 39.3 ± 11.9 | 42.2 ± 9.5 | -1.768 | 0.079* |
| Concentrate intake (kg/cow/day) | 4.1 ± 4.0 | 4.0 ± 2.2 | 0.254 | 0.800 |
| Milk yield (kg/farm/day) | 19.2 ± 24.6 | 17.2 ± 17.9 | 0.627 | 0.532 |
| Milk yield (kg/cow/day) | 8.7 ± 5.1 | 8.1 ± 5.6 | 0.693 | 0.489 |
| Milk price (KES) | 42.4 ± 3.8 | 41.1 ± 2.2 | 2.826 | 0.005** |

$^{***}$ $P < 0.01$, $^{**} < 0.05$ and $^{*}<0.1$

[1] Tropical Livestock Unit, i.e. 1 TLU = 250 kg, cow – 400 kg, heifers – 200 kg, after weaning – 100 kg and calves – 50 kg.

### 4.3.3 Adoption level and intensity of fodder conservation technologies

**Levels of adoption**

Farmers conserve silage more in UL than in PUL (Table 9). Farms using silo and container silage vary between locations while Polythene lined pit and plastic tubing methods did not differ. Farmers conserving hay and crop residue storage in both locations did not differ. Methods of hay and crop residue conservation did not differ, except for farms using baled hay which was higher in UL than PUL. Crop residue storage was the major fodder used in both UL and PUL, majorly conserved as stovers (maize stalks), except in a few farms being chopped and fortified. The proportion of farms that purchased fodder during the dry season was less in UL than in PUL. Fodder scarcity was experienced in both locations. Purchased fodders were less used in UL relative to PUL and in addition, fodder trees and conserved fodders were the other common sources of fodder used in both locations during the scarcity. The majority of farmers in both locations used conserved fodder throughout the year, more so in PUL, while few farms feed conserved fodder only during periods of scarcity (mostly dry season).

Table 9. The proportion of farms (%) using different methods of fodder conservation technologies in urban (UL) and Peri-urban (PUL) of Tharaka Nithi County (levels of adoption)

| **Variables (Technology)** | **UL (n=68)** | **PUL (n=93)** | ***P*-value** |
|---|---|---|---|
| *Silage* | *29* | *13* | *0.010*** |
| Polythene lined pit | 11 | 10 | 0.746 |
| Silo | 8 | 1 | 0.044** |
| Plastic tubing | 7 | 4 | 0.503 |
| Container | 4 | 0 | 0.080* |
| *Hay* | *43* | *40* | *0.715* |
| Baling | 26 | 15 | 0.066* |
| Loose | 18 | 22 | 0.498 |
| Standing hay | 7 | 3 | 0.302 |
| *Crop residue* | *63* | *67* | *0.652* |
| Stovers | 60 | 65 | 0.495 |
| Chopped and fortified stovers | 4 | 3 | 0.253 |
| Fodder scarcity | 71 | 69 | 0.815 |
| Buy fodder in the dry season | 75.0 | 93.8 | 0.005** |
| Use fodder trees | 77.1 | 82.8 | 0.450 |
| Use conserved fodder | 97.9 | 98.4 | 0.837 |

*** $P < 0.01$, ** < 0.05 and *<0.1

[1] Farms could use more than one method of conservation technologies.

**Intensity of adoption**

The quantity of fodder conserved as silage and hay as well as the period the conserved fodder was expected to last did not differ ($P < 0.05$) between UL and PUL (Table 10). However, silage, hay and period the conserved fodder was expected to be used was higher ($P < 0.1$) at UL relative to PUL. The quantity of crop residue conserved and the total quantity of fodder conserved did not differ.

Table 10. Conserved fodder (tons/season) and expected duration of use

| Variable | UL (n=68) | PUL (n=93) | T-Test | *P*.value |
|---|---|---|---|---|
| Silage (ton/farm/season) | 10.2 ± 9.1 | 5.9 ± 5.9 | 0.760 | 0.065* |
| Hay (ton/farm/season) | 2.0 ± 3.2 | 0.9 ± 0.8 | 1.772 | 0.068* |
| Crop residue storage (ton/farm/season) | 2.3 ± 2.6 | 5.3 ± 6.8 | -1.162 | 0.231 |
| Total fodder (ton/farm/season) | 5.1 ± 7.3 | 4.6 ± 4.1 | 0.255 | 0.799 |
| Duration of conserved fodder (month) | 3.6 ± 4.2 | 2.6 ± 2.3 | 1.893 | 0.058* |

$^{***}$ $P < 0.01$, $^{**}$ < 0.05 and *<0.1

### 4.3.4 Determinants of fodder conservation technology intensity in UL and PUL

The study findings demonstrate that the quantity of fodder conserved was determined by different variables for the three fodder conservation technologies (*Eq. 4.3.3*).

**Evaluated equation**

$$Y_j = \beta_{0j} + \beta_{1j}X_1 + \beta_{2j}X_2 + \cdots + \beta_{11j}X_{11} + \varepsilon j \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq. 4.3.3)}$$

$Y_j$ = (Intercept*-0.036*-0.149*-0.076) + (farm location*0.351) + (total land*0.175*0.160) + (herd size*0.420) + (milk yield per farm*0.282) + (sex*0.308) + (source of fodder during feed scarcity -0.701*-0.582) + (period the current stock expected to last*0.246*0.247) + (concentrate feeds*-0.135) + (breed kept*-0.510*1.280) + (extension services*0.357).

Silage conservation was significantly and negatively influenced by fodder source during feed scarcity and extension services ($P < 0.05$). In addition farm location, land size, total milk yield per farm and sex were important at $P < 0.1$. Hay conservation was significantly determined by; total land size, herd size, period the current stock is expected to last $P < 0.05$ and additionally, use of concentrate feeds and breed kept was important at $P < 0.1$. While crop residue storage was significantly ($P < 0.1$) determined by; the period current stock is expected to last and breed kept.

Farm location had a positive association with silage conservation ($P < 0.1$). The positive relationship implies that compared to being in PUL being in UL increases the intensity of silage conservation by 35%. Total land had a positive association with silage ($P < 0.1$)

and hay ($P < 0.05$) conservation, the result which implies that an increase in land size per unit (Ha) increases the quantity of conserved silage by 18% and hay by 16%. Total herd size had a strong positive association with hay conservation, the results imply that an increase in herd size per unit (TLU) increases the quantity of conserved hay by 42%. Breeds kept had a positive influence on both hay and crop residue conserved, the relationship implies that keeping of only the Ayrshire breed ($P < 0.1$) increases hay conservation by 51% compared to keeping only Friesian breeds. It also means keeping other breeds also increases the hay ($P < 0.1$) by 70% and crop residue storage ($P < 0.05$) and by 128% respectively.

Total milk yield per farm had a positive ($P < 0.1$) association with silage conservation, which imply at an increase in total milk yield per unit (kg/farm/day) increases the quantity of conserved hay by 28%. The expected period that the current conserved fodder will last had a positive association ($P < 0.05$) with the quantity of conserved hay and crop residue storage. The results imply that a unit increase in the period (month) the conserved fodder is expects to last increases quantity of fodder conserved both in hay and crop residue each by 25%. Concentrate feeds used daily had a negative influence ($P < 0.1$) on the conservation of hay. The result implies that an increase in concentrate feeds used daily per unit (kg/cow/day) reduces the chance of hay conservation by 14%.

Tree leaves use as a main source of feed during scarcity had a negative influence ($P < 0.05$) on crop residue storage. The relationship which implies that use of tree leaves as the main source of feed during feed scarcity reduces the conserved crop residue by 58%. While a unit (farm) increase in the use of conserved fodder as the main source of fodder during feed scarcity reduces the use of silage by 70%. The sex of a farmer heading dairy production had a positive influence ($P < 0.1$) the quantity of silage conserved. The positive relationship implies that compared to female-headed farms male headed farm increases the silage conserved by 31%. Access to extension service had a positive influence ($P < 0.05$) on the conservation of silage. The relationship implies that unit access to extension service increases the quantity of silage conserved by 36%.

Table 11. Determinants of fodder conservation technologies (silage, hay and crop residue storage) used in urban locations (UL) and Peri-urban (PUL) of Tharaka Nithi County

