ADOPTION OF IMPROVED FORAGE TECHNOLOGIES AND ITS EFFECT ON HOUSEHOLD INCOME AMONG DAIRY FARMERS IN BOMET COUNTY, KENYA

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REG NO: A56/36178/2019

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURAL AND APPLIED ECONOMICS

DEPARTMENT OF AGRICULTURAL ECONOMICS

FACULTY OF AGRICULTURE

UNIVERSITY OF NAIROBI

JULY, 2023

DECLARATION

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

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DEDICATION

I dedicate this piece of work to my late father Malual Dut Deng as well as to all my brothers, and sisters.

ACKNOWLEDGEMENT

I am highly grateful to Almighty God for granting me health and strength throughout the study. My sincere gratitude goes to my supervisors, Prof. John Mburu and Dr. Lucy Karega Njeru, for their patience and guidance. God bless them all.

My profound gratitude goes to African Economic Research Consortium (AERC) for sponsoring my studies with financial support to enhance my studies and field research. I am grateful to Africa Milk Project for their financial support to enable me collect part of the data. It was a rare opportunity and I do not take it for granted. I am also grateful to all lecturers of the Department of Agricultural Economics of the University of Nairobi for their continuous support in this academic journey.

Special thanks to the stakeholders of the Africa milk project, especially Edith Wairimu and Caroline Chepkemoi who guided me in the field. Many thanks to my brother Bul Malual Dut for always supporting me unconditionally. I also wish to acknowledge my editor Miss Hellen Judith Icumar for being part of this journey

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LIST OF ABBREVIATIONS AND ACRONYMS

CIDP	-	County Integrated Development Plan
FAO	-	Food and Agriculture Organization of the United Nations
GDP	-	Gross Domestic Product
IFTs	-	Improved Forage Technologies
ILRI	-	International Livestock Research Institute
IMR	-	Inverse Mill Ratio
KDB	-	Kenya Dairy Board
KNBS	-	Kenya National Bureau of Statistics
KSHS	-	Kenyan Shillings
MLE	-	Maximum Likelihood Estimation
MOALF	-	Ministry of Agriculture Livestock and Fisheries
NGOs	-	Non-Governmental Organization
ODK	-	Open Data Kit
OECD	-	Organization for Economic Cooperation and Development
OLS	-	Ordinary Least Squares
RUM	-	Random Utility Model
SNV	-	SNV Netherlands Development Organization
SSA	-	Sub-Saharan Africa

ABSTRACT

Promoting the adoption of improved forage legumes among dairy farmers is pertinent to improving protein intake by the animals and hence increasing dairy productivity. This study characterized dairy forage technologies, assessed the factors influencing the adoption of improved forage technologies and established their effects on household income. The study adopted a cross-sectional survey design and a multistage sampling technique for the 282 dairy farmers. Data was collected using both structured and semi-structured questionnaires. The factors influencing the adoption of improved forage technologies was analyzed using Multivariate probit. The effects of improved forage technologies on household income was analyzed using the endogenous treatment regression model.

The results show that 11 percent, 5 percent, 6 percent and 8 percent of farmers adopted the four technologies of desmodium, lucerne, sesbania sesban and calliandra respectively. The multivariate probit results showed that membership in dairy cooperative, years of schooling, distance to market, gender, experience, farm size, extension services, perceived benefit of the technology, breed type and the number of lactating cows significantly influenced adoption of improved forage technologies. The endogenous treatment regression model results show that adopting improved forage technologies increased household income. It was concluded that the adoption of improved forage technologies has an impact on household income and the adoption of forage legumes was still low. The study recommends that government and policy makers should come up with ways to encourage adoption of forage legumes, mainly fodder trees such as organizing field days, establishment of demonstration fields and research stations, training centers for forage training and encourage more farmers to join dairy cooperatives.

Keywords: *Improved forage technologies, smallholder dairy farmers and Household Income.*

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

The demand for dairy products in developing countries is projected to double by 2050 (Paul et al., 2020), as a result of this increase in demand, dairy farmers are required to embrace balanced feeding to increase dairy productivity (SNV, 2013; Vernooij, 2016). Forages are the foundation of the livestock industry across the world (Njarui et al., 2017), thus, using forage legumes such as lucerne and desmodium together with nappier and hay can improve dairy productivity.

In Kenya, dairy farming is mainly concentrated in the Kenyan Highlands and the Southern Rift Valley area due to the favorable rainfall. In the Southern Rift Valley, all the grazing systems are practiced. These grazing systems are characterized by feeding of concentrates and forages such as napier grass, forage legumes, hay, silage and grazing on naturally grown forages. It is an essential subsector of the Kenyan economy because it contributes 14% to Kenya's agricultural gross domestic product (GDP) (Tegemeo, 2021). Dairy farming is an essential source of livelihood for more than 750 million resource-poor farmers in developing countries (Maleko et al., 2016). It is of paramount importance to improve the performance and productivity of the animals through enhanced forage technologies in order to meet the global demand for milk and reduce hunger.

Milk production in Kenya has increased in recent years from 3.5 million tons in 2017 to 3.9 million tons in 2019 (FAO, 2021). This trend was due to a rise in dairy cow's head, but productivity per cow is still low (FAO, 2018; Auma et al., 2018). The average milk production per cow in Kenya is estimated to be between 6 to 8 liters per cow per day (Muraya et al., 2018). This is low compared to other Countries like Israel, with an average of over 40 liters per cow per day. In order to increase dairy productivity, there is need to increase the use of quality forages (FAO, 2012; Gebreselassie, 2019). Ensuring the correct feeding of dairy cattle with forages rich in protein would increase milk production.

Despite the huge contribution of improved forage technologies to dairy productivity, their adoption is still low among dairy farmers in Kenya (Creamers & Aranquiz, 2019). According to Paul et al. (2020), adoption of improved forage technologies in East Africa is still limited and at crossroad. Similarly, Njarui et al. (2016) observed that over 80% of farmers used maize stoves, which are low in nutritional value to feed their dairy cows, especially in the dry season. This practice has made milk production inconsistent and below its potential yield, especially in the dry season when feeds are scarce (Auma et al., 2016).

The challenges of increasing the adoption of improved forage technologies among smallholder dairy farmers in East Africa, include lack of knowledge on forage production and establishment, high cost of planting materials, low investment, lack of support, dwindling land sizes, poor extension services, shortage of forage seeds and decreasing land size (SNV, 2013, Tegemeo, 2016; Salo et al., 2017; Paul et al., 2020). This has forced smallholder dairy farmers to rely on cheap, easily accessible, low quality feeds such as maize stoves to feed their livestock (Herrero et al., 2013). Furthermore, the sector is dominated by smallholder farmers who have limited land, are illiterate, lacks capital, and knowledge due to inadequate training (Salo et al., 2017; Ahmed & Mesfin, 2017; Bosire, et al., 2019). These smallholder dairy farmers however, contribute about 80% of total milk production (Auma et al., 2016). This makes the sector critical in improving the livelihood of rural people thus, coming up with innovative approaches to overcome the challenges of access to quality forages is of paramount importance in improving dairy productivity and profitability (Ngeno, 2018; Paul et al., 2020).

Adoption of improved forage technologies refers to the used of various quality feeds, such as improved napier grass, which has a high leaf-to-stem ratio and thus higher nutritional value, forage legumes such as desmodium, lucerne and fodder trees. These are considered to have a high dietary value sufficient to provide the energy and protein required by a dairy cow. A farmer is deemed to be an adopter if he engages in the production of at least one of the improved forage technologies namely; lucerne, desmodium, sesbania sesban and calliandra.

In East Africa, most farmers use improved forage legumes alongside local forages. Most legumes serve many purposes such as food, soil erosion control, cover crop, firewood, improving soil fertility through nitrogen fixation and feeds for livestocks (Muoni et al., 2019). In the face of growing extreme weather conditions, researchers and development partners have developed and promoted various forage legumes and in particular, fodder trees because they are drought tolerant and are vital source of crude protein (Franzel et al., 2014). There is limited information on the adoption rate of these forage legumes and their effects on household income is not known. There is therefore need to generate more information on the adoption of forage legumes among dairy farmers in Kenya in order to formulate policies for increasing dairy productivity.

1.2. Statement of the Research Problem

Studies have identified unbalance diet and feed shortages as some of the major factors limiting dairy productivity in Kenya (ILRI, 2017; Kilelu et al., 2018). Adoption of improved forage legumes such as desmodium, lucerne and fodder trees can increase dairy productivity. These Forage legumes were introduced in 2012 to dairy farmers by Kenya agricultural research institute because they are an alternative source of protein, are fast growing, and tolerant to harsh climate. These forage legumes are also an important source of nitrogen fixation in the soil leading to soil fertility (Kebede et al., 2016). The adoption of forage legumes however, is still low (Creamers & Aranquiz, 2019). According to Wairimu et al. (2021), the majority of farmers still graze their dairy cows on natural grass in Bomet. This has made it difficult to increase milk productivity because of lack of a balanced diet and the use of low-quality feeds.

Although research has been conducted on the adoption of improved forage technologies (IFTs) (Maina et al., 2020; Makau et al., 2020; Paul et al., 2020), the adoption of improved forage legumes such as lucerne and desmodium, which can be used as animal supplements due to their high crude protein content, is still limited. Previous studies, for example (Njarui et al., 2017; Maina et al., 2020), have focused less on forage legumes but have documented much on the adoption of nappier and brachiaria grass which are energy-rich forages. There is also limited information on the effect of these improved forage legume technologies on welfare indicators such as household income. This study makes an attempt to fill this knowledge gap.

1.3. Purpose of the Study

To assess the adoption of improved forage technologies (IFTs) and its effect on household income in Bomet County, Kenya.

1.4 Objectives of the Study

a) To characterize dairy forage technologies practiced by dairy farmers.

b) To analyze factors that affect the adoption of improved forage technologies.

c) To assess the effect of adopting improved forage technologies on household income.

1.5. Hypotheses

a) Socio-economic and institutional factors do not affect the adoption of improved forage technologies.

b) Adopting improved forage technologies does not affect dairy farmers' household income.

1.6. Justification of the Study

Livestock is a source of livelihood for many people (Baltenweck et al., 2018), so increasing their productivity through proper animal nutrition could be a sure way out of poverty. Findings on the characterization of dairy forage technologies will fit into the Bomet County Integrated Development Plan (CIDP), where one strategy aims to diversify farming enterprises and technologies (CIDP, 2018-2022). Findings on the constraints to forage and milk production will help the County government and development partners like the Africa milk project to draw practical solutions to reduce limitations to forage and milk production in Bomet County. Furthermore, assessing factors that hinder the adoption of improved forages will help government, researchers, and NGOs to develop innovative ways to reduce barriers of access to quality feeds. Increasing access to quality feeds such as improved forage legumes will help increase dairy productivity. This will contribute to SDG 2 of zero hunger and the African milk technical dairy innovation platforms.

Furthermore, milk is the second highest income earner in Bomet county after tea (MOALF, 2014). The effect of improved forage technologies on household income would help motivate farmers to scale up the adoption of improved forage technologies if they realized that it actually increased milk production. This is because many dairy farmers lack knowledge on the importance and the change, which the use of improved forages can bring to their income. Encouraging the adoption of improved forage legumes like lucerne and fodder trees can be a sure way to end hunger, reduce poverty and will therefore, contribute to Kenya's achievement of Big Four Agenda and the SDG number one on ending poverty.

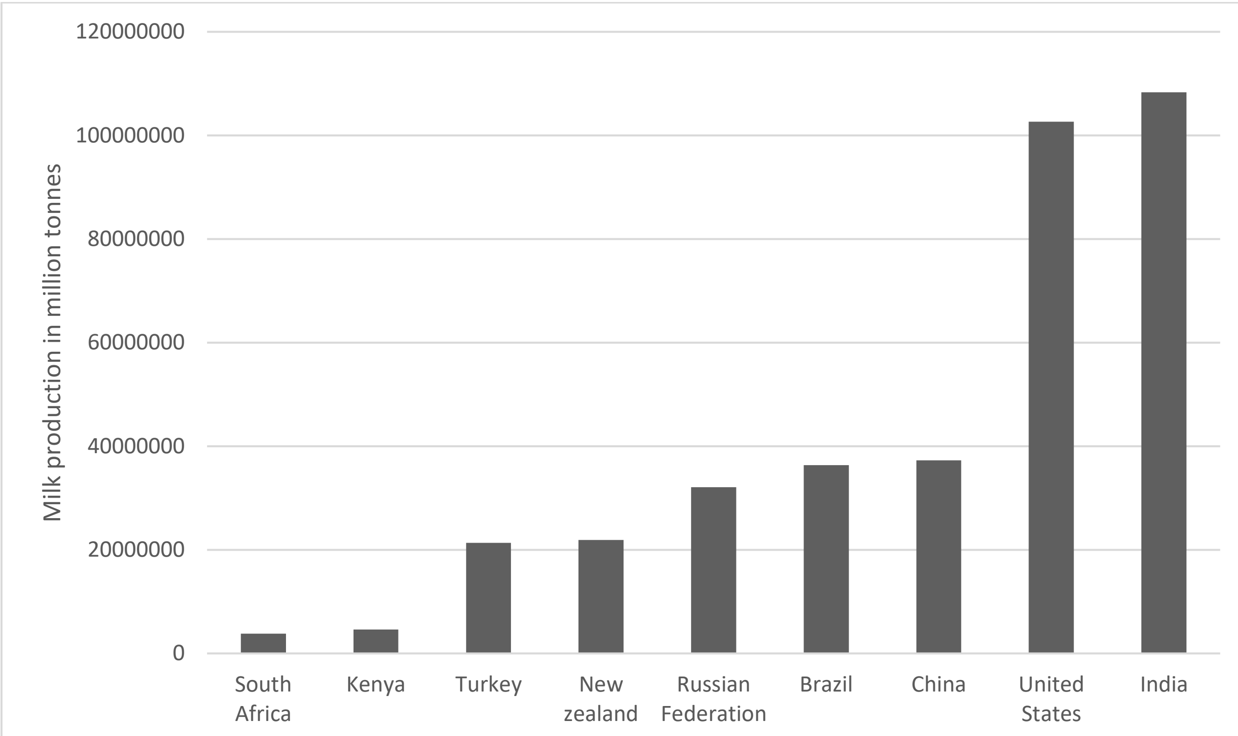
CHAPTER TWO

LITERATURE REVIEW

2.0. Global Dairy Industry

World milk production stood at 930 million tonnes representing a 0.6 % increase from 2021 (FAO, 2022), driven by the rise in milk production from Asia and a small increase gained from Central America and the Caribbean. Cow's milk is the leading liquid milk produced worldwide, standing at 81%, buffalo milk at 15% and goat milk at 4% (OECD-FAO, 2020). India is the leading producer of milk in the world, at 1083 million tonnes (figure 2.1). In the European Union, milk output dropped because of dry weather, high input cost and fuel. In the Russian federation however, milk output increased by 2.2 percent attributed to government support and investment in profitable large modern dairy farms, (FAO, 2022). Milk output in Africa was estimated at 51 million tonnes in 2022, a 0.5 percent decrease because of an anticipated decline in milk production from South Africa, Ethiopia and Kenya attributed to bad weather, high input cost among others (FAO, 2022). South Africa and Kenya are the two major countries that produce enough milk for domestic and export in Africa.

Kenya's dairy sub-sector accounts for 14% to Kenya's agricultural gross domestic product (GDP) (Tegemeo, 2021). It is an essential source of livelihood for rural people since they are the primary milk producers, supplying about 80% (Auma et al., 2016; Odero-Waitituh, 2017). Despite being the major producers in the Kenyan dairy industry, small-scale dairy farmers face challenges such as bad weather, lack of knowledge and proper training in dairy production technologies, illiteracy, and dwindling land sizes (Tegemeo, 2016; Ahmed & Mesfin, 2017). Kenya, for instance, reported low milk collection in 2019 due to declined rains that led to poor pastures and the high cost of animal feeds (FAO, 2020). Despite the many problems faced, milk production is projected to increase by 5% annually in the following decades, which will be driven by growing export potential to neighboring countries, the emergence of the middle class, and increased urbanization (Rademaker et al., 2016; MOALF, 2019).



Source: FAOSTAT (2022)

Figure 2.1: Milk Production (in tonnes) among the Leading Milk Producer Countries for 2021

2.1. Review of Availability of Feed and Forage Resources in Kenya

An adequate and balanced diet is paramount for body condition maintenance, milk production, growth, and fertility. The use of concentrates such as dairy meal is still not impressive, standing at 50% and sometimes less (SNV, 2013). As a result of this, milk production is still below the genetic potential of most lactating cows (ILRI, 2018). Factors limiting milk production include unbalanced diets, seasonal fodder shortages, unavailability of improved fodder seeds, lack of adequate storage facilities, and low skill levels required for fodder production (ILRI, 2017; Kilelu et al., 2018).

