

**ADOPTION OF DAIRY FARMING TECHNOLOGIES AND  
MILK PRODUCTIVITY AMONG SMALLHOLDER FARMERS  
IN MERU COUNTY, KENYA**

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EMBU**

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## DECLARATION

This research thesis is my original work and has not been presented elsewhere for a degree or any other award.

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## **DEDICATION**

I dedicate this work to the Almighty God, whose grace, wisdom and strength have sustained me throughout this journey. I am deeply grateful for the guidance, sound mind, skills and good health granted to me during the course of the study. I also dedicate this thesis to my beloved wife Purity for her unwavering moral, financial and academic support. To my children Melvin, Velma and Hilma this work is a source of inspiration and a testament to the power of dedication and hard work. May it motivate you to pursue your dreams with passion and resilience.

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## **AUTHORSHIP DECLARATION: CO-AUTHORED PUBLICATIONS**

This thesis entails co-authored work, part of it is already published, some of it is under review in a peer-reviewed journal and part of it is ready for submission. The details of the work are as outlined below.

**Chapter Three:** Is the adoption of modern dairy farming technology interrelating? A case study of smallholder dairy farmers in Meru County Kenya. Published in *Heliyon* (Online)

**Chapter Four:** Role of Modern Dairy Farming Technologies in Enhancing Milk Productivity: A case of Meru County Kenya. Journal of Global Innovations in Agricultural Sciences Published in (JGIAS)

**Chapter Five:** To evaluate the effect of support services on intensity of adoption of MDFTs among smallholder farmers in Meru County. The manuscript is ready for submission to the peer-reviewed journal.

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## **LIST OF ABBREVIATIONS/ ACRONYMS**

DSS	Dairy Support Services
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
KDB	Kenya Dairy Board
KNBS	Kenya National Bureau of Statistics
MDFT	Modern Dairy Farming Technologies.
MoALF	Ministry of Agriculture Livestock and Fisheries
NDMP	National Dairy Master Plan
NGO	Non-Governmental Organization
OLS	Ordinary Least Squares
SDG	Sustainable Development Goals
SPSS	Statistical Package for Social Sciences

## **DEFINITION OF TERMS**

Adoption	This study defined adoption as the acceptance and continued use by smallholder farmers of available and accessible dairy farming technologies that may ease their time, energy and lead to optimal production.
Dairy farming	This study defined dairy farming as raising cattle for the production of milk.
Dairy farming technologies	In this study, this refers to dairy farming innovations, methods, tools, and equipment, as well as practices used to improve milk production, health, and farm efficiency.
Determinants	This study defined determinants as any factor or element that directly influences the adoption of modern dairy farming technologies and milk productivity.
Productivity	This was defined as the amount of milk produced by a cow within a given period of time, usually measured per cow per day.
Smallholder farmers:	The study defines a smallholder farmer as any farmer who owns between 1 and 10 dairy animals and relies primarily on family labour.

## ABSTRACT

In dairy enterprises, technologies are critical in enhancing milk production. However, the adoption rate of these technologies in Kenya is not known. Therefore, this study assessed the adoption of modern dairy farming technologies (MDFT) and milk productivity among smallholder farmers in Imenti South Sub-County, Meru County, Kenya. The specific objectives were to assess the determinants of adoption of MDFT, determine the effects of adopting MDFT on productivity, and evaluate the extent of extension support services on the acceptance and adoption of MDFT. Relevant data were collected using a cross-sectional survey design where questionnaires were administered to 355 dairy farming households. The multivariate probit model was used to assess the determinants of adoption of modern MDFT. The results revealed that education level, household income, access to credit, number of extension contacts, farming experience, farmer group membership, and livestock monetary value were positively associated with the adoption of sweet potatoes by 32%, Rhode grass 28.53%, Lucerne 23%, Hay 82%, silage 38.87%, clean soft 76.90% milking machine 2.54% and feed mixture 9.01 %. High education level and frequent extension contacts positively influenced the adoption of fodder establishment technologies as well as preservation technologies. Farming experience in dairy farming affected the adoption of well-constructed and clean sleeping areas for the dairy cows and the growth of Rhodes grass. Household incomes affected the growth of Rhodes grass and feed mixture adoption among the dairy farmers. Further, the effects of adopting MDFT on milk productivity were determined using the Cobb-Douglas production function. The results reviewed the frequency of extension visits, years of experience in dairy farming, cost of water and feed, dairy equipment technology, cow health technology, fodder preservation technologies, improvement of fodder quality, and advancement in cow genetics influenced milk productivity positively at different levels. Additionally, an ordered probit model was used to evaluate the intensity of extension support services on the adoption of modern MDFT. The results indicated that extension frequency services, timely access to artificial insemination, veterinary services, selling milk through a co-operative, access to market information, household size, marital services, and access to credit services positively enhanced the adoption of MDFT. The study indicates that there is a need to make extension services available and increase the frequency to the farmers, as this promotes the adoption of modern MDFT. Further findings of this study recommend that the county government and relevant stakeholders in the dairy sector should create policies that encourage farmers to join the dairy cooperative society, for it acts as leverage for information dissemination to farmers.

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background information

Globally, the agricultural sector remains the backbone of many countries' economies and a key contributor to food security. However, with population growth, the global demand for food is expected to rise in the coming decades. This creates uncertainty about whether global agriculture can meet this demand through increased food production and expanded food supply. Efforts to diversify agriculture and boost production sustainably could enhance food availability and help eradicate hunger. The dairy sector, for example, continues to support nourishing the world, producing about 979 million tonnes of milk in 2024, with increasing output in subsequent years. Milk and other dairy products are regularly consumed by roughly 80% of the global population. Over 150 million households worldwide are actively involved in milk production (FAO, 2024).

In Low-and Middle-Income Countries (LMICs), milk production is done by smallholders, which supports their household livelihoods, food security, and nutrition (Banda et al., 2021). Milk not only provides quick returns but also forms an income source for small-scale farmers. However, the existing dairy technologies and knowledge cannot enable smallholder farmers to produce milk that meets the demand in the market. To improve the dairy sector, increasing and expanding investments in agricultural research and extension systems are needed, especially in developing countries (Mele, 2023; Nyokabi et al., 2023). Awareness and adoption of modern technologies proven in developed countries need to be facilitated in developing countries to overcome knowledge barriers, eliminate technology gaps, and improve milk production efficiency (Pandey et al., 2022).

African smallholder farmers have adopted some technologies to expand the range of activities and gratify needs and wants (Khoza et al., 2021). Most of the African countries have acquired technologies from developed countries. However, several factors constrain the technology transfer and adoption by smallholder farmers. These constraints include limited resources, inadequate training and extension services, poor government policies, poor technology protection, and negative attitudes and perceptions towards technology.

An enabling environment for technology transfer must be created in developing and less developed countries. The output from the technological transfer should be physical components and local buildup of technical knowledge and skills (Ciborowski & Skrodzka, 2019). The technology provides adequate employment opportunities and sufficient income for the agriculture-dependent people. In the Kenyan situation, public and private institutions in collaboration with Non-Governmental Organisations (NGOs) have disseminated knowledge through group trainings and technologies like silage making, cultivation of high-quality fodder, cow mattresses and use of artificial insemination to the people (Bourne et al., 2021).

Dairy development in LMICs is crucial in improving milk production, enhancing incomes, creating employment opportunities, and boosting the nutritional standards of people (Burkitbayeva et al., 2019). Alternative farming activities need to be explored to ease reliance on low and unreliable income from cash crops (Mutea et al., 2025). Despite indications of dairy development's potential to reduce poverty, smallholder dairy production is becoming increasingly vital and significantly improves the livelihoods of rural communities. In Kenya, dairying is growing rapidly but faces challenges, including ineffective management practices and healthcare, high input costs coupled with low product prices, resulting in low productivity (Muthee et al., 2025).

The dairy industry contributes 14% of the agricultural gross domestic product of Kenya (FAO, 2024). The industry encompasses and supports a range of value chain actors spanning from farmers, milk traders, processors, and consumers to several service providers. The dairy industry is one of the most successful and vibrant industries because it increases domestic milk production and has high processing capacity, per capita milk consumption, and export potential (Gichuhi, 2022). For instance, Kenya's per capita milk consumption of 110 litres per year is the highest in Sub-Saharan Africa, and it is expected to rise to 130 litres per year by 2030 (National Dairy Master Plan, 2010-2030).

The dairy technologies encompass the use of crossbred animals, improved feed technology, improved management, artificial insemination (AI), value addition, and vaccination, among others (Singh et al., 2021). But cattle farming in rural areas of Imenti South sub-county in Meru County is constituted mainly of smallholder farming systems being managed using traditional production methods, which are characterised by poor

breeds, poor feeding, poor housing conditions, inferior health care services, and low capital investment. The effect of several technologies, such as improved feed production and conservation, clean milk production, and the use of concentrated minerals and salts, among others, would be beneficial to improve dairy production. Understanding the extent of farmers' adoption of dairy technologies is critical to the success of the development and implementation of policies and programs in the dairy industry. Previous adoption-oriented research has examined the use and dissemination of dairy-related technologies and the factors affecting adoption on smallholder farms (Maleko et al., 2018; Maina et al., 2020). However, studies by Migose et al. (2018) found that constraints imposed by the factors that influence the awareness, availability, costs, benefits, and risks are associated with the adoption of different livestock technologies and management practices. Despite of this, little work has been done to examine the extent of adoption of dairy technologies and their impact on productivity in rural smallholder dairy farms (Bidhan et al., 2024).

In Meru County, dairy farming is important and highly valued due to the small landholding size that enables farmers to engage in a crop and livestock integrated mixed farming system (MoALF, 2022). Dairy farming is an important farming enterprise in the area due to its agro-ecological characteristics (Adolwa et al., 2023). For instance, Imenti South sub-county has 40,000 dairy cattle and 37,000 households that produce an average of 2100 litres/cow/year (Muriithi et al., 2019). This is slightly above the national average of 1800 litres/cow/year documented in the national dairy master plan (MoALF, 2022). MDFTs' promotion efforts have been made by different organisations because the country is a potential and close to urban market centre, and there is the presence of milk cooperatives in the area. To increase the supply of milk for users and milk collector cooperatives, MDFTs have been distributed to farmers who were selected as dairy package participants for a long time in the past (MoALF, 2022). In Imenti sub-county, dissemination of technologies and training has been offered for farmers, government professionals, and other NGOs (Murungi, 2020).

Despite its potential and large population, the contribution of the Kenyan dairy sector is low at both the national and household levels (Kiplagat et al., 2024). This low production level of the sector is attributed to the inefficient productivity of the dairy cattle as a result of the traditional method of production. Since then, different MDFTs, such as artificial

insemination, among others, have been transferred through both governmental and NGO and private sectors, and even large efforts have been made to disseminate dairy technologies through the support of governmental and NGO in different parts of the country, including the study area (MoALF, 2022). It is therefore important in this study to assess the factors that determine the adoption of MDFTs, such as improved fodder production and conservation, clean milk production, and use of concentrate minerals and salts, among others, and their impacts on dairy productivity in the study area.

### **1.2 Statement of the problem**

Despite the importance of dairy farming in Meru County, its production has been declining. Attempts have been made to enhance production by introducing various MDFTs such as high nutritional fodder crops technology, fodder preservation, milk value addition, and vaccination, among others. However, the rate of adoption of these MDFTs among smallholder farmers is very low. In addition, few studies exist on the effect of the adoption of MDFTs on milk productivity. The government, in collaboration with NGOs, has offered various support services, such as training and milk price intervention, to farmers in order to increase the amount of dairy output. Yet still, the effect of support services on the intensity of adoption of modern dairy farming technologies among smallholder farmers has not been evaluated. Therefore, this study aimed to narrow the identified knowledge gaps.

### **1.3 General objective**

The general objective of this study was to assess the adoption of modern dairy farming technologies and effects on milk productivity among smallholder farmers in Imenti South Sub-County, Meru County.

#### **1.3.1 Specific objectives**

1. To determine the factors that influence the adoption of modern dairy technologies among smallholder farmers in Imenti South Sub-County, Meru County.
2. To assess the effects of the adoption of modern dairy technologies on milk productivity among smallholder farmers in Imenti South Sub-County, Meru County.

3. To assess the effects of support services on the intensity of adoption of modern dairy technologies among smallholder farmers in Imenti South Sub-County, Meru County.

#### **1.4 Research questions**

1. What factors influence the adoption of MDFT among the smallholder farmers in Imenti South Sub-County, Meru County?
2. What is the effect of adoption of MDFT on milk productivity among the smallholder farmers in Imenti South Sub-County, Meru County?
3. What is the effect of support services on the intensity of adoption of MDFT among smallholder farmers in Imenti South Sub-County, Meru County?

#### **1.5 Justification of study**

The rate at which modern dairy technologies are adopted by farm households varies significantly across different agro-ecologies and even within the same agro-ecology due to various technological and non-technological factors (Korir et al., 2023). Consequently, the contributions and benefits of dairy technologies differ among farm households (Deolu-Ajayi et al., 2023). Therefore, for policy development and effective management of extension programs, information on extension support services that influence the adoption of dairy technologies, as well as the impact of these technologies on the livelihoods of smallholder farmers, is crucial. Based on this, the study provides research-based insights into the extent of adoption of improved modern dairy technologies and their effects on milk productivity in the target area.

Understanding the most suitable dairy farming technologies has prompted positive changes among smallholders, thereby improving their disposable income, food and nutritional security in rural areas. This directly supports the Sustainable Development Goals (SDGs), specifically “end poverty everywhere (SDG 1)” and “end hunger (SDG 2).” The adoption of MDFT has the potential to increase the farm-level output and household income, contributing positively to the achievement of Vision 2030’s economic pillar, which aims for an annual economic growth rate of 10%. An increase in production and income also promotes household food security among farmers, aligning with the food security and nutrition pillar of the Kenyan government's strategic direction (Riany, 2018).