| | Silage | | | | Hay | | | | Crop residue | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Coef.** | **S. E** | **t** | **P>t** | **Coef.** | **S. E** | **t** | **P>t** | **Coef.** | **S. E** | **t** | **P>t** |
| UL | 0.351 | 0.203 | 1.73 | **0.086*** | 0.104 | 0.173 | 0.6 | 0.551 | -0.210 | 0.196 | -1.07 | 0.287 |
| Age | -0.157 | 0.097 | -1.62 | 0.108 | -0.067 | 0.083 | -0.8 | 0.424 | 0.005 | 0.094 | 0.05 | 0.96 |
| Total land (ha) | 0.175 | 0.094 | 1.86 | **0.065*** | 0.160 | 0.080 | 1.99 | **0.048**** | 0.048 | 0.091 | 0.53 | 0.598 |
| Herd (TLU) | -0.130 | 0.136 | -0.95 | 0.342 | 0.420 | 0.116 | 3.62 | **0.000***** | -0.030 | 0.132 | -0.23 | 0.82 |
| Total milk (kg/farm/day) | 0.282 | 0.164 | 1.72 | **0.087*** | -0.068 | 0.140 | -0.49 | 0.627 | -0.113 | 0.159 | -0.71 | 0.479 |
| Milk productivity (k/cow/day) | -0.129 | 0.123 | -1.05 | 0.296 | 0.003 | 0.105 | 0.03 | 0.979 | 0.119 | 0.119 | 1 | 0.319 |
| Price of milk per liter | -0.024 | 0.094 | -0.26 | 0.797 | 0.014 | 0.080 | 0.18 | 0.857 | -0.014 | 0.091 | -0.16 | 0.877 |
| Expected f. period (months)[1] | -0.070 | 0.092 | -0.76 | 0.45 | 0.246 | 0.079 | 3.13 | **0.002**** | 0.247 | 0.089 | 2.77 | **0.006**** |
| Feeds intake kg/cow/day | -0.105 | 0.089 | -1.18 | 0.242 | 0.105 | 0.076 | 1.37 | 0.172 | 0.100 | 0.087 | 1.16 | 0.249 |
| Concentrate feed kgs/cow/day | -0.090 | 0.088 | -1.02 | 0.31 | -0.135 | 0.075 | -1.79 | **0.075*** | 0.050 | 0.085 | 0.58 | 0.563 |
| Male | 0.308 | 0.180 | 1.71 | **0.089*** | 0.105 | 0.154 | 0.68 | 0.495 | 0.199 | 0.174 | 1.14 | 0.256 |
| No formal education | 0.107 | 0.552 | 0.19 | 0.846 | 0.298 | 0.471 | 0.63 | 0.529 | 0.011 | 0.534 | 0.02 | 0.984 |
| Secondary | -0.017 | 0.205 | -0.08 | 0.935 | 0.171 | 0.175 | 0.98 | 0.329 | -0.098 | 0.198 | -0.5 | 0.62 |
| College | -0.163 | 0.259 | -0.63 | 0.532 | 0.000 | 0.222 | 0 | 0.999 | -0.293 | 0.251 | -1.17 | 0.246 |
| University | -0.233 | 0.381 | -0.61 | 0.543 | -0.067 | 0.326 | -0.21 | 0.837 | -0.165 | 0.369 | -0.45 | 0.656 |
| Casual Labour | -0.327 | 0.439 | -0.74 | 0.458 | -0.230 | 0.375 | -0.61 | 0.541 | 0.113 | 0.425 | 0.27 | 0.791 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Formal employment | -0.120 | 0.326 | -0.37 | 0.713 | 0.184 | 0.278 | 0.66 | 0.509 | 0.203 | 0.316 | 0.64 | 0.521 |
| Self-employed | -0.218 | 0.346 | -0.63 | 0.531 | 0.037 | 0.296 | 0.13 | 0.9 | -0.286 | 0.335 | -0.85 | 0.396 |
| Membership_yes | -0.149 | 0.261 | -0.57 | 0.568 | -0.076 | 0.223 | -0.34 | 0.733 | -0.075 | 0.252 | -0.3 | 0.767 |
| Ayrshire | -0.072 | 0.322 | -0.22 | 0.824 | 0.510 | 0.275 | 1.85 | **0.066*** | 0.146 | 0.312 | 0.47 | 0.64 |
| Fresian/Ayshire | -0.192 | 0.182 | -1.05 | 0.295 | -0.150 | 0.156 | -0.96 | 0.338 | 0.277 | 0.177 | 1.57 | 0.119 |
| Other and cross-breeds | -0.382 | 0.453 | -0.84 | 0.401 | 0.701 | 0.387 | 1.81 | **0.072*** | 1.280 | 0.439 | 2.92 | **0.004**** |
| Farm gate | 0.122 | 0.205 | 0.6 | 0.552 | -0.026 | 0.175 | -0.15 | 0.881 | -0.031 | 0.198 | -0.16 | 0.874 |
| Main fodder source in scarcity | | | | | | | | | | | | |
| Buy from other farmers | 0.205 | 0.281 | 0.73 | 0.466 | -0.287 | 0.240 | -1.2 | 0.233 | 0.392 | 0.272 | 1.44 | 0.152 |
| Tree leaves | 0.252 | 0.271 | 0.93 | 0.354 | 0.321 | 0.231 | 1.39 | 0.168 | -0.582 | 0.262 | -2.22 | **0.028*** |
| Conserved fodder | -0.701 | 0.345 | -2.03 | **0.044**** | 0.172 | 0.294 | 0.58 | 0.561 | 0.002 | 0.334 | 0.01 | 0.994 |
| Access to extension (yes) | 0.357 | 0.180 | 1.98 | **0.049**** | -0.152 | 0.154 | -0.99 | 0.325 | -0.053 | 0.174 | -0.3 | 0.763 |
| Feed_period | -0.076 | 0.286 | -0.27 | 0.791 | -0.315 | 0.244 | -1.29 | 0.199 | 0.155 | 0.277 | 0.56 | 0.576 |
| cons | -0.036 | 0.341 | -0.11 | 0.915 | -0.149 | 0.291 | -0.51 | 0.609 | 0.076 | 0.330 | 0.23 | 0.819 |

[1] Expected feed. period – refer to the period the conserved fodder is expected to last (months)

*** $P < 0.01$, ** < 0.05 and *<0.1

## 4.4 Discussion

### 4.4.1 Farm and farmer characteristics in UL and PUL in fodder conservation technologies

Fodder scarcity being a big challenge for dairy farming in Kenya and efforts to promote the adoption of fodder conservation technologies such as silage and hay have not brought much fruit. To understand the adoption drivers of fodder conservation technologies and enable the recommendation of appropriate policies for both urban and Peri-urban dairying, the study was necessary. The study aimed to determine the use of fodder conservation technologies among smallholder dairy farms in urban and peri-urban locations in the highlands and midlands of Kenya.

Farmers in UL were younger than PUL, probably as a result of young people migrating to urban for better jobs (Mudavadi *et al.,* 2020; Tulu *et al.,* 2023). Male farmers dominate dairy farming especially in UL probably because of more migration of male and the dominance in control of family resources (Ngetleh *et al.,* 2023). The lack of difference in education and membership between UL and PUL could be a result of the distance covered in the study which was limited by the fund's availability and time. However, a large proportion of farmers have a university education level in UL relative to PUL, probably because most of them migrate to UL for better jobs (Omollo, 2017). Farms members to dairy cooperatives or groups did not differ between UL and PUL, probably because farms in both locations are able to access dairy cooperatives and dairy groups (Omollo, 2017; Desta, 2022). Farming was the major occupation in both locations, with self-employment as the dominant occupation option in UL relative to PUL, probably because of the high population and market opportunity in UL as well as the difference in education and availability of production resources in UL and PUL. While formal market channels dominate the market, the informal milk channel was high in UL relative to PUL, which could simply be because of the high demand for milk in the highly populated markets (Table 7) (KNBS, 2019). Urban location being highly associated with more business opportunities more so in developed urban setups (Ngetleh *et al.,* 2023).

Land size both for crop and fodder production did not differ ($P < 0.05$) which could be because UL and PUL farmers utilized land owned outside the study location, mostly in the lower ecological zone (AEZ) (Van der Lee 2020; Desta, 2022). Lack of difference in herd size ($P < 0.05$) between UL and PUL could be due to the small distance covered by the study. In addition, UL and PUL are still occupied by urban dwellers commuting to nearby towns or organizations, synergized by food and cash crop competition in the location (Van der Lee 2020; Lawrence *et al.,* 2023). However, keeping heifers was significantly high in UL relative to PUL, because heifers are required for continuous stock replacement and probably breed improvement for better production to meet rabid growing informal milk markets. In addition, UL attracts more production due to good milk prices (Table 8) where large herd size was one way to meet high milk demand (Migose *et al.,* 2018; Aranguiz & J., 2019; Ndambi *et al.,* 2020).

Feed intake for both forage feeds and concentrate feeds was low and did not differ, a reflection that the feed scarcity (Table 9) was experienced in both UL and PUL, consequently leading to underfeeding and low productivity of 8 kg/cow/day (Table 8) (Ndambi *et al*., 2020). Milk yield both kg/cow/day and kg/farm/day did not differ between UL and PUL, probably due to the similarities in the two regions including production resources, education and access to extension service. The high milk price in UL could probably be due to high milk demand in the informal milk market relative to PUL as a result of good market quality for milk (Migose *et al.,* 2018).

The proportion of farms adopting silage was significantly higher in UL than in PUL ($P < 0.05$) possibly driven by good milk market in UL (Ngetleh *et al.,* 2023). Hay and crop residue storage did not differ between UL and PUL, explained by the similarities in production resources and probably conservation practices in the two locations. In addition, the methods used to conserve fodder in each technology did not differ, except those conserving silage using silos, an indication that despite the common challenge of fodder scarcity, farmers in UL have adopted better method than farmers in PUL.

The quantity of silage conserved didn't differ between UL and PUL, however, the slight difference could be to supports large herds and sustains high milk yield in UL, aiming at meeting and sustaine the increasing milk demand (Sakwa *et al.,* 2020; Ngetleh *et al.,* 2023). The results further influenced by more university education, additional income from the self-employed farmers, good milk prices from the informal market in addition slightly large herd size and young farmers  in UL1 (Table 7). The findings which were also reported by Ngetleh *et al.,* (2023) that young farmers and better milk prices are likely to influence farmers' decisions to invest in silage. In the present case, UL farms invested more in silos (Table 9), probably because UL farms are more likely to be resource endowed owing to good milk prices. Silo has a large capacity for fodder storage, therefore, could explain silage as the leading in the large quantities stored, required to maintain large herd sizes in UL (Balehegn *et al.,* 2022).

The quantity of conserved hay and methods used did not differ due to similarities in production resources and education levels probably due to the distance covered by the study, limited by finance and duration of the study. The results were out of our expectations that PUL could have conseved more due to less pressure in production resources relative to UL mainly sourced from outside the study location. Specifically, baled hay were the most traded technology due to its ease of handling, storage, quantification and transport expected to be more in UL relative to PUL (Aranguiz & J., 2019; Balehegn *et al.,* 2022).

The quantity of crop residue stored and the methods used to store did not differ between locations, probably because some of the farmers in both locations own land for food crop production outside the study location (Migose *et al.,* 2018). The results which was out of our expectation that land size available for food crop production could be bigger in PUL relative to UL. Crop residue storage was the most common fodder despite being second in the quantity conserved and low to our expectations, probably limited by cash crops and other businesses competition for space within the study sites (Petrikova *et al.,* 2024).

Fodder scarcity was common among farmers despite having adopted fodder conservation technologies an indication of inadequacy in intensity of adoption in both locations (Table 10). The total quantity of fodder conserved did not differ between UL and PUL, however, hay and period expected to use the conserved fodder was slightly high in UL relative to PUL. A high standard deviation on the quantity of fodder conserved could indicate the great variation in fodder conserved and confirmation that few farms could be conserving enough, while others conserve inadequate quantities or are still unable to overcome the challenges and embrace fodder conservation. A smaller proportion of farms in UL purchase fodder during scarcity relative to PUL, a reflection that during scarcity UL relies more on conserved fodder relative to PUL, which could imply more fodder conservation in UL. Farms that use fodder bought from other farms and fodder trees during scarcity did not differ between UL and PUL.