The most common forage species used in zero and semi-zero grazing systems in Kenya include napier grass (*pennisetum purpureum*), maize (zea mays), and lucerne (*medicago sativa*) (Creemers

& Aranquiz, 2019). Stall feeding, characterized by cut and carry of forage species such as maize, brachiaria grass supplemented with concentrates, is the common feeding system used in this farming system (Njarui et al. 2016). There is a growing demand for forages in Kenya which has led to the emergence of commercial forage producers, and also attracted entrepreneurial businessmen and women who want to take advantage of the growing opportunities in the sophisticated dairy supply chain, such as feed milling and other services (Kilelu, 2018; Creemers &Aranquiz, 2019). Feeding is essential in milk production, as a result government, researchers, and research institutions have developed and encouraged the adoption of improved forage technologies such as lucerne, fodder trees, and brachiaria grass to increase milk production. Therefore, this study focused on adoption of quality forage legumes such as lucerne, desmodium, and fodder trees (sesbania sesban and calliandra) and its effect on household income.

2.2. Link between Improved Forage Technologies and Household Welfare

The use of quality and adequate balance feed for dairy cows is critical for milk production (FAO, 2012; Franzel et al., 2014; Paul et al., 2020; Makau et al., 2020). Milk yield and composition are highly determined by genetic makeup, nutrition, and management. Improvement in genetics through good breeding influence milk production by 30 percent, while cow's nutrition and management determine 70 percent of milk production and composition. Thus, improving the adoption of forage technologies provides dairy farmers with adequate and quality feeds, which is a significant pathway for poverty reduction and food security. Kashongwe et al. (2017), studied the impacts of feeding practices by smallholder farmers on milk production in both peri-urban and rural settings. He found that feeding strategies are linked to high milk production of at least 10 liters per cow per day. Auldist et al. (2013), noted that energetic ration feeds that contain alfalfa hay, corn silage, and corn grain lead to more significant responses in terms of yield of milk fat and marginal milk production.

Franzel et al. (2014), found that fodder trees increased income of farmers who used them as an alternative source of protein to increase milk production. Kebebe (2017), assessed the impact of adopting improved forage technologies on nutrition and income. On the part of income, he did find that adoption of enhanced forages increase household income by US$ 217 (21700 kshs) for adopters and US$ 63 for non-adopters. A study by Makau et al. (2020), sought to determine the association between diet supplementation with fodder trees and milk production found that a 1kg increase in fodder trees fed to dairy cows per day increases milk production. FAO (2012), observed that appropriate and balanced diets helps in increasing milk production and reduced the daily cost of feeding dairy animals. Similarly, Franzel et al. (2014), noted that fodder trees are important feeds for animals as they require less capital and labor, less land, and are easy to grow.

Adoption of improved forage technologies is linked to increased milk production (Ndah et al., 2017). Thus, increased milk production will likely increase household income through the sale of milk. Previous research conducted in Cambodia, Kenya, Vietnam and China reported the financial benefits of using improved forage technologies (Macleod et al., 2015; Ashley et al., 2018; Maina et al., 2020). The cost of feeds represents 80% of the total cost. Therefore, expensive feeds and the lack of adequate feeds are what hinders dairy productivity in Kenya. Increasing the adoption of improved forage technologies and encouraging own feed formulation would reduce costs and increase household income (Tegemeo, 2016; Lukuyu et al., 2019). These studies show an existing association between improved forage technologies, milk production, and household income.

2.3. Review of the Empirical Literature

2.3.1 Factors Influencing Adoption of Improved Forage Technologies

Adoption of improved forage technologies is central to increasing milk productivity (FAO, 2012). Previous studies have explored adoption of improved forage technologies (Turinawe et al., 2012; Njarui et al., 2017; Ndah et al., 2017; Gebreselassie., 2019; Maina et al., 2020; Balehegn et al., 2020). These researchers used models such as logit and probit, tobit, double hurdle, multinomial logit and probit to model adoption decisions. They identified socioeconomic and institutional factors such as access to extension, perceived benefits of technology, group membership, farm size, and land tenure to be the factors that significantly influence the adoption of improved forages. Adoption is still low because of dwindling land sizes, poor extension, and shortage of forage seeds (Salo et al., 2017).

A study by Maina et al. (2020) on 'Socio-economic factors and impacts of the adoption of brachiaria grass' in Kenya using the propensity score matching method found that brachiaria grass leads to an increase in milk production and adoption is influenced by the type of breed kept by the farmer, benefit derived from using technology, extension services, and membership in the farmer groups. Brachiaria grass however, is an energy-rich forage. There is limited information on adoption of improved legumes, which are high in crude protein critical for normal growth and body maintenance. This study focused on forage legumes such as lucerne, desmodium and fodder trees, which are rich in protein.

Njarui et al. (2017) 'assessed factors that influence the adoption of forages in smallholder farming system' in Kenya using logistic regression and a sample size of 786 farmers. The study revealed that factors such as experience in livestock farming and education positively influence the adoption of forages. Distance to the urban market, farm size, and household size negatively affect the adoption of forages. The model used does not consider the possibility of simultaneous adoption of forages. Some technologies offer greater benefit when they are used together. Therefore, the researcher may have over and underestimated the results, thus yielding biased and inconsistent estimates. This study employed multivariate probit to account for simultaneity in decision making.

A study by Teklay & Teklay (2015) on 'Factors that influence the adoption of improved forage production' in Ethiopia using logistic regression and a sample size of 56 farmers revealed that age, education and land tenure do not affect the extent of adoption of forages while membership in collective action, labor constraint, and rate of extension services significantly and positively affect forage production. The study by Teklay & Teklay (2015) was however, based on a small sample size. When the sample size is small, the margin of error increases. The results generated may have been due to chance and therefore, it makes the result less conclusive. This study attempts to generate appropriate sample size in order to make the results more conclusive.

Gebreselassie (2019) while studying 'determinants for adoption of improved forages' in Ethiopia found that acceptance level and use of quality forages is influenced by factors such as 'land scarcity, lack of forage seed and planting materials, lack of awareness, lack of capital, and poor extension services influence acceptance and use of quality forages in Ethiopia.' The study recommended incorporating improved crops, soil, and water conservation technologies to increase access to forage seeds and create awareness to encourage mass adoption. The conclusions however, were based on the author's intuition which is prone to error. This study employed an econometric model to draw an objective decision.

Balehegan et al. (2020) reviewed 'biophysical, socio-economic, and technological challenges hindering adoption of technologies and policies to increased access to quantity and quality feeds' in low and middle-income countries. The study recommended implementation of strategies to improve the supply of quality feeds. Based on the past empirical studies in Sub-Saharan Africa and Tanzania in particular, Ndah et al. (2017) found that the adoption rate of improved forage technologies is still low. Factors such as improved forages' ecological benefit and institutions' nature positively influence adoption. Similarly, Bashe et al. (2018) assessed the determinants and influence of improved forage technology in Ethiopia. These factors however, are not location-specific. Ecological factors such as soil, light and temperature differ in Ethiopia and Kenya. Furthermore, the policy environment is different in Ethiopia and Kenya, therefore, this study assessed the current factors affecting access to improved forage technologies in Bomet County, Kenya.

2.3.2. Improved Forage Technologies and Household Income

Improved forage technologies are associated with higher milk yields and increased income for the farmers (Kebebe, 2017). Livestock acts as a source of financial security for rural farmers thus, improving dairy productivity through improved forage technologies could increase household income (Baltenweck et al., 2020). Ashley et al. (2014) studied the ‘socioeconomic impact of improved forage availability on cattle production systems’ using a case study of 120 cattle farmers. The study found that improved forage availability increases annual income for cattle farmers. The study only focused on beef cattle. Beef cattle do not require the same amount of feeds as dairy cattle. Dairy cows for example, require a higher amount of calcium than beef cattle. Another weakness of the study is that since it was based on the case study approach, it may not have represented the whole cattle population.

Ashley et al. (2018) examined the socio-economic ‘impact of forage technology adoption by smallholder cattle farmers in Cambodia’ using partial budget analysis and Monte carlo simulation. The study found that adoption of forage technology leads to increased household income. The study focused on rice straw, cut and grass, grazing on native grass, grazing on native pastures, crops by-products and crop residues as the forage technologies. This current study however, focused on fodder trees among other improved forage legumes to assess their effects on household income. With the advance of extreme weather such as drought, fodder trees offer cheap alternative source of crude protein because they are a rich source of crude protein, fast growing and tolerant to drought and hence can provide feeds throughout the year.

Kebebe (2017), examined the 'nutritional and income impact of using dairy technologies in a mixed crop-livestock production system in Ethiopia' using propensity score matching. The study found that improved dairy technologies such as crossbreed dairy cows and improved forage positively impacts household income. The propensity score matching however, does not account for endogeneity from unobserved characteristic. The current study used an endogenous treatment regression model to account for both observed and unobserved characteristics.

2.4. Review of Economic Models on Technology Adoption

Since smallholder farmers are rational economic agents, adoption of agricultural technologies happens when the maximum returns from using the technology are greater. Several studies have used different models to assess determinants of technology adoption among farmers. In this regard (Ayuya et al., 2012, Danson-Abbeam et al., 2017 ; Nguyen-Van et al., 2017) used multinomial logit. Eakins (2016) used the double hurdle model. (Ogada et al., 2014; Thuo et al., 2014; Kansiime et al., 2014) used multinomial probit. Adoption of some of these technologies involves two stages; the first stage represents factors influencing adoption and the second stage is the level of adoption (Eakins, 2016). When there are more than three variables in a decision, polychotomous models such as multinomial logit and probit are used (Ayuya et al., 2012).

In this study, multinomial logit and probit are appropriate since the dependent variable has more than two categories: desmodium, lucerne, sesbania sesban and calliandra. The problem with multinomial logit and probit, on the other hand, is that it assumes that all choices are uncorrelated or independent (Kanyenji et al., 2020). A farmer sometime adopts multiple technologies at once to deal with the many problems facing them (Teklewold et al., 2013). Multivariate probit was used in this study. Multivariate probit is appropriate in cases where the decision to adopt has correlated outcomes (Greene, 2002). In previous studies, a multivariate probit has been used (Gesare et al., 2013; Yirga et al., 2015; Donkoh et al., 2019 and Benimana et al., 2021) to account for potential correlation and simultaneous adoption of multiple technologies.

2.5. Theories Underpinning the Concept of Adoption

The main theories used in understanding the concept of agricultural technology adoption are expected utility theory, diffusion innovation theory, household production theory and random utility theory.

The expected utility theory was developed by Bernoulli in the 18^{th} century. It was used in the analysis of decision making under uncertainty (Jversky, 1975). Here the decision maker chooses between uncertain prospects by comparing their expected utility values that is the weighted sums obtained by adding the utility values of outcomes multiplied by their respective probabilities (Moscati, 2016). Consider for example, a prospect (Z) with prices x_1, x_2,.. x_n and probabilities π_1,π_2 .... π_n. The expected value is given as the weighted sum of the prices where weights are the respective probabilities.

$$E(z) = \pi_1 x_1 + \pi_2 x_2 + . \ldots\ldots + \pi_n x_n$$

$$= \sum_{i=1}^{n} \pi_i \, x_i \text{ where } \sum_{i=1}^{n} \pi_i = 1$$

Where (Z) represents adoption of improved forage technologies

Random Utility Theory

In random utility theory, utility is the driving factor. Therefore, an individual is likely to choose a given alternative based on the utility he/she derives from it. Random utility theory simulates the choice of a decision maker from a set of alternatives that maximize his or her utility (Cascetta & Papola, 2001).

According to cascetta (2009), the random utility model is based on the following assumptions;

a) An individual chooses from a set of mutually exclusive alternatives

b) The decision maker assigns each alternative a perceived utility and selects an alternative, which gives him/her maximum satisfaction.

c) The utility assigned to each choice depends on observable characteristics such as; age, education etc.

d) Utility is not known with certainty.

Adoption of random utility model for this study is advantageous because it captures the strength of preference (Alos-Ferrer & Garagnani, 2019). The choice of adopting improved forage technologies affects vaious farm outcomes such as milk production, food security status of participating farmers and household income.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Conceptual Framework

In Figure 3.1, various socio-economic factors such as age, education levels, gender, farm size among others are believed to play a crucial role in improving the adoption of improved forage technologies. SNV (2013), noted that dwindling land sizes, poverty, and lack of skills due to poor education are some of the factors constraining adoption of improved forage technologies among smallholder dairy farmers in Kenya. Strengthening socio-economic factors will ensure quick and easy adoption of these technologies. The institutional and technological factors include membership in cooperatives, access to credit, perceived benefits of the technology, and access to extension, among others. Some of these factors such as membership in cooperatives provide credit, training and facilitate linkage with extension services (Abate et al., 2014). Access to extension services is believed to equip farmers with crucial knowledge and skills. Therefore, improving access to these factors can facilitate the adoption of improved forage technologies. Adoption of improved forage technologies is anticipated to increase milk productivity and household income through milk sales. This is because using quality and adequate feeds increases milk production (FAO, 2012).

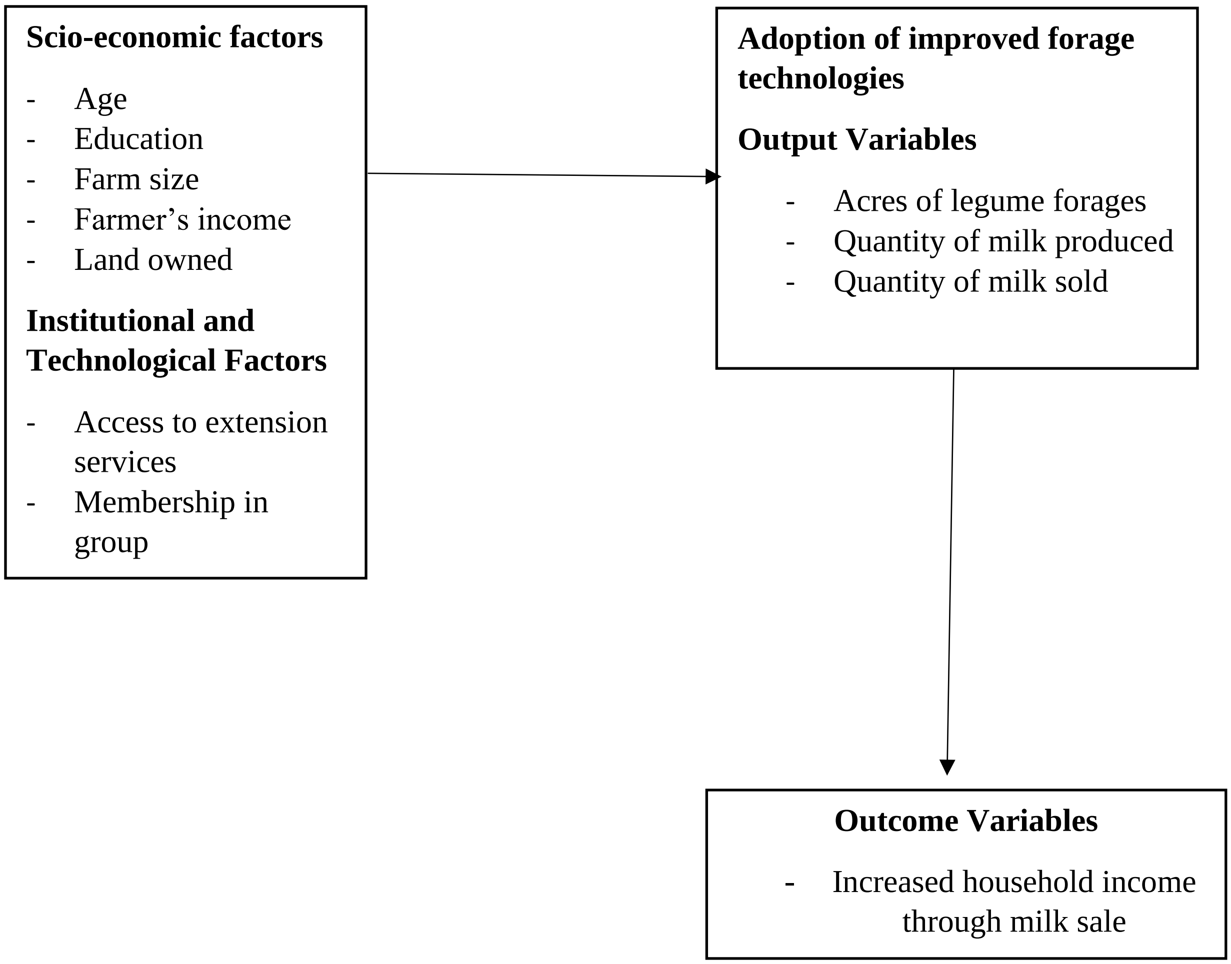


Figure 3. 1: Illustration of the Link Between Improved Forage Technologies and Household Income

Source: Author's Conceptualization

3.2. Study Area

This study was carried out in Bomet county, located in the Rift Valley region of Kenya. It has a geographical area of 2,530.9 km^2 and a total population of 875,689 (434,287 males and 441,379 females) and a population density of 346 per square kilometer (KNBS, 2019). Rainfall is highest in the lower highland zone with annual rainfall of 1000mm to 1400mm followed by midland and upper midland. Upper midland zone receives relatively low rainfall among the three zones. Bomet comprises five sub-counties: Bomet central, Bomet East, Chepalungu, Sotik, and Konoin. Out of five sub-counties, this study focused on two Sub-counties; Sotik and Chepalungu, the Africa milk project focused areas. Bomet is a multi-ethnic county with Kipsigis sub-tribe of the Kalenjin tribe being the largest tribe.