## **CHAPTER TWO**

### **LITERATURE REVIEW**

#### **2.1 Overview**

This chapter provides a review of literature relevant to the research problem. It also investigates the factors influencing dairy farming technology adoption and their impact on milk productivity. Additionally, the chapter looks at the effect of the extension support services on the intensity of MDFTs adoption. Furthermore, the section examines several extension support services that promote their adoption by smallholder farmers. Additionally, the chapter offered the study's theoretical and conceptual underpinnings.

#### **2.2 Empirical literature review**

This section reviewed empirical studies relevant to the adoption of dairy farming technologies among smallholder farmers, emphasising extension services, determinants of adoption, and productivity outcomes. The review was organised around three primary themes derived from the study objectives.

##### **2.2.1 Modern dairy farming technologies among smallholder farmers**

Due to cultural adaptability, smaller land sizes, and the fact that dairy farming has become a commercial endeavour, a study on the post-liberalisation of the Kenyan dairy industry found that there are more foreign cows in the country's highlands (Van der Lee et al., 2018). The findings disregarded the degree to which smallholder farmers adopted dairy technologies, instead concentrating on the impact of socioeconomic factors on this technology's adoption. The current study was able to fill this gap by defining and assessing the degree of MDFT adoption among smallholder farmers.

The dominance of indigenous breeds hampered smallholder farmers' attempts to adopt dairy farming technologies, according to a study on a few socioeconomic and institutional factors influencing the adoption behaviour of dairy cattle by smallholder farmers in Kenya (Lukuyu et al., 2019). On the other hand, illness concerns, the need for fodder, an unstable milk market, and breeding difficulties made it difficult to accept foreign cows. Additionally, FAO (2019) noted that rural farmers in the Kenyan highlands are not adopting dairy technology at a high rate due to a lack of advisory services and weak

connectivity. The current study examined the extent to which smallholders have adopted improved dairy farming technology, whereas the previous studies concentrated on economic considerations, awareness processes, and traditional practices. According to a 2018 FAO report, rising human populations and declining incomes are the main drivers of dairy fodder production and consumption. As a measure for future implementations and policy suggestions, it is necessary to evaluate the current fodder technology and the degree of adoption among smallholder farmers, according to the literature. Therefore, the current study determined the degree to which smallholder farmers have used fodder establishment technologies.

Low quality and quantity of feed supplies are present in Githunguri, Kenya, according to a study on the adoption level of fodder establishment and conservation techniques (Gitonga, 2014). This resulted from a greater emphasis on food crops than on conservation and fodder cultivation. There may be some competition between cow fodder and human meals. In light of the results, the current study determined the degree of MDFT adoption in response to varying household preferences on the distribution of funds for fodder establishments and preservation. These resources comprised structures, land, milking equipment, and fodder. The few rural women in Tanzania who have embraced exotic cow breeds attributed this to social influences and the lack of resources accessible to them, according to a study on the adoption status of dairy farming technology (Alessandra et al., 2017).

### 2.2.2 factors influencing the adoption of modern dairy farming technologies among farmers

Dairy farming technology varies widely, including the adoption of high-performance cow breeds, increased fodder production, and more efficient conservation practices (Maleko et al., 2018). Furthermore, clean milk production and milk value addition can help increase dairy productivity (Vyas et al., 2020). The proficiency gained via the use of technology is intended to alleviate labour, time, and financial restrictions while increasing production. Adoption is the process of individual farmers accepting and scaling up technology to boost dairy output (Maina et al., 2020).

Adoption is currently defined in research as the decision to apply an improved practice to enhance life skills, goals, and behavioural influences (Liu et al., 2018). Socioeconomic

and institutional factors, participation in development, equity in the technology diffusion process, and power relations, among others, all influence adoption at the rural family level (Curry et al., 2021). Conversely, Marmont et al. (2024) found that the initial acceptance of dairy farming technology was typically followed by dissemination, which defined the process by which change occurred in the structure and function of a social system. Additionally, a study on the spread of knowledge and innovation in agriculture revealed that rural communities are part of a global society and share its challenges (Douglas & Donaldson, 2023). As a result, the dissemination and introduction of innovation, knowledge, and technologies are central to social transformation in rural areas, though in a complex and often paradoxical manner. The study also noted that analysing how technologies spread and impacted societal structures cannot be conclusive without considering specific factors (Douglas & Donaldson, 2023). These include the way information is packaged based on technology adoption, dissemination methods, and perceived features of new technologies during and after distribution. These same factors may influence the process as well. To address this gap, the current study specifically examined the determinants of the adoption of MDFT and its effect on milk output among smallholder farmers in Meru County.

### **2.2.3 Adoption of improved dairy farming technologies on productivity**

A study in East Africa on building on the successes of smallholder dairying found that fodder production in Kenya was facing challenges due to rising input prices, global warming, and global inflation, with dairy cow production being the most affected in terms of scarcity and seasonality. This was corroborated by Ajak et al.'s (2021) study in Kenya on smallholder dairy production, which discovered that the most significant barrier to dairy cow output in the country was a lack of fodder, particularly during the dry season. The study also found that the lack of fodder was caused by climate change, seasonal unpredictability, input prices, and a large dairy cow population. The preceding research focused on nature and resources, notwithstanding. The above studies did not focus on other dairy farming technologies and their effect on farm-level output among smallholder dairy farmers.

In 2024, the Kenya Dairy Board (KDB, 2024) projected that Kenya has an annual processing capacity of 5.2 billion litres of milk. The report found that the volume of milk produced in the country would increase as a result of promoting quality fodder, high-quality animal feeds, the use of superior genetics, and expanding milk storage. Although the targets were not achieved as expected, this has been contributed to by many reasons; however, it was easy to attribute it to the current dairy feeding practices among smallholders. There was a notion that one of the reasons for low adoption could be the lack of a direct connection in smallholder farmers' minds between inadequate feeding of dairy cows and low milk yields. It is therefore important to evaluate the impact of other MDFTs on milk output among smallholders.

A study on livestock genomics in developing countries found that improvement through breeding aimed at increasing milk yields has been very low due to poor implementation of government policy in breeding, lack of a proper national herd recording system, and local breeds, which are genetically poor for milk production (Marshall et al., 2019). According to Mungube et al. (2019), whose case study was on the feeding management of dairy cows, inadequate nutrition was cited as a major constraint that negatively affects the growth and viability of dairy farming. A well-fed animal will grow faster, reach the reproductive stage early, produce more milk, remain in good health, and maintain good body condition. Ibtisham et al. (2018) found that dairy animals require certain foods for body maintenance and production. The maintenance ratio varies with breed and size of the animal, whereas the production ratio is required by dairy cattle for milk production. The above studies did not consider the effects of the adoption of other dairy farming technologies on milk production among smallholder farmers, and the current study comes in to fill the gap. In addition, there is a need for an economic analysis to be done to evaluate the effect of the adoption of these technologies on dairy productivity.

Dairy cattle are also fed concentrates and mineral salts to help them produce more milk. These are critical in rectifying nutritional inadequacies in forages and poor feed (fodder) intake (Garamu, 2019; Magan et al., 2021). Concentrates' availability and pricing vary, particularly in developing nations where animals compete with humans for food. The emphasis should be on homemade or village-produced processing byproducts rather than professionally compounded feeds (Magan et al., 2021). An Ordinary Least Squares (OLS)

regression study revealed that providing water to dairy cows has a positive and significant influence on milk yield among smallholder farmers in South Africa (Nkonki et al., 2019). The study also discovered that dairy cattle suffer more quickly from low water consumption than from dietary deficits. If there is no free access to water, milk output and feed intake will suffer. The current study will use the Cobb-Douglas production function model to examine the impact of adopting improved dairy farming technology on dairy productivity among stallholder farmers in Meru County.

#### **2.2.4 Support services on the adoption of modern dairy farming technologies**

According to Arulmanikandan and Vaishnavi (2024), the extension services to farmer ratio was fairly low, and funding provision for public extension services had dropped over the years, while private extension had not increased to cover the resulting gap. Access to input loans and market output access increased the adoption of MDFT among Kenyan smallholder farmers (Fiorillo & Amico, 2024). The study also discovered that at certain output levels, producers found themselves with milk that couldn't find reliable market outlets. The farm market price was low and set by the processors. Some farmers in the country had called on the government to examine milk production pricing; otherwise, milk would become a luxury item affordable only.

According to (Arulmanikandan & Vaishnavi 2024) found the extension services to farmer ratio was quite low and budgetary provision for public extension services had dwindled over the years while private extension has not expanded to fill the ensuing gap created by the decline in public extension. Access to input credit and market output access had a positive effect on the adoption of modern dairy farming technologies among smallholder farmers in Kenya (Fiorillo & Amico, 2024). The study further identified that, at production levels, farmers find themselves with milk that cannot find dependable market outlets. The farm market price was low and determined by the processors. Some farmers in the country have called on the government to review milk production prices or else milk would soon become a luxury item affordable only to the rich.

The unreliable infrastructure for the distribution of semen was found to affect artificial insemination as a dairy farming technology adopted by smallholder farmers (Kashoma & Ngou, 2023) Artificial Insemination (AI) service providers have compromised the quality

of AI services, thus discouraging many farmers from adopting the technology. In both developing and developed countries, animal diseases, parasite infestation and public health problems constitute a major problem to livestock production and the safe utilization of animal products; thus, there is a need for dairy-intensive dairy veterinary services (Albert et al., 2024).

By raising awareness of the benefits of the technology and subsequently enhancing farm management abilities, the provision of livestock training had a favourable and noteworthy impact on the degree of adoption of dairy technology (Becerra-Encinales et al., 2024). The results of this study, which used a two-fold hurdle model, showed that farmers in areas with training available may adopt more dairy technology than farmers in areas without training. Furthermore, the research revealed increased awareness of enhanced technologies through training, the provision of consistent and dependable technical support, the accessibility and affordability of concentrate feeds, improved and prompt delivery of medication, the expansion of artificial intelligence facilities, the provision of purebreds, and the reinforcement of extension services. This study evaluated other support services, such as training, milk intervention prices, and access to output market services, among others, and their effect on the adoption of dairy farming technologies.

## **2.5 Research gaps**

According to the research, the dairy sub-sector is extremely vital to the Kenyan economy. The studies covered in this chapter focused on the factors that influence dairy farming technology adoption. However, the literature contains little information on the extent to which smallholder dairy producers have implemented these technologies. Furthermore, little research has looked into the effect of MDFTs adoption on smallholder farmer production. Furthermore, little is known about the effect of support services on the smallholder farmers' adoption of MDFTs. Based on the limitations identified above, the current study will assess the factors of adoption of MDFTs and their effect on productivity among smallholder farmers in Meru County.

## **2.6 Theoretical framework**

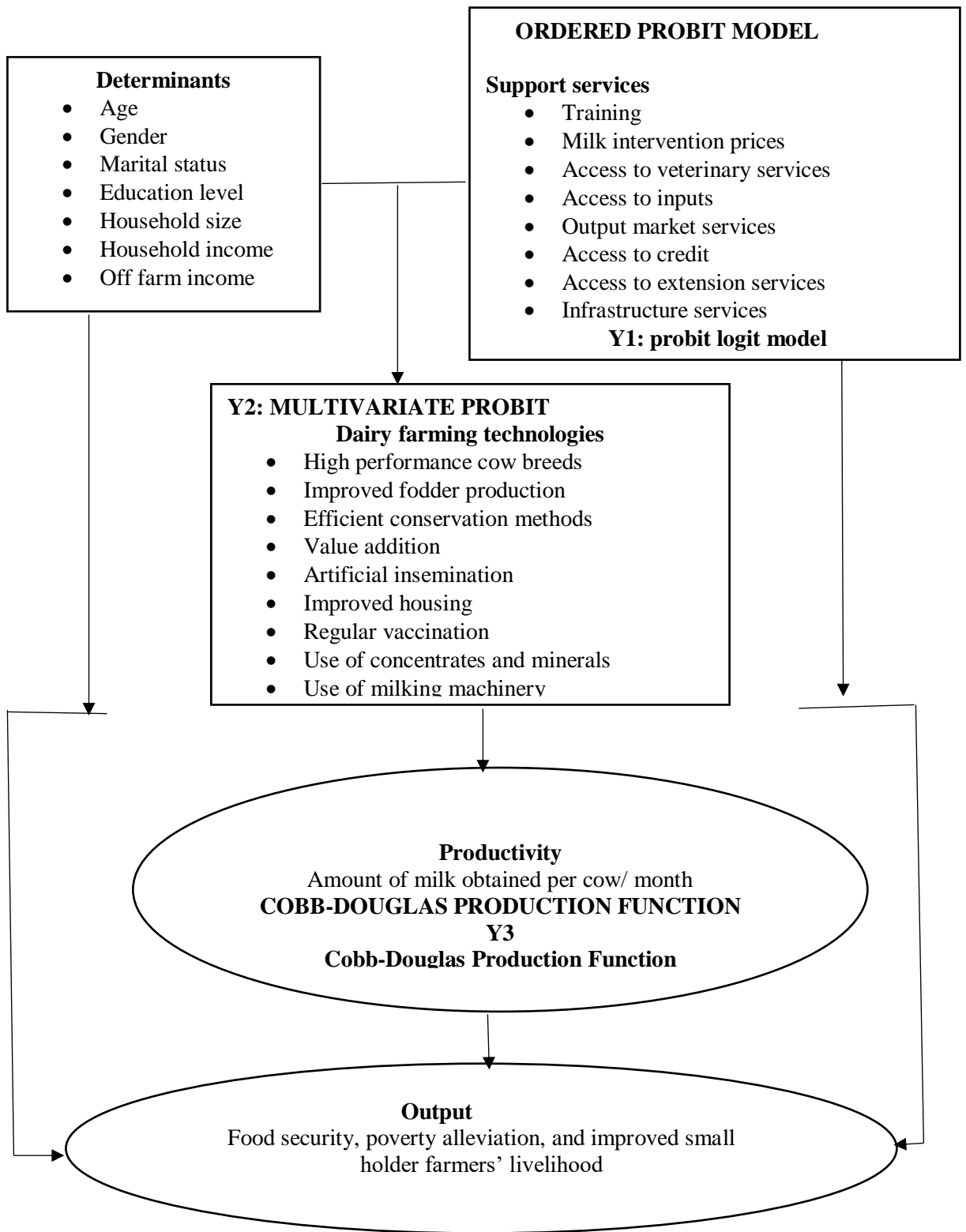
The first objective of this study used (Wani and Ali's 2015) Innovation Diffusion Theory to assist in anchoring the research in the technological process from innovation to adoption. This theory is concerned with understanding the genesis, dissemination, and

level of technological adoption in a social system. According to Wani and (Wali and Ali's 2015). Innovation is a perceived new practice marked by knowledge, persuasion, and decision-making by an individual or a societal system. On the other hand, diffusion is defined as a process that involves a communication channel, time, and social system. According to the author, potential adopters evaluated technology qualities, including relative benefit, compatibility, complexity, trialability, and observability. For instance, if a dairy technology is perceived as significantly more advantageous (relative advantage), aligns with current agricultural practices (compatibility), demonstrates ease of use (low complexity), allows for small-scale experimentation (trialability), and yields observable results (observability), it is more likely to be adopted by farmers. This theory was relevant in this study in many ways. First, it provided a conceptual framework for assessing the adoption of modern dairy technologies, including enhanced feeding systems, AI, and disease management practices. Second, it facilitated the identification of factors that influence the adoption process, such as the role of extension support services, farmer characteristics, and perceptions of technology attributes. Through this theoretical lens, the study explored not only whether these technologies were being adopted but also the methodologies and rationales behind these decisions within the specific context of Meru County.