### 4.4.2 Determinants of fodder conservation technology intensities in UL and PUL

Table 11. The study findings demonstrate that the quantity of fodder conserved was determined by different variables for the three fodder conservation technologies. Silage conservation was significantly influenced by the options of fodder source during feed scarcity and extension services ($P < 0.05$) and additionally farm location, land size, total milk yield per farm, sex ($P < 0.1$). Hay conservation was significantly determined by; total land size, herd size, period the current stock were expected to last ($P < 0.05$) and use of concentrate feeds and breed kept ($P < 0.1$). Crop residue storage was significantly determined by; the period the current stock were expected to last, the use of fodder trees as the main fodder source during period of scarcity and breed kept ($P < 0.05$).

Farm location did not differ ($P < 0.05$), however, it had a positive association with silage conservation, which implies that compared to being in PUL, farms in UL increase the intensity of silage conservation. The results associated with large herd size and young farmers in UL than PUL as a result of young people migrating to urban for better jobs (Mudavadi *et al.,* 2020; Tulu *et al.,* 2023). The sex of a farmer heading dairy production did not differ ($P < 0.05$), even though it had a positive influence on the quantity of silage conserved, the relationship which implies that compared to female-headed farms, male-headed farm increases the silage conserved. Male farmers dominate dairy farming especially in UL probably because males being considered bread-winners migrate more than females in such for better jobs and dominate control of family resources as well as decision-making relative to females (Mungai Njugun *et al.,* 2022; Ngetleh *et al.,* 2023). Access to extension service had a positive influence on the conservation of silage, the relationship which implies that an increase in access to service increases the quantity of silage conserved. The results linked to knowledge acquisition in UL through extension and education, however, access to extension service did not differ between UL and PUL (Kogo *et al.,* 2024).

Total land had a positive association with silage and hay conservation, the result which implies that an increase in land size per unit (Ha) increases the quantity of conserved silage and hay. The result reflects that an increase in land allows farmers to plant more fodder and probably the improved varieties that will yield more biomass for conservation. The results are similar to Lukuyu *et al*., (2019) and Sakwa *et al.,* (2020) findings that additional land increases the adoption of improved seeds. Land size did not differ ($P < 0.05$) which could be because UL and PUL farmers utilized land owned outside the study location, mostly in the lower ecological zone (AEZ) were land size is still large (Van der Lee 2020; Desta, 2022). The lack of difference in land used to produce fodder could also be due to the small distance covered by the study. In addition, UL and PUL are still occupied by urban dwellers commuting to nearby towns or organizations, synergized by food and cash crop competition in the location (Lawrence *et al.,* 2023). Total herd size had a positive association with hay conservation, the results imply that an increase in herd size increases the quantity of hay conserved. The results linked to ease of conserving, storing and use of hay in feeding, despite being of poor quality, according to the results by Ndambi *et al.,* (2020).

Total milk yield per farm did not differ ($P < 0.05$), but it had a positive association with silage conservation, which implies that an increase in total milk yield per unit increases the quantity of conserved silage. The results mean that farmers with large herd sizes increase the hay storage (from their farm or source from outside the farm). According to Ndambi *et al.,* (2020), hay were used in bulk but were of poor quantity. Therefore, farms with high milk yield increase the quantity of conserved silage compared to low milk yield farms. The results associated with good feeding with the use of quality silage feeds. In addition, Urban has more informal milk markets and attracts more production due to good milk prices where large herd size was one way to meet high milk demand (Migose *et al.,* 2018; Aranguiz & J., 2019).

Breeds kept had a positive influence on both hay and crop residue storage, the relationship which implies that keeping only the Ayrshire breed increases hay conservation compared to keeping only Friesian breeds. It also means keeping other breeds also increases hay and crop residue storage. The results could be associated with the Ayrshire breed's light feeding nature compared to the Friesian breed, in addition, other breeds including crossbreeds are also not heavy feeders (Lukuyu *et al.,* 2019). Therefore, crop residue and hay are associated with low-quality feeds (Ndambi *et al.,* (2020). Concentrate feeds used daily dint differ ($P < 0.1$), however, it had a negative influence on the conservation of hay the result implies that an increase in concentrate feeds used reduces the quantity of hay conserved, possibly meaning concentrate feeds are being used as a substitute for forage feeds. Sakwa *et al.,* (2020) also reported that energy feeds are being considered as substitutes instead of supplementary feeds.

The period expected the conserved fodder is to last had a positive association with the quantity of conserved hay and crop residue storage. The results imply that a unit increase in period (month) expects the conserved fodder to last increases both hay and crop residue stored. The results imply the impact of hay and crop residue technology on the overal fodder availability period. Contrary to our expectation that silage technology was the highest in the quantity of fodder compared to hay and crop residue storage. The technology was not influenced by the period the conserved fodder were expected to last, probably because of the low adoption of the technology and ensiling maize, Napier grass and crop residue mixture in some farms, as well as inadequate knowledge of the use of fodder conservation technologies (Maina *et al.,* 2019).

The negative relationship in the use of tree leaves implies that a unit increase in the use of tree leaves as the main source of feed during feed scarcity reduces fodder conserved relative to the non users. The tree leaves used as the main fodder during scarcity were mostly fodder trees associated with good nutrition among other non-nutritious plants, therefore, farms that aimed at high production are expected to focus on health feeds which include fodder trees and in contrary reduces the use of poor-quality materials like crop residue (Lukuyu *et al.,* 2019; Makau *et al.,* 2020; Tesfaye, M., & Gutema, P. 2022). While negative influence in the use of conserved fodder as the main fodder during scarcity means a unit increase in the use of conserved fodder during feed scarcity reduces the silage conserved relative to farms with more fodder options. It also reflect the low adoption of fodder conservation technologies. The used of conserved fodder during the period of scarcity was expected to positively contribute to more fodder conservation especially silage as the main fodder during scarcity and with the largest quantity of fodder conserved (Table 10). However, the results probably implies that the few farmers conserving silage were using fodder throughout the year compared to farms conserving fodder using other technologies. Quantity of fodder conserved could also be expected to be motivated by ready market in UL relative to PUL.

### 4.5 Conclusion and Recommendation.

The study compared the fodder conservation characteristics of farms in UL and PUL. We found that the common fodder conservation technologies include silage, hay and crop residue storage. The levels of fodder conservation technology adoption are low in both UL and PUL, as farms still rely on crop residue and fresh Napier grass. Despite the low adoption of fodder conservation technologies, silage was relatively high in UL than in PUL. The quantity of fodder conserved was determined by different variables for the three fodder conservation technologies. Silage conservation was significantly influenced by the options used in the farm as main fodder sources during feed scarcity and access to extension services. Hay conservation was significantly determined by; total land size, herd size and the period the conserved fodder stock was expected to last. While crop residue storage was significantly determined by; the period the current stock were expected to last and breed kept. This means that high production resources and knowledge per farm facilitate and enhance the production and conservation of fodder. The results are summarized as; farms in UL with relatively better urban markets for milk conserves more fodder utilizing better conservation technologies (silage) relative to less developed market PUL. The study concludes that fodder conservation follows dairy development, that is the more developed the dairy sector is the more the utilization of fodder conservation technologies. The overall conservation of silage and hay remains low and additional interventions including; knowledge dissemination and further research on the influence of the market will bridge technological gaps and should be considered to address the factors hindering fodder conservation as a means to mitigate drought and fodder scarcity.

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**Conflict of Interest:** All authors declare no conflict of interest. And that they have read and agreed to the published version of the manuscript

**Authors contribution**: Both authors contributed equally to the task and have reviewed the draft and agreed to publish this version of the manuscript.

**Data Availability:** All relevant data is contained in the paper. Additional information and further explanation can be obtained through the corresponding author when required.

**Compliance with ethical standards**

**Approval:** Data was collected with approval by the National Commission for Science Technology and Innovation (NACOSTI)

**Informed or Participant's consent:** Prior information was passed to individuals expected to participate in the study, through opinion leaders and extension officers

# CHAPTER FIVE

## STRATEGIES OF POSITIVE DEVIANTS IN FODDER CONSERVATION IN SMALLHOLDER DAIRY FARMING SYSTEMS IN HIGHLANDS AND MIDLANDS OF KENYA

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## ABSTRACT

Fodder scarcity and low quality affect the productivity of dairy cattle in Kenya yet only a few smallholder dairy farmers show positive deviance in fodder conservation. Information on the strategies of such positive deviant (PD) farmers is scanty. The objective of this study was to determine strategies that distinguish PDs from peers (non-PDs) in fodder conservation among smallholder dairy farmers in the highlands and midlands of Kenya. A cross-sectional survey was conducted among farms producing and conserving fodder in Tharaka Nithi County. Multistage sampling procedures were used; purposive sampling of the Sub-counties and locations, random selection of villages and proportional selection of 242 farms through snowball chain referral. Data were collected on demographic, socio-economic, farm characteristics and fodder conservation. Farms were categorized as PDs (n=24) or non-PDs (n=97). The PDs conserved fodder adequate to last dry season (about 3 months) and had milk yield 15 kg/cow/day and above, while non-PDs do not qualify for both criteria. Chi-square and T-test were used to analyze categorical and continuous variables respectively. Logit regression was used to examine independent variables that influence the probability of PDs. Farmers with high school and tertiary education who accessed extension services were PDs while non-PDs had non-formal and primary education and access extension less. Farms conserving hay and silage dominated PDs. Land in hectare (ha) and herd sizes in Tropical Livestock Unit (TLU) distinguished PDs (1.7 ha and 9.0 TLU) from non-PDs (0.7 ha and 3.3 TLU). The strategies that distinguished PDs from non-PDs were allocating land to fodder production, high milk yield kg/cow/day, large herd size and access to extension services. Increasing access to extension and resources (land) raised the chances of PDs in fodder conservation. Knowledge of PDs strategies is important for fodder conservation, improving productivity and informing the direction of future research.

**Keywords**: Dry season, farm practices, fodder scarcity, hay, silage, technologies

## 5.1 INTRODUCTION

In Kenya, dairy farming contributes about 4% of the national gross domestic product and provides livelihood, especially in rural households FAO, 2022. Demand for milk and milk products remains high due to the rapidly rising human population, urbanization and rising income, which cannot be met by the current national annual milk production, which was 5,516 thousand tons in 2021 (FAO, 2022). Dairy cattle in smallholder farming systems produce 80% of the national milk output. The systems depend on rain-fed fodder production and fodder scarcity is severe during dry seasons (Radeny *et al.,* 2020; FAO, 2022). Due to the effects of climate change, droughts are intense and frequent and fodder scarcity is prolonged, impacts seen on cow productivity, i.e. milk yield per cow (Migose, 2020; Radeny *et al.,* 2020).