Sotik Sub County is a hilly place with agriculture as the main economic activity. It has a total population of 227,855 (112369 males, 115482 female) (KNBS, 2019). Tea and maize are the two major crops grown in the area. Dairy farming is one the major economic activities in the area with administrative ward having established a cooling plant (Bii, 2017).

Agriculture is the main economic activity in which dairy farming is among the leading economic activities in all sub-counties (MoALF, 2014). Dairy farmers still graze their cattle with natural grass (Wairimu et al., 2021). Use of improved forage technologies can improve dairy productivity but the use of these improved forage technologies is still limited. The improved forage technologies considered in this study are; lucerne, desmodium, sesbania sesban and calliandra. These technologies among others were developed, improved and promoted by Kenya agricultural research institutes since 2012 to be used by smallholder dairy farmers as supplements and protein sources. Kenya’s dairy industry comprises of two significant players; small-scale farmers who own 1 to 3 exotic cows and large-scale farmers who keep a large number of dairy cattle, mostly from seven and above. Small-scale is characterized by cut and carry systems with limited use of concentrates. Large-scale farmers are highly specialized, have excellent management systems, and high-quality feeds.

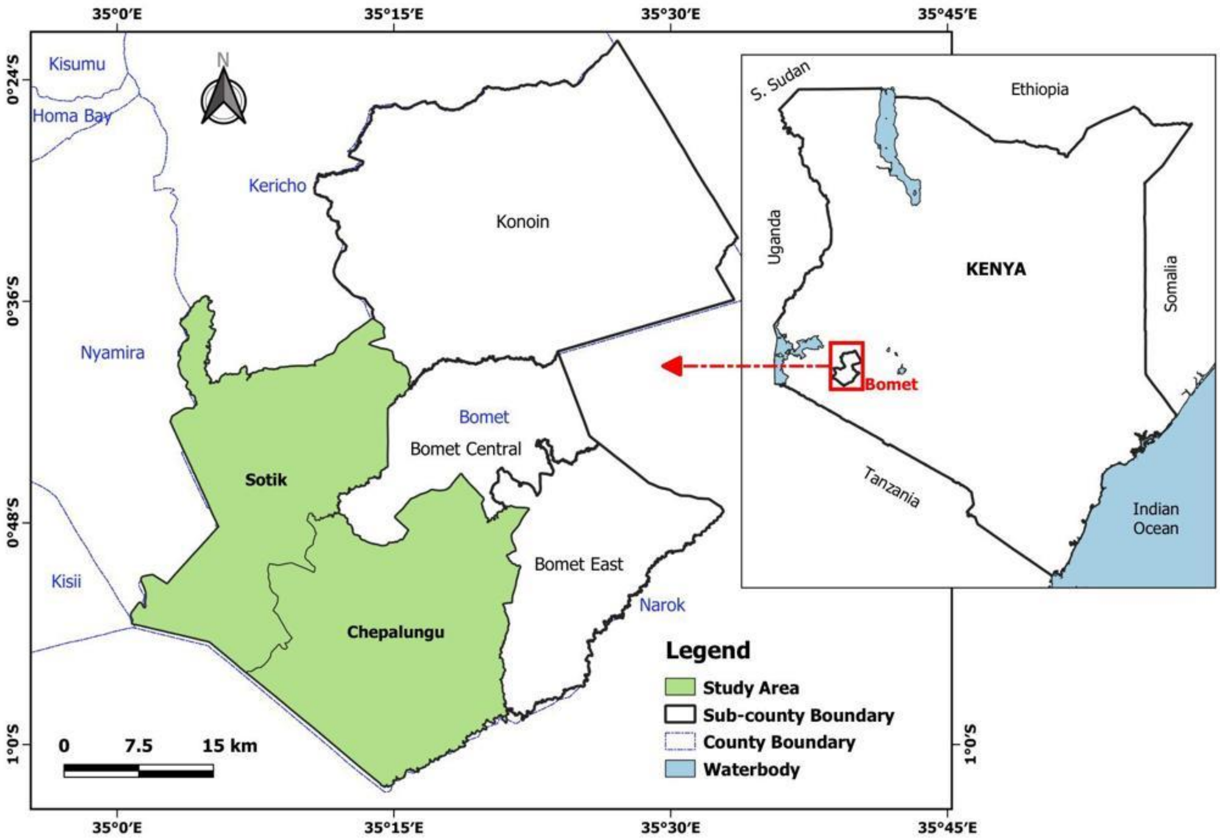


Figure 3. 2: Map of Sotik and Chepalungu Sub-Counties of Bomet County, Kenya

Source: Generated from Arc-GIS by the Author

3.3. Research Design

The study employed a cross-sectional design. The cross-sectional design is a cost-effective way of collecting information in a short period (Kothari, 2004). The study adopted both qualitative and quantitative approach. The qualitative approach involved the use of focus group discussions and key informant interviews. Focus group discussions targeted farmers to understand different forage technologies grown and used by farmers, understand constraints to forage production and what they think should be done. Quantitative approach was adopted to enable inferences on the population of interest (Amin, 2005). Furthermore, the quantitative approach allowed the researcher to solicit information that could be quantified. Notably, the study adopted a descriptive and econometrics approach. Quantitative approach was employed mainly to find out the differences between adopters and non- adopters. It was also employed to understand the relationship between variables used in the study.

3.4. Method of Data Collection and Sampling Procedure

3.4.1. Data Sources

Data was mainly obtained from primary sources which included; County government officials and smallholder farming households. Secondary sources included; FAO and World Bank publications, Kenya dairy board annual reports and government publications.

3.4.2. Sample Size Determination

This study relied on a baseline data collected in 2019 by the Africa Milk Project. Africa Milk project was carried out in three milk sheds which include; Mukurweini Wakulima Dairy Limited (MWDL), Happy Cow Limited (HCL) and New Kenya Cooperative Creameries NKCC Sotik factory. A milk shed is where a single dairy processing plant sources its milk from (Wairimu et al., 2021). This study focused only on the NKCC Sotik factory and its collection areas. NKCC collects milk from Bomet and Nyamira counties. The total number of respondents in the baseline survey were 355 and 283 respondents were from Bomet and 72 from Nyamira respectively. This study focused on Bomet county only. Data of respondents in Bomet County was extracted from the baseline data of the Africa-Milk Project. The total number of respondents in Bomet County was 283 respondents, and all these respondents were considered for the study.

3.4.3. Sampling Procedures

The study used multistage sampling technique. Multistage sampling technique is suitable for this study because of its advantage of concentrating resources on the limited number of units of the frame (Singh & Masuku, 2014; Amare et al., 2019). The study adopted the sampling approach used by Wairimu et al. (2021). Even though this study relied on baseline data collected in 2019 by Africa milk project, some data was still collected on the same farmers and that is why the study adopted a sampling approach by Wairimu et al. (2019). The sampling approach used by Wairimu

(2021) had four different sampling units. These were; firstly, farmers who supply milk directly to processing plants, secondly, middlemen or traders who supply milk to plants, thirdly, farmer's groups who collect milk and the processor who picks from them and fourthly, cooperatives who supply milk directly to the plants. This study only uses farmers as the only unit of analysis because they were the ones engaged in planting of fodder for dairy cows. In the first stage, NKCC processing plant was purposively selected. In the second stage, the milk collection systems were selected. In the third stage, the main production areas where these milk collection systems are located were purposively selected. List of dairy farmers from within the main production area was obtained from baseline data collected by Africa Milk Project in 2019.

In the fourth stage, all the respondents identified were interviewed. In Bomet County, the total number of respondents who were part of the baseline study was 283. Since the total number of respondents were small to allow sampling to be done, all of them were interviewed. However, only 271 respondents were interviewed because some respondents could not be reached and others were deceased. This study was linked to a baseline study by the Africa Milk Project, which characterized dairy innovations adopted by dairy farmers in Bomet county. These innovations included housing cows, herd management practices, feeds and feeding, reproduction, animal health, milk hygiene, milk sale channels, and access to credit. This current study focused on feeds and feeding by assessing the adoption rate and their effects on household income of dairy farmers in Bomet County.

3.4.4. Data Types and Data Collection Methods

The study used primary data collected across a wide range of smallholder dairy farmers. Data collection was based on categories such as feed resources, socioeconomic characteristics, farm characteristics (farm size, ownership of land), income sources, and animal characteristics (number of lactating cows and breed type).

Both quantitative and qualitative methods were employed in this survey. Qualitative data involved the use of focus group discussions and key informant interviews. Two focus group discussions were conducted in each of the two sub-counties where Africa Milk Project was implemented. Each group consisted of twelve members each. Key informant interviews were done with county officials, agro vets, and county veterinary doctors to get a snap shot of the county's dairy sector. Quantitative data was collected from dairy farmers' households using structured and semi-structured questionnaires. The questionnaire enabled information to be collected from a large sample in a short period (Creswell, 2009). Here, a pretested questionnaire in a kobo toolbox was administered to dairy farmers in the study area. Enumerators were assigned to designated areas and face to face interview was used to collect data from individual farmers. According to Doyle (2014), a face-to-face interview helps the researcher control the data collection process and quality by ensuring that respondents do not skip some questions, which otherwise can be impossible through other forms of interviews**.** Questionnaires were composed of the following sections; Section A was on household and demographics (land tenure/land use, household and dairy assets, household financial resources), and section B captured information on livestock inventory and management. Section C captured information on dairy cows' management (dairy cows' characteristics and milk production, dairy cows' feeds and feeding, dairy cows' reproduction, and dairy inputs). Section D captured information on marketing, farm milk network and sources of information.

3.5. Analytical Framework

A random utility framework was used to guide the study. According to this theory, consumers will always choose an alternative with greater utility (Greene, 2002). Therefore, consumers adopt improved forage technologies if the benefits of adoption are greater than the benefits of non-adoption.

This theory assumes that a farmer is a utility-maximizing agent who will choose a technology or set of technologies that give them maximum returns. Given two technologies T_1 and T_2 with corresponding utilities $u_1$and u_2. Assume $u_1 > u_2$, a farmer will choose T_1 instead of T_2 because he/she gets a maximum return from using T_1. The benefit or utility derived from choosing T_1 can be expressed as a linear sum of two components;

i. Exogenous variables or farmer's characteristics represent observable components and
ii. an error term that means unobservable farmer's characteristics. This is expressed as follows;

$$d_{ji} = w_{ji} + u_{ji} \tag{1}$$

Where d_{ji} is the utility resulting from the use of a particular technology, w_{ji} captures observable components of the utility and u_{ji} is an error term that captures unobservable components.

The adoption decision is believed to lead to a binary choice model, which involves adoption and non-adoption of improved forage technology. This adoption decision can be represented by y, as shown below.

$$y_i = x_i\beta + v_i \tag{2}$$

Where y_i is the outcome variable of the adoption decision (household income) with $y = 1$ if a farmer adopts improved forage technologies and $y = 0$ for non-adoption. x_i is a set of exogenous variables included in the model (number of lactating cows, experience, group membership, access to extension) among others? The variables included in the model were guided by previous studies on the adoption of agricultural technologies (Njarui et al., 2017; Marwa et al., 2020; Maina et al., 2020), β is a vector of parameters to be estimated, v_i is a disturbance term.

From Equation (1) above, utility is not observable; what is observable is the adoption decision which happens when; $y^* = 1$ (adoption is observed) and $y^* = 0$ (no adoption) otherwise

The variable y in Equation (2) is a dependent variable bound between (0,1) and this, therefore, gives rise to a Binary Choice Model.

3.6. Empirical Framework

3.6.1. Characterization of Dairy Forage Technologies

This objective was analyzed using descriptive statistics to summarize different socio-economic and demographic variables. The independent t-tests were used to determine the statistical significance differences in the means of adopters and non-adopters of improved forage technologies. Bar charts were also used to visually represent various constraints to forage and milk production.

3.6.2. Factors Influencing Adoption of Improved Forage Technologies

This objective adopted multivariate probit because of its ability to account for the adoption of multiple technologies whose outcomes are interrelated (Kassie et al., 2015). Multivariate is simply an extension of bivariate probit (Otieno et al., 2011). From random utility theory, the general multivariate probit model can be expressed as follows

$$S_{jik} = X_{ji}\beta_k + \varepsilon_k \quad (k = 1,2,3) \qquad (3)$$

Where S_{jik}(j=1,2……j) represents latent variable of participation in improved forage technologies i adopted by farmer j. k denotes improved forage technologies included in the model, namely *desmodium* (1), *lucerne* (2), *sesbania sesban* (3) and *calliandra* (4). X_{ji} is the combined effects of explanatory variables that affect adoption decisions, β_k is a vector of estimators, ε_k is a disturbance term. A farmer will adopt improved forage technologies if $S_{ji} = 1$ and $S_{ji}^* > 0$ and will not adopt if $S_{ji}^* \leq 0 \quad (S = 0)$

Equation (1) above can be expanded as shown below

$$\begin{cases} S_1^* = X_1\beta_1 + \varepsilon_1 \quad with\ S_1 = 1 \ \ if\ S_1^* > 0,\ \ and\ 0\ otherwise \\ S_2^* = X_2\beta_2 + \varepsilon_2 \quad with\ S_2 = 1 \ \ if\ S_2^* > 0,\ \ and\ 0\ otherwise \\ S_3^* = X_3\beta_3 + \varepsilon_3 \quad with\ S_3 = 1 \ \ if\ S_3^* > 0,\ \ and\ 0\ \ otherwise \\ S_4^* = X_4\beta_4 + \varepsilon_4 \quad with\ S_4 = 1 \ \ if\ S_4^* > 0,\ \ and\ 0\ otherwise \end{cases} \qquad (4)$$

Where S_1^*, S_2^*, S_3^* and S_4^* are binary variables which are equal to one if a farmer j adopts i technologies (*desmodium, lucerne, calliandra* and *sesbania sesban*); X_1, X_2, X_3, X_4 are combined effects of explanatory variables; β_1 to β_4 represents unknown parameters to be estimated; ε_1, ε_2, ε_3& ε_4 represents error terms. Multivariate probit allows simultaneous selection of multiple technologies; the error term then follows a multivariate normal distribution with zero conditional means, a variance normalized to unity for easy parameter identification and the symmetric covariance matrix Ω is given by

$$\Omega = \begin{matrix} 1 & \rho_{12} & \rho_{13} \\ \rho_{21} & 1 & \rho_{23} \\ \rho_{31} & \rho_{32} & 1 \end{matrix} \qquad (5)$$

Where ρ_{ji} represents the correlation between different improved forage technologies.

3.6.2.1. Description of the Variables Included in Multivariate Probit

Gender of the Farmer

The gender in this study is considered an important variable. This is because some respondents tend to have easy access to resources based on their gender. Abebaw & Haile (2013) found that 'Male-headed households participate more in agricultural activities than female-headed households.' This is because, in Africa, men control decisions related to access to land, livestock, and credit and can quickly obtain information than women. Furthermore, women are always preoccupied with household duties. It was expected to influence adoption and household income positively and was captured as a dummy variable.

Farm Size

Asset holdings such as land, ox, livestock, and radio were hypothesized to positively influence the adoption of improved forage technologies (Teklay & Teklay, 2015). Asset holding such as land is an indicator of wealth that can increase investment in forage planting, and management practices such as milk handling can increase income (Bashir, 2014).

Breed Type

The variable was hypothesized to positively increase the probability of adopting improved forage technology and income. Dairy farmers who keep exotic breeds were expected to use more improved forage technologies. As farmers acquire more improved dairy breeds, improved forage technologies increase. Turiname et al. (2012) reported that an increase in improved cow breeds increases the adoption of improved forage technologies.

Education of the Household Head

Refers to the time a farmer takes to obtain their current level of formal education. It was expected to influence adoption and household income positively. This is because more educated farmers can access information, learn about the benefits of adoption, and are always willing to try new technology (Ngeno, 2018).

Experience in Dairy Farming

Experience was expected to influence adoption and milk income positively. It was captured as the years an individual has been a farmer. More experienced farmers were expected to learn about the benefits of growing improved forages through their years in dairy farming (Njarui et al., 2017).

Membership in Cooperatives

Membership in cooperatives was measured as a dummy variable and expected to influence milk income and adoption of improved forage technologies positively. This is because cooperatives are expected to provide support services, bargain for a better price, training of their members. Therefore, the probability of adoption was expected to be higher among members of cooperatives (Abate et al., 2014).