The second objective adopted the economic theory of production. This theory indicates that efficiency refers to the relative performance of processes employed to convert a given input into an output (Bravo-Ureta et al., 2021). A producer is a decision-making unit that converts productive resources into valuable goods and services that satisfy consumer demands. The producer uses available resources to make a commodity that will be sold at a profit, using input combinations that minimise cost. (Younas et al. 2024) defined agricultural productivity as the ratio of total farm output to total farm inputs. According to (Dessie et al. 2019), producers' primary goal is to maximise production levels. This can be achieved through efficient utilisation of resources and new technology, which leads to greater product quality and higher levels of technical efficiency, resulting in increased output. This study was anchored to this theory by looking at how farmers effectively and efficiently use improved dairy farming technologies to maximise the amount of output obtained at the farm level.

## **2.7 Conceptual framework**

Figure 2.1 depicts the interrelationship between the independent and the dependent variables. Both demographic factors and support services were presumed to determine dairy farming technologies adoption. It was also presumed that the adoption of dairy farming technologies would have an impact on productivity in terms of milk quantity. The binary logit model was used to determine the effect of support services on the adoption of dairy farming technologies. The multivariate probit (MVP) model was used to determine the extent of adoption of dairy farming technologies. Productivity was measured in terms of the amount of milk output obtained by farmers per day per cow. To determine the effect of the adoption of dairy farming technologies on productivity, the Cobb-Douglas production function will be used. The study aimed to alleviate poverty and food security and improve smallholder farmers' livelihoods.



**Figure 2.1: Study conceptual framework**

## CHAPTER THREE

### **Is the adoption of modern dairy farming technology interrelated? A case study of smallholder dairy farmers in Meru County, Kenya**

#### **Abstract**

There have been initiatives to encourage the use of modern dairy farming technologies (MDFT). Nevertheless, the use of these technologies is still much underutilised. The purpose of this study was to examine the factors that influence MDFT adoption in Meru County. This study examined the elements that help or hinder the simultaneous adoption of several technologies using data from 355 smallholder dairy producers in Meru County, Kenya. Adoption choices made by dairy farm households dealing with various MDFTs were assessed using a multivariate probit model. The findings demonstrated a strong link between the eight MDFTs, indicating the interdependence of contemporary technologies. According to the findings of the MVP model, the adoption of MDFTs was positively and significantly impacted by household income, education level, the number of extension contacts, farmer group participation, loan availability, farming experience, and livestock monetary worth. Both education level and extension contacts positively impact the adoption of preservation and fodder establishment technologies. The adoption of hygienic, well-organised sleeping quarters for dairy cows and the development of Rhodes grass were positively impacted by farming experience in dairy farming. Rhodes grass growth and feed mixture adoption among the population were positively impacted by household income. In order to improve the adoption of MDFTs, this work highlight the need for policy implications and insight into the necessity for the county government and commercial milk processing enterprises to boost extension frequency. Expanding access to reasonably priced credit is also necessary; the government should take this into account by creating and bolstering smallholder low-interest, effective local credit programs and institutions.

**Keywords:** Adoption, Modern Dairy Farming Technologies, Multivariate Probit Model.

### **3.1 Introduction**

Globally, agricultural sector is critical in enhancing food availability and achieving food security (Balasundram et al., 2023). Despite a broad consensus that global demand for food is expected to increase in the coming decades, there are concerns about whether global agriculture systems will keep pace to service the high demand through an expansion in the food supply (Barrett, 2021). Enhancing food supply through increased agricultural productivity and expansion of cultivable land is considered a viable strategy for addressing hunger (Kanojia et al., 2023). Given this, the dairy industry is vital to world nutrition, producing 881 million tonnes of milk in 2021 with subsequent rises yearly (FAO, 2022). Approximately 6 billion people, or more than 80% of the world's population, usually drink liquid milk or other dairy products. According to the (FAO, 2022), around 150 million households worldwide are involved in milk production.

Milk is predominantly produced by smallholders in most developing countries, and it helps support household livelihoods, food security, and nutrition. Farmers benefit from MDFT, which increases milk yields, improves production efficiency, and lowers labour costs. Despite the benefits of these technologies, adoption levels have been poor among smallholders in developing countries. Smallholder producers benefit from milk's quick returns. However, the current dairy farming technologies and knowledge are insufficient to allow smallholder farmers to produce milk that fulfils market demand. Common MDFTs, such as the adoption of milking machines and new breeds of dairy animals, are capital-intensive, limiting their adoption levels. This demonstrates the need to increase spending in agricultural research and extension institutions, especially in developing nations to enhance the dairy sector (Mele, 2023; Nyokabi et al., 2023).

Furthermore, there is a need to invest in dairy farming methods that would push African agriculture towards higher productivity while minimising environmental impact (Sekaran et al., 2021). The transfer of technology from developed to developing countries should be promoted to support compatible modern dairy practices, to minimise technology gaps, and to overcome knowledge barriers (Pandey et al., 2022). Therefore, a deeper comprehension of the barriers that stifle small-scale dairy farmers' adoption decisions of the MDFT is essential for creating pro-poor policies that might encourage and stimulate

its adoption and raise milk yield. Notwithstanding the multiple benefits of adopting the MDFT, it is unclear why the adoption rate is still very low. Also unclear from the existing body of literature are the underlying determinants of MDFTs adoption. Furthermore, we consider eight MDFTs as farmers adopt many of these technologies together to boost farm productivity. The eight MDFTs considered in this study are correlated in three aspects, namely fodder establishment technologies (FET), fodder preservation technology (FPT), and dairy equipment technology (DET), an aspect missing in the existing literature.

In Kenya, the dairy industry contributes for 14% of agricultural GDP (FAO, 2022). Farmers, milk traders, processors, consumers, and a variety of service providers all benefit from the sector. The dairy business is considered successful and thriving because to rising domestic milk output, processing capacity, per capita milk consumption, and export potential (Gichuhi., 2022). It supports the poor and smallholders who own one to three cows. There is potential for growth of the dairy sub-sector domestically and regionally to be able to meet the growing need for whole, raw, low-fat, and skimmed milk. For instance, Kenya's per capita milk consumption of 110 litres per year is the highest in Sub-Saharan Africa, and it is expected to rise to 130 litres per year by 2030 (National Dairy Master Plan, 2010-2030). It benefits the poor and smallholder farmers who own one to three cows. There is room for growth in the dairy sub-sector both domestically and regionally to fulfil the increased demand for whole, raw, low-fat, and skimmed milk. Kenya, for example, has the greatest per capita milk consumption in Sub-Saharan Africa, with a projected increase to 130 litres per year by 2030 (National Dairy Master Plan, 2010-2030).

Among other things, the dairy technologies include the utilisation of crossbred animals, better feed technology, better management, artificial intelligence, value addition, and immunisation (Singh et al., 2021). Poor breeds, inadequate nutrition, subpar housing circumstances, inadequate health care facilities, and minimal capital investment are the hallmarks of the smallholder agricultural system that mostly makes up dairy farming in Meru County's rural districts. The use of concentrated minerals and salts, clean milk production, enhanced feed output and conservation, and other technologies would all have a positive impact on dairy production. The success of developing and implementing policies and programs in the dairy industry depends on an understanding of the level of adoption of dairy technologies.

Data analysed using multinomial endogenous switching regression from a study on the potential of dairy farms in Ethiopia's central highlands revealed that those who adopted improved dairy farming technologies, such as better feed and improved breeds, produced more milk than those who did not, making them more food secure (Feyissa et al., 2023). (Wairimu et al. 2022) conducted a study in Kenya that looked at the factors that influence smallholder dairy farmers' adoption of Technical Dairy Innovations (TDIs), such as better cow feeding and health management. They found that housewife education, the number of dairy cows, and credit availability all had a positive impact on TDI adoption, while farm size, household income, and access to dairy information did the same. Also, a study conducted in the Tanga region, Tanzania, by (Ndah et al., 2022) established that positive community attitude and recognition of ecological benefits by smallholder farmers positively and significantly influenced the adoption of improved forages in dairy production systems.

However, institutional factors like market conditions negatively affected the adoption of improved forage in the region. (Rahman et al., 2023) studied among smallholder dairy farmers in rural Bangladesh considered four improved DFTs, namely, concentrate feed, deworming, AI, and vaccination. In this study, access to extension contacts and information access to farmers through radio and television positively influenced the adoption of these improved technologies. Animal welfare is becoming vital in dairy animal production in developing countries. The welfare status of animals can range from the feed given to the animals to the sleeping area as a mechanism of boosting milk yields (Hernandez et al., 2022).

Most of the smallholder dairy farmers keep their animals under zero grazing units built primarily using wood and metallic rails. Fodder scarcity and low quality have affected the productivity of dairy animals in Kenya. A study conducted in Tharaka Nithi County, Kenya, established that knowledge, herd size, and land under fodder growing positively and significantly influenced fodder conservation, which in turn led to increased milk yields (Thomas et al., 2023).

Increased education levels and herd size were found to positively influence the adoption of multiple technologies among dairy farms in Ethiopia that employed negative binomial regression (Korir et al., 2023). High-quality feed promotes growth, reproduction, and

overall animal health. A mixture of dairy feeds to ensure quality and proper nutrition leads to increased milk productivity (Baris., 2023). Access to extension services was found to have a significant effect on the uptake of crossbred cows DFT among smallholder farmers in Manipur (Singh., 2023). A study by (Skevas., 2020) evaluated the measurement of production inefficiency and inefficiency heterogeneity, setting results, and results analysed using the maximum likelihood frontier model showed inefficiency was overestimated when heterogeneity is not accounted for, suggesting technology heterogeneity dominates inefficiency heterogeneity when tabulating conditional and unconditional probabilities.

Due to the small landholding size that allows farmers to participate in crop and livestock-integrated mixed farming systems, dairy farming is essential in the region (MoALF, 2022). Furthermore, because of its agroecological features, it is a significant farming operation in the region (Adolwa et al., 2023). For example, Imenti South generates an average of 2100 litres per cow annually and has 40,000 dairy animals and 37,000 households (Muriithi et al., 2019). According to the national dairy master plan, this is marginally more than the 1800 litres per cow per year national average (MoALF, 2022). Given the country's potential, proximity to major market areas, and the existence of milk cooperatives in the region, various organisations have been working to promote improved dairy feed technologies. The government and other non-governmental organisations have distributed technologies and provided training to farmers and professionals (Murungi, 2020). However, there is limited evidence on the factors that influence the adoption of various dairy feed systems. As a result, the purpose of this study is to assess the factors influencing the adoption of dairy farming technology among smallholder dairy farmers in Meru County, Kenya. The current study contributes to a growing corpus of research on adoption (Gelata et al., 2024; Korir et al., 2023; Kaushik et al., 2023; Akzar et al., 2023).

The significance of this study lies in two main areas: first, it examined techniques that acknowledge the interdependence of various dairy practices and jointly analysed the decision to adopt MDFTs. It determined how the various technologies correlated with each other and how such correlations can be explained. It also aids in the formulation of development practitioners' and policymakers' strategies for advancing MDFTs. Second, the study focused on the relative significance of MDFT classified as sweet potato vines,

Rhodes grass, lucerne hay, silage, milking machines, feed mixture, and clean soft sleeping areas that have not been considered in previous literature and are the most prevalent among smallholder farmers in this area.

## **3.2 Methodology**

### **3.2.1 Study area**

The study took place in Kenya's Meru County. The county borders four other counties: Isiolo to the north, Tharaka Nithi to the southwest, Nyeri to the southwest, and Laikipia to the west. The area is located between latitudes 300 and 5199 meters above sea level, and the temperature is both cool and warm. Meru County contains nine sub-counties. The current investigation took place in the Imenti South sub-county (Appendix 1). The selection of Imenti South Sub-County was based on its dairy agricultural prominence. The sub-county's total population is 206,506 (Kenya National Bureau of Statistics, 2019). The sub-county is located between latitudes 000N and 050N and longitudes 350E and 370E. The area's temperatures range from 12.4°C to 24.5°C, with an average annual rainfall of 800 mm to 2000 mm (Government of Kenya, 2019). Long rains occur between March and June, whereas brief rains fall between October and December. The primary cash crops farmed in the area are tea and coffee. The main food crops farmed are bananas, maize, sorghum, cassava, and millet. Due to the tiny amount of land owned, farmers have turned to extensive dairy farming. The primary animals in the area are cattle, goats, pigs, sheep, poultry, and rabbits. Friesian, Ayrshire, Jersey, and Holstein Friesian are the most common dairy cow breeds in the region, with each household owning 2-3 dairy cows (Murungi, 2020).