Silage and hay-making, are technologies adopted by farmers to enhance the conservation of adequate and quality fodder (Balehegn *et al.,* 2020). Smallholder farms in the highlands and midlands of Kenya conserve fodder (6 tons) with the largest quantity being maize silage conserved by few farmers (Kogo *et al.,* 2022). Stovers, though of low quality constitute the second-largest quantity of fodder conserved by the majority of the farmers (Auma *et al.,* 2018; Kogo *et al.,* 2022). The government of Kenya through research institutions and development agencies offers farmer extension services; subsidized inputs; low-cost technologies and practices such as the inclusion of quality fodder and fodder trees to the feeds at on-farm research; irrigation water to improve fodder production and marketing (GoKb, 2017; Radeny *et al.,* 2020).

Fodder production and conservation are limited by land and labour scarcity, erratic rainfall, drought and old age as well as inadequate technical knowledge and skills (Auma *et al.,* 2019). Resource-limited farmers are unable to acquire fodder conservation equipment and facilities such as balers, harvesters and fodder stores (Balehegn *et al.,* 2022). Due to the constraints and the way they respond, farmers differ in the adoption of fodder conservation strategies where some farmers are successful, the so-called positive deviants (PDs) while other farmers are unsuccessful farmers, the non-positive deviants (non-PDs) (Habermann, 2023). The PDs conserve adequate quantities of silage and hay of good quality and thus do not have dry-season fodder scarcity due to unique strategies, behaviors and practices in fodder conservation used (Birhanu *et al.,* 2017; Migose, 2020).

Strategies associated with positive deviance in dairy farming include large herd size, high productivity and good market quality. Having more knowledge due to a high level of education or access to extension services and training has also been associated with increased milk production among smallholder dairy farmers (Migose, 2020). Successful farmers seek knowledge, skills and credit facilities (material and equipment) and proper utilization of limited resources (Birhanu *et al.,* 2017; Istaitih *et al.,* 2023). Membership in dairy cooperatives and the willingness to invest in diverse technologies also contribute to the storage of large quantities of fodder. Access to milk markets with relatively high prices for the farmer is also associated with PDs since farmers are motivated to improve behaviors and husbandry practices (Birhanu *et al.,* 2017; Migose, 2020). Practices that enhance fodder conservation include the use of simple equipment such as box balers, well-ventilated and leak-proof roof store for hay and plastic tubes for silage that reduce labor requirements. Other behaviors include baling, chopping and shredding hay to facilitate storage and reduce feed wastage (Balehegn *et al.,* 2020).

A positive deviant approach can be used to analyze the behaviors, productivity and resilience strategies of such farms. PDs approach as a method to analyze constrain and success has been used in various fields (studies) including nutrition, medicine, psychology and evaluating improved feed technologies). The approach is considered more informative than the most commonly reported conventional approaches to studying the adoption and utilization of fodder conservation technologies (Baxter and Lawton, 2022; Phaf, 2024).

Information is scanty on the strategies used by PDs to overcome constraints in fodder conservation (adequate and quality fodder). Therefore, the objective of the present study was to determine the fodder conservation strategies used by smallholder dairy PDs in the highlands and midlands of Kenya. The study will inform policy reforms in an attempt to influence non-PDs toward successful fodder conservation leading to improvement in productivity and sustainability. The study will also direct the future to the most efficient and means of success.

## 5.2 MATERIALS AND METHODS

### 5.2.1 Study area

The study was conducted in Tharaka Nithi County in Kenya as previously described (Kogo *et al.,* 2022). Briefly, the County lies between longitude $37_o$ 19' and $37_o$ 46' East, latitude $00_o$ 07' and $00_o$ 26' South. Agroecological Zones (AEZ) are divided widely into highlands, midlands and lowlands. The main livelihood activity is agriculture, with 18,185 (16.6%) being smallholder dairy farming households concentrated in the highlands and midlands. Production systems are mixed crop-livestock where dairy farming is rainfed and about 80% of farms produce and conserve fodder (KNBS, 2019; Radeny *et al.,* 2020). The county has five sub-counties (Chuka, Maara, Igambang'ombe, Tharaka South and North).

### 5.2.2 Study design, sampling and data collection

A cross-sectional survey was conducted, where data were collected using a structured questionnaire. A sampling formula by Cochran & Wiley, (1977) for a large population with the desired level of precision and confidence level was used:

$$n = (z/m)^2 \, p \, q \quad \text{...........................................} \textit{(Eq 5.2.1)}$$

Where:

$z$ = confidence level at 95%, $m$ = margin of error (0.05), $p$ = estimated value of the population expected to respond from the unknown population ($P$ = 80%), $q$ = (1-$p$), the estimated proportion of target attributes (household) in population and will respond in a given way to a survey question, $q$ = 20%

Therefore, $n = (1.96/0.05)^2 \, (0.8)(0.2) = (39.2)^2(0.16) = 246.86 \approx 246$ households

Three sub-counties with a high population of dairy cattle were purposively selected. Farms were sampled using multistage sampling procedures where, the 1st stage was a purposive sampling of three sub-counties (Chuka, Maara and Igambangombe) in the highlands and midlands where dairy farming dominates. 2nd stage was in each sub-county 2 - 7 locations that had a high number of dairy cattle were selected. 3rd stage was a random selection of 3-7 villages in each location and 4th stage was a proportional selection of 2 - 8 farms in each village through snowball chain referral (KNBS, 2019). In total, 242 farms were selected. The criteria for farm selection were that the farm must be practicing dairy farming and conserving fodder.

Quantitative data were collected using questionnaires with structured and semi-structured questions. Information included in the questionnaire were: demographics (Education level, occupation, age and sex); socio-economic characteristics (extension access, milk market access and membership to dairy cooperative or groups); farm characteristics (land size, herd size and milk yield) and farmer behavior and fodder conservation practices (fodder scarcity, type of fodder conserved, quantity of fodder conserved, technology of fodder conservation, method of fodder conservation). Technologies of fodder conservation include silage, hay and crop residue while the methods of fodder conservation for silage include: silo, polythene line pit, container and tubing. Hay includes: baled, loose straws, standing and chopped. Crop residue includes; maize stalks, chopped and shredded. Farmers (household heads) were interviewed and information was filled in the questionnaires. Information on milk yield was recalled per day while the quantity of fodder conserved was recalled for a period of one year. Interviews lasted for 40 to 60 minutes on each farm. Data were collected during the dry season from July to August 2021 with the assistance of sub-county livestock production extension officers.

### 5.2.3 Data analyses

#### Descriptive analyses

Farms were first categorized into two groups: PDs and non-PDs. The selection criteria were that PDs conserve fodder to last the entire dry season (about 3 months: between February and April or between August and October) and produce >15 kg/cow/day of milk. Farms that did not meet both criteria, i.e. conserved fodder for < 3 months but produced

≤ 15kg of milk or conserved fodder for ≤ 3 months but produced more than 15kg of milk. In total 121 farms qualify PDs (n=24), non-PDs (n=97) and farms that did not qualify to be categorized either as PDs or non-PDs (n=125).

Quantitative variables were converted to universal standards where a 2.5-acre piece of land was 1 hectare (ha), breeds kept were pure exotic breeds (Friesian, Ayrshire, Jersey and Guernsey) and crossbreeds of either exotic dairy breeds or indigenous zebu breed and a cow of 250 kg was 1 Tropical Livestock Unit (TLU) (Rothman-Ostrow *et al.,* 2020). Feed intake and milk yield were calculated in kg/cow/day, conserved fodder in tons/farm/season and milk price in KES/kg. The milk yield was calculated as average milk yield (kg/farm/day) divided by the total number of lactating and dry cows.

For the quantitative variables the Shapiro-Wilk test was used to determine the normality of residuals and non-normal variables were categorized: herd size (≤5 & >5 TLU), land (≤0.6 & >0.6 ha) and milk yield (≤15 & >15 kg/cow/day). Pearson's Chi-square test and Fisher's exact 2-tailed test were used to test the relationships between PDs and non-PDs for categorical variables at $P < 0.05$. The variables included education, sex, occupation, extension access, membership to cooperatives, milk market, breeds kept, feed scarcity, period of using conserved fodder, fodder type and technologies used. The independent two-sample t-test was used to compare the means of PDs and non-PDs for quantitative continuous variables including age, land size, herd size, concentrates supply, feeds intake, milk yield, quantity of fodder conserved and period to use the conserved fodder.

**Regression analysis**

A univariable binary logit regression model was first fitted to all the data that was subjected to Chi-square and T-test (descriptive analysis above). The analysis was conducted to filter the significant predictor variables influencing the probability of PDs or non-PDs as indicated by the occurrence of dichotomous events (Miller, 2011). The PD status was treated as discrete with a binary variable (1 for PDs or otherwise 0 for non-PDs). Significant predictors ($P \leq 0.1$) were fitted to a multivariable logit regression in a forward-backward approach using generalized linear models (GLM).

$$Logit = L_i = \text{II(X)} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \dots + \beta_p X_p + \epsilon_t \quad \dots\dots\dots \textit{(Eq 5.2.2)}$$

Where:

$L_i$ is equal to II(X) as the probability of a farm being a PD or non-PD, $X_1, X_2, X_3, \dots Xp$ the predictor variables, $\beta_0$ is the intercept, $\beta_{1,} \beta_{2,} \beta_3 \dots \dots \beta_p$ is the coefficient to be estimated in the model and $\epsilon_t$ is the error term. The coefficients (β) of the output represent the unit change in the dependent variable for every unit change in the independent variable. The model assumes data linearity, normality of the residuals and homoscedasticity. All analyses were performed in R software version 3.6.0 (R Core Team 2018).

## 5.3 RESULTS

### 5.3.1 Demographic and socio-economic characteristics

Education and access to extension services differed between PDs and non-PDs (Table 12). The majority of PDs attained college and university education, while the majority of non-PDs attained primary education. The proportion of PDs with access to extension services was higher compared to non-PDs. While only PDs with farming as the main occupation were less compared to non-PDs. The majority of PDs sold milk through informal channels (milk bars, organizations and institutions) and mostly considered the formal market during surplus production. The majority of non-PDs sold milk through formal channels (Dairy cooperatives and groups) and 23% of the non-PDs did not sell milk. Age, sex, occupation and membership in dairy cooperatives did not distinguish PDs from non-PDs.