Distance to Urban markets

This was a continuous variable that was measured in kilometers. It was hypothesized to negatively affect the adoption of improved forage technologies. Urban markets are sources of improved forage seeds; therefore, longer distances will force farmers to rely on low-quality sources from fellow farmers (Awotide et al., 2016).

Access to Off-farm Income

This is income obtained outside farming activities. It was expected to influence adoption and household income negatively. This is because access to off-farm income decreases the desire to engage in dairy farming activities and the adoption of improved forage technologies (Ngenoh, 2018).

Perception of Benefit of the Technology

This was measured as a dummy variable with a value of 1 for positive perception and 0 for negative perception. It was hypothesized to increase adoption of improved forage technologies. Maina et al., (2020), found that farmers who perceived Brachiaria to increase milk production were more likely to adopt Brachiaria grass.

Access to Extensions

Extension services availability increase the adoption of agricultural technologies (Ghimire et al., 2015). Extension provides awareness and information on the importance of adopting best management practices (Baumgart-Getz et al., 2012). The extension was hypothesized to positively influence the adoption of improved forage technologies and was captured as a dummy variable.

Number of Lactating Cows

Studies, for example, Njarui et al. (2017) found the number of lactating cows to increase the likelihood of adoption. This study adopted the same line of thinking and hypothesized that the number of lactating cows increased household income and the probability of adoption of improved forage technologies.

Access to Credit

This variable was captured as a dummy. It was anticipated to be positive. This is because quality forage seeds are expensive and only farmers who have access to credit can afford them (Mabe et al., 2018).

Table 3.1: Description of Explanatory Variables used in Multivariate Probit Model

Variables	**Description**	**Unit of measurement**	**Expected signs**
Dependent Variables			
Decision to adopt improved forage technologies (IFTs) or not			
Independent Variables			
Access to credit	Access to affordable credit services	Yes=1 No=0	+
Education in years	Time spent to obtain a given level of formal education.	Years	+
Membership in dairy cooperative	Membership of household head in any farmer groups	Yes=1 No=0	+
Off farm income	activities practice by the household head outside farming	Yes=1 No=0	–
Access extension services	Any extension services received by the respondents	Yes=1 No=0	+

Experience in dairy	Number of years spent in dairy farming	Number	+
Gender	Gender of the household head	Male=1 Female=0	+/-
Distant to market	Distance of the respondent house to the nearest urban market	Kilometers	-
Farm size	Total farm size of the household head	acres	+
Perceived benefit of technology	Knowledge of benefits accrued in using a technology	Yes=1 No=0	+
Number of lactating cow	Lactating cows owned by the household head	Number	+
Breed type	Type of breed kept by the farmer	Exotic=1 Local=2	+

Source: Author's compilation from existing literature

3.6.3. Effects of Adoption of Improved Forage Technologies on Household Income.

An endogenous treatment regression model was fitted to estimate the effects of one or combination of any of these improved forage technologies. Past studies such as Ahmed & Mesfin (2017) used propensity score matching to estimate the 'impact of agricultural cooperatives membership on the wellbeing of smallholder farmers in Eastern Ethiopia'. Marwa et al. (2020) also used propensity score matching to evaluate the impact of 'ICT-based extension services on dairy production and household welfare' in Kenya. The propensity score matching however, does not account for endogeneity arising from unobservable characteristics. This objective therefore, employed an endogenous treatment regression model. Heckman (1976) popularized the model to account for endogeneity caused by both observable and unobservable characteristics. Endogeneity arises because the selection is not random, so participants may self-select (Millimet & Tchernis, 2013). Farmers who are practicing improved forage technologies and are well informed may willingly enter the program. This motivational drive cannot be easily observed. It will likely be reflected in the error term, thus inducing a correlation between the adoption of improved forages and the error term. This is called sample-induced endogeneity (Certo et al., 2016). Following Owoo et al. (2017), the two-step endogenous treatment regression model is specified.

$d_i^* = z_i\, \alpha + \mu_i$ (selection equation) with $d_i^* = 1$ if $d_i^* > 0$ and 0 otherwise (6)

$y_i^* = x_i\beta + \delta d_i + v_i$ outcome equation (household income) (7)

Where d_i^* denotes latent participation in the adoption of improved forage technologies, z_i represents exogenous variables, α is an unknown parameter to be estimated, μ_i is a disturbance term. The error terms μ_i and v_i are assumed to follow a bivariate distribution with zero mean.

$$\begin{pmatrix} \sigma & \rho \\ \rho & \sigma \end{pmatrix} \quad (8)$$

If participants self-select into the program, endogeneity may arise. This implies that the expected value of the error term of the outcome equation (income) condition on access to adoption decision is non-zero. Therefore, the conditional mean of income in equation (7) can then be expressed as

$$E(y_i/d_i) = x_i\alpha + E(\frac{v_i}{z_i}, \mu_i) = x_i + E(v_{i/\mu_i} \quad (9)$$

Such that $E(V_i/\mu_i) \neq 0$. Thus, the conditional expectation of the error terms v_i and μ_i are expressed as;

$$E(v_i/\mu_i) = E(v_i/\mu_i \varpi x_i\beta) = E(\sigma v_i, \rho/\mu_i) = \rho\sigma_u \; \frac{\varphi(\beta x_i)}{\phi(\beta x_i)} \quad (10)$$

Where φ and ϕ are normal probability density functions and cumulative density functions of the standard normal distribution.

To correct for self- selection bias, binary probit was applied in the selection equation (6) and inverse mill ratio (IMRλ) was obtained and used as an instrument in the outcome equation (Wooldridge, 2012). This is formulated as follows;

$$\lambda = \frac{\varphi(-\beta_1 x)}{1-\phi(\beta_1 x)} \quad (9)$$

Where φ and ϕ are as defined above. The inverse mill ratio (rho) can correct the problem that may arise due to selection bias (Greene, 2002). According to Certo el al. (2016), there is endogeniety if the correlation coefficients between the two error terms (rho) in the selection equation (participation in adoption of improved forage technologies) and outcome equation (household income) is non-zero. Therefore, to correctly estimate the effects, this difference needs to be considered (Abdullah et al., 2017). The outcome equation with IMR inclusive then becomes:

$$y_i^* = x_i\beta_i + \phi d_i + \theta\lambda s_i + \varepsilon_i \quad (10)$$

Where y_i^* represents household income level derived from summing up revenues from all household income sources. These sources of income include; income from dairy (milk, feed and manure), income from other livestock activities, income from all crops, income from other farm activities (draft animal renting, machinery and equipment rental), income from non-farm activities, income from pension, income from remittances. This approach was adopted from (Danso-Abbeam et al., 2018). d_i is participation in adopting improved forage technologies measured as a dummy variable. y_i^* is observed when d_i=1. x_i is the combined effect of explanatory variables on adoption and household income, s_i is the exclusion criteria, β, ϕ, and θ are unknown parameters to be estimated. However, the two steps have its limitation because it requires complex adjustments to obtain consistent estimates. To overcome this problem, Wooldridge (2002) recommended the use of maximum likelihood estimation method to generate consistent estimates. Previous studies, for example (Danso-Abbeam et al., 2018; Amare et al., 2019; Adeyanju et al., 2021), used average treatment effect (ATE) to estimate impact by comparing the expected outcome for participating and non-participating farmers. Hence, following (Millimet & Tchernis, 2013), the average treatment effect is given as

$$ATE = E(y_i|x_i = 1) - E(y_i|x_i = 0) \quad (11)$$

3.6.3.1. Description of the Variables in the Outcome Equation

Number of Dairy Cows

The variable refers to the number of dairy cows owned by a farmer. It was hypothesized to influence the adoption of improved forage technologies and household income. Households with more dairy cows were more likely to adopt improved forage technologies and have more milk income. Studies such as Okello et al. (2021) found the number of dairy cows to be positively associated with the intensity of adoption of dairy technologies in Kenya.

Access to Training

This variable was hypothesized to increase adoption and household income. Technical training in dairy information technology, forage establishment and maintenance, farm machinery, business plan and milk hygiene was expected to increase household income. Benimana et al. (2021) found that access to training increases the use of alternative maize storage technologies in Rwanda.

Milk Production

This variable was captured as a continuous variable. It refers to the amount of milk produced by each cow in a farm. Milk production was measured in litres of milk produced. It was hypothesized to increase household income. Studies such as Okello et al. (2021) found milk production to increased household income in Kenya.

Ownership of Transport Means

Ownership of transport means such as motorbike, bicycle, cart and pick-up truck was expected to positively influence income. Akrong (2020) found positive association between ownership of transport and access to high value market by mango farmers in Ghana.

Access to Information

This variable was captured as a dummy variable. Farmers use both extension agents, radio, and electronic media to access information. If farmers have ready access to information on buyers and sellers of forages and concentrates, market prices, unexpected shocks such as economic down turn and weather shocks, disease outbreak, certification and accreditation, then they were expected to have more household income.

Adoption of Improved Forage Technologies

This variable was captured as a dummy variable. Value of 1 was assigned to farmers who have adopted any of the four technologies namely; desmodium, lucerne, sesbania sesban and calliandra. Value of 0 was assigned to non-adoption. It was hypothesized to increase household income. Ashley et al. (2018) found use of improved forage technologies to increase household income in Cambodia.

Table 3.2: Description of Variables used in Endogenous Treatment Regression Model

Variables	**Description**	**Unit of measurement**	**Expected signs**
Dependent Variables			
Household income.	Total revenues from all income sources in Kenyan shillings		
Independent Variables			
Breed type	Type of breed kept by the farmer	Exotic=1 Local=0	+
Adopt legume	Use or grow any of the legume forages	Yes=1, No=0	+
Membership in dairy cooperative	Membership of household head in any farmer groups	Yes=1, No=0	+
Access to extension service	Any extension services received by the respondents	Yes=1, No=0	+
Age	Number of years of the respondent	Years	+
Education in years	Time spent to obtain a given level of education by respondents	Years	+

Farm size	Total farm size of the household head	acres	+
Off farm income	Access to income out of agriculture income	Yes=1, No=0	-
Access to credit	Any credit receive by the respondent at any time of the year	Yes=1, No=0	+
Number of dairy cows	Total number of dairy cows owned by the household head	Number	+

Source: Author's compilation from existing literature

3.6.3.2. Model diagnostic tests

3.6.4.1 Test for multicollinearity

Multicollinearity happens when two or more explanatory variables have an exact linear relationship. The presence of multicollinearity leads to high R^2 value and few significant t-ratios (Gujarati et al., 2010). In this study variance inflation factor (VIF) was applied to check the present of multicollinearity. After running OLS regression. VIF was calculated as follows:

$$VIF = \frac{1}{1-R_i^2} \quad (12)$$

Where R_i^2 is the R^2 for the auxiliary regressors

According to Gujarati & Porter (2010), there is multicollinearity if the VIF value is greater than 10.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Descriptive Results

The demographic and socio-economic characteristics of the respondents (Table 4.1) show that the average daily milk production was 14 liters per cow for adopters compared with 10 liters for non-adopters. This implies that adopters produce more milk than non-adopters. The difference in milk production between adopters and non-adopters is significant at 5% confidence level. This difference can be attributed to the use of legume forages such as Lucerne, desmodium, and fodder trees which have high protein content that can increase milk production (Kiptot et al., 2015).

The average daily milk income was Kshs 457.35 (1$=100Kshs) for adopters and 325.83 (1$=100 Kshs) for non-adopters. This difference is significant at 5% confidence level. This difference can also be attributed to the use of legume forages which are rich in protein, minerals and vitamins and essential for high milk production when fed to cows, leading to more income from the sale of milk. This is because legumes forages have potential of increasing milk production and can be used as an alternative for expensive dairy meals hence saving money (Lukuyu et al., 2019).

The mean years of formal education for adopters were slightly higher (10 years) than that of non-adopters (9). The difference was statistically significant at one percent level. Adopters had a higher education than non-adopters.

Table 4. 1: Socio Economic and Demographic Characteristics of the Respondents in Bomet County

Variable	Adopters	Non-adopters	Pooled	t-ratios
Daily Milk Income (kshs)	457.35	325.83	359.2	$\mathbf{2.35}^{**}$
Daily Milk Production (litres)	13.86	9.84	10.9	$\mathbf{2.37}^{**}$
Education (Years)	9.74	8.52	8.84	$\mathbf{2.06}^{**}$
Experience (Years)	18.74	17.81	**18.05**	0.50
Farm Size (Acres)	6.04	3.56	4.20	$\mathbf{2.99}^{***}$
Number of Lactating Cows	2.41	1.59	2	$\mathbf{4.10}^{***}$
Distance to Market (KM)	1.41	1.55	1.5	**-0.62**
	Adopters n=70	**Non-adopters n=200**	**Pooled n=270**	$\boldsymbol{chi^2}$
Extension	53	18	27	$\mathbf{0.00}^{***}$
Benefit of Technology	89	95	94	$\mathbf{0.042}^{**}$
Information	49	63	59	$\mathbf{0.04}^{**}$
Breed Kept (Exotic=1)	83	83	83	0.98
Gender (male=1	53	20	29	$\mathbf{0.00}^{***}$
Membership Coop	21	36	32	$\mathbf{0.25}^{**}$
Access to credit	37	32	33	0.43
Off-farm Income	23	26	25	0.66

Source: Own Survey data 2021. Note: p>0.1=$*$, p>0.05= $**$, p>0.01=$**$

The average farm size for adopters was approximately six acres and four acres for non-adopters. The difference is statistically significant at one percent confidence level. Adopter farms were larger than non-adopter farms. Farmers' land holding is an indicator of their wealth. This can explain why farmers with larger farms are able to adopt more forage legumes. Land scarcity is also one of the significant problems to dairy and forage production in Kenya. Farmers prefer to use the available land for food crops because the gain from forage production takes long.

Regarding the number of lactating cows, there was a significant difference between adopters and non-adopters. Adopters kept approximately three cows while non-adopters kept two cows. This difference was significant at 1 percent confidence level. Pooled results show that the majority of dairy farmers kept about two cows each. This shows that dairy farming is one of the most important economic activities in Bomet County.

The majority of the respondents have no access to extension services. Pooled results show that only 27 percent of the respondents have access to extension services. This is significant at 1 percent confidence level. The low access to extension services could explain the low adoption of improved forage technologies among dairy farmers in Bomet County. This low adoption is the reason for the persistent low milk production among dairy farmers in most parts of Kenya. Extension services help in improving the adoption rate of improved forage technologies because they provide awareness and increase the uptake of knowledge.

About 53 percent of adopters were male compared to 20 percent female. This was expected considering that males control resources such as land in an African context and are more likely to attend formal training. Thongoh et al. (2021), reported that more males than females are associated with increased knowledge on the value chain. This is attributed to the fact that the value chain activities such as production and marketing require resources to engage in and because males' control most of the resources, they can be able to engage in it.

The results also show that more than 93 percent of the respondents agreed that adopting improved forage technologies can increase milk production. This indicates that the respondents are aware of the importance of legume forages. The problem is the lack of knowledge on forage establishment and unaffordable seeds. The three percent of adopters who believe that legume forages cannot yield any benefit in regard to milk production can be attributed to the disappointment people get from adoption, for example when lucerne is fed to cows while fresh causes bloating.

About 49 percent of the respondents had access to information on market prices and trends from fellow farmers, NKCC extension agents, and radios. Information plays a crucial role in linking consumers and producers in the dairy sector. It also helps farmers know the emerging agricultural technologies critical for improving dairy productivity.

Only 21 percent of adopters belong to dairy cooperatives against 36 percent. The reason can be attributed to the fact that the majority of the respondents were from the Sotik sub-county and these farmers supply their milk directly to the NKCC processing plant, which offer almost the same services provided by dairy cooperatives to farmers.

4.**1.1. Major Constraints of Milk Production among Dairy Farmers in Bomet County**

Figure 4.1 shows constraints to milk production in Bomet county. Most farmers mentioned poor health, inability to use more milk and expensive concentrates as the major challenges limiting increased milk production. The high prices of concentrates can be attributed to challenges inflicted by covid-19 on businesses worldwide since primary concentrates like cotton seed cakes are imported. The problem of inadequate feed is attributed to the fact that the majority of farmers in the study area graze their animals on natural grass. This is because they have large land sizes which favor grazing. Natural grass however, lacks the required quality and quantity. These findings are similar to Wairimu et al. (2021), who noted that grazing with natural grass was the main mode of feeding in the study area.