### **3.2.2 Research design and sample size**

This study adopted the cross-sectional survey design. This design is the most suitable since it permits the researcher to collect primary data at one point without manipulating the environment of the study. This study considered 37,000 dairy farming households in Imenti South Sub County (MoALF, 2022). This consisted of the smallholder farmers in dairy groups and those who did not belong to any group. The sample size was calculated using the Watson (2001) as shown below;

$$n = \left( \frac{p(1-p)}{\frac{e^2}{z^2} + \frac{P(1-P)}{N}} \right) / R \dots\dots\dots 3.1$$

Where n is the sample size, N is 37,000, P is the estimated variance (0.3), e is the desired precision (0.05), z is the confidence level (95% = 1.96), and R is the response rate 90% (0.9). The sample size was calculated as;

$$n = [0.3(1 - 0.3) \div (0.05^2/1.96^2) + (0.21/37,000)] \div 0.9[0.21 \div 0.000] \div 0.9000$$

= 355 dairy farming households.

### 3.2.3 Sampling technique and data collection

Purposive and proportionate sampling methods were used to choose dairy farmers from the study region. Unlike the other eight sub-counties in Meru County, the Imenti South sub-county was chosen specifically for its dairy farming supremacy. Furthermore, the area's ecological zones promote the use of MDFTs. In the first stage, village units in the six wards were purposefully chosen based on the prevalence of dairy production. Second, the probability proportionate to size technique was used to calculate how many dairy farming households should be interviewed in each village unit.

The number of dairy farming households in each ward was calculated using the proportion to size formula, which involved dividing the number of dairy farming households in each ward by the total number of dairy farming households in all six wards and multiplying by the sample size. The smallholder dairy farmers provided primary data using a well-structured questionnaire. The data obtained included adoption of dairy farming management strategies such as fodder production in many categories, such as sweet potato vines and silage, hay, Rhodes grass, lucerne and silage, dairy farm equipment, improved breeds, and land acreage under fodder.

**Table 3.1 Distribution of sampled households in the study area**

<b>Sampled wards</b>	<b>No of village units</b>	<b>Total HHS</b>	<b>Sampled HHS</b>
Abogeta East	24	8970	86
Abogeta West	16	5980	57
Igoji East	22	4980	48
Igoji west	15	5606	54
Nkuene	16	9222	88
Mitunguu	6	2242	22
<b>Total</b>	<b>99</b>	<b>37000</b>	<b>355</b>

Note: HHS: Households

### **3.3 Econometric framework**

Due to agricultural complexities and in particular the dairy sector, farmers must adopt several strategies and technologies to address present-day dynamic dairy sector challenges. Adoption of simultaneous multivariate technologies is inevitable among dairy farmers (Henchion et al., 2022). The dairy farming technologies adopted by farmers are interrelated, as the adoption of one of the technologies leads to the adoption of others.

#### **3.3.1 Multivariate probit model**

This econometric formulation employed the MVP model to investigate the determinants of dairy farming technology adoption among smallholder dairy farmers in Meru County; the adoption of specific technologies is not independent of other technical choices on the same farm. The MVP compensates for the correlation between error terms. The MVP models the association between a set of covariates and each of the distinct technologies while also allowing for correlation of unseen and unmeasured factors. Correlation between different adoption decisions may be attributed to technical complementarities and substitutability if such an MVP model comprises of eight binary choice equations: sweet potato, Rhodes grass, lucerne, silage, hay, milking machine, feed mixture, and clean soft. We now have eight dependent binary variables. Considering 355 households facing a decision on whether or not to adopt the variable DFTs. Let  $U_0$  represent the benefits to the farmer from whether or not to adopt the available DFTs and use traditional dairy

farming methods and let  $uk$  represent the benefits of adopting the eight technologies. The multivariate probit model is specified as below:

$$Y_{ipk} = X_{ip}\beta_k + \varepsilon_{ip} \dots\dots\dots 3.2$$

where  $Y_{ipk}$  represents the net benefit that the farmer derives from adopting the  $K^{th}$  DFTs.  $X$  refers to the latent explanatory variables, which comprise socio-economic and institutional factors.  $\varepsilon$  refers to the error term. The observed binary outcome equation for each technology adopted is described below:

$$Y_{ipk} = \{1 \text{ if } Y_{ipk} > 0, \text{ and } 0 \text{ otherwise}\} \dots\dots\dots 3.3$$

### 3.3.2 Variable description

The dependent variables considered in this study are the dairy farming technologies, namely, growing sweet potato vines, Rhodes grass, hay, silage, lucerne, usage of milking machines; clean and soft sleeping areas; and feed mixtures, while the independent variables will comprise socio-economic and institutional factors such as age, gender, household size, farm size, access to credit, and extension services, among others, as shown in Table 3.2.

Growing sweet potato vines and Rhodes grass is widely adopted by a sizeable number of dairy farmers, as they help farmers cut the feeding cost, and these feeds boost milk yields. Silage is dry matter that has more energy and is more digestible than hay and has a high fibre content (15-27%). Due to its high digestibility, it's preferred by dairy farmers, as it boosts milk output. Hay has a high protein content, key to heifers as well as dairy cows, as it is essential in maintaining and repairing body tissues. Adoption of hay feed provides dairy cows with vitamins and minerals such as vitamins E, K, and A.

Lucerne not only influences milk yield but also improves soil structure and reduces erosion. This technology is key to dairy farmers in the study area because it can tolerate drought during the dry season. Usage of milking machines extracts milk from cows using a vacuum attached to the end of the teat to suck the milk and convey it to a container. In the study, it was only adopted by a few farmers who practice intensive dairy farming. The clean and soft sleeping area is a technology that ensures cows sleep in a draught-free and ambient area that is free of cow dung and urine. Lastly, the feed mixture ensures that dairy cows are given feed with the right nutrients at the right time to boost milk yields.

**Table 3.2: Variable definitions and measurements used in the MVP model.**

<b>Variable</b>	<b>Measurement</b>
<b>Dependent variable</b>	
Sweet potato vines	Dummy (1 = yes, 0 = no)
Hay	Dummy (1 = yes, 0 = no)
Rhodes grass	Dummy (1 = yes, 0 = no)
Milking machine	Dummy (1 = yes, 0 = no)
Clean soft	Dummy (1 = yes, 0 = no)
Feed mixture	Dummy (1 = yes, 0 = no)
Lucerne	Dummy (1 = yes, 0 = no)
Silage	Dummy (1 = yes, 0 = no)
<b>Independent variable</b>	
Gender	Dummy (1 = yes 0 = no)
Age	Years
HH size	Number
Education level	years of schooling
Farming years	Years of experience
Feeding times	NO of times per day
Chaff cutter	Dummy (1= yes 0 = no)
No. of extension contacts	Number of days
Livestock monitory value	Amount in KSH
Access to credit	Dummy (1= yes, 0 = no)
Land ownership	1= tile deed, 2 = without title deed, 3 rented in, 4= rented out
Household income	Amount in KSH
Milking times	No per day
Labour	1= family, 2= hired, 3= both
Group membership	Dummy (1= yes, 0 = no)

### 3.4 Results and Discussion

#### 3.4.1 Descriptive Statistics

Table 3.3 presents the descriptive data of the respondents in the study region. According to the findings, 54% of the farmers interviewed were men and 45.9% were women. The mean age of the dairy farmers interviewed was 59 years. This means that the majority of the farmers who had adopted dairy farming technology were elderly, which could be attributed to long-term expertise in the dairy sector. The average household size among responders was five individuals. The average number of years spent in school by dairy farmers in the research area was ten years, implying that the majority of farmers who had adopted dairy farming technology had acquired. The results also suggest that the average farm size was 3.5 acres, implying that the dairy farmers had a significant piece of land from which to grow animal feed such as sweet potato vines and Rhodes grass.

**Table 3.3: Descriptive statistics analysis of smallholder dairy farmers**

<b>Variables</b>	<b>Frequency</b>	<b>Percentage</b>
Gender (1= Male 0= Female)		
Male	192	54.08
Female	163	45.92
Household head age (years)	Mean= 59; Sdv =13.78	Min= 30; Max =90
Household size	Mean =5.0; Sdv =1.49	Min= 2; Max=9
Education (years spent in school)	Mean= 10; Sdv=4.67	Min= 0; Max =17
Dairy cattle owned	Mean= 5; Sdv= 1.32	Min= 1; Max=10
Farm size (acres)	Mean =3.5; Sdv =1.72	Min=1; Max =10
Feeding times per day	Mean =1.4 Sdv =0.49	Min =1; Max=2
Milking times per day	Mean =2.0 Sdv 0.346	Min =2; Max =4
Dairy cows owned	Mean =2.0; sdv 0.98	Min =1; Max 13
Access to credit		
Yes	128	36.06
No	227	63.94
Group membership		
Yes	285	78.87
No	75	21.13

The mean number of dairy cattle owned by the smallholder farmers in the study area 2 cows. This points to the fact that many of the households have steady flow of milk throughout the year. Also, the average milking times and feeding times per day for the dairy cows among smallholder farmers in Meru County are two and one, respectively. Farmers aim at maximising their milk yields daily; that is why they milk at least twice a day. Moreover, majority (94.08%) of the respondents who had adopted the dairy farming technologies had access to extension services, while 5.92% did not access the extension services. In addition, only 36.06% of the respondents had access to affordable credit, while 63.94% had no access to affordable credit. This implies that dairy farmers inadequately access credit, which is pivotal in adopting the DFT, such as milking machines, which are capital-intensive.

### 3.4.2 The adoption rate of the eight MDFT

Out of the MDFTs considered in this study, hay and clean soft sleeping areas were the most widely adopted, at 82.82% and 76.90%, respectively. Farmers consider having their dairy cows in a clean area that is draught and cow dung-free. The adoption rate of growing sweet potatoes and Rhodes grass was 32.29% and 28.53%, with farmers adopting sweet potato vines more because they directly boost the dairy cows' yields.

**Table 3.4: Frequencies of modern dairy technology adopted by farmers.**

<b>Dairy technology</b>	<b>Adoption rate (percentage)</b>
<b>Fodder establishment technologies</b>	
Sweet potato vines	32.29
Rhodes grass	28.53
Lucerne	23.38
<b>Fodder preservation technologies</b>	
Hay	82.82
Silage	38.87
<b>Dairy equipment technologies</b>	
Clean soft	76.90
Milking machines	2.54
Feed mixture	9.01

Also, silage was adopted by 38.87% of the smallholder dairy farmers. 23.38% of the farmers grew lucerne on their farms, as it is drought-tolerant. The usage of milking machines was the least adopted (2.54%) by farmers, probably because they are expensive and fit for large-scale dairy farmers. Furthermore, feed mixture was used by only 9.01% of the dairy farmers.

### **3.4.3 Adoption decisions: MVP model results**

MPM was used to determine the factors affecting the adoption of dairy farming technologies among smallholder farmers. The independent variables considered in the modelling include household age, gender of the respondent, farming experience, land ownership, number of milking times per day, labour, household income, extension contact, access to credit, market assessment, and farmers' groups. The model results indicated that household size had a positive and significant effect on adoption of the silage dairy farming technology at the 5% level of significance. The plausible explanation for this is that increasing household size increases the family labour force, which is key in silage cutting and conservation. This study is in line with (Korir et al., 2023), where household family size was found to positively influence the adoption of DFTs among smallholder dairy farmers in Ethiopia.

The findings further reveal that education level positively and significantly influenced the adoption of sweet potato vines, Rhodes grass, hay, lucerne, and silage dairy farming technologies. This indicates that more educated farmers know the need and net importance of adopting different dairy farming technologies to boost their milk yields. This study concurs with (Feyissa et al., 2023). A study carried in Ethiopia revealed that education level had a positive and significant effect on the adoption of improved feed, breed, and improved feeding conditions (MDFTs).

The years of experience in dairy farming has a positive effect on the adoption of well-structured and clean sleeping areas for the dairy cows and the growth of Rhodes grass. This is because farmers who have done dairy farming for several years comprehend the importance of having a clean and dry sleeping area for their cows. A study by Ayenew et al. (2020) found that farming experience had a positive and significant effect on the adoption of various agricultural technologies among smallholder farmers.