Table 12. Mean (±) and proportions of farmers (%) for socioeconomic and demographics variables comparing PDs and non-PDs in fodder conservation

| Factor | Category | PDs (n = 24) | Non-PDs (n = 97) | *P*-value* |
|---|---|---|---|---|
| Age (years) | Continuous | 51 ± 11 | 53 ± 15 | 0.660 |
| Education | Non-formal education | $0^a$ | $4^a$ | 0.012 |
| | Primary | $12^a$ | $43^b$ | |
| | Secondary | $3^a$ | $29^a$ | |
| | College/University | $50^a$ | $24^b$ | |
| Sex | Male | $58^a$ | $57^a$ | 0.885 |
| | Female | $42^a$ | $43^a$ | |
| Occupation | Farming | $62^a$ | $78^b$ | 0.090 |
| | Formal employment | $25^a$ | $8^a$ | |
| | Business | $13^a$ | $8^a$ | |
| | Casual labor | $0^a$ | $4^a$ | |
| Access to extension service | No | $29^a$ | $72^b$ | <0.001 |
| | Yes | $71^a$ | $28^b$ | |
| Membership to dairy cooperatives | No | $8^a$ | $25^a$ | 0.080 |
| | Yes | $92^a$ | $75^a$ | |
| Access to milk market | Formal | $43^a$ | $73^a$ | 0.050 |
| | Informal | $57^a$ | $27^a$ | |

### 5.3.2 Farm characteristics

The proportion of PDs that kept Friesians was higher than non-PDs (Table 13). The proportion of farms that kept a mixed herd of both Friesian and Ayrshire did not differ between PDs and non-PDs. The proportions of PDs that kept the Ayrshire breed and those that kept other breeds (Guernsey, Jersey and crossbreeds of exotic and zebu breeds) was less than non-PDs. The proportion of PDs that produced Brachiaria (*Urochloa spp)* and Boma Rhodes *(Chloris gayana)* were higher than non-PDs while the proportion of farms that produced natural grasses was less for PDs than non-PDs. Farms that produced fodder trees and legumes were less than 20% for both the PDs and the non-PDs. (Appendix 3. Comparison of PDs and non-PDs (%) on the source of fodder and the type of fodder produced and conserved in Tharaka Nithi County).

The proportions of farms that used hay and silage technologies were higher for PDs than non-PDs while farms that used crop residue storage were lower for PDs than non-PDs.

Farms adopted one or more fodder conservation technologies and 3% of farms utilized a combination of crop residue storage, hay and silage and the majority (54%) utilized crop residue storage alone (Appendix 4. Comparison of PDs and non-PDs (%) in the use of fodder conservation technologies). Methods used to conserve fodder differed between PDs and non-PDs, except crop residue stored as stovers and baled hay. (Appendix 5. Comparison of PDs and non-PDs (%) using different methods of fodder conservation in Tharaka Nithi County). The proportion of farms that conserved silage using silo and polythene-lined pits was higher for PDs than non-PDs. The proportions of farms that conserved hay of Boma Rhodes, silage of green maize *(Zea mays)* and hay of Calliandra were higher for PDs than non-PDs.

Table 13. Comparison of PDs and non-PDs (%) on breeds, fodder produced and conserved

| **Farms practice** | **PDs (n = 24)** | **Non-PDs (n = 97)** | ***P*–value*** |
|---|---|---|---|
| Breed | | | |
| Friesian | (79)[a] | (55)[b] | 0.019 |
| Friesian and Ayrshire | (21)[a] | (30)[a] | |
| Ayrshire | (0)[a] | (14)[b] | |
| Other breeds[1] | (0)[a] | (1)[a] | |
| Type of fodder produced | | | |
| Brachiaria | (30)[a] | (6)[b] | 0.005 |
| Boma Rhodes | (30)[a] | (1)[b] | <0.001 |
| Natural grasses | (10)[a] | (46)[b] | 0.002 |
| Fodder conservation technology | | | |
| Hay | (63)[a] | (30)[b] | >0.001 |
| Silage | (46)[a] | (10)[b] | |
| Crop residue storage | (50)[a] | (74)[b] | |
| Type of fodder conserved | | | |
| Boma Rhodes (hay) | (45)[a] | (15)[b] | 0.005 |
| Green maize silage | (43)[a] | (28)[b] | 0.024 |
| Calliandra (hay) | (17)[a] | (2)[b] | <0.001 |

* Chi-square $p$ values at $P < 0.05$. [1] Jersey, Guernsey and Crossbreed between exotic breeds or between exotic and indigenous breeds (Zebu). The different superscript indicates a significant difference between PDs and non-PDs.

Means of variables describing farm characteristics differed between PDs and non-PDs (Table 14). Total land size, land on crop and land on fodder were larger for PDs than non-PDs. Total herd size, lactating cows, heifers, weaners and calves were larger for PDs than non-PDs. Concentrate supply was higher for PDs than non-PDs. Fodder supply was higher for PDs than non-PDs. Milk yield per cow was higher for PDs than for non-PDs. Total fodder conserved was higher for PDs than non-PDs. Silage conserved did not differ between PDs and non-PDs. Crop residue and hay conserved were higher for PDs than non-PDs.

Table 14. Mean (± SD) of the selected farm characteristics for PDs and non-PDs

| **Characteristics** | **PDs (n=24)** | **Non-PDs (n=97)** | ***P*-value*** |
|---|---|---|---|
| Total land size (ha) | 1.7 ± 1.4 | 0.7 ± 0.7 | <0.001 |
| Land on the crop (ha) | 1.3 ± 0.3 | 0.4 ± 0.1 | <0.001 |
| Land on fodder (ha) | 0.4 ± 0.7 | 0.2 ± 0.3 | 0.006 |
| Total herd size (TLU)[a] | 9.0 ± 5.3 | 3.3 ± 2.2 | <0.001 |
| Lactating cows | 5.6 ± 4.3 | 2.2 ± 1.6 | <0.001 |
| Heifers | 1.5 ± 1.3 | 0.7 ± 0.7 | <0.001 |
| Weaners and calves | 0.7 ± 0.5 | 0.1 ± 0.2 | <0.001 |
| Concentrate supply (kg/cow/day) | 6.4 ± 1.9 | 2.9 ± 2.2 | <0.001 |
| Fodder supply (kg/cow/day) | 34.1 ± 14.3 | 38.8 ± 15.5 | 0.213 |
| Milk yield (kg/cow/day) | 19.6 ± 5.1 | 4.5 ± 3.9 | <0.001 |
| Fodder conserved (tons/farm/season) | 17.8 ± 25.2 | 2.6 ± 9.5 | <0.001 |
| Silage | 23.6 ± 28.4 | 15.0 ± 23.6 | 0.497 |
| Crop residue storage | 4.6 ± 2.9 | 1.2 ± 1.6 | <0.001 |
| Hay | 3.1 ± 3.5 | 0.8 ± 0.8 | <0.001 |
| Period to use conserved fodder (months) | 8.1 ± 7.7 | 1.6 ± 0.8 | <0.001 |

* T-test value at $P < 0.05$, [a] Tropical Livestock Unit (TLU) i.e. 1 TLU = 250 kg, cow – 400kg, heifers – 200kg, after weaning – 100kg and calves – 50kg.

### 5.3.3 Factors contributing to success in fodder conservation

Some of the variables tested were important predictors of success in fodder conservation (Table 15). Coefficients (B) for all significant independent variables (land on fodder, total herd size, access to extension and milk yield) were positively correlated to the dependent variable. Exp(B) (odds ratio) of 0.003 as a constant shows that with all other factors held constant there is no chance (zero) of fodder conservation. Farms with land > 0.6 ha for fodder production increased the fodder conserved 12.9 times higher for every unit change on land compared to farms with ≤ 0.6 ha (48%). Farms with herd size > 5 TLU conserve fodder 5 times higher for every unit change in herd size compared to farms (74%) with small herd size ≤ 5 TLU. Farms with milk yield > 15 kg per cow per day conserve fodder 98.9 times higher for every increase in milk yield (kg per cow per day) compared to farms (76%) with low milk yield ≤ 15 (kg per cow per day). Lastly, farms with access to extension services conserve fodder 8.2 times more for every access to extension services compared to farms with no access to the extension service.

Table 15. Binary Logit regression results showing predictors of positive deviance in fodder conservation

| **Variable** | **Categories** | **B (Coefficients)** | **S. E** | **Exp(B) (Odds ratio)** | ***P.* value** | **2.5%** | **97.5 %** |
|---|---|---|---|---|---|---|---|
| Constant | | -5.79 | 1.28 | 0.003 | <0.001 | -8.91 | -3.75 |
| Land on fodder (ha) | > 0.6 | 2.55 | 0.93 | 12.852 | 0.006 | 0.91 | 4.70 |
| | ≤ 0.6 | Ref | Ref | Ref | | | |
| Total herd size | > 5 | 1.61 | 0.81 | 5.007 | 0.046 | 0.09 | 3.35 |
| (TLU)[a] | ≤ 5 | Ref | Ref | Ref | | | |
| Milk yield | > 15 | 4.59 | 0.98 | 98.908 | <0.001 | 2.91 | 6.86 |
| (kg/cow/day) | ≤ 15 | Ref | Ref | Ref | | | |
| Extension service | Yes | 2.11 | 0.86 | 8.225 | 0.014 | 0.55 | 4.01 |
| | No | Ref | Ref | Ref | | | |

AIC: 55.8 (df 120). B – Coefficient estimate. Exp(B) - Odd ratio. * $P < 0.05$, 2.5% and 97.5% - Lower limit and upper limit respectively. S.E - Standard error. Ref - Reference category. [a] Tropical Livestock Unit (TLU) i.e. 1 TLU = 250 kg, cow – 400kg, heifers – 200kg, after weaning – 100kg and calves – 50kg.

## 5.4 DISCUSSION AND CONCLUSION

### 5.4.1 Demographic and socioeconomic characteristics

In Kenya, the adoption of fodder conversation technologies is low and only a few farms become successful (Habermann, 2023). The PD approach is useful to investigate the strategies used by successful individuals (Baxter and Lawton, 2022). Education differed between PDs and non-PDs (Table 12). The difference between PDs and non-PDs in the proportion of farms that had primary and tertiary level education implying the PDs had better education than the non-PDs. Tertiary education allows PDs to make better decisions and adopt fodder technologies (silage and hay) and practices forecasting the length the dry season than non-PDs (Birhanu *et al.,* 2017; Tulu *et al.,* 2023). This was expected because educated farmers are likely to understand and comprehend technology principles better than non-educated farmers. According to Tesfaye and Gutema, (2022) Improved forage technology uptake increases with better access to education by farmers. We conclude that knowledge acquired through education facilitates or enables farmers to become PDs, therefore, education is one strategy to become PDs. Gender was not significant contrary to our expectations that men control most of the resources but in agreement with success in gender equity and forage technology integration reported by Njuguna-Mungai *et al.,* (2022). Occupation injection of capital from formal employment could have been neutralized by business groups and farmers working on casual labor. Age could have been neutralized by knowledge possessed by the young against production resources privileged to the old.