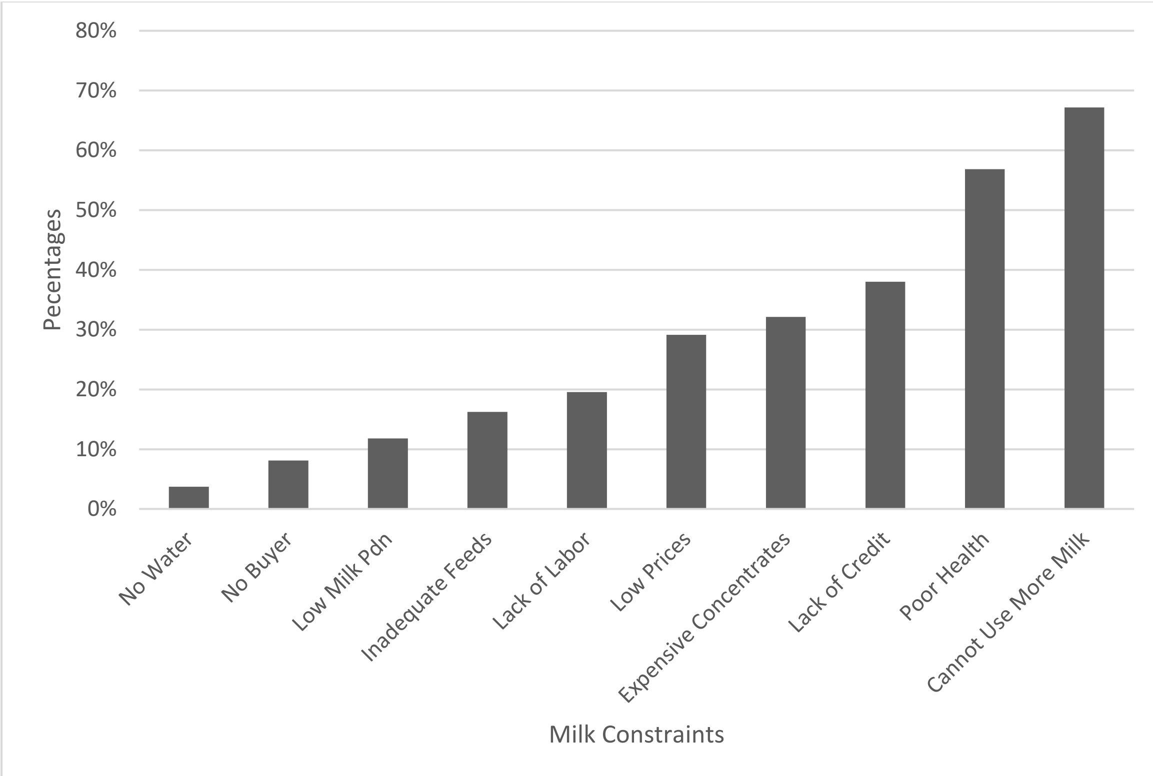


Figure 4. 1: Constraint to Milk Production in Bomet County

4.1.2. Different Ways to Increasing Milk Production

The results in Figure 4.2 show that most farmers want to produce their feeds to increase milk production. This means that farmers know the importance of nutrition to dairy cows. Results also reveal that improvement in management practices would increase milk production in Bomet County. This observation is similar to the conclusions made by Richard et al. (2015) who found that better management practices such as deworming, feeding cows with dairy meal and hay are positively associated with the volume of milk sold.

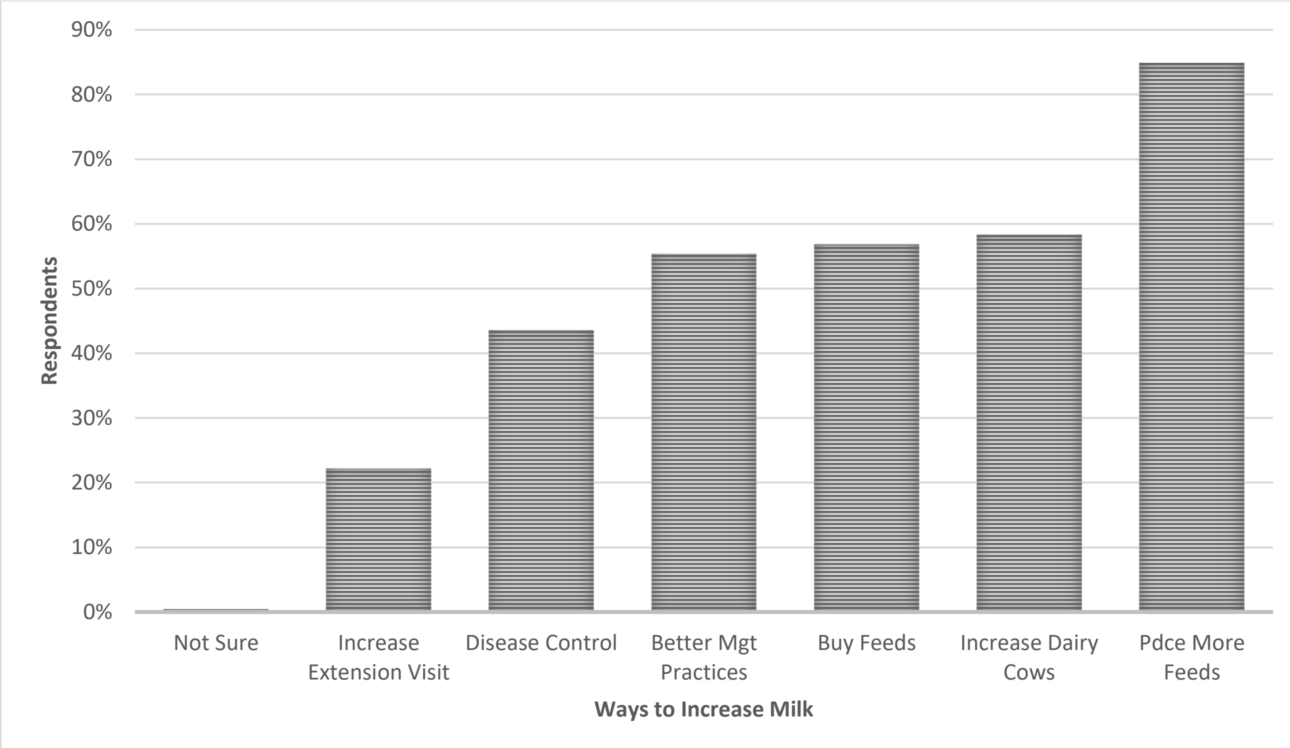


Figure 4. 2: Ways to Increase Milk Production

4.1.3. Adoption Patterns of Different Forages in Bomet County

Results in Figure 4.3 show the adoption patterns of different improved forage technologies among dairy farmers in Bomet County, Kenya. As show in Figure 4.3, napier grass is the leading forage grown by dairy farmers in Bomet County, followed by rhode grass at 15 percent. Adoption of forage legumes such as desmodium, lucerne and fodder trees (sesbania sesban and calliandra) is low compared to napier and boma rhodes. More than 75% of farmers grow napier. This is because most policies by non-governmental organizations, research institutions and government are geared towards supporting cultivation of Napier grass (Njarui et al., 2021). Furthermore, its vigorous growth, high biomass productivity, deep root system that is tolerant and can survive in a wide range of soil conditions make it a preferred choice compare to other forages (Ndwiga et al., 2019). The low adoption of forage legumes can be attributed to bloating risk associated with consumption of fresh legumes (Abdisa, 2018).

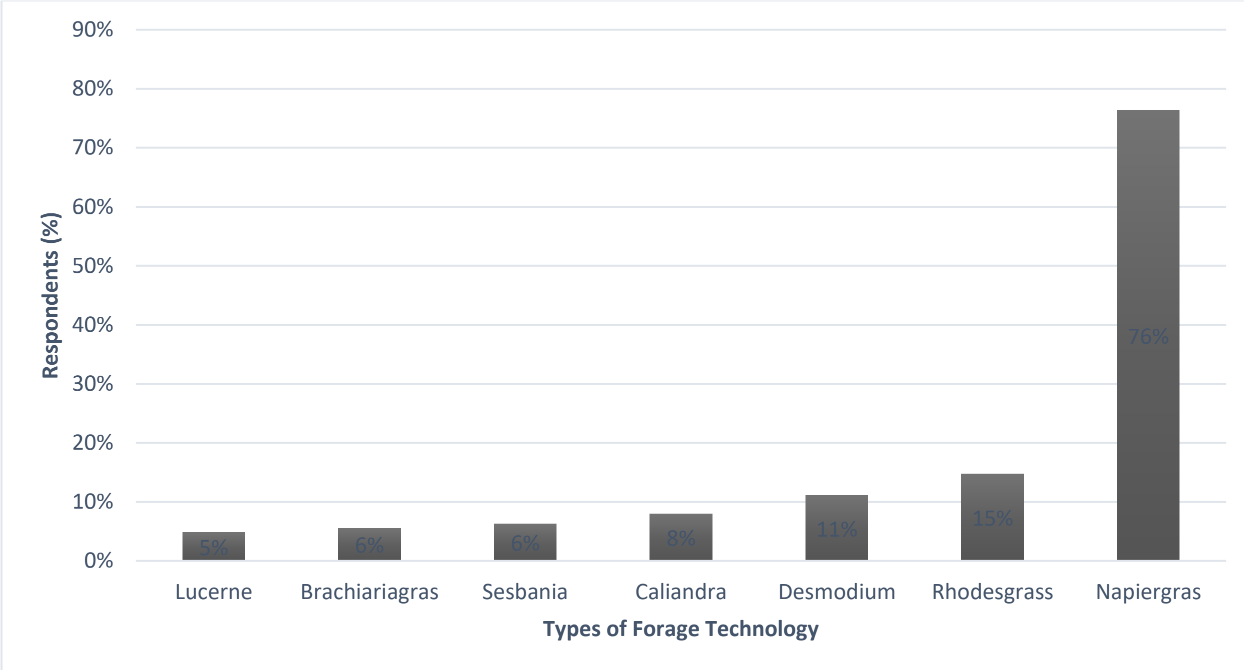


Figure 4. 3: Adoption Rate of Different Forages in Bomet County

4.1.4. Major Constraints to Forage Production in Bomet County

The results in Figure 4.4 show that the two major problems limiting forage production in Bomet County are expensive seeds and lack of knowledge on forage production and establishment. The planting materials for forage legumes are expensive and farmers also lack knowledge on how to establish it. In the survey, farmers raised concerns over how expensive seeds from agro-dealers are and sometimes were unavailable especially during the planting season. Often they rely on fellow farmers to obtain these seeds. Richard et al. (2015) also noted that farmers had no idea where to obtain forage seeds especially for fodder trees like calliandra.

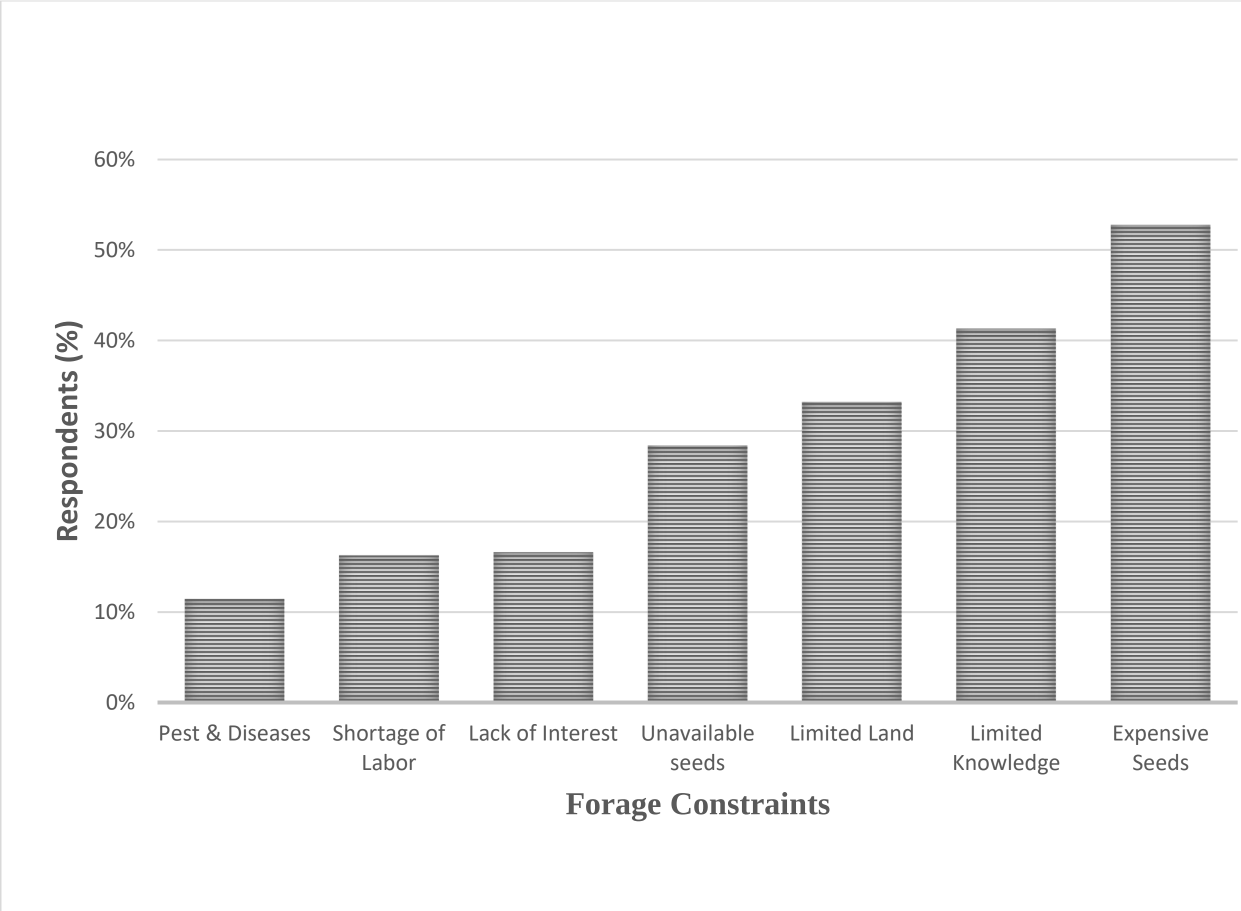


Figure 4. 4: Major Constraints to Forage Production in Bomet County

4.2. Factors that Influence the Adoption of Improved Forage Technologies

Multivariate probit was used to assess the factors influencing the adoption of improved forage technologies (Table 4.3). Pairwise correlation coefficients between error terms of the adoption equation was assessed (Table 4.2). The correlation coefficients were statistically significant and positive. This implies that the four technologies (desmodium, lucerne, sesbania sesban and calliandra) complement each other. Adoption of one technology increases the probability of adopting any of the four technologies if the right conditions are provided such as access to extension, availability and pricing.

Table 4. 2: Pairwise Correlation Coefficients of Error Term of the Adoption Equation

Technology	Desmodium	Lucerne	Sesbania Sesban	Calliandra
Desmodium	1			
Lucerne	$\mathbf{0.390}^{***}$	1		
Sesbania Sesban	$\mathbf{0.268}^{***}$	$\mathbf{0.327}^{***}$	1	
Calliandra	$\mathbf{0.301}^{***}$	$\mathbf{0.273}^{***}$	$\mathbf{0.337}^{***}$	1

Note: p>0.1=∗, p>0.05= ∗∗, p>0.01=∗∗∗

Source: Own survey data 2021.

Table 4. 3: Maximum Likelihood Estimates of the Factors Influencing Adoption of IFTs

Variables	Desmodium		Lucerne		Sesbania		Calliandra	
	COEF	MFE	COEF	MFE	COEF	MFE	COEF	MFE
Household characteristics								
Gender of household head (1=Male)	0.68***	0.12	0.30	0.03	0.02	0.002	-0.04	0.01
	(0.25)		(0.30)		(0.28)		(0.24)	
Experience in dairy (Years)	0.01	0.001	0.03***	0.002	-0.01	0.001	0.001	0.00
	(0.01)		(0.01)		(0.01)		(0.01)	
Education of household head (Years)	0.02	0.004	0.09***	0.01	0.06*	0.01	-0.02	-0.00
	0.02		(0.02)		(0.03)		(0.03)	
Off-farm income (1=Yes)	0.11	0.02	0.40	0.04	-0.39	-0.04	0.37	0.05
	(0.28)		(0.39)		(0.24)		(0.32)	
Farmer characteristics								
Farm size (Acres)	0.02	0.004	-0.04**	-0.003	0.04**	0.004	0.04***	0.01
	(0.02)		(0.01		0.02)		(0.01)	
Number of Lactating cows	-0.12	-0.02	0.05	0.004	-0.24**	-0.03	-0.10	-0.01
	(0.08)		0.07)		(0.11)		(0.07)	
Breed type (1=exotic)	0.06	0.011	-0.81***	-0.07	-0.44	-0.05	0.65**	0.09
	(0.27)		(0.24)		(0.34)		(0.31)	
Distance to Market (km)	0.12**	0.022	-0.02	-0.002	0.09	0.01	0.05	0.01
	(0.06)		(0.08)		(0.06)		(0.05)	
Farmers' Perception								
Benefit of Technology (1=Yes)	0.13	0.023	-2.55***	-0.23	-3.10***	-0.31	-3.19***	-0.44
	(0.40)		(0.51)		(0.40)		(0.45)	
Institutional characteristics								
Access to credit(1=Yes)	0.09	0.02	0.07	0.01	0.15	0.02	0.23	0.03
	(0.23)		0.26		(0.24)		(0.24)	
Group membership(1=Yes)	0.43	0.08	0.62*	0.06	-0.60**	-0.06	-0.15	-0.02
	(0.28)		(0.34)		(0.29)		(0.25)	
Access to extension(1=Yes)	0.14	0.02	0.19	0.02	0.93***	0.10	0.80*	0.11
	(0.33)		(0.44)		(0.34)		(0.42)	
Constant	-4.22***		-2.26**		0.98		-1.11	
	(1.03)		(1.11)		(1.12)		(1.36)	
Wald chi2 (56)	800***							
Likelihood ratio test χ^2 (6)	60***							

Source: Own survey 2021. P<0.1=*, p<0.05= **, p<0.01=***. MFE: Marginal effects; n=244. Robust standard errors in parenthesis.