**Table 3.5: Factors affecting adoption of dairy farming technologies**

Variable	Sweet vines	potatoes hay	Rhodes grass	Milking machine	Clean soft	feed mixture	Lucerne	silage
Gender	-0.085 (0.151)	0.14 (0.169)	-0.183 (0.153)	-0.351 (0.351)	0.164 (0.157)	0.176 (0.208)	-0.212 (0.158)	0.001 (0.148)
Age	0.004 (0.007)	0.004 (0.008)	0.004 (0.007)	-0.009 (0.015)	-0.009 (0.007)	0.003 (0.009)	0.003 (0.007)	0.003 (0.007)
HH Size	0.004 (0.068)	0.127 (0.078)	-0.051 (0.068)	0.116 (0.163)	0.062 (0.071)	-0.171 (0.101)	-0.107 (0.071)	0.160** (0.067)
Education_level	0.504*** (0.094)	0.236** (0.104)	0.254*** (0.092)	0.280 (0.197)	0.044 (0.094)	0.044 (0.121)	0.212** (0.096)	0.405*** (0.091)
Farming years	-0.004 (0.009)	-0.016 (0.010)	0.008*** (0.009)	0.007 (0.020)	0.016** (0.010)	-0.017 (0.014)	0.002 (0.010)	-0.001 (0.010)
Feeding times	-0.086 (0.156)	-0.201 (0.182)	0.139 (0.157)	-0.037 (0.334)	0.127 (0.163)	-0.137 (0.227)	-0.157 (0.162)	-0.018 (0.157)
Chaff cutter	-0.508* (0.280)	0.285 (0.298)	0.742 (0.369)	9.424 (289.387)	-0.387 (0.324)	4.447 (186.205)	0.075 (0.308)	0.080 (0.293)
No. of extension contacts	0.089	-0.085	0.300***	0.546***	0.183	-0.280	0.341***	0.348***

	(0.104)	(0.122)	(0.106)	(0.210)	(0.114)	(0.161)	(0.108)	(0.107)
Livestock	0.000	0.000	0.000*	-0.000	0.000	-0.000	0.000	0.000*
monetary value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Access to credit	0.009	-0.031	-0.128	-0.533	0.329**	0.099	-0.011	0.099
	(0.160)	(0.183)	(0.164)	(0.398)	(0.173)	(0.229)	(0.168)	(0.157)
Land ownership	0.140	-0.182	0.187	0.503	0.200	-0.245	-0.044	0.214
	(0.175)	(0.191)	(0.174)	(0.386)	(0.188)	(0.251)	(0.183)	(0.168)
Household	0.000	-0.000	0.000*	0.000	-0.000	0.000*	-0.000	0.000
Income	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Milking times	0.766	0.134	-0.800	1.040	-0.071	-3.926	-0.676	-0.681
	(0.529)	(0.394)	(0.664)	(0.690)	(0.238)	(254.057)	(0.640)	(0.556)
Labor	0.118	0.085	-0.036	0.165	-0.210	0.096	0.079	0.061
	(0.110)	(0.128)	(0.107)	(0.223)	(0.111)	(0.157)	(0.113)	(0.106)
Group	0.001**	0.000	0.000	-0.000	0.000	-0.000	0.000	-0.000
membership	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Observation	355	355	355	355	355	355	355	355

Standard errors in parentheses

\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

Furthermore, an increase in household income had a beneficial and significant impact on the spread of Rhodes grass and feed mixture adoption among dairy farmers. This means that households with income can purchase several types of food for their dairy cows and mix them to increase their family milk output. This finding is consistent with (Nyandika's., 2022) conclusion that there is a greater possibility of agricultural production system modification as farm revenue increases. (Okello et al., 2019) also found a statistically significant beneficial relationship between farm revenue and the adoption of zero grazing as a dairy farming method.

Several contacts with an extension agent positively and significantly influenced the adoption of planting Rhodes grass, usage of milking machines, and Lucerne and silage DFTs at 1%. This implies that contact frequency between farmers and extension officers helps farmers access information on DFTs from the government and NGOs. It enables farmers to make relative decisions among the various technologies and select the one that suits their farm. This study collaborates with (Zemarku et al., 2022), where extension contacts were found to positively and significantly associated with the adoption of improved dairy farming technologies such as crossbreed cows in the Wolaita zone, Southern Ethiopia.

An increase in farmers' access to credit positively and significantly increased the probability of farmers adopting clean and soft dairy farming technology. The probable reason for this is that farmers who access affordable credit are better positioned to build standard dairy cow housing units that are well ventilated and free from draught. Similarly, a rise in the amount of financial availability positively improved the probability of farmers' adoption of agricultural technologies among smallholder dairy producers. (Wairimu et al.,2022). (Bayan 2020) found similar results on the effect of loans on the adoption of dairy farming technologies at the farm level in Assam, India. Also, livestock monetary value had a positive and significant effect on sweet potato vines, hay, clean soft Lucerne, and silage. This implies that farmers who have hybrid dairy cows have invested heavily in feed.

A farmer's involvement in a group had a favourable and large impact on the adoption of sweet potato vine planting and dairy farming technology. The findings show that being a member of a farmers' group benefits farmers because they may acquire extension contacts

through the groups, and it also serves as a platform for them to learn the necessity of providing dairy animals high-quality feed to increase milk output. Furthermore, farmers in groups can quickly access instruction on approved dairy farming technologies. These findings are consistent with (Donker et al. 2018) and (Nadhika et al. 2018), who found that group membership has a favourable influence on smallholder farmers' adoption of agricultural innovations. Membership in a group contributes to the development of farmers' social capital by influencing access to public resources, especially in rural areas. Group involvement had a good and significant impact on the adoption of improved feeding strategies. (Di Marcantonio et al., 2022) used the endogenous switching regression model to analyse DFTs in four European countries: France, Spain, Germany, and Poland.

### **3.5 Conclusions and recommendations**

The dairy farming technologies considered in this study included sweet potato vines, hay, Rhodes grass, the use of milking machines, clean soft sleeping areas, feed mixtures, lucerne, and silage. Adoption of these dairy farming technologies is positively influenced by dairy farming experience, access to extension, farmers' membership in groups, household income, household size, education level, and access to credit. Dairy farming years negatively influenced hay adoption, meaning that they have considered other feeds that have higher nutrients, like sweet potato vines.

The county government and other relevant stakeholders in the dairy industry should improve the frequency of extension contact with smallholder dairy farmers in order to promote various dairy farming methods and allow farmers to make informed decisions. This would increase the use of MDFT among smallholder farmers. It is necessary to make credit facilities available and cheap to farmers by lowering the interest rate on loans obtained by them. This will allow farmers to purchase new dairy equipment. Promotion of innovative technology, such as sexed breeds, is necessary to increase overall milk yield at the household level. The government should also create policies that favour the creation of new farmer cooperatives to ensure each dairy farmer has cooperative attachment, as this will act as a leverage ground for information passage on new MDFTs.

## CHAPTER FOUR

### **Role of Modern Dairy Farming Technologies in Enhancing Milk Productivity: A case study of Meru County, Kenya**

#### **Abstract**

In the evolving dairy farming landscape, entrepreneurs strive to optimise milk yield by adopting modern dairy farming technologies (MDFTs). These technologies encompass the implementation of improved feeding strategies and good animal health management, utilisation of improved breeding practices, and maintenance of optimal cow comfort. The adoption of these MDFTs leads to increased milk production among the smallholders, which significantly contributes to income generation through the sales of milk to local markets and dairy processors, opens employment opportunities, and empowers women economically. Despite the proven efficacy of these advancements, their adoption remains disproportionately low, contributing to the persistent inefficiencies in the sector. This study sought to evaluate the impact of MDFT adoption on farm-level milk production among smallholder dairy farmers in Meru County, Kenya. 355 dairy farming homes in the research area provided data through the use of proportional and purposive sampling approaches. The impact of implementing MDFTs on milk productivity was assessed using the Cobb-Douglas stochastic production model. The findings revealed that several key factors, like support services, input costs, dairy equipment, cow health, fodder establishment and preservation techniques, and genetic enhancement of dairy herds, significantly influenced the amount of milk that was produced by an individual cow per day. These results underscore the urgent need for policy reforms aimed at strengthening the integration of training programs on MDFTs. Specifically, there is a pressing necessity to facilitate knowledge dissemination and expedite the widespread adoption of transformative dairy farming innovations. By fostering a conducive environment for technological advancement.

**Keywords:** Modern dairy farming technologies, adoption, milk productivity, Cobb-Douglas production function

#### **4.1 Introduction**

Dairy production constitutes a vital sub-sector of livestock farming that provides affordable and nutritious food to millions of people worldwide (Bidhan et al., 2024). Besides its role in food security, the sector significantly contributes to employment opportunities, particularly for smallholder farmers and women in rural areas (Bidhan et al., 2024). Globally, India is the largest producer of milk, accounting for 25% of global milk production according to the year 2023 statistics (Gayathri & Mohanty, 2023). In SSA, dairy farming has experienced substantial growth over the past decades and is driven by increasing demand for dairy products (Balehegn et al., 2022). The sector in this region has faced a couple of setbacks, like feed and water shortages and the exorbitant cost of concentrate and supplements for dairy animals.

Kenya stands as one of Africa's leading milk producers, with the dairy industry exhibiting an upward trajectory with a 3-4% annual growth. Implementation of dairy farming innovations is the present need of farmers, especially in this era of scarce resources and a ballooning population creating demand for more food (Balasundram et al., 2023). Kenya is one of the largest milk producers in Eastern Africa, with an estimated 4.5 million dairy cows and producing over 750 million litres of milk (Mburuet al., 2024). Africa has the highest annual per capita milk production, ranging from 80 to 100 million litres. The sector contributes 3.5% of national GDP and about 13% of the yearly agricultural GDP (Mandalet al., 2024). According to the KNBS economic survey of 2024, there was a 17.4% increase in quantities of milk processed and cream in 2023, with quantities of butter and ghee doubling from the later percentage. Additionally, the dairy sector has been christened as an enabler of the Bottom-up Economic Transformation Agenda (BETA) by the Livestock Value Chain Support program.

Kenyan milk is primarily produced at the micro level (by smallholders), which contributes to the global economy at the macro level. In 2023 alone, the country produced approximately 5.2 billion litres of milk (Perin & Enahoro, 2023). Despite the notable improvement in milk yield, persistent challenges continue to impede optimal productivity (Nyokabi et al., 2023). The challenges include poor cattle breeds due to crossbreeds of exotic and zebu, seasonal fluctuations in milk production due to rainfall shortages, and poor animal husbandry (Kotykova et al., 2024). The sub-sector contributes approximately

14% of the national GDP. The Kenyan government has prioritised dairy farming as a key driver of economic growth and food security (Momanyi & Pepela, 2024). In Meru County, dairy farming plays a significant part in the local economy, with about 180,000 heads of dairy cattle reared in the area, according to the Kenya Dairy Board. Meru benefits from the good climatic conditions for subsistence and commercial dairy farming, characterised by adequate rainfall and cool temperatures. Farmers are fairly linked to milk cooperatives, which play a major role in collecting, processing, and marketing milk on behalf of the farmers (Fernando et al., 2021). Meru Dairy Cooperative Society has been at the forefront in supporting farmers with crucial services like AI, transportation of milk, extension services, and veterinary services. All these efforts were aimed at improving milk yield per cow per day (Wambu and Gichuki, 2024).

A study conducted in Ethiopia on negative energy balance and its implications on dairy productivity and reproduction indicates that poor feeding of dairy cows leads to low yield per head (Mekuriaw, 2023). The limited utilisation of veterinary services like vaccination against viral diseases and treatment of sick dairy cows against infectious diseases lowers the quality and the quantity of the milk (Oktanella et al., 2023). Among small-scale farmers, mastitis remains a persistent challenge due to insufficient financial resources. The disease has prevailed for decades due to poor housing, especially a lack of clean and soft sleeping areas, poor milking techniques, and poor milking equipment, leading to a decline in milk production. Moreover, a study by (Hatew et al. 2023) in Ethiopia highlights that cow genetics determines the milk production potential of the individual cow besides incorporating other practices like high nutritional value feeds, both concentrates and improved fodder. Cow comfort due to good housing, disease control, and genetics is crucial in boosting milk productivity (Hatew et al., 2023).

Dairy farmers who select cows with superior genetic traits significantly increase milk production, milk quality, and general performance of the cow (Zamorano-Algandar et al., 2023). Fodder establishment management and preservation are key in milk production (Raj et al., 2023). These fodder technologies enable the farmer to feed their animals with high-quality feeds during dry seasons to keep milk production steady all seasons. The high cost of buying fodder preservation materials, deficits in knowledge about silage-making and hay baling, and a shortage of storage structures in most farms have left many

farmers with challenges in managing their cows to realise high milk production. The dismal productivity in dairy stems from the low adoption of modern dairy farming technologies (MDFTs). Additionally, challenges relating to diseases, poverty, climate, and limitations like low capital, small land size, labour, and managerial skills contribute to low milk production.

Despite the prevalence of MDFT among smallholders in Meru County, milk productivity is still low. Additionally, there is a knowledge gap on how farmers can leverage the cost of adopting MDFTs and income from milk output. The main goal of this study was to examine the role of MDFTs in enhancing milk yield per cow. The study acknowledged the combination of various factors of production like feed and water, treatment and vaccination, high-quality fodder production, and preservation, which are key in milk production yield per cow.

## **4.2 Methodology**

### **4.2.1 Study area**

The research was conducted in the Imenti Sub-County of Meru County, which lies within the slopes of Mount Kenya (Appendix 1). The county has nine sub-counties where dairying is practiced, although the study was conducted in Imenti South Sub-County because of the prevalence of dairy cow farming. The additional details of the study area are provided in Section 3.2.1.

### **4.2.2 Sampling technique and data collection**

South Imenti, an administrative Sub-County of Meru County, was selected as the focal study area due to its prominence in dairy farming. To ensure a robust and representative analysis, purposive and proportionate sampling techniques were employed. For decades, South Imenti has been recognised as the main feeder of milk to most of the milk plants in the region, the reason being the ecological zone favours dairying since the implementation of MDFTs, which is key to milk production, is possible. In the initial stage, the six wards were chosen purposefully based on the prevalence of dairy farming production. Second, the probability proportional to size (PPS) technique was used to determine how many dairy farming homes (DFHH) should be questioned in each ward. To determine the

number of DFHHs from each ward. The proportion to size formula was used, with the number of DFHHs in each ward divided by the total number of such DFHHs in all six wards and then multiplied by the sample size. Face-to-face interviews with dairy farmers were conducted as primary data collection, using trained enumerators utilising a well-structured questionnaire. The data on the amount of milk collected on a daily basis was also collected from farmers. The primary data collected included the adoption of MDFTs such as improved fodder technologies, fodder preservation technologies, dairy farm equipment technologies, improved breed technologies, cow comfort technologies, and dairy support services like vaccination, treatment AI, extension, and the total amount of milk recorded (kgs) per day from every cow.