Access to extension services is important for successful fodder conservation (PDs). This explains why PDs had more access to extension than non-PDs (Table 12), were educated and probably had more desire to seek more knowledge from extension and expertise explanation in areas of their interest. High levels of education and enhanced access to extension services were also reported to influence the use of technologies (Balehegn *et al.,* 2022; Boote *et al.,* 2022). Provision of extension services, milk aggregation and marketing as well input access are some of the factors promoting dairy cooperatives in good proximity to farmers (Aum *et al.,* 2019; Migose, 2020). Boz & Xkilic, (2020) and Istaitih *et al.,* (2023) reported that institutions such as cooperative public institutions and producer organizations cooperate with farmers to carry out various extension activities to accelerate the adoption and diffusion of silage technology. Membership to dairy cooperatives did not differ which could be because almost all farms had equal access to cooperatives and in addition, few studies have been done on successful fodder conservation in the Kenyan contest. Access to the milk market is linked to dairy cooperatives, therefore, did not differ between PDs and non-PDs. However, the majority of the PDs sold milk in the informal milk market which attracts a higher price of milk than dairy cooperatives or groups (Migose, 2020; Ndambi *et al.,* 2020). High prices of milk increase revenue which avails resources for farmers to invest further in fodder and equipment (balers and silage tubes).

### 5.4.2 Farm characteristics

Positive deviant farmers kept Friesian cattle more than non-PDs (Table 13). The Friesian has a high potential for milk yield when provided with enough quality feeds, the breed is mostly kept in farms with more production resources (PDs). This could trigger farmers to invest more in the conservation of quality fodder. The majority of the non-PDs kept the Ayrshire breed which requires less feed but also produces lower milk compared to Friesian. The non-PDs would prefer Ayrshire because they require fewer resources to feed (Lukuyu *et al.,* 2019). Brachiaria and Rhodes were the quality fodder majorly used by PDs while non-PDs relied on natural grasses. The fodders dominate the PDs with the expectation to increase the productivity of dairy cattle. PDs produced high-quality fodder and conserved large quantities of fodder (PDs definition). The majority of PDs than non-PDs conserved hay of high quality (Rhodes and Calliandra) as well as silage of green maize, which gives the expected high milk yield therefore, promoted in the region through seed subsidies and extension service (GoKb, 2017). Non-PDs may not use quality fodder probably because of less knowledge and limited resources (Table 14), common to the majority of smallholder farmers (Migose, 2020).

Hay and silage were majorly used by PDs while non-PDs used crop residues. The results are in agreement with other previous studies that farmers who conserved hay or silage produced more milk than those who did not conserve (Boz & xKılıç, 2020; Istaitih *et al.,* 2023). Methods preferred by farmers include silo and polythene lined pits for silage making as well as baled and loose straws for hay-making. Balehegn *et al.,* (2022) also reported that silos as the most preferred method for silage making while box baling and loose straws were preferred for hay-making. Crop residue stored and natural grasses were the main fodder for the non-PDs despite being of low quality. The preference by farmers probably could be because it is cheap and readily available and does not require expertise or skills to preserve (prepare). Maize is the major food crop in the region and the residue conserved either as stover's storage or chopped and stored stovers (Auma *et al.,* 2019; Lukuyu *et al.,* 2019). The low education and less access to extension services by non-PDs could have limited the technical knowledge and understanding of hay and silage technologies as well as the value addition of crop residue.

The land size is an important factor necessary for successful fodder conservation (Brandt *et al.,* 2020; Tesfaye and Tessema, 2023). Land size was larger for PDs than non-PDs (Table 14), which could be the advantage that PDs allocate more land to fodder production. Increased fodder production could lead to increased fodder conservation (Tesfaye and Tessema, 2023). Large land size also explains the importance of production resources (land, labor and capital) in fodder conservation and benefits through economies of scale enhanced by PDs' advances in knowledge and skills. Land size, herd size and the breed reared influence the successful use of silage technology (Boz & xKılıç, 2020; Istaitih *et al.,* 2023). The findings also agree with Gupta *et al.,* (2020) and Desta, (2022) findings that; large land size, herd size, heavy feeding breeds and milk yield explained the large amount of fodder conserved.

Herd size is an important factor for successful fodder conservation (PDs) with large herd size being a driving factor for fodder conservation. Herd sizes were larger in PDs compared to non-PDs and the national average herd size kept in the majority of smallholder dairy farmers in Kenya (between 3-5 milking herds). The large herd size allowed PDs to obtain large volumes of milk and gain also through the economies of scale, thus successful dairy farming could be associated with the availability of capital resources (large herd size). Moreover, it is the reason for more conservation of fodder to produce and sustain high milk yield as well as reducing fodder scarcity during the dry season, an exercise which is resource-demanding (Balehegn *et al.,* 2020; Istaitih *et al.,* 2023).

Concentrate feeds used by PDs were higher than non-PDs, the large quantity of concentrate feeds is required to increase milk yield and therefore, to maintain high milk yield the PDs use high concentrate (Brandt *et al.,* 2020; Ndambi *et al.,* 2020). High milk yield and large quantities of fodder conserved were expected among PDs since it was our criteria for grouping PDs and non-PDs. The high milk yield among PDs could also be related to the keeping of productive breeds (Friesian) and adequate quality feeds used (Auma *et al.,* 2018; Lukuyu *et al.,* 2019).

In conclusion, positive deviance in fodder conservation is favored by a high level of education, access to extension services, large land and herd size and high milk yield as shown by the PDs data. Encourage farmers to use better technologies such as silage and hay used by PDs to foster the conservation of fodder. Therefore, success in fodder conservation technologies can be enhanced by farmer education through training and improved access to extension services.

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**Authors contribution**: T.K. conceptualized the idea, collected and analyzed the data and drafted the manuscript. S.A.M. R.Y. and D.N. contributed to data analysis and drafting of the manuscript. All authors reviewed the draft and agreed to publish this version of the manuscript.

**Data availability:** Data is available upon request through correspondence mail.

**Ethics approval:** Data was collected with approval by the Kenya National Commission for Science, Technology and Innovation (NACOSTI) under license number: NACOSTI/P/21/11411. Written approval to interview the participants was granted by the Department of Agriculture, Livestock and Fisheries of the County Government of Tharaka Nithi.

**Participants' consent:** Informed consent was obtained from all individual participants included in the study.

# CHAPTER SIX

# GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATION

## 6.1 Discussions

Factors important in fodder conservation include: sex, and extension services, farm location, land size, herd size, milk yield (farm/day and cow/day), use of concentrate feeds, breed kept, duration expected to use the conserved fodder, source of fodder during scarcity, main source of fodder in the farm during feed scarcity as well as fodder conservation technologies used. The sex of the farmer's head influenced the fodder conserved, where male-led farms were conserving more fodder, more so silage and dominate dairy farming specifically in UL relative to the female lead farms. Farms led by elder farmers compared to young farmers dominate fodder conservation probably contributing to low adoption of fodder conservation and conservation technologies, while farmers in UL were younger than PUL. This could probably be because of young male migration and dominance in the control of family production resources. (Maina *et al.,* 2020; Istaitih *et al.,* 2023; Ngetleh *et al.,* 2023; Tulu *et al.,* 2023).

Education and membership in groups did not differ significantly between UL and PUL farmers and didn't contribute to fodder conservation (Omollo, 2017; Desta, 2022). Possibly as a result of the distance covered in the study, limited by the fund's availability and time. However, education and access to extension services were significantly high in PDs than non-PDs, a reflection of more desire to seek more knowledge, In addition, it positively influenced the conservation of silage (Balehegn *et al.,* 2022; Boote *et al.,* 2022; Kogo *et al.,* 2024). Boz & Xkilic, (2020) and Istaitih *et al.,* (2023) reported that institutions accelerate the adoption and diffusion of silage technology. While the formal milk market dominates the market channels, the informal milk channel was high in UL relative to PUL, simply because of the high milk demand in UL. The majority of the PDs sell milk in the informal milk market which attracts a higher price of milk than in formal channel and increases the revenue in PDs to invest further in fodder and equipment (Migose, 2020; Ndambi *et al.,* 2020; Ngetleh *et al.,* 2023).

The average land size (1.04ha) was a significant contributor to fodder conserved faced with population growth pressure. Herd size and land size did not differ ($P < 0.05$) between

UL and PUL, probably because the two towns are occupied by urban dwellers, synergized by food and cash crop competition in the two locations (Lawrence *et al.,* 2023). The land size was larger in PDs than non-PDs (Table 14), giving and advantage to the PDs to allocate more land to fodder production and consequently more fodder conservation (Bonilla *et al.,* 2017; Ndambi *et al.,* 2020; Tesfaye and Tessema, 2023).

Large land size, herd size, breed reared and high milk yield explain and influence the successful use of silage technology, it also explains the large amount of fodder conserved in PDs (Boz & xKılıç, 2020; Istaitih *et al.,* 2023). Total herd size was an important factor in determining the quantity of fodder conserved. Herd size was positively association with hay conservation, that was an increase in herd size increases the quantity of hay conserved (Ndambi *et al.,* 2020). Milk production average (8.4 kg/cow/day), the value within 7.8-11.8 kg/cow reported by IFAD, (2015). Therefore, farms with high milk yield increase the quantity of conserved silage and hay compared to low milk yield farms. The results associated with good feeding and the use of quality silage feeds (Tuei, *et al*., 2021).