The test for Multicollinearity showed that it was absent. The VIF values were less than ten thus no multicollinearity (Appendix.1). The wald test (wald (χ^2) (6) = 800; P= 0.000) shows the high explanatory power of the model. The likelihood ratio test (χ^2) (6) = 60 was significant at one percent confidence level implying that the null hypothesis of no correlation of covariance of the error terms in the adoption equation was rejected. This means that adoption of one technology increases the likelihood of adopting another technology.

Among the socio-demographic variables, gender positively and significantly influenced desmodium adoption at 1 percent confidence level. The male households were 12 percent more likely to adopt desmodium than females because men are more likely to attend training and field demonstrations of new technologies hence increasing their awareness. This implies that male households were more likely to adopt these technologies than female households. This finding is similar to the findings by Bashir (2014), who found that being male was positively associated with the use of improved seeds in Ethiopia.

Experience in dairy farming positively and significantly increases the probability of using lucerne at 1 percent confidence level. Experience in dairy farming increases the probability of choosing lucerne by 0.2 percent. This implies that farmers who have spent many years doing dairy farming were expected to have gained the necessary skills and resources and know the benefits of different forage technologies. This finding is in agreement with Okello et al. (2019), who observed that experience and age positively and significantly influenced the adoption of zero-grazing farming technology in the Bondo sub-county.

Education of the household head significantly and positively influenced adoption of lucerne and sesbania sesban at 1 percent and 10 percent confidence level. Years spent in school by the household head increases the likelihood of adoption of both lucerne and sesbania sesban at 1 percent. Education enables individual farmers to gather crucial information necessary for the successful establishment and management of forage production. Since lucerne has higher yields, it makes a preferred choice for more educated farmers. These results are consistent with a study by Danso-Abbeam et al. (2017), who found that education increases farmers' awareness of the benefits of adoption.

Farm size decreases the probability of choosing lucerne. It however increases the probability of adopting sesbania sesban and calliandra by 1% and 0.4%. This implies that since sesbania sesban and calliandra are grown on hedges and do not require large pieces of land, farmers with large pieces of land prefer to grow them at hedges to act as windbreakers. The negative relationship between lucerne and farm size is due to the fact that lucerne requires a large piece of land like any other food crop, so farmers instead substitute lucerne with naturally grown leguminous clover from their farms. This is consistent with the findings of Njarui et al. (2017) who found that families with larger farm sizes are less likely to adopt improved forage technologies because they can easily obtain natural grass from their farms as feeds for their animals.

The number of lactating cows decreased the probability of choosing sesbania sesban by 3%. Results being significant at 5% confidence level. Farmers complained that an increase in the number of lactating cows would require major investment in improved feeding method. This is because most dairy farmers are poor and could not afford the cost of keeping many dairy cows. For instant seeds for fodder trees are expensive and unavailable. This is true because more than 50% of farmers reported high cost of seeds as the major limiting factor to the adoption of forage legumes in general. Therefore, having a high number of lactating cows would require dairy farmers to invest in improved forage legumes such as fodder trees in order to increase milk production and this is an expensive endeavor. This finding conforms to that of Oyekale (2013), who observed that as the number of dairy cows increased, the probability of keeping dairy cows decreased.

Breed type decreased the probability of using lucerne by 7%. However, it increases the probability of choosing calliandra by 9%. Results are significant at 1 percent and 5 percent confidence level. This imply that with the advance of extreme weather which makes it impossible to grow major forages such as lucerne and desmodium, farmers prefer to use calliandra because it is a fast-growing and drought-tolerant fodder that can be used as a supplement especially for dairy cows in the dry season when feeds are scarce (Franzel et al., 2014). This result conforms to the findings by Marwa et al. (2020) who found that breed type positively influences the adoption of icow services in Kenya.

Distance to the nearest market increases the probability of adopting only desmodium by 2 percent. Results being significant at 5 percent confidence level. A longer distance to the market increases transaction costs. During survey, farmers reported that they received some seeds from fellow farmers who grow desmodium. Therefore, to avoid longer distance, farmers tend to grow desmodium which is being grown by the majority of farmers than other forage legumes. These results are consistent with Jerop et al. (2018), who found that distance positively influenced adoption of agricultural innovations among smallholder farmers in Kenya.

Perceived benefit of the technology on milk production decreased the probability of choosing lucerne by 23 percent, sesbania sesban by 31 percent, and calliandra by 44 percent. This is contrary to the expectation and maybe because of bloating risks associated with fresh pasture consumption, mainly forages with high legume content, such as high-quality alfalfa grass (Abdisa, 2018). Lucerne, for example, was reported by several farmers during the focus group discussions and survey to lead to bloating when fed fresh to dairy cows.

Membership in a dairy cooperative increased the likelihood of choosing lucerne by 6 percent while decreasing the likelihood of using sesbania sesban by 6 percent. Results being significant at 10 percent and 5 percent respectively. During survey and focus group discussions, farmers reported a high cost and a limited access to quality seeds to be the major factors limiting the adoption of fodder trees. Additionally, despite the low adoption of lucerne among farmers, it is being actively promoted by development partners and County governments and can easily be obtained from agro vet shops. Since agricultural cooperatives facilitate access to market information for inputs, they can easily encourage their members to adopt lucerne, which is more popular than the costly sesbania sesban. This finding is consistent with Candemir et al., (2021), who found that cooperatives play a crucial role in farm economic sustainability and adoption of environmentally friendly practices.

Access to extension positively and significantly influences adoption of sesbania sesban and calliandra at 1 percent and 10 percent confidence level. Extension services increase the probability of adoption of sesbania sesban by 10 percent and calliandra by 11 percent. Extension services is a significant source of technology improvement, and farmers who are regularly exposed to information such as field demonstration are likely to increase their uptake of technologies because of increased awareness (Ngenoh, 2018). Improving access to extension particularly for fodder trees would help scale up their adoption. These findings are similar to Maina et al. (2020), who found that access to extension increases the adoption of Brachiaria grass in Kenya.

4.3. Effect of Adoption of Improved Forage Technologies on Household Income

The Wald chi square test of independence is statistically significant ($p<0.000$), confirming a correlation between the error term of the selection equation and the error term of the outcome equation. The adoption of improved forage technologies therefore, is related to household income. This justifies the use of endogenous treatment regression model to correct the bias. In this case, the average predicted outcome (ATE) is the same as the average treatment effect on treated individuals because the treatment indicator variable has not interacted with any of the outcome covariates (Adeyanju et al., 2021); that is, average treatment effect (ATE) equals average treatment effect on treated respondents (ATET

Table 4. 4: Results of the Endogenous Treatment Effect Regression Model

Variables	Selection Equation (Probit)		Household income (OLS)	
	Coef	RSE	Coef	RSE
Gender of household head (1=Male)	1.249***	0.227		
Experience in dairy farming (Years)	0.000	0.009	-0.002	0.006
Education of household head (Years)	0.024	0.028	0.013	0.016
Off-farm income (1=Yes)	0.492*	0.289		
Farm size	-0.023	0.020	0.019**	0.009
Number of Lactating cows	0.031	0.064		
Breed type (1=Exotic)	0.980***	0.207	-0.094	0.169
Milk Production (liters)	0.326*	0.170		
Number of Dairy Cows			0.033*	0.020
Distance to Market (KM)	-0.204***	0.079		
Ownership of transport means (1=Yes)			0.182	0.117
Benefit of Technology	-0.454	0.438		
Membership in Farmer's group (1=Yes)	-0.422*	0.252	0.588***	0.143
Access to credit (1=Yes)			0.076	0.122
Access to extension (1=Yes)	-0.386	0.261	0.149	0.154
Access to training (1=Yes)	-0.418	0.417	0.489**	0.193
Access to Information (1=Yes)	-0.386*	0.227	0.062	0.125
Adopt legume			1.270***	0.235
Constant	-1.640	1.842	8.703***	0.729
/athrho	-0. 551***	0.188		
/lnsigma	-0.192***	0.054		
rho	-0.501	0.141		
sigma	0.826	0.046		
Lambda	-0.414	0.126		
Wald test of indep. Egns. (rho=0): chi2(1) = 8.63 Prob > chi2 = 0.003				

Source: Own survey data. Note: p>0.1=*, p>0.05= **, p>0.01=***, RSE: Robust Standard Errors

Farm size effect on household income was positive and significant at 1 percent confidence level. This result means that farmers with larger farms were expected to have more income. Farmers with larger farm sizes could grow more feeds for their animals to increase milk production and sell excess feeds to farmers with small pieces of land. This study is consistent with the study by Anang et al. (2019), who found that income increased with farm size in the study of adoption and income effects of extension in Ghana.

The number of dairy cows owned by a farmer positively and significantly affect household income at 10 percent confidence level. The number of dairy cows a farmer owns is an indicator of wealth. This means that more dairy cows would mean more milk and hence more revenue from the sale of milk. This is consistent with Ngeno (2018), who found that the number of animals kept in the farm positively impact net returns to the farmer.

Membership in dairy cooperatives was found to affect household income positively and significantly at 1 percent confidence level. Dairy cooperatives have milk coolers for storing milk, which help reduce milk loss. Cooperatives provide extension services such as milk hygiene, training to maintain the quality of milk; therefore, farmers can fetch high prices for their milk. This result is consistent with Danson-Abbeam et al. (2018), who found that membership in a farmer's group has a positive effect on farm income.

Access to training has a positive and significant effect on household income. Training is a source of information that exposes farmers to technologies and this is crucial for dairy productivity. For example, trainings on improved feeds and feeding, milk hygiene, and milking practices can help increase dairy productivity. Training on improved forage legumes feeding, in particular, is very critical because forage legumes are an essential source of protein intake, which is vital for dairy productivity (Gebreselassie, 2019).

Results from regression analysis show that the adoption of forage legumes has a positive effect on household income. Adoption of improved forage technologies was significant and positive at 1 percent confidence level. This means that farmers who adopt forage legumes have higher incomes than those who do not. The average treatment effect of adoption of improved forage technologies (ATE) is 1.3. This implies that as adoption increases by 1 percent, household income increased 1.3 times. Results from focus group discussions with farmers and key informant interviews with local chiefs, agro-dealers and county officials show that most farmers use napier and natural grass to feed their animals; therefore, there is a lack of a balanced diet. This means that those using legume forages are more likely to increase milk production and income from milk sales. These findings agree with Ashley et al. (2018), who found that adoption of forage technology increased household income among smallholder farmers in Cambodia. Similar results were made by Maina et al. (2020), who reported increased milk production from the use of brachiaria grass.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1. Summary

This study focused on the adoption of improved forage technologies and its effect on household income; a case of forage legumes in Bomet County, Kenya. The study is a follow-up on the same respondents considered during the baseline study of the Africa Milk Project in Bomet county. The specific objectives were to characterize forage technologies, establish the factors influencing adoption and the effects of adopting improved forage technologies on household income. Descriptive statistics were used to profile the adoption rate of different forage technologies. Multivariate probit was used to analyze factors influencing the adoption of improved forage technologies and endogenous treatment regression model for the effect of improved forage technologies on household income.

Descriptive results show that the adoption rate of forage legumes (desmodium, lucerne, sesbania sesban and calliandra) was low at 30 percent. Adopters were significantly different from non-adopters in terms of education, experience in dairy farming, farm size, access to extension services and gender among others. Furthermore, adopters had higher average daily milk income and milk production than non-adopters.

Adoption of improved forage technologies was positively and significantly influenced by dairy cooperative membership, years of schooling, gender, distance to market, access to extension services, farm size and experience in dairy farming. Number of lactating cows, perceived benefit of the technology, and breed type negatively and significantly influenced adoption of improved forage technologies according to multivariate probit results.

Results of the endogenous treatment regression model showed that adoption of improved forage technologies significantly and positively affected household income. Adoption of improved forage technologies that was hypothesized to increase household income was significant and positive at one percent confidence level. This means that adoption of improved forage technologies increased household income. Other positive drivers of household income were: access to training, membership in farmer's groups, number of dairy cows owned by a farmer, farm size, and gender of the household head.

5.2. Conclusions

Adoption of forage legumes is low among dairy farmers in Kenya even though it is a source of animal protein intake which is likely to increase dairy productivity. This study established the factors influencing the adoption of improved forage technologies and their effects on household income.

The results revealed that membership to farmers' groups and access to extension services are the significant factors that influence the adoption of improved forage technologies. This variable indicates that farmers in dairy development groups are more likely to adopt improved forage technologies. Similarly, access to extension services is low, which explains low adoption among dairy farmers in Bomet County. According to the findings from a survey, one of the significant barriers to adoption of improved forage technologies in Bomet County is lack of knowledge on forage establishment and maintenance. The government should develop strategies to improve access to extension services.

Adoption of improved forage technologies positively affects household income; however, their use is still low at 30 percent compared to energy-rich forages (nappier, boma rhodes and brachiaria) at 97 percent. Many farmers are aware of the importance of integrating forage legumes in their feeds but have not yet adopted them. Policymakers should devise ways to increase the adoption of forage legumes to improve animal nutrition and milk production.

5.3. Recommendations

5.3.1. Policy Recommendations

Since the adoption of improved forage legumes is low, the government and policymakers should work on strategies to improve the adoption of forage legumes, mainly fodder trees, by organizing field days and establishment of demonstration fields. This will increase the adoption of forage legumes in large scale and thus increase dairy productivity and consequently increase farmers' income through the sale of milk.

Given that membership in a dairy cooperative influenced the adoption of improved forage technologies, government and development partners should empower farmers' groups. Farmers' groups act as an important channel for passing information on emerging agricultural technologies.

Considering the fact that access to extension services positively influenced adoption decisions, government and development agents should set up workshop centers and demonstration fields in different sub-counties in Bomet and extension agents be assigned to these stations to train farmers in forage growing and establishment. Encourage adoption of ICT for extension such as ICT-supported water and irrigation technologies. This will help farmers to be up to date with the latest technologies and, therefore, ensure forage availability throughout the year.

5.3.2. Recommendations for Further Research

Future research could focus on ways of addressing bloating from the use of fresh legumes, especially from the use of lucerne. This could be the reason why adoption is still low.

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APPENDICES

Appendix 1: Pairwise correlation and VIF

. vif

Variable	VIF	1/VIF
lnmilkpdn	1.39	0.719066
expdairy	1.35	0.739590
educ	1.35	0.741794
farmsize	1.34	0.745060
gen	1.25	0.798341
nolactingc~s	1.16	0.860022
iftbenefit	1.15	0.868163
offfarminc	1.14	0.874800
accessextn	1.14	0.878919
info	1.13	0.885032
mbrshipcop	1.12	0.890543
distmkt	1.10	0.908215
acsscrdt	1.09	0.919503
breedtype	1.03	0.969359
Mean VIF	1.20	

	adoptl~e	gen	educ	lnmilk~n	expdairy	farmsize	nolact~s
adoptlegume	1.0000						
gen	0.3189	1.0000					
educ	0.1250	-0.0648	1.0000				
lnmilkpdn	0.3438	0.0857	0.2560	1.0000			
expdairy	0.0306	0.1569	-0.2989	0.0447	1.0000		
farmsize	0.1797	0.1915	0.0902	0.3965	0.2631	1.0000	
nolactingc~s	0.2431	0.3040	-0.0259	0.1224	0.0470	0.0155	1.0000
breedtype	0.0017	0.0629	0.0746	0.0233	0.0255	-0.0103	0.0211
offfarminc	0.0268	0.0210	-0.1118	-0.0594	0.2874	0.0327	0.0264
iftbenefit	0.1250	0.1064	-0.1547	0.0342	0.1471	0.0383	-0.0163
mbrshipcop	0.1366	-0.0560	0.0708	-0.1671	-0.0654	-0.1363	-0.0286
acsscrdt	-0.0478	0.0464	-0.1405	-0.1378	0.0938	-0.0177	0.0315
accessextn	-0.3439	-0.3173	0.0574	-0.0327	-0.1248	-0.0849	-0.1819
distmkt	-0.0380	0.0748	-0.0413	0.1980	0.0369	0.1291	0.0249
info	0.1241	0.0057	0.1088	0.1625	0.0930	0.1480	-0.0191

	breedt~e	offfar~c	iftben~t	mbrshi~p	acsscrdt	access~n	distmkt
breedtype	1.0000						
offfarminc	0.0323	1.0000					
iftbenefit	0.0853	0.1489	1.0000				
mbrshipcop	0.1017	0.0075	0.0808	1.0000			
acsscrdt	-0.0348	0.0485	0.1186	-0.0841	1.0000		
accessextn	0.0541	0.0750	0.0548	0.0621	0.0295	1.0000	
distmkt	-0.0129	-0.0389	0.0527	-0.1548	-0.0490	0.0199	1.0000
info	-0.0583	0.1489	0.1863	-0.0682	-0.0479	0.0002	0.0385

	info
info	1.0000

Appendix 2: Pairwise correlation coefficients of error term of the adoption equation

Technology	Desmodium	Lucerne	Sesbania Sesban	Calliandra
Desmodium	1			
Lucerne	0.390***	1		
Sesbania Sesban	0.268***	0.327***	1	
Calliandra	0.301***	0.273***	0.337***	1

Note: p>0.1=∗, p>0.05= ∗∗, p>0.01=∗∗∗

Source: Own survey data 2021.