### **4.3 Conceptual framework**

The conceptual framework in Figure 4.1 below illustrates the interaction between the independent variable X (MDFTs, represented by rectangular-like shapes) and the dependent variable Y (milk productivity). The framework is tethered to the economic theory of production, which offers a background on output. Agricultural productivity is determined by the ratio of total farm input used in production to farm output value. The theory gives insight into what transfers when a farm combines input, typically capital and labour, to produce output. It also shows if the farm is economically efficient by working on its six principles: factor shares, factor substitutability, the marginal product of labour and capital, return to scale total factor productivity, and economic growth (Thomas et al., 2020). Regarding this, the dairy production framework focuses on the element that affects milk productivity. Its logical flow revolves around milk production elements, which are separated into subcategories based on their impact on productivity. The key component is milk productivity, which is influenced by major contributing factors like cow genetics, cow comfort, nutrition, animal health, and good calf raising. A set of sub-factors influences key factors, where genetic factors influence cow genetics, and cow comfort is influenced by clean, soft bedding and good shed architecture. Nutrition is based on clean water, high-yielding fodder crops, preserved silage supplements, and concentrates. Health care includes veterinary care and vaccinations.



$$\ln Y = A + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 \dots \dots \dots \beta_n \ln X_n \dots \dots \dots 4.2$$

In addition to the measured inputs utilized in milk production, the model considered other factors that affected the amount of milk yield as described below:

$$\ln Y = \ln \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \dots \beta_n \ln X_n + \alpha_1 Z_1 + \dots \alpha_1 Z_1 + \varepsilon \dots \dots 4.3$$

Y represents total milk yield,  $\beta_0$  is the vertical intercept, and  $X_1$  to  $X_n$  represent inputs used.  $\beta_0$  to  $\beta_n$  are input coefficients.  $\alpha_1$  is the marginal impact or coefficient and shows the elasticity of production, and  $Z_1$  to  $Z_n$  are the selected factors.  $\ln$  is a natural logarithm, and  $\varepsilon$  is the error term.

## 4.5 Results and Discussion

### 4.5.1 Descriptive results

In Table 4.1, milk yield per day is the main dependent variable used in the study. To determine what influences the amount produced by an individual cow per day, several factors (independent variables) were considered.

**Table 4.1: Variables definition and description**

Variable	Measurement
<b>Dependent variable.</b>	
Milk yield	Yield in litres
<b>Independent variable</b>	
Age	Years
Gender	1= male, 0 = female
Dairy farming experience	No. of Years
No of extension visits	Number
Water cost	Kenyan shillings
Feed cost	Kenyan shillings
Dairy equipment tech	Dummy for yes =1, 0 = No
Cow health tech	Dummy for Yes =1, 0 = No
Fodder preservation tech	Dummy for Yes =1, 0 = No
Improved fodder tech	Dummy for Yes =1, 0 = No
Cow genetics tech	Dummy for Yes =1, 0 = No
Cow comfort tech	Dummy for Yes =1, 0 = No

#### **4.5.2 Variable description**

Milk output was considered the dependent variable, while the independent variable included the MDFTs adopted by the farmers and social, economic, and intuitional factors as highlighted in Table 4.2. The descriptive statistics of this study found that most of the sampled households were headed by men, with the results indicating that 54.08% were males versus 45.92% were females (Table 4.2). The average level of education is 2, ranging from level 1 to level 5; this signifies that many of the dairy farmers in the study area had achieved basic education, meaning that farmers can easily understand the benefits of using new modern technologies in dairy farming, manage resources effectively, and use the knowledge acquired from extension officers to increase productivity.

The household mean size was 5.0 members; this suggests that this could be a source of cheap, cost-effective labour that was readily accessible by most of the dairy farming households. Family labour requires little or no pay to carry out essential dairy practices, like cleaning, feeding, milking, and tending to animals. From the analysis, 2 cows are the mean number owned by farmers in the study area. This indicates that many households have a sustainable supply of milk all year long. Also, the mean frequencies of milking and feeding lactating dairy cows per day stood at two. DF aims to optimise greater lactation efficiency and reduce the chances of mastitis by milking their cows more frequently. Accessibility to credit empowers farmers to acquire dairy farming equipment and invest in modern technologies that help increase milk yield. The descriptive statistics show that 36.06% of dairy farmers obtained credit.

The descriptive statistics indicate that few farmers have adopted dairy equipment technologies like milking machines at 3.49% and feed mixtures at 9.01%, indicating that most farmers are reluctant to invest in such machinery due to high initial capital as well as lack of knowledge about the machines. The adoption of improved fodder crop establishment and preservation was poorly adopted by dairy farmers in the study area; according to statistics, sweet potato vines were adopted by 38.31%, Rhodes grass by 30.70%, lucerne by 23.94%, and silage by 40.85%.

**Table 4.2: Descriptive statistics for variables used in the analysis**

<b>Variables</b>	<b>Mean</b>	<b>Std. Dev</b>	<b>Min</b>	<b>max</b>	<b>Percentage</b>
Male	-	192	-	-	54.08
Female	-	163	-	-	45.92
Household size	5.0	1.49	2	9	
Education level	2.5	0.82	1	5	
Productivity	9	5.14	5	34	
Sweet potato vines	0.38	0.48	0	1	
Improved nappier	0.65	0.47	0	1	
Lucerne	0.23	0.42	0	1	
Rhode grass	0.30	0.46	0	1	
Silage	0.40	0.49	0	1	
Hay	0.82	0.37	0	1	
Clean soft	0.76	0.42	0	1	
Feed mixture	0.09	0.28	0	1	
Milking machine	0.03	0.19	0	1	
Feeding times per day	1.4	0.49	1	2	
Milking times per day	2.0	0.346	2	4	
No. ext visit	1.6	0.346	1	5	
Access to credit					
Yes		128			36.06
No		227			63.94

Sdv = Standard Deviation

Table 4.3 shows the summary of the average daily amount of milk collected in six wards of the study area. The farmers from the three regions, Nkuene, Igoji West, and Abogeta West, recorded higher amounts of milk than their counterparts in the lower area of the study area. This is because the upper zone has a favourable mild and cool climate with enough rainfall to support high-quality fodder crops, hence higher amounts of milk. Lower zones, Igoji East, Abogeta East, and Mitunguu, experience lower rainfall amounts, with some areas having sandy soils, which are easily drained and therefore unable to

support the growth of fodder crops essential in dairy production. The percentage change in the amount recorded in this region on average ranges from 4.5% to 1.8%, implying that the amount of milk varies with the year's season due to weather changes at different times of the year as well as the lactation stage of the cow.

**Table 4.3: The average amount of milk supplied to Mt. Kenya dairy per day**

<b>Ward</b>	<b>Amount of Milk</b>	<b>of Active Members</b>	<b>No of Societies</b>	<b>% Change In the month</b>
Nkuene	59,767	7501	7	4.48
Abogeta East	14,496	2000	6	2.37
Abogeta West	41,708	6012	10	3.20
Igoji East	12,336	2542	5	2.37
Igoji West	33,894	5234	7	2.86
Mitunguu	12,169	1945	7	1.78
<b>TOTAL</b>	<b>17,4370</b>	<b>25327</b>	<b>42</b>	<b>17.06</b>

Source: Meru Dairy Co-operative Union Ltd 2024

#### **4.5.3 Econometrics results**

Estimates of Frontier Production Function: Based on the detailed results of the half-normal distribution stochastic Cobb-Douglas production function using STATA software, the extension visit frequency, dairy farming years, water cost, feed cost, dairy equipment technologies, cow health technologies, fodder preservation technologies, improved fodder technologies, and cow genetics had a positive and significant influence on milk productivity. Further, the results show that the level of lambda is above 1.0, implying that the level of inefficiency is high. Suggesting that many dairy farmers in the study area were allocating resources ineffectively, making poor decisions in allocating resources, drought, and a lack of information. Assessing reproductive performance, milk yield, and influential factors in dairy cows. The effect of the independent variable on milk yield is discussed below.

**Table 4.4: Results from the half-normal distribution model.**

Variables	Coef	Std Err	Z	P-value
Age	0.0206	0.0165	1.25	0.021
Gender	0.3150	0.3873	0.81	0.315
Access to credit	0.5350	0.3900	1.37	-0.535
No extension visits	0.4132	0.2251	1.87	0.413*
Dairy farming years	0.0540	0.0237	2.27	0.054***
Water cost	0.0102	0.0019	5.19	0.010***
Feed cost	0.0006	0.0019	8.47	0.001***
Dairy equipment tech	0.9632	0.5535	1.74	0.964*
Cow health tech	0.0188	0.0005	3.47	0.002***
Fodder preservation tech	1.2234	0.3444	3.55	1.223***
Improved fodder tech	1.4921	0.2414	6.18	1.492***
Cow genetics tech	0.9810	0.5062	1.94	0.981*
Cow comfort	0.50006	0.4503	1.11	0.501
<hr/>				
<i>Waldchi2(13) =</i>				
<i>379.73</i>				
<i>Log likelihood =</i>				
<i>951.70737</i>				
<i>Prob &gt; chi2 =</i>				
<i>0.0000</i>				
<i>Lambda 2.200102</i>				
<i>Observations</i>			<i>355</i>	<i>355</i>

*Maximum Likelihood estimates of the half-normal distribution frontier function.*

*\*, \*\*, and \*\*\* = significant at 10%, 5%, and 1% levels of significance, respectively.*

The results revealed that extension frequency positively and significantly influenced milk yield at a 10% significance level. This implies increased extension contacts between government and NGO extension officers and smallholders, enhanced farmer access to information on the adoption of MDFTs by smallholder dairy farmers, and increasing milk

productivity (Ogola et al., 2023). The technologies adopted due to increased extension frequency include fodder establishment, fodder preservation, use of high-quality, clean, soft, aerated, and spacious sleeping cubicles, feed mixture, and milking machines (Kirimi et al., 2024). These results correlated with the study done in Njoro, Kenya, which established that extension contact positively and significantly influenced milk output as a result of adopting modern technologies (Ogola et al., 2023).

Based on the results, farming experience was found to be significant at 5% with a negative effect on milk yield. An increase of one year of experience reduced the chances of increasing the level of milk yield by 0.0540%. This implies that experience in terms of years can lead to old people experiencing low adoption of new technologies, which can impede an increase in milk productivity. A study conducted in Ethiopia to evaluate determinants of modern agricultural technology advancements for teff production established that age, educational level, and extension contact positively and significantly affected technology advancements (Fikire and Emeru, 2022).

The results indicate that water cost was positive and significant at 1%, implying that dairy farming requires adequate water due to factors like dry matter intake by the animal, amount of milk produced by the cow, feed moisture content, and hot weather conditions. In lactating cows, water is a critical component of their diet; for dairy cows to produce to their optimal potential, enough water should be provided (Akbar et al., 2020). It also collaborates with another study that established that a dairy cow consumes 82 L per cow per day (Monteiro et al., 2024). Additionally, plenty of water is needed for cleaning stalls as well as for irrigating fodder crops during dry seasons to ensure a sufficient supply of feed throughout the year. For efficient production of milk, a clean and adequate amount of water should be given to help digest food and absorb nutrients effectively to increase milk production.

Additionally, feed cost and water cost positively and significantly influenced milk output at a 1% significance level. This implies that farmers in the study area use commercially acquired concentrates to boost milk yield. Feed cost directly determines the milk yield output per herd, as it influences both the quality and quantity of the feeds (Hassen et al., 2022). Feed quality is determined by the feedstuffs used to prepare them, influencing

higher costs and hence inefficiency in most farms in the study area (Garamu, 2019). Adoption of fodder production and conservation will reduce the cost of using commercial feeds, hence enabling farmers to produce within the profitable range of production (Kogoet al., 2024).

According to the results, dairy cow health was found to be significant at the 1% level. Cow treatments through vaccination, deworming, and general treatment have led to an increased amount of milk yield per day. Treatment against mastitis and other diseases like foot and mouth disease is critical in the dairy enterprise since it helps to reduce udder infections that lead to a decline in milk production. These findings agree with the study of (Rainaet al. 2023), indicated that an outbreak of foot and mouth disease caused a reduction of about 7 kgs of milk per cow per day for about 8 weeks. This clearly indicates that the prevention of diseases like mastitis through vaccination should be done a few weeks before calving to prevent such diseases.

Furthermore, the establishment of high-quality fodder crops and preservation has a positive and significant effect on milk yield at 1% and 5% levels, respectively. Fodder preservation is a key element in dairy farming; this is essential since it ensures a constant supply of feed throughout the year (Brar et al., 2024). Silage and hay are the main methods used to preserve harvested forage in the study area, although additives are included to increase palatability. This study aligns with the study that was conducted in India by (Kishore et al. 2023), which indicates the establishment and preservation of fodder as silage, hay, and bailage ensured a constant supply of feed throughout the year. Farmers who have established multiple fodder crops such as sweet potato vines (16-20% CP), lucerne (17-25% CP), supper Napier hybrid grass (12-16% CP), and Rhodes grass (10-16% CP) in their farms registered higher amounts of milk yield (Chikwanha et al., 2024). This study concurs with the study conducted by Méndez et al. (2024) on assessing intake, digestion, and milk yield for Holstein cows, and results revealed that a higher amount of milk recorded is dependent on the nutritive value of the feeds fed to the dairy cow. Additionally, a study by Abdi on the effect of high nutritive feeds on milk productivity (Hassenet al., 2022) indicates that fodder with a high level of protein improves milk output per cow per day.

#### **4.6 Conclusion and recommendations**

The study evaluated a variety of dairy technologies, including cow comfort technologies, cow genetics, improved fodder, fodder preservation technologies, and dairy equipment. The results indicate that these technologies significantly influenced milk production. Furthermore, the number of extension visits, dairy farming years, water costs, and feed costs were found to influence milk production. Given these results, the county government and other stakeholders in the dairy sector should scale up on increasing extension contact frequency among the small-scale dairy farmers to create awareness on fodder preservation, improved fodder, dairy equipment, and good cow genetics. for this will boost the level of milk produced by an individual cow per day.