High milk yield in PDs were related to the keeping of productive breeds (Friesian) and adequate quality feeds used and the reason for more conservation of fodder to produce and sustain high milk yield and reduce fodder scarcity (Lukuyu *et al*., 2019; Brandt *et al*., 2020; Ndambi *et al.,* 2020; Istaitih *et al*., 2023). Breeds kept had a positive influence on both hay and crop residue storage, that is Ayrshire breed increases hay conservation as keeping of other breeds increases hay and crop residue storage compared to keeping only Friesian breeds. The results associated with the Ayrshire breed light feeding nature (Lukuyu *et al*., 2019). In addition, PDs use more concentrate feeds than non-PDs, where an increase in concentrate feeds used reduces the quantity of hay conserved (Sakwa *et al.,* 2020). Adoption of fodder conservation was low indicated by low quantities conserved and fluctuating fodder availability and fodder scarcity experienced in most (64%) of the farms during the dry period (Pradesh, 2016). During this period farmers use: Conserved fodder, concentrate feeds, buy from outside, tree leaves, forest/roadside and natural grass (Njarui *et al.*, 2016).

Although the majority of the farms used conserved fodder throughout the year, they reduced the quantity of fodder fed during the dry season (Mudavadi *et al.,* 2020). Maize, Napier and boma Rhodes were the highly conserved fodder. Napier grass being known to adapt well to less moisture and with the shortest chain in line with the fodder value chain (Auma *et al*., 2018; Maleko, *et al.,* 2018). Brachiaria and Rhodes were the fodder majorly used by PDs while non-PDs relied mostly on natural grasses (Table 13) (Migose, 2020). Crop residue stored was majorly maize stover, among other crop residues, because maize were a staple food in Kenya (Lukuyu *et al.,* 2019; Yusuf, *et al.,* 2022).

Successful farms benefitred through economies of scale through large land size, herd size and the good breed reared influence the successful use of silage technology (Boz & xKılıç, 2020; Gupta *et al.,* 2020; Desta, 2022; Istaitih *et al.,* 2023). Hay and silage were majorly used by PDs while non-PDs used crop residues, low education and less access to extension services by non-PDs could have limited the technical knowledge and understanding of hay and silage technologies as well as the value addition of crop residue (Boz & xKılıç, 2020; Istaitih *et al.,* 2023). Hay was the second most adopted technology, with the least quantity in the fodder conserved, being preferred due to its convenience and ease of storage rather than its nutritional impact (low quality) thus the need to improve its quality (Maleko *et al.,* 2018). The bulk of the conserved hay was baled hay and the common concerns from farmers include; the presence of foreign materials in commercial hay and low-quality (Ndambi *et al.,* 2020).

Silage being the least adopted technology was also the technology conserving the largest quantity of fodder, probably due to the long storage of ensiled feeds and the economics of scale since most of the silage processing were machine-based (SNVKenya, 2019). Silage could be best done through cost sharing to reduce cost and increase the period the conserved fodder were expected to last. Therefore, Ndambi *et al.,* (2020) suggested that members belonging to a group or cooperatives can organize a cost-sharing program for expensive silage-making machines and increase the use of silage as the main fodder during scarcity to increase the quantity of fodder conserved (Maleko *et al.,* 2018b). Silage was more highly adopted in UL than in PUL ($P < 0.05$) possibly driven by good milk demand, income from employment, most likely resource endowment in UL and supported by the large herd to sustain high and increasing milk yield (Sakwa *et al.,* 2020; Ngetleh *et al.,* 2023).

The use of silage alone, silage and hay combination as the major feed during scarcity influences the quantity of fodder conserved. The results could be because of quality and the quantity of fodder conserved. However, silage commercialization being a new thing for most farmers and it were yet to be optimized to sort fodder scarcity, the findings are in agreement with Ndambi *et al.,* (2020). The period conserved fodder were expected to be used increases with increase in the quantity of fodder conserved, mitigating fodder scarcity from unpredicted droughts and climate change. It also had a positive association with the quantity of hay and crop residue storage, while silage technology influenced the period negatively even with the highest quantity of fodder. Probably because of the ensiling maize and crop residue mixture in some farms (Maina *et al.,* 2019).

Fodder tree leaves negative relationship implies that a unit increase in the use of tree leaves as the main source of feed during feed scarcity reduces fodder conserved relative to the use of crop residue (Makau *et al.,* 2020; Tesfaye, M., & Gutema, P. 2022). The use of crop residue storage as the major fodder during periods of fodder scarcity negatively influences the quantity of fodder conserved probably because of the reduction in feed stored when expecting crop residue from food crops. Crop residue storage technology was the highest used fodder for being readily available, cheap, easy to store and use and ranked second in quantity conserved (Auma *et al*., 2018; Lukuyu *et al*., 2019; Balehegn *et al.,* 2020). The quantity stored and the methods used to store did not differ between locations, probably limited by space due to competition from cash crops and other businesses within the study sites (Petrikova *et al.,* 2024). Despite being of low quality just like hay through further preparation quality can be improved for a better outcome; chopping and shredding, ensiling, supplementation and urea treatments (Kashongwe *et al.,* 2017; Balehegn *et al.,* 2022).

### 6.2 Conclusion

Precisely fodder conservation depends on technology adopted by smallholder farmers and this is a critical step in improving productivity. We found that the common fodder conservation technologies include silage, hay and crop residue storage, driven by different variables. Silage conservation (farm location, land size, total milk yield per farm, sex, options used as fodder source during feed scarcity and extension services): Hay conservation (total land size, herd size, period the current stock were expected to last, use of concentrate feeds and breed kept): Crop residue storage (period the current stock were expected to last and breed kept).

The levels of fodder conservation and technology adoption are low, as farms still rely on crop residue and fresh Napier grass. Silage conservation was the highest in the quantity of fodder conserved both in PDs and UL relative to non-PDs and PUL respectively. Positive deviance in fodder conservation was favored by a high level of education, access to extension services, large land and herd size and high milk yield. Silage and hay technologies were used in PDs to foster the conservation of fodder, enhanced by the availability of production resources. Large land size, herd size, long duration of using the conserved fodder and use of hay-silage combination enhance fodder conservation.

The study concludes that fodder conservation follows dairy development, that is the more developed the dairy sector is the more the utilization of fodder conservation technologies. Which is an important step towards improving productivity and the achievement of government objectives. That can be enhanced by farmer education through training and improved access to extension services and further research on influence of market will bridge technological gaps. Therefore, government subsidies, mechanization costs, sensitization grants and means to lower expensive production resources through government tax relief, especially concerning fodder conservation, also as a means to mitigate climate change, drought and fodder scarcity.

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## PUBLICATION LIST

1. Paper one

   **Kogo, T**., Yegon, R., & Migose, S. A. (2022). Characterization Of Fodder Conservation Technologies Among Farmers In Tharaka-Nithi County. *East African Agricultural and Forestry Journal*, *86*(1-2), 13.

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2. Paper two

   **T.K. Kogo**, R. Yegon and S.A. Migose.

   Determinants of fodder conservation technologies among smallholder dairy farming systems in the peri (urban) highlands and midlands of Tharaka-Nithi County, Kenya.

   *To be submitted*

3. Paper three

   **Kogo Thomas**, Rebecca Yegon, Daniel. Nthiwa and Salome A. Migose (2024) Strategies of positive deviants in fodder conservation among smallholder dairy farming systems in highlands and midlands of Kenya.

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**Abstract in conference proceedings**

An Assessment of Fodder Conservation Technologies Among Farmers in Tharaka Nithi, Kenya *SCIENTIFIC CONFERENCE BOOK OF ABSTRACTS Theme: Climate Smart Research for Sustainable Agriculture and Livelihoods Venue : Lake Naivasha Resort*.22nd -26th Nov 2021, pg 73

**Kogo Thomas**, Migose, S and Yegon, R1. Poster 20:

# APPENDICES

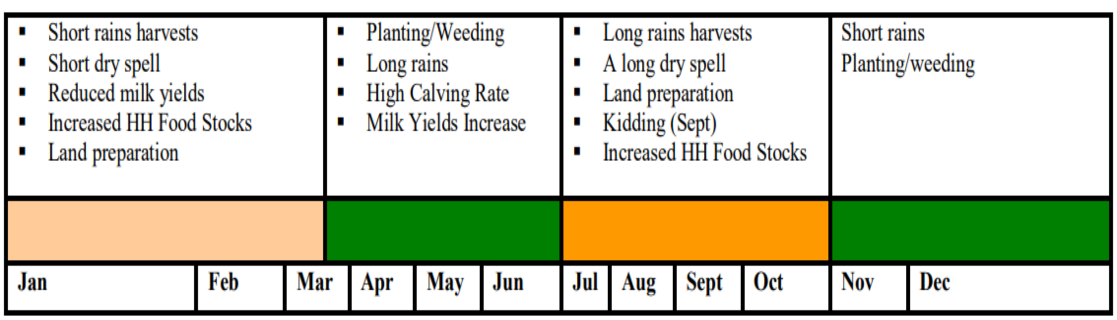
Appendix 1. Fodder conservation technology combinations

| | | Technologies combinations used | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | CR.H | H | S | CR | CR.S | CR.S.H | S.H | |
| Farm type | Count | $6_{a, b}$ | $20_{b, c}$ | $1_{a}$ | $62_{b}$ | $5_{a, b, c}$ | $1_{a, b}$ | $2_{a, b}$ | 97 |
| | Non-PDs (%) | 6.1% | 21.2% | 1.0% | 63.6% | 5.1% | 1.0% | 2.0% | 100.0% |
| | Count | 4a, c | 4b, c | 5b | $2_{c}$ | $2_{a, b, c}$ | $2_{a, c}$ | 5a, b | 24 |
| | PDs (%) | 15.0% | 15.0% | 20.0% | 10.0% | 10.0% | 10.0% | 20.0% | 100.0% |
| Total | Count | 10 | 24 | 6 | 64 | 7 | 3 | 7 | 121 |
| | PDs and non-PDs (%) | 7.6% | 20.2% | 4.2% | 54.6% | 5.9% | 2.5% | 5.0% | 100.0% |

Each subscript letter denotes a subset of technologies used categories whose column proportions do not differ significantly from each other at the .05 level.