Appendix 3: Results of multivariate Probit

```
Multivariate probit (SML, # draws = 5)          Number of obs   =        244
                                                Wald chi2(48)   =     800.31
Log pseudolikelihood = -195.81904               Prob > chi2     =     0.0000
```

	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
desmosdium						
gen	.6829963	.2460243	2.78	0.006	.2007975	1.165195
educ	.0228158	.0233191	0.98	0.328	-.0228887	.0685203
expdairy	.0053037	.0084683	0.63	0.531	-.0112938	.0219013
farmsize	.0217535	.0186455	1.17	0.243	-.014791	.0582979
nolactingcows	-.1186665	.0771384	-1.54	0.124	-.2698551	.0325221
breedtype	.062751	.2666261	0.24	0.814	-.4598266	.5853285
offfarminc	.1074217	.2771273	0.39	0.698	-.4357378	.6505812
iftbenefit	.1315071	.4029418	0.33	0.744	-.6582443	.9212585
mbrshipcop	.4193142	.2830829	1.48	0.139	-.1355181	.9741465
acsscrdt	.0938741	.2290579	0.41	0.682	-.3550711	.5428192
acssextn	.134915	.3265298	0.41	0.679	-.5050717	.7749017
distmkt	.1211192	.0605421	2.00	0.045	.0024589	.2397796
_cons	-4.214457	1.030012	-4.09	0.000	-6.233242	-2.195672
lucerne						
gen	.3002183	.2989564	1.00	0.315	-.2857256	.8861621
educ	.0859102	.0231498	3.71	0.000	.0405375	.1312829
expdairy	.0269262	.0070301	3.83	0.000	.0131474	.040705
farmsize	-.0359872	.0151174	-2.38	0.017	-.0656169	-.0063576
nolactingcows	.0493301	.070458	0.70	0.484	-.088765	.1874252
breedtype	-.8062217	.2394043	-3.37	0.001	-1.275446	-.3369979
offfarminc	.4025489	.3916151	1.03	0.304	-.3650025	1.1701
iftbenefit	-2.544581	.5084661	-5.00	0.000	-3.541157	-1.548006
mbrshipcop	.6210609	.3365079	1.85	0.065	-.0384824	1.280604
acsscrdt	.0662578	.2551698	0.26	0.795	-.4338658	.5663813
acssextn	.1881213	.4410296	0.43	0.670	-.6762809	1.052523
distmkt	-.0197072	.0819459	-0.24	0.810	-.1803181	.1409038
_cons	-2.257709	1.108251	-2.04	0.042	-4.429841	-.0855771
sesbania						
gen	.0216844	.2814158	0.08	0.939	-.5298804	.5732492
educ	.0571911	.0335724	1.70	0.088	-.0086096	.1229919
expdairy	.0119039	.0094549	1.26	0.208	-.0066275	.0304352
farmsize	.0432241	.021044	2.05	0.040	.0019787	.0844696
nolactingcows	-.2424172	.1081931	-2.24	0.025	-.4544718	-.0303625
breedtype	-.4410766	.3374903	-1.31	0.191	-1.102545	.2203924
offfarminc	-.3925416	.241989	-1.62	0.105	-.8668313	.0817482
iftbenefit	-3.051358	.4021708	-7.59	0.000	-3.839598	-2.263118
mbrshipcop	-.5981758	.2869725	-2.08	0.037	-1.160631	-.0357201
acsscrdt	.1469394	.238888	0.62	0.538	-.3212724	.6151513
acssextn	.9262769	.3358882	2.76	0.006	.2679482	1.584606
distmkt	.0932992	.0643459	1.45	0.147	-.0328163	.2194148
_cons	.9811043	1.122438	0.87	0.382	-1.218834	3.181043

caliandra						
gen	-.0361028	.2395128	-0.15	0.880	-.5055392	.4333336
educ	-.0145082	.0315093	-0.46	0.645	-.0762653	.047249
expdairy	.0010751	.0082712	0.13	0.897	-.0151363	.0172864
farmsize	.038071	.0134277	2.84	0.005	.0117533	.0643888
nolactingcows	-.1041691	.0719597	-1.45	0.148	-.2452075	.0368694
breedtype	.6455274	.3131469	2.06	0.039	.0317708	1.259284
offfarminc	.3662517	.318863	1.15	0.251	-.2587083	.9912118
iftbenefit	-3.186932	.4519388	-7.05	0.000	-4.072716	-2.301148
mbrshipcop	-.1504403	.245678	-0.61	0.540	-.6319603	.3310797
acsscrdt	.2290494	.2347153	0.98	0.329	-.2309841	.6890828
acssextn	.7970554	.4147842	1.92	0.055	-.0159067	1.610018
distmkt	.0520136	.0528162	0.98	0.325	-.0515042	.1555314
_cons	-1.104756	1.355127	-0.82	0.415	-3.760757	1.551244
/atrho21	1.719013	.3662964	4.69	0.000	1.001085	2.436941
/atrho31	.6800236	.2292683	2.97	0.003	.230666	1.129381
/atrho41	.7459581	.1483445	5.03	0.000	.4552083	1.036708
/atrho32	.5768275	.1964245	2.94	0.003	.1918425	.9618125
/atrho42	.5842145	.1813673	3.22	0.001	.228741	.939688
/atrho43	.9873298	.3346438	2.95	0.003	.33144	1.64322
rho21	.9377441	.0441885	21.22	0.000	.7620497	.9848287
rho31	.5915348	.1490443	3.97	0.000	.2266602	.8108074
rho41	.6327314	.0889549	7.11	0.000	.4261708	.7765847
rho32	.5203558	.1432386	3.63	0.000	.1895232	.7450842
rho42	.5257219	.1312404	4.01	0.000	.2248334	.7350789
rho43	.7562215	.1432708	5.28	0.000	.3198141	.9279213

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0:
chi2(6) = 60.0439 Prob > chi2 = 0.0000

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Appendix 4: Results of endogenous treatment regression model

```
Linear regression with endogenous treatment     Number of obs     =        195
Estimator: maximum likelihood                   Wald chi2(12)     =      85.13
Log pseudolikelihood = -304.76675               Prob > chi2       =     0.0000
```

	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
logincome						
expdairy	-.0017815	.0056246	-0.32	0.751	-.0128055	.0092425
educ	.0134017	.015692	0.85	0.393	-.0173541	.0441575
farmsize	.018935	.0091064	2.08	0.038	.0010868	.0367833
nodairycows	.0326106	.0195746	1.67	0.096	-.0057549	.070976
breedtype	-.0943828	.1686317	-0.56	0.576	-.4248949	.2361293
mbrshipcop	.5878435	.1433849	4.10	0.000	.3068142	.8688728
acsscrdt	.0759148	.1218637	0.62	0.533	-.1629337	.3147633
accessextn	.1492747	.1538113	0.97	0.332	-.15219	.4507393
training	.4888366	.1931746	2.53	0.011	.1102213	.8674518
owntrans	.1814798	.1171129	1.55	0.121	-.0480572	.4110168
infodairy	.0620374	.1248005	0.50	0.619	-.1825671	.3066418
1.adoptlegume	1.270001	.234796	5.41	0.000	.8098096	1.730193
_cons	8.702912	.7285178	11.95	0.000	7.275044	10.13078
adoptlegume						
gen	1.249341	.2271089	5.50	0.000	.8042161	1.694467
expdairy	.0003732	.0098911	0.04	0.970	-.019013	.0197593
educ	.024204	.0275599	0.88	0.380	-.0298123	.0782204
farmsize	-.0225679	.019764	-1.14	0.254	-.0613046	.0161688
lnmilkpdn	.3257598	.1699233	1.92	0.055	-.0072838	.6588033
nolactingcows	.0307935	.0635871	0.48	0.628	-.093835	.155422
breedtype	.97976	.2416461	4.05	0.000	.5061423	1.453378
offfarminc	.4915094	.2885694	1.70	0.089	-.0740762	1.057095
iftbenefit	-.4541713	.4376394	-1.04	0.299	-1.311929	.4035862
mbrshipcop	-.4216609	.2515144	-1.68	0.094	-.9146201	.0712982
training	-.4182573	.4164978	-1.00	0.315	-1.234578	.3980634
infodairy	-.3854837	.2269046	-1.70	0.089	-.8302085	.0592411
accessextn	-.3860454	.2610975	-1.48	0.139	-.8977871	.1256964
distmkt	-.2042036	.078706	-2.59	0.009	-.3584646	-.0499427
_cons	-1.639763	1.841663	-0.89	0.373	-5.249357	1.969831
/athrho	-.5511636	.1876621	-2.94	0.003	-.9189745	-.1833526
/lnsigma	-.1915265	.0542851	-3.53	0.000	-.2979234	-.0851296
rho	-.5013918	.140485			-.7254119	-.1813252
sigma	.8256977	.0448231			.7423582	.9183932
lambda	-.413998	.1264143			-.6617655	-.1662306

```
Wald test of indep. eqns. (rho = 0): chi2(1) =     8.63   Prob > chi2 = 0.0033
```

Appendix 5: Household survey questionnaire

University of Nairobi

Assessment of the Adoption of improved forage technologies and its effect on household income.

A person eligible for this interview should be a farmer keeping 5-10 dairy cows in zero and semi-zero grazing system. Head of household or persons in a position to make decision on a farming activities is eligible for interview

Seeking consent

Thank you for your time. We are researching on a topic and we would like to interview you. The reason for the interview is to get insight on adoption of forage technologies in Bomet County. You have been randomly selected for this interview to give us your insight and your contribution is voluntary and will highly help in making this endeavour a success. Your responses plus the other respondents will strictly be used for academic purposes to help policy makers to come up with innovative ways to reduce barriers of access to IFTs. The information gotten from you will be kept confidential. The interview will approximately take one hour to finish.

I now request your permission to begin the interview.

Thank you

1. County	
2. Sub-Country	
3. Village	
3. Enumerators' code	
5. Date of interview (DD/MM/YYYY)	

SECTION A. HOUSEHOLD AND DEMOGRAPHIC DATA

A.1. Provide the following details about the household head

Interview only household head or person in position to make decision on farm related activities:

Age of the respondent (number)	
Highest level of education of the respondent (codes)	
Marital status of the respondent (codes)	
Give number of family members (including infants and children)	

Marital status codes: 1 = Single 2 = Married/living together 3 = Widowed (er) 4 = Divorced 5=Other (specify)	Level of education codes: 1 = Illiterate 2 = Primary school 3 = High School 4 = Tertiary 5 = University 6 = Other	

A.2. Land tenure / Land use

2.1. Give the following information on land use/tenure

Total farm size or land area (codes)	Status of land (codes)	Total land own (number)	Total land rent (number)	Rent Amount in Kshs

Farm size codes:		Status of land codes
01= Two	11= Twelve	1 = Own
02= Three	12= Thirteen	2 = Lease/rent
03 = Four	13= Fourteen	
04= Five	14 = Fifteen	
05= Six	15 = Sixteen	
06= Seven	16 = Seventeen	
07= Eight	17 = Eighteen	
08= Nine	18 = Nineteen	
09= Ten	19 = Twenty	
10 = Eleven	20 = Other	

2.2. How much land is allocated to each of the following?

Homestead (codes) Crops (codes) Forage Production (codes)

Codes for amount of land		
1=$^1/_8$	**4=$^3/_4$**	**7=1 $^1/_2$**
2=$^1/_4$	**5=1**	
3=$^1/_2$	**6=1 $^1/_4$**	

A3. Household and dairy assets

3.1. Provide details of asset ownership in the table below

Asset type	Assets	Number
Farm tools, Machines and equipment	Water pump	
	Wheel barrow	
	Tractor	
	Plough	
	Milking storage	
	Spraying Knapsack	
	Baler	
	Other ( )	
Buildings	Forage sheds	
	Hay loft	
	Manure pits	
	Cattle stalls	
	Milking rooms	
	Sheep and Goat farm	
	Biogas digester	
	Solar Panels	
	Others ( )	
Communications	Telephone	
	Television	
	Radio	
	Other ( )	
Transportation	Motor cycle(Bike)	

Car

Truck

Bicycle

Tricycle

Cart

Other (   )

A.4. Household financial resources

4.1 Provide details about source of income in the last 12 months

Sources of Income	Rank for the sources	Amount
Income from dairy		
Income from all other farm activities(goat keeping, poultry, bee, forage sale)		
Income from off-farm income		

Codes for ranking sources of income		
1= Main source of income	2= Second source	3= Third source

4.2. Give details on past and present access to credit in the table below

Access to credit (codes)	Main Source of the credit (codes)	Main Purpose of credit (codes)

Access to credit codes	Source of credit codes		Purpose of credit codes	
1= yes	1=micro finance	6=Agricultural finance corporation	1=purchase farm inputs(fertilizer, seeds)	6= purchase feeds
2= No	2=Commercial Banks	7=Local money lenders	2=buy dairy cows	7=machinery
	3=cooperatives	8=Kenya women finance	3=marketing and value addition	8=pay laborers
	4=NGOs	9=SACCOs	4=buy land	9=irrigation facilities
	5=Government credit schemes	10=Others	5=construct new structures	10=others

4.3. provide details of major constraint of access to credit. Select all that apply……………………………………………………………………………………………...(codes)

Codes of constraints to credit access	
1=Absence of good security on loans(collateral)	4=lack of Knowledge
2=Unaffordable rates of interest	5=others
3=Unavailability of credit providers	

SECTION B. LIVESTOCK INVENTORY & MANAGEMENT

B1: Livestock Inventory

1.1. Give different types of livestock kept in your Farm. Select all that apply……………………………… (codes)

Livestock codes	
1=dairy cows	5=sheep
2= goats	6=fish keeping
3=Poultry	7=Rabbits
4=Bees	8= Other ( )

B2: Livestock Management

2.1. Do you Keep livestock records in your farm?

1. Yes ( ) 2. No ( )

2.2. Do you use any kind livestock identification in your farm?

1. Yes ( ) 2. No ( )

2.1. If yes, give details of the form of livestock record keeping and identification use?

Forms of written record (codes) Forms of livestock identification(codes)

Forms of record codes		Forms of identification codes	
1=Breeding Records	5=Death and birth Records	1=Non	5=Color
2=Production Records	6=Extension visit record	2=Name	6=others(specify)

3=Veterinary or Treatment Records	7=Feeding record	3=Tag number
4=Sales and purchases records	8=Others(specify)	4=Branding/Notching/ Tattooing

SECTION C: DAIRY COWS' MANAGEMENT

C1. Dairy cows' characteristics and milk production

1.1.How long have you been practicing dairy farming (in years)? -------------

1.2. How many dairy cows do you own (number)? --------------------------

1.3.Provide details in terms milk production characteristics for all dairy cows in the table below

Dairy cows	Daily milk production (liters per day	Average daily milk production (per day)
Cow 1		
Cow 2		
Cow 3		
Cow 4		
Cow 5		
Cow 6		
Cow 7		
Cow 8		
Cow 9		
Cow 10		
Other (specify)		

1.4. Did you produce milk in the last one month?

1. Yes ( ) 2. No ( )

1.5 If yes provide details on milk production in the past one month in the table below

Milk production	**Last one month**
Daily number of milking cows (n)	
Daily milk production (I/day/farm)	
Daily milk household self-consumption (I/day/farm)	
Total amount of milk in liters sold to cooperative/group per day (Processor)	
Average price per liter (in kshs) for milk sold to others	
Amount of milk fed to the calves per day	
Amount of milk in liters per day that is given to workers/friends	

1.6 do you have plan to increase milk production in your farm (if no jump to 1.8)
1. Yes (   ) 2. No (   )