## CHAPTER FIVE

**To evaluate the effect of support services on intensity of adoption of MDFTs among smallholder farmers in Imenti South Sub-County, Meru County.**

### **Abstract**

The dairy support services have raised significant awareness about the adoption of MDFTs. These services are a key driver behind the positive acceptance of new technologies in agricultural production. In the evolving world, farmers must embrace and adopt modern farming techniques because they are more efficient in monitoring animal health, breeding, milk production, milking, and feeding in dairy farming. Various services, including access to resources, can motivate farmers to use multiple MDFTs, leading to increased milk production in many households. This study aimed to evaluate the impact of support services on the level of MDFT adoption among smallholder farmers in Meru County. The study adopted purposive and proportionate sampling techniques for data collection, gathering information from 355 dairy farming households within the area. AI services, extension services, timely veterinary care, access to credit, and training on MDFTS were included. A multiple linear regression model was used to determine how support services affect MDFT adoption. The results showed that support services such as credit, veterinary services, market information, extension services, and MDFT training had a significant impact on adoption. This study emphasises the significance of improving extension activities, responding quickly to veterinary and AI situations, and boosting access to credit to enhance the use of MDFTs in the region.

**Keywords:** Modern dairy farming technologies, adoption, support services, ordered Probit regression.

## **5.1 Introduction**

Milk demand is increasing due to the growing population in various communities worldwide (Espinoza-Sandoval et al., 2024). As a part of agriculture, there is uncertainty whether the sector will meet the demand for dairy products. Therefore, dairy farming must play a vital role in fulfilling this demand (Kazi, 2025). According to 2024 statistics, the dairy subsector contributes to 40% of the global GDP (Astuti et al., 2024). More than 150 million households globally participate in milk production, a number that grows each year (Abbas et al., 2024). There are significant economic benefits of this sub-sector in developing countries, starting with the government, communities, farmers, and residents. These benefits include food provision, revenue generation, job creation, and industrial development.

To maximise milk production per household and meet the high demand caused by the soaring population, the adoption of MDFTs is essential because these technologies are critical for improving herd health, efficiency, and overall yield. In Africa, this subsector has played an exemplary role in supporting the economies of many countries, especially in East Africa. The dairy sector has been instrumental for decades in enhancing food security (Zolin et al., 2021), creating jobs for women and youth (Gandhi, 2024), sustaining industries by providing raw materials, and improving the living standards of many rural citizens. Despite technological advancements aimed at increasing milk production, the adoption of new technologies faces setbacks due to a lack of essential support services like extension services, limited access to credit, poor market accessibility, and inadequate road infrastructure for transporting inputs, milk, and other goods to processing plants.

Additionally, there is a need to invest in support services like extension, credit, AI, veterinary, and society groups (Jafri et al., 2024). These support services help to create awareness of tech-driven productivity through extension services and provide capital to acquire modern equipment like milking machines and construction of standard structures. These further help farmers to improve the genetics of their dairy cattle through the use of high-quality semen and get high-quality veterinary services on time, and farmers can market and get payment for their milk on time. In Kenya, the subsector for decades has provided raw milk, processed milk products, meat, skin, and manure. The sector

contributes 14% to the annual agricultural GDP (Kiplagat et al., 2025). In Meru County, most households rely on livestock for income, particularly dairy farming (Wambu & Gichuki, 2024). The area is well known for its dominance in dairying, as it produces and supplies milk to the Mt. Kenya Cooperative Society, which in turn produces milk products under the brand name Mt. Kenya Dairy Milk.

The main milestone in dairy farming in this region has been catalysed by the adoption of MDFTs. The acceptance of these technologies has been fuelled by support services that have been provided by different organisations at different levels. The uptake of extension services has created an unwavering bridge between traditional and modern dairy farming methods, providing an avenue for learning new advanced ways of dairy farming (Mburu et al., 2024). This has sensitised farmers to make the best decisions when selecting combinations of technologies that can yield optimum results. In addition to this, AI services have created ground for upgrading and introducing high-quality breeds of dairy cattle to most farms. The uptake of this technology has shifted farmers from natural methods of servicing their dairy cows to a more promising method that gives birth to a stock that is a high producer of milk.

Another driver of MDFT's acceptance is the accessibility to credit services. Access to this service provides purchasing power for dairy equipment, quality inputs, investment in modern infrastructure, and expansion of herd size and creates a bridge between the production cycle and income (Fiorillo & Amico, 2024). Several scholars have explored the use of support services in agricultural production. A study by (Becerra-Encinales et al. 2024) on the effect of extension services on the adoption of modern technologies in agriculture found that the extension services enhanced the uptake of modern technologies within the paradigm of sustainable agricultural development. According to (Arulmanikandan & Vaishnavi 2024), the extension service provider-to-farmer ratio is quite low, posing a great challenge in the agricultural sector, especially in the present day, where the farmer's well-being should be incorporated in extension structures. Furthermore, dairy farming and budgetary provision for public extension services have dwindled over the years, while private extension has not expanded to fill the resulting gap created by the decline in public extension; as a result, the acceptance of modernised technologies takes time before they are accepted, resulting in low production. The study

shows that agriculture extension services contributed to the adoption of modern technologies in agricultural production (Alam et al., 2024). This clearly indicates that farmers who had access to technical assistance and extension services were able to understand and manage their farms and, therefore, were able to produce efficiently.

Additionally, access to credit is essential in financing productive technologies needed in dairy farming. Dairy technologies such as equipment like milking machines, feed mixtures, the establishment and preservation of fodder, and standard structures are needed in dairying for maximum milk production, though much capital is required. However, many farmers have limited access to credit, a thing that has jeopardised financing of essential equipment and materials needed in dairy production (Kyire et al., 2025). A study by (Alam et al., 2024) shows that access to credit positively affected the adoption of modern farming technologies among smallholder farmers.

The unreliable infrastructure for the distribution of semen was found to affect AI as a dairy farming technology adopted by smallholder farmers (Alam et al., 2024). AI service providers have lowered the quality of AI services, deterring many farmers from implementing the technology. Animal illnesses, parasite infestations, and public health issues are key concerns for livestock production and the safe use of animal products. The provision of veterinary services among smallholder farmers, which is critical in enhancing milk output, ensures animal health among dairy farmers. The government and non-governmental groups should help farmers by providing prompt veterinary services (Migose et al., 2018). The primary goal of this study is to identify the important characteristics that influence the frequency of adoption of contemporary dairy farming technology in the study area.

## **5.2 Methodology**

### **5.2.1 Study area**

The data collection took place between March and May 2023 in the Imenti sub-county of Meru County in Kenya (Appendix 1). Details of the study area are described in Section 3.2.1.

### 5.2.2 Sampling procedure and data collection

The study was undertaken in South Imenti Sub-County of Meru County, selected because of its strong engagement in dairy production. A combination of purposive and proportionate sampling was adopted to capture representative data. South Imenti has historically been one of the leading suppliers of milk to processing plants in the county, largely due to its favourable ecological conditions that support intensive dairying and the successful adoption of Milk Development and Farmers' Training (MDFTs) initiatives. At the first stage, all six wards within the Sub-County were purposively included, given their significant contribution to milk production. Thereafter, the Probability Proportional to Size (PPS) approach was applied to allocate the number of dairy farming households (DFHHs) to be surveyed within each ward. The allocation was determined by computing the ratio of DFHHs in each ward to the total number across the six wards, then multiplying the result by the desired sample size. Primary data were obtained through direct interviews with household heads engaged in dairy farming. Trained enumerators administered a structured questionnaire to ensure accuracy and consistency in the information collected.

### 5.3 Analytical framework

The study adopted Ordered Probit model was utilised in the analysis of our study to analyse the amount of adoption of the MDFTs among small-scale dairy farmers. This model was picked because the attribute of the number of MDFTs adopted by a single farmer is graded from 4 to 8. This model is suitable for analysing relationships with an ordinal dependent variable representing preference levels, taking values from  $\langle 4,5,6,7,8 \rangle$ . The probit model accommodates multiple ordered outcomes, making it appropriate for modelling.

The ordered probit uses the following form:

$$Y^* = \beta X_1 + \varepsilon$$

$y^*$  represents the exact but unobserved dependent variable categorised ordinally and coded as 4, 5, 6, 7 and 8.

$X_i$  is the vector of independent variables,  $\beta$  is the vector of regression coefficients, and  $\varepsilon$  is the error term, which is considered to be normally distributed (zero mean and unit



**Table 5.1: Operationalization of the support services among the respondents'**

Variable	Expected results	Description
Gender	+	The male was denoted by code 1 and the female by code 0
Marital status	+	This variable classified respondents as 1= married 2=window 3=single 4= single 5= widower
Timely access to AI	+	This variable indicates if farmers received AI service promptly or delayed after requesting from AI providers
Access to credit	+	The variable indicates whether the respondent was able to access the credit services, denoted by 1 if the respondent received credit or 0 if the respondent never received any credit services either from SACCOs or any other money-leading group, e.g., merry-go-round.
receive market info	+	This variable was a dummy variable where those respondents who received the service were denoted by 1 and those who never received the service were denoted by 0
DFTI farmers group	+	This was indicated by whether the respondent was a recruit in a farmer group that created awareness of new technology in dairy farming. This variable was suggested by 1 if the farmer was a member of any group or 0 if the farmer was not a member of the group.
NO treatment	+	This variable was indicated by the number of farmers.
No extension visits	+	This variable is indicated by the frequency at which the respondent was receiving the extension officers in their farms, ranging from 1 to 4 times
Accessibility road	+	This variable indicated that respondents had different levels of accessibility when transporting inputs in their farms, denoted by 1 if highly accessible. 2 if less accessible and 3 if not accessible.

## 5.5 Results and discussion

The results in Table 5.2 summarise the outcome of the data collected relating to support services which had a strong influence on the adoption of MDFTs in the study area. In regard to this, the results reveal that the mean adoption rate of technologies stands at 5.22%, a percentage that is below the average number of selected technologies. The average mean extension visit frequency is 1.52, suggesting that most farmers in the area received extension services once, and this impeded the adoption of MDFTs due to farmers' low motivation, limited exposure, and one-time visits that cannot alter deeply held traditional practices. Most farmers sold their milk through a cooperative society, with the study showing 80.56% of the farmers had accessed cooperative services. This implies that dairy farmers were assured of a milk market and timely payments, although the prices were not to the farmers' satisfaction. Additionally, farmers benefited from organised training and extension services, boosting the adoption of MDFTs.

**Table 5.2: Descriptive statistics for independent and dependent variables**

<b>Variable.</b>	<b>Measurement</b>	<b>n</b>	<b>% Mean</b>
NO. Tech	No of technologies adopted Range from 3 to 13.	355	5.22
No extension visits	No of times a famer receives an extension officer annually	355	1.52
Timely access to AI	1 if the received service on time =0 if the service is delayed.	355	Yes =76.06 No= 23.94
Access to credit	1 if accessed credit 0 if not.	355	Yes=1 No=
accessibility road	Low 1 Medium 2 High 3	355	1.37
sold coop	1 if sold through a coop 0 if otherwise	355	1= 80.56 19.44
Km nearest to motorable road	Km	355	1.74
Receive market info	Yes =1 or no=0	355	1= 63.94 0= 36.06

The adoption frequencies of MDFTs are categorised into five classes that indicate the extent of adoption for every technology that was considered in our study; we therefore used the following scale: less than 20% very low, 20% to less than 40% low, 40% to less than 60% moderate, 60% to less than 80% high, and above 80% very high. From the analysis, dairy equipment and fodder technologies are categorised as low-adopted technologies. On the other hand, improved nipper hay and clean, soft, and spacious cubicles were well adopted by the majority of farmers in the study area.

**Table 5.3: Technology adoption frequency table**

<b>MDFT</b>	<b>frequency of adoption</b>	<b>Categories</b>
<b>Fodder production technologies</b>		
Sweet potato vines	32.29	Low
Improved napper	76.90	High
Lucerne	23.38	Low
Rhode grass	28.53	Low
<b>Fodder preservation technologies</b>		
Silage	38.87	Low
Hay	82.82	Very high
<b>Structure technologies</b>		
Clean soft	76.90	High
Spacious and Good air circulation technologies	87.32	Very high
<b>Equipment technologies</b>		
Feed mixture	9.01	Very low
Milking machine	2.54	Very low
Pure breed	48.73	Moderate

### **5.5 Effect of support services on the intensity of adoption of MDFTs**

An ordered probit regression model was used to determine the effect of support services on the intensity of adoption of MDFTs. In this study, the independent variables that were

considered include no extension visits, timely access to AI, treatment, Access to credit, accessibility road, HH size, marital status, sold coop, distance to motorable road, years of school, and receiving market information as shown in Table 5.4

To determine what support services, influence how extensively MDFTs are adopted by farmers, marginal effects from ordered probit models were analysed. The analysis categorised the intensity of adoption of MDFTs into five levels, corresponding to how many technologies, ranging from 4 to 8, were adopted by small dairy farmers. SDFs, these categories were used as the dependent. The chi-square test was significant at 5% ( $\text{Prob} > \chi^2 = 0.0000$ ). The model's explanatory capability, shown by Pseudo  $R^2 = 0.2205$ , suggests that the chosen independent variable accounts for approximately 22.0% of the variation in how widely MDFTs are utilised by small-scale farmers in the study area. The figure is generally considered reasonable for the logistic models. However, while the ordered probit model estimated the direction (positive or negative) of the influence of each factor that affects the utilisation level of MDFTs, it did not quantify the exact amount of change or associated probabilities. Therefore, marginal effects were used to interpolate the model more correctly.

The results indicated that the frequency of extension visits was positive at coefficient level of 0.145 this means that more extension visits increase the likelihood of a farmer being in a higher category of adoption similar to the work by (Okello et al. 2021). This study aligns with a study conducted in Iran by (Amghani et al., 2025) that shows that enhancing agricultural knowledge and awareness through extension services enhances technology acceptance and management, increasing dairy farming production. A similar study by (Amrullah et al. 2025) indicates that extension access positively and significantly played a major role in the adoption of dairy technologies in Indonesia. Farmers who had adopted the technologies in their farms had recorded income increases.