CR – Crop residue, H – Hay, S – Silage

Appendix 2. Seasons in Tharaka-Nithi County




*Tharaka Nithi NDMA July 2020 Drought Early Warning Bulletin, committed to ending Drought Emergencies*

Appendix 3. Comparison of PDs and non-PDs (%) on the source of fodder and the type of fodder produced and conserved in Tharaka Nithi County

| **Fodder** | **PDs (n = 24)** | **Non-PDs (n = 97)** | ***P*- value** |
|---|---|---|---|
| Source | | | |
| On-farm | 100 | 99 | 0.345 |
| Purchased | 63 | 76 | |
| Type of fodder produced | | | |
| Napier grass | 100 | 100 | 0.832 |
| Maize (silage) | 45 | 43 | 0.544 |
| Caliandra | 20 | 20 | 0.626 |
| Brachiaria | 30 | 6 | **0.005** |
| Boma Rhodes | 30 | 1 | **<0.001** |
| Desmodium | 20 | 8 | 0.117 |
| Natural grasses | 10 | 46 | **0.002** |
| Type of fodder conserved | | | |
| Napier grass[a] | 65 | 55 | 0.603 |
| Green maize silage[a] | 85 | 57 | **0.014** |
| Boma Rhodes[b] | 45 | 15 | **0.005** |
| Brachiaria[b] | 10 | 1 | 0.073 |
| Calliandra[b] | 17 | 2 | **<0.001** |
| Natural grass[b] | 15 | 4 | 0.092 |

Chi-square at $P < 0.05$

[a] Fodder conserved either as hay or silage

[b] Fodder conserved as hay

Appendix 4. Comparison of PDs and non-PDs (%) in the use of fodder conservation technologies in Tharaka Nithi County

| **Technology use/farm** | **PDs (n = 24)** | **Non-PDs (n = 97)** | **Total (%)** |
|---|---|---|---|
| CR | $13^{a}$ | $64^{b}$ | 54 |
| H | $21^{a}$ | $22^{a}$ | 22 |
| CR.H | $21^{a}$ | $4^{b}$ | 7 |
| CR.S | $8^{a}$ | $5^{a}$ | 6 |
| S.H | $13^{a}$ | $3^{a}$ | 5 |
| S | $17^{a}$ | $1^{b}$ | 4 |
| CR.S.H | $8^{a}$ | $1^{b}$ | 3 |

CR – Crop residue, H – Hay, S – Silage. Chi-square at P < 0.05.

The different subscript letter denotes a subset of technologies used that differ significantly from each other.

Appendix 5. Comparison of PDs and non-PDs (%) using different methods of fodder conservation in Tharaka Nithi County

| **Technology conservation methods** | **PDs (n = 24)** | **Non-PDs (n = 97)** | ***P* - value** |
|---|---|---|---|
| Crop residue storage method | | | |
| Maize stovers | 58 | 80 | 0.325 |
| Chopped & ensiled | 21 | 4 | |
| Hay-making method | | | |
| Baled | 29 | 15 | 0.403 |
| Loose straw | 13 | 12 | |
| Standing hay | 4 | 3 | |
| Silage making method | | | |
| Silo | 21 | 4 | 0.071 |
| Polythene lined pit | 13 | 2 | |
| Tubing | 0 | 3 | |
| Container | 17 | 0 | |

Chi-square at P < 0.05

Appendix 6. Questionnaire

**DATA COLLECTION FROM FARMERS CONSERVING FODDER SCHEDULED TO START ON 30TH MAY, 2021**

Dear farmer

**RE: Fodder conservation technologies**

I am a postgraduate student at the University of Embu. I am researching fodder conservation technologies, in fulfillment of the degree of Master of Agriculture Resource Management. You are one of the selected participants of this study. The findings of this study will be of value to policymakers and planners towards increased milk production and strengthening regulations. The study will focus on the selected factors, to explore their impacts on fodder conservation among dairy farmers of Tharaka Nithi County, Kenya. The information you provide is confidential and will be for academic research purposes only where possible it will be upon request. I will make the study findings available to you. I will greatly appreciate your cooperation. Thank you in advance.

Yours Faithfully,

Thomas Kogo A500/1306/2019

**SECTION A; GENERAL FARM INFORMATION**

1) **Farm details** (Tick where applicable)

Sub-County ______________________________

Location _________________________ Sub-location _______________________

Village _______________________ Date: ______________________________

Name: ________________________________________________________

Sex: Male [ ] Female [ ]

2) The highest level of formal education for the head of dairy activities;

Non-formal ( ), Primary ( ), secondary ( ), college ( ), university ( )

3) Where do you sell your milk to?......................................

| Distance to sale milk (km) | Farm distance from Chuka town (km) | Google map Coordinates | Road type | Milk price/litre |
|---|---|---|---|---|
| | | | | |

4) How much do you spend in your dairy farm?

| Task | Rate/days | Cost (Ksh) |
|---|---|---|
| | | |
| | | |
| | | |

5) In this villages who are the farmers known to be smart in fodder production, conservation and milk production?

| **No.** | **Name of the farmer** | **Village of the farm** | **The farm is excellent (thick where applicable)** | |
|---|---|---|---|---|
| | | | **In fodder conservation** | **In milk yield** |
| **1.** | | | | |
| **2.** | | | | |

**SECTION B. FARM AND CATTLE CHARACTERISTICS**

6) Which management system do you use in dairy production? (thick where applicable)

| Zero-grazing ................. | Semi Zero-grazing .............. | Grazing .............. |
|---|---|---|
| Any other; | | |

7) What is your total land size, land under fodder crops or grazing field?

| **Land** | **Land size potion (acreage)** |
|---|---|
| Total land | |
| Fodder crops | |
| Food crops | |
| Grazing field | |

8) How many cattle do you have? How many are mature, young, lactating, milk produced?

| **Total cattle in the farm** | **Mature cattle (> 12 months)** | **Lactating cow** | **Dry cow** | **Heifers** | **Bull** | **Milk produced (litres)** |
|---|---|---|---|---|---|---|
| | | | | | | |
| Comment on this production | | | | | | |

9) How many are calves? How old are they? What age are the previous calves (months)

| | |
|---|---|
| Age of calves e.g. a and b (months)e.g. a(1 month), b(3months), | |
| Previous calves age (months) e.g a(12M), b(14M), | |
| **Total calves** | |
| Any comment | |

10) In scale of 1-5 rate the health state of the animals

| Cattle number | Score |
|---|---|
| 1. | |
| 2. | |
| 3. | |
| Any comment? | |

11) Are you a member of any farming group or cooperative? YES NO

If yes, what is their assistance in terms of feed?

……………………………………………………………………………………………..........
..........................................................................................................................

12) How is feed availability and average milk yield in the year?

| **Feed** | **Season** | **Situation** | **Months** | **Av milk yield (litres)** |
|---|---|---|---|---|
| Availability | | Plenty | | |

| | | | | |
|---|---|---|---|---|
| | Wet season | Shortage | | |
| | Dry season | plenty | | |
| | | Shortage | | |

13) What is your main source of fodder during the dry period?

______________________________________________________________________

14) Have you in the past lost any cattle due to feed scarcity? YES NO

If yes, what had happened?

.......................................................................................................................................
.......................................................................................................................................

**SECTION C: FODDER AND CONSERVATION TECHNOLOGIES**

15) How frequent do you harvest your fodder?

________________________________

a. How many times do you conserve fodder in a year?

_________________________

b. What is the portion of harvested fodder is conserved for future use?
c. Do you use conserved fodder to feed throughout the year? (YES), (NO)

If No, which months only?

………………………………………….............................................................

If yes, explain what you do to ensure that?

.......................................................................................................................................
.......................................................................................................................................

16) Which type of fodder do you conserve or buy to feed your dairy cattle? What are the quantities in each type? what is the level of satisfaction on the feeds? (1-not enough, 3-enough, 5-excess)

| **NO** | **Type of fodder conserved** | **Quantity ($M^3$/tons/bales)** | **Source** | **Satisfaction** |
|---|---|---|---|---|
| **1.** | | | | |
| **2.** | | | | |

17) What type of conservation technologies do you use to store fodder? What are the estimated quantities under each technology? And what is the expected time of use? Storage of each technology feeds?

| **E.g. Hay (standing, chopped, straws, caked) silage (tubing, polythene sheet, silo, pit)** | | | | |
|---|---|---|---|---|
| **No** | **Technologies used to conserve** | **Quantity (kg, bales, $m^3$ tons/)** | **Expected time of use** | **Storage site** |
| **1** | | | | |
| **2** | | | | |

Any other conservation technology known but not used? Why reject technology?

.................................................................................................................................
.........................................................................................................................

18) What are the reasons for the main choice of fodder conservation technologies you use?

…………………………………………………………………………………….........
.................................................................................................................................
.......................................................................................................................

19) How many trainings have you attended on fodder conservation and dairy animal feeding?

...............................................................................................................

If any, which technologies were you taught?

.................................................................................................................................
.........................................................................................................................

20) What type and quantity of conserved fodder are used daily? and how important is it to milk production? (On a scale of 1-5, rate the technologies; 1-not important, 2- some-how important, 3 important, 4- to some extent important, 5- very important)

| **No** | **Technologies/crop** | **Quantity used daily** | **Importance** |
|---|---|---|---|
| **1** | | | |
| **2** | | | |

21) Which of the following activities are you practicing and which one do you think it contributes to your success?

(Tick & on a scale of 1-10**,** 1-low 10-high rate each practice contribution to milk yield)

| No | Technologies/practices | practicing | Contribution |
|---|---|---|---|
| 1 | Treatment of fodder before feeding | | |
| 3 | Conserve some leguminous plants | | |
| 4 | Feed with concentrates | | |
| 5 | Feed processing before feeding | | |
| 6 | Purchase of extra feeds when in scarce | | |
| 7. | Farm/office visit by/to extension | | |
| 8. | Feed ration formulation | | |
| 9. | Good/enough fodder storage facility | | |
| 10. | | | |

22) What are the other means used by farmers to sort out fodder scarcity apart from fodder conservation?

| No | Technologies | (1-dry spell, 2-wet season, 3-throughout) |
|---|---|---|
| 1. | | |
| 2. | | |

23) In your opinion, what are some of the challenges to fodder conservation and to what extent do they influence the adoption of fodder conservation technologies? (Tick the challenges existing in your farm in the influence number accordingly).

| Factors | No. effects | Small effect | Moderate effect | Great effect | V. great effect |
|---|---|---|---|---|---|
| Reducing land size | | | | | |
| Growing population | | | | | |
| Level of education | | | | | |
| Access to Market | | | | | |
| Weather information | | | | | |
| Equipment's/mechanization | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Extension services | | | | | |
| Drought | | | | | |
| Fodder diseases | | | | | |
| Farm visits | | | | | |
| Training | | | | | |
| Labour | | | | | |
| Associated expenses | | | | | |
| Forage wastage in process | | | | | |
| | | | | | |

Any comment or solutions to this constrains

……………………………………………………………………………………….........
..........................................................................................................................