1.7. If yes, state the ways of how you plan to do it. Select all that apply…………………………………… (codes)

Codes for increase milk production	
1=Produce more feeds	5=Increase the number of extension visit
2=Invest in animals' disease control	6=Invest in better management practices
3=Buy more feeds	7=Not sure
4=Increase number of dairy cows	8=Others (specify)

1.8. state major constraints to increased milk production. Select all that apply…………………………. (codes)

Codes for constraint to milk production	
1=Lack of credit to buy animals	7=Inadequate feed
2=I cannot use more milk	8=Expensive concentrates
3=lack of credit to buy feeds	9=Poor health
4=My animals cannot produce milk	10=No buyer/cooperative
5=The price of milk is too low	11=Lack of enough water
6= Lack of labor	12=Others (specify)

1.9. If no in 1.6 above, give main reasons-----------------------

Main reasons	
1=Low prices	4=Lack of transport
2=Lack of access to market	5=Others(Specify)

3=Inadequate feeds

C2. Dairy Cows Feeds and Feeding

2.1.what is the main system of feeding dairy cows in your farm?

feeding system in Rainy season Feeding system in dry season

Codes for feeding system	
1=only grazing (free range or tethered)	4=only stall feeding(zero-grazing)
2=Mainly grazing with some stall feeding	5=others (specify)
3=Mainly stall feeding with some grazing	

2.2. Please indicate the inventory of animal feeds available in your farm. Select all that apply………... (codes)

Codes for Animal feeds	
1=Napier grass (Pennisetum Purpureum)	11=grass hay
2=Maize (Zea maize)	12=legume hay
3=Brachiaria grass	13=poultry waste
4=Rhode grass(chloris gayana)	14=weeds
5= Star grass(cynodon dactylon)	15=other industrial by-product(e.g brewers waste e.t.c.)
6=Kikuyu grass(Pennisetum clandestinum)	16=legumes fresh (e.g Lucerne)
7=Forage trees	17=Fodder trees(e.g sesbania sesban)
8=Natural grass	
9=Maize Stove	
10=Maize silage	

2.3. Did you grow any kind of forage in the last 12 months?

1. Yes ( ) 2. No ( )

2.4. If yes, indicate the forage types, where it is grown and sources of planting material

Forage types (codes)	Sources of planting material (codes)	Where it is grown (codes)

Forages codes	Sources of planting material (codes)	Where its grown codes

1=Desmodium	6=Napier grass	1=Cooperatives	1=in the line on Contours	6=inter-cropped with Nappier grass
2=Sesbania Sesban	7=Vetches	2=Government	2=External Boundary	7=under fruit trees
3=Lucerne	8=Rhodes grass	3=Research organization (e.g. ILRI)	3=as pure stand	8=Others (specify)
4= Brachiaria grass	9=Leucaena leucocephala	4= NGOs	4=internal boundary	
5=Calliandra	10=Others (specify)	5= Others (specify)	5= inter-cropped with other crops	

2.5. Do you use fodder trees?
1. Yes ( ) 2. No ( )

2.6. State the common fodder tree species use in your farm (Codes). Select all that apply……………………..

Codes for fodder tree species	
1. calliandra	3=Leucaena Leucocephala
2. Sesbania Sesban	4=Others(specify)

2.7 Did you get any training in forage production technologies in the last one year (tick only that apply?
1. Yes ( ) 2. No ( )

2.8.If yes, how often do you get training (select only that apply) ----------------------?

Frequency of Training	
1=weekly	3=quarterly
2=monthly	4=annually

2.9.who provides the training (select all that apply)? ------------------------------

Provider		
1=Cooperative/farmer groups	3=NGOs	5=Fellow farmers
2=Government	4=Research institutions (e.g KALRO)	6= Others (specify)

2.10. Do you think use of improved forage technologies help to increase milk production?
1. Yes ( ) 2. No ( )

2.11. if no in 2.3 above, give the major reasons (select all that apply……………………………………………………?

Reasons		
1=Not heard	4=no enough land	7= shortage of labor

2=unavailability of planting material	5=pest and diseases	8= lack of interest
3=high cost of planting material	6=not aware of benefit	9= Others (specify)

2.10. Did you do any forage conservation in the last 12 months?

1. Yes ( ) 2. No ( )2

2.11. if yes which one ---------------------------

Conservation method	
1=silage	2=hay

2.12. Do you use supplementary feeds in your farm?

1. Yes ( ) 2. No ( )

2.13. If yes, what are the supplementary feeds that you use (select all that apply)

Supplementary feeds	
1=concentrates	3=Fodder trees
2=Mineral licks	4=Others(specify)

2.14. state the average amount of supplements used (in grams).

concentrates	Mineral licks	Fodder trees

Codes for average amount		
1=1/8	4=1	7=4
2=1/4	5=2	8=5
3=1/2	6=3	9=Others(specify)

2.15. What is the frequency of supplementary feeding in your farm (select all that apply)?..

Frequency	
1=Once daily	6=Monthly
2=Twice daily	7=Only when need arise
4=Thrice daily	8=Others(specify)
5=Weekly	

2.16. In the event of an acute household feed shortage what are your immediate responses (coping strategies). select all that apply…………………………………………………………………………………………
……

Coping strategies codes:	4 = Transhumance	7 = Loan out animals
	5 = Sell animals	8 = Share human food with animals

1 = Prioritize feeding the best animals 2 = Prioritize feeding sick animals 3 = Prioritize feeding calved females	6 = Slaughter animals	9 = Other: (specify in cell)

2.17. Strategies to prevent household feed shortage? (Adaptation strategies). Select all that apply …….

Prevention strategies codes: 1 = Transhumance 2 = Reduce herd/flock size through sales	3 = Collect and store bush hay 4 = Collect fodder from trees 5 = Purchase feed supplement	6 = Store more crop residues 7 = Other: (specify) 8= Silage making, 9=Hay making

C3. Dairy Cows' reproduction

3.1. Between AI, bull and other, which method of serving female cows do you prefer for your cattle?
Select only that apply
(codes)………………………………………………………………………………………………………

Codes for breeding techniques 1=Artificial insemination(AI) 2=Bulls 3= Other (sexed semen, synchronized estrus etc.?)

3.2. If AI is use, name the possible sources (codes). Select all that apply………………………………………………….

Codes for sources of AI 1=Gov't extension officers 2=Private Inseminator 3=NGOs 4=Cooperative 5=Others(specify)

C4. Dairy Inputs

4.1. How do you source your inputs and services for your dairy cows?

Inputs and services	**Model of sourcing inputs and services (codes) (select one)**	**Why do you choose this source of inputs and/or services? (codes) (select one)**

Concentrates & minerals		
Animal health		
Artificial insemination		
Extension		
Loans		
Other (specify)		

Model codes:	Reason of choose codes:
1 = Purchase directly from private service providers 2 = Cooperative owned agro vets through check off system 3 = Private Service providers contracted by	1 = Variety of product and/or services offered 2 = Offer lower price 3 = Offer goods on credit 4 = Less distance to the source

SECTION D. MARKETING, FARM MILK NETWORK, SOURCES OF INFORMATION

D1. Milk Marketing

1.1.Did you sell milk in last 12 months? 1. Yes ( ) 2. No ( )

1.2.If yes, give more details about fresh milk you sold to different types of buyers in the last 12 months?

Buyer types (codes)	**Number of buyers of this type? (average)**	**Time of the day (codes)**	**Quantity per day (Liter)**	**Price/Liter (local currency)**	**How is price determined? (codes)**	**Who receives the money? (codes)**	**Do you have a formal contract (1 = Yes ; 0 = No)**	**Nature of milk payment (codes)**	**Other arrangement (codes)**	**Distance to selling/collection point (km)**	**Who transported? (code)**	**Transport mode (code) (main mode of transport)**	**Time taken in minutes**	**Cost of transport (local currency)**	**Type of milk test (codes)**

Milk buyer codes: 1 = Individual customers 2 = Private milk-traders 3 = Dairy co-op. collection center 4 = Chilling plants (N/A in Kenya) 5 = Other (specify) Time of the day codes: 1 = Morning 2 = Evening 3 = Both	How is price determined? (codes): 1 = Market price 2 = Seller decides 3 = Buyer decides 4 = Buyer and seller agree and fix price based on quality 5= Buyer and seller agree and fix price based on quantity Who receives the money? (codes): 1 = Husband 2 = Spouse 3 = Household (Husband and spouse) 4 = Other (specify	Nature of payment codes: 1 = Buyer pays cash 2 = Buyer pays end of month, verbal contract 3 = Buyer pays end of month, written contract 4 = Buyer pays in advance, verbal contract 5 = buyer pays in advance, written contract 6 = Other (specify) Other arrangements codes: 0= No other arrangement 1 = Buyer provides feeds on credit 2 = Buyer provides AI on credit 3 = Buyer provides loans 4 = Buyer gives deposit 5 = Other (specify)		Who transported? (codes): 1 = Farmer (no hired transport) 2 = Buyer (no hired transport) 3 = Hired transport (farmer paid) 4 = Hired transport (buyer paid) 5 = Other (specify) Transport mode codes : 1 = On-foot 2 = Draft animal / carts 3 = Bicycle 4 = Motorcycle 5 = Public vehicle/ bus 6 = Private pick-up, van, truck 7 = Other (specify)	Type of milk test codes: 1 = Not tested 2 = Lactometer 3 = Smear test 4 = Flavor/ Visual test 5 = Other (specify

D2. Farm milk Network

2.1. Do you have any member of the household registered as a member of a dairy co-op or dairy self-help group or dairy innovative platform (DIP) that collects milk? (If No skip to 2.9)
1. Yes ( ) 2. No ( )

2.2. If yes, what is the name of the cooperative or group? ---

2.3. who is registered as a member. Select only that apply………………………………………………… (codes)

1 = Head		4 = head's father	6 = Son	8 = Other joint (specify):________________
2 = Spouse	3 = Household (All)	5 = head's mother	7 = Daughter	11= Other (specify):____________________

2.4. Is the member holding an elected or appointed leadership position? 1. YES ( ) 2. NO ( )

2.5. Is the household currently delivering milk to that co-op or group? 1. YES ( ) 2. NO ( )

2.6. If not currently delivering milk to diary co-ops, please explain why not? ---------------------- (codes)

1 = Immature cows 2 = Dry cows 3 = Sold all cows	4 = Cows died 5 = Selling milk elsewhere at a better price 6 = Consuming all the milk	7 = Dairy co-op collapsed / not taking milk any more 8 = Delayed payments 9 = Other (specify) __________

2.7. Does this co-operative/group/own a chilling plant? 1. Yes (   ) 2. No (   )
2.8. If yes, has the household member bought any shares in this chilling plant? 1. Yes (   ) 2. No (   )
2.9. If you are a member of a dairy co-op or self-help group, what services of the dairy co-op/Self Help Group do you use? Indicate with ticks:

Services	**Milk collection**	**Veterinary services**	**Selling of dairy inputs**	**Provider of AI**	**Credit for feeds**	**Credit for AI**	**Insurance**	**Others (specify)**
Services you would like to use from Dairy co-op (1=Yes; 0=No)								
Services currently availability in coop (1=Yes; 0=No)								
Services you would like to use from Self Help Group (1=Yes; 0=No)								
Services currently availability group (1=Yes; 0=No)								

D3. Access to information and Institutional Services

3.1. Did you access information on dairying in the last 12 months?

1. Yes (   )   2. No (   )

3.2. If yes, indicate for each type of information, source and how you accessed information:

The type of information (codes)	**The two mains sources of information starting with the most important (codes)**		**How did you access information starting with the most important? (codes)**	
Feeds				
Concentrate feeding				
Fodder and forage feeding				
Grazing management				
Fodder establishment				
Fodder harvesting & processing				
Fodder conservation				
Feeds ration formulation				
Calf nutrition				
Cattle management				
Cattle housing				
Cattle breeding				
Cattle reproduction				
Health and diseases management				
Manure management				
Milk management & marketing				
Milk prices				
New milk outlets (contracts)				
Milk hygiene management				
Milk quality standard				
Others				
Financial services (loans)				
Livestock training schemes				
Other specify: /_______________/				

Source of information codes:	Method of access to information codes:
1 = Government ministries	1 = /N/A
2 = Farmer/ self-help farmer groups	2 = Extension briefs
3 = Private entrepreneurs/sector	3 = N/A
4 = NGOs, Specify	4 = N/A
5 = Cooperative societies	5 = N/A
6 = A research organization, specify	6 = Media (Radio, Print, TV etc.)

7 = A learning institution specify	7 = Field days, demos, barazas etc.
8 = Ongoing projects, Specify	8 = Training workshops, seminars etc.
9 = Other (specify)	9 =Poster/Banners

3.3. Did you get access any extension services for the last one year?

1. Yes ( ) 2. No ( )

3.4. Who are the main providers of extension services? Select all that apply………………………………. (codes)

Providers of extension services	
1=Government	3=Cooperatives
2=NGOs	4=KALRO

3.5. What are the main activities provided by extension agents (? select all that apply………………………………………………………………………………………………… ………………… (codes)

Activities provided	
1. Training on improved forage production	4=Milk quality Management
2. Veterinary services	5=Feed Formulation
3. Livestock book keeping	6=Others (specify)

Appendix 6: Focus group discussion and Key informant interviews

FGD ID…………………………………………………………………………

Farmers/distributers/others

Number of participants……………………………………………………….

Sub –county…………………………………………………………………….

Village……………………………………………………………………………..

1. Tell us the various forage species used by dairy farmers in Bomet county (includes forage source from the market)?

a) What are the common forage species used by many dairy farmers in different dairying systems

- ✓ Zero grazing (cut and carry system)
- ✓ Semi-intensive farming system (semi- zero grazing)

b) Among the forages used and grown by farmers, which forage species gives the highest returns in terms of milk production

c) State where forage planting materials are sourced. Urban market or within village and who provides the planting materials

d) Do you sometimes buy forage (for example fresh Napier grass, Brachiaria grass, hay and silage) from commercial forage producers. If yes mention the forages that you mainly buy from commercial forage producers.

e) can you comment about the quality of commercial forages provided by commercial forage producers. What type of forages are mainly sold by commercial forage producers?

f). What improvements and changes can commercial forage producers adopt to increase quality of forage and yield.

2). What new forages do you think government and other organizations can introduce in the dairy farming systems between energy and protein rich forage.

a) Name the common forage conservation method used by farmers. name the sources of planting material
b) What forage species are used to make hay and sillage in dairy farming system
c) Which forage crops and preservation technologies are best suited to reduce the problem of seasonality.
d) What are the major constraints facing forage production, what can government and other organizations do to address constraints to forage production?
e) State the major feeds used in rainy and dry season in Bomet County
f) What forage conservation do you think should be introduced.

3). Over the past year, have you ever or any one in your family participated in farmers' training workshop

3a). How often did you participate in farming workshops or training in improved forage growing? Who provide the training

3b). Overall has your participation increased or decreased over the past year? If so, what is the reason for the change

3c). What did trainers do to motivate you to participate in trainings.

3d). Are women and youth involved in the trainings?

3e). If there are those who did not participate in some trainings what do you think prevented them.

f). What do you think can be done to enable more farmers to participate in growing and used of improved or quality forage training?

4). Describe the major constraints to milk production in your county

4a). Rank the constraints. Which one affects milk production the most

4b). Did government or any other organization intervene to address the problem? If yes what action did they take, if no why not

4c). Do you get visits from government extension agents in your county? If yes, how often do they come to visit your farms and what services do they provide

4d). What can government; farmers and others like NGos or cooperatives do to resolved constraints to milk production

Key Informant Interviews

Instructions for note-taking: Do not use the respondents' name. Enter the KII ID number on the paper form.

KII ID: ……………………………………………………………………………………

Date: ……………………………………………………………………………………….

Sub-county………………………………………………………………………...

Profession…………………………………………………………………………....

1. Tell us about yourself, what do you do for work and the ways you are involved with smallholder dairy farmers
2. Has there been any change in the number of dairy farmers who have adopted improved forage technologies over the past years? What are those improved forage technologies?

a). Has there been changes in the number of smallholder dairy farmers

b). Changes in the volume of milk produced in the county

c). What are the common forage species grown in smallholder dairy farming system in Bomet

d). What are the common forage species used by many dairy farmers in different dairying systems?

- Zero grazing (cut and carry system)
- Semi-intensive farming system (semi- zero grazing)

e). Among the forages used and grown by farmers, which forage species gives the highest returns in terms of milk production.

f). which forage species would you recommend to be introduced in smallholder dairy farming system for increase milk production in Bomet County

3. could you comment on the availability of agro vet suppliers and commercial forage producers

a). what services and goods are provided by agro vet suppliers and commercial producers

b). what are the problems, if any associated with sourcing inputs and goods from agro vet suppliers and commercial forage producers?

c). what do you recommend government can do to curb problems associated with sourcing inputs from agro vet suppliers and forages from commercial forage producers?