**Table 5.4: Results of the effect of support services on the adoption of MDTs**

Variable	Ordered probit Coefficient	Robust std.err.
No extension visits	0.145*	.145
Timely access to AI	0.996***	.996
NO treatment	0.996***	.507
Access to credit	0.795***	.794
accessibility road	0.053*	.052
HH Size	0.157***	-.157
Marital status	0.252***	.252
sold coop	0.958***	.958
Year's school	0.017	.016
Km to motorable Road	0.017	0.54
Receive market info	0.298**	.297
cut1	-0.571	
Cut2	3.085***	
Cut3	4.377***	
Cut4	5.268***	
Cut5	6.077***	
Cut6	6.639***	
Cut7	7.263***	
Cut8	7.618***	

Number of observations = 355

Wald  $\chi^2$  (21) = 194.48

Prob >  $\chi^2$  = 0.0000

Pseudo  $R^2$  = 0.2205Log

pseudo-likelihood = -408.51435

The ordered regression results further revealed that timely access to AI had a positive coefficient of 0.996. This implies that for farmers who received AI service on time, had a higher probability of moving up the ordered scale to levels 7 and 8. This is because animals inseminated at the right time increase conception rates, shorten calving intervals, and reduce cost since there is no repeat insemination cost incurred by the farmers. Delayed AI services led to repeated insemination, which discouraged the farmer from using AI and reverted to natural mating. This study concurs with the study that was conducted by (Ayantoye et al. 2025) on advances in timed insemination. The study indicated that timed insemination increases pregnancy rates, shortens conception times, reduces the number of

services per conception, and reduces pregnancy loss. This, in turn, increased reproductive efficiency, hence encouraging farmers to use AI as the best method for serving their animals. Similarly, a study that was conducted in Ethiopia showed that farmers were using neighbour bulls to serve their animals due to the low rate of conception when the farmers used AI (Gedefa et al., 2025). The key challenge was delayed service due to poor transportation of semen, which reduced the conception rate of the served animals. The study further indicates that the use of AI increased the conception rate when it was done on time (Gedefa et al., 2025).

Dairy treatment has a positive coefficient of 0.996. Farmers who provide regular treatments through vaccinations, deworming and disease treatment to cattle are much more likely to adopt MDFTs at a higher level. Treatment lowers disease infection and increases the productive lives of dairy cattle according (Várhidi et al., 2024). Farmers who invest in animal health are usually more progressive, aware of modern practices, and willing to adopt complementary technologies (Liu et al., 2019). This study confirmed the research that was conducted in Bangladesh on smart practices in modern dairy farming, examining the transformational pros of sustainable benefits. (Shamsuddoha & Nasir, 2025)

Increased rate of credit accessibility from Sacco and other money-lending institutions has a strong and positive coefficient of 0.795. Access to credit reduced the chances of farmers being in low adoption categories of 4 and 5 and increased the chances of being in the higher levels of 7 and 8. Access to create a guaranteed capacity for the farmers to buy modern equipment and build a high-standard dairy structure necessary for dairy farming. The availability of capital increased the chances of dairy farmers using high-quality semen that is expensive to improve their dairy stock. This study confirmed that accessibility to credit positively and significantly influenced the adoption of MDFTs at 1%. This study aligns with the findings of the study by (Ngeno 2024) that indicated that accessibility to credit in southwestern Kenya influenced the adoption of dairy feed technology and homemade rations for dairy cows.

Market information significantly influenced the adoption of farming technologies; the results shows that access to market information had a positive coefficient of 0.289

indicating that farmers who had reliable access to market information were more likely to move into higher categories. Access to this information empowers dairy farmers in making decisions about certain technologies that improve productivity and income. The study conducted by (Henchion et al. 2022), shows that market information helps farmers focus on the dairy production cycle that ranges from breeding, feeding, and milking to meet milk demand. Farmer membership in a cooperative group through which they sell their milk had a positive effect on the adoption of MDFTs. The study found that participants who sold their milk through a cooperative society were more likely to adopt MDFTs. Since they could access credit facilities and purchase dairy equipment and inputs. Additionally, membership in a dairy cooperative society allowed farmers to easily access extension services and dairy training. These studies agree with (Akzar et al. 2024) that membership in a milk cooperative society positively impacts the adoption of dairy technologies. Empirical evidence from Izmir, Turkey, shows that cooperatives have more impact on agriculture technologies that increase efficiency in dairy production (Malkoc Kinikli & Yercan, 2025).

The household size has a positive coefficient of 0.157, household size increased the likelihood of being in a higher category. The most plausible explanation is that rising household size provides the work force required for silage production, napper planting, cutting, and transportation. This study agrees with the study by (Henchion et al. 2022), which indicates that labour is needed in the establishment of Napier grass, which was among the technologies considered in this study. Furthermore, the respondents' marital status influenced the adoption of numerous technologies in the research area at the 1% level of significance. Generally, marital status influences the adoption of technologies by determining household structure, resources, and decision-making. Typically, married individuals are found in larger households, which means more cheap labour is available to handle tasks like fodder establishment, feeding, milking, and general handling of dairy cows since there are more hands to do these tasks. This study corresponds with a study that was done in semi-arid Dodoma, Tanzania, by Awoke et al. (2025), which indicated that there was less conflict between the decision-makers and their spouses regarding training about the adoption of agricultural technologies.

## **5.6. Conclusion and recommendations**

This study investigates the impact of support services on the level of adoption of specific MDFTs. Several support services were discovered to have an impact on the intensity of adoption of these technologies, including the frequency of extension officer visits, timely access to AI services, access to credit, access to veterinary services, accessibility to good roads, membership in cooperative societies, and access to market information. These support services were proven to have a beneficial and considerable influence on the adoption of new dairy technologies. To conclude, the study urges for the county government and other important stakeholders to improve the extension frequency, since this will generate awareness of the numerous MDFTS. Additionally, there is a need to make AI services more available to farmers by the county government when required by farmers, for this will increase efficiency in dairy farming in the county. Credit facilities should be accessible to dairy farmers, for this will facilitate the purchase of essential dairy equipment and the construction of the standard dairy structure. The government should put in place policies that enable every dairy farmer to sell their milk through a society, for this will enable the farmers to access a good market for their milk as well as receive information about new MDFTs.

## **CHAPTER SIX**

### **CONCLUSION AND RECOMMENDATIONS**

#### **6.1 Conclusions**

The conclusion of this study was based as per the study objectives. The first objective of the study was to determine the factors The MVP model was adopted to analyse the results. The findings revealed that households with high income, the education level status of the head of the family, the extension visit frequency, accessibility to credit, dairy farmers being members of dairy groups, experience gained in dairy farming, and livestock monetary value had an upper hand in the adoption of MDFTs. Therefore, this study concludes that the adoption of different MDFTs is determined by key elements like education level, household income, number of extension contacts, farmer group membership, farming experience and access to credit.

The second objective assessed the effects of the adoption of MDFTs on productivity among smallholder farmers in Meru County, Kenya. The Cobb-Douglas model was employed in the analysis. The study found that several key factors, like support services (for example, extension services), input costs, dairy equipment like feed mixtures, health of the cow, fodder establishment and preservation technologies, and genetic enhancement of dairy herds, influenced the amount of milk that was produced by an individual cow per day.

The third objective assessed the effects of support services on the intensity of adoption of MDFT among smallholder farmers in Imenti South Sub-County, Meru County. The Ordered probit model results indicated that access to veterinary services, credit, market information services, extension services, and training significantly influenced the intensity of adoption of the MDFTs among smallholder dairy producers in the study area

#### **6.2 Recommendations**

Based on the findings of this investigation, the following recommendations were made.

##### **6.2.1 Determinants of adoption of MDFT among smallholder farmers**

The relevant stakeholders in the dairy industry should intensify extension contact frequency among smallholder dairy farmers. This enhanced engagement facilitates the

distribution of diverse MDFT among farmers, allowing them to make educated decisions and so increasing the degree of adoption of MDFT.

The government should create supportive policies that encourage the creation of new farmer cooperatives. These structures provide a platform that enables farmers to share information about MDFT.

### **6.2.2 Assessing the effect of adoption of MDFTs on milk productivity**

Key players in the dairy sector should amplify extension contact frequency among dairy farmers to create awareness of benefits relating to the adoption of MDFTs on the level of milk production per individual cow per day.

Enhancing dairy farmers' accessibility to affordable credit is essential. This can be achieved by lowering the interest rate of agricultural loans. Affordable credit enables farmers to purchase modern equipment used in dairy production.

### **6.2.3 Assessing the effect of support services on adoption of MDFTs**

The relevant stakeholders, both government and non-governmental institutions, should increase the extension frequency in the study area to enhance MDFT information delivery, for this will create awareness of the various MDFTs available for the farmers.

The government should put in place policies that enable every dairy farmer to sell their milk through a society, for this will enable the farmers to access a good market for their milk as well as receive information about new MDFTs.

## **6.3. Areas for further research**

To improve dairy productivity in Meru County, further research on the adoption and integration of artificial intelligence technologies in dairy farming practices could be vital. This technology could help in monitoring cow health, optimising feeding systems, and improving the overall milk production. Another important area for further study is post-harvest handling of milk and the associated contamination risk. Understanding the challenges farmers face in milk storage, transportation, and processing and identifying practical, affordable solutions that can help improve milk safety and quality.

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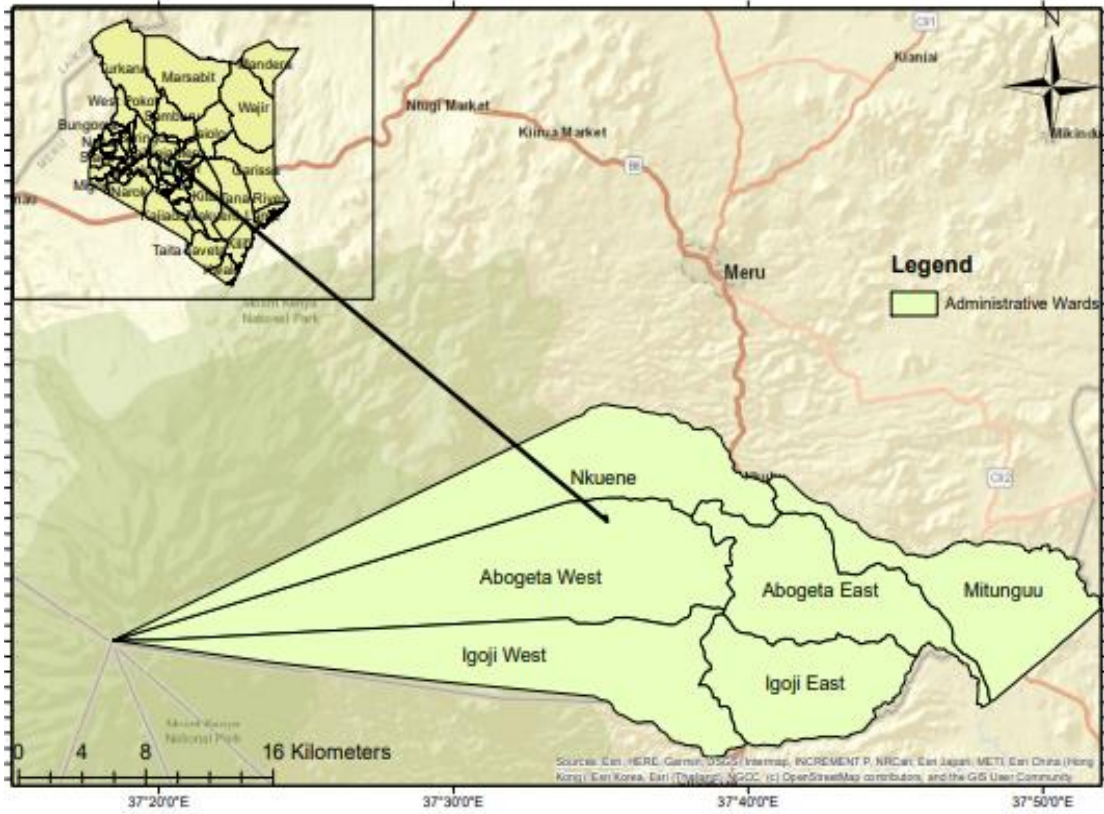
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# APPENDICES

## Appendix 1: Map of the study area



**Appendix 2: Covariance matrix of the multivariate probit (MVP) model for the 8 MDTs adopted.**

	<b>Sweet potatoes</b>	<b>Lucern</b>	<b>Rhodes hay</b>	<b>silage</b>	<b>Cleansoft</b>	<b>Milk machine</b>	<b>Feed mixture</b>	
Sweet potatoes	1.0000							
Lucern	0.1327	1.0000						
Rhodes_grass	0.1376	0.0022	1.0000					
Hay	0.0523	0.0859	0.0063	1.0000				
Silage	0.2413	0.1807	0.2235	0.0901	1.0000			
Cleansoft	0.0004	0.0027	0.0378	0.0212	0.1261	1.0000		
Milking machine	0.1340	0.0933	0.1379	0.0839	0.1171	-0.0177	1.0000	
Feed mixture	0.0058	-0.0112	-0.1129	0.0059	0.0397	-0.0842	0.0572	1.0000

### **Appendix 3: Introductory letter**

Andrew Kirimi  
University of Embu  
P.O.BOX 60-100  
Embu

Dear Sir/Madam

#### **REF: DATA COLLECTION**

I am a student at University of Embu pursuing a degree of Master of Science in Agricultural Education and Extension. In Kenya, I'm conducting research on on uptake of improved dairy farming technologies and productivity among smallholder farmers in Meru County. I would like to invite you to participate in this study by filling out the questionnaire enclosed. The requested data will be used to gather information on on uptake of improved dairy farming technologies and productivity among smallholder farmers in Meru County. The information you provide will be kept totally confidential for the sole purpose of academic research. The research permission from NACOSTI is attached.

Yours faithfully,  
Andrew Kirimi  
Researcher

### **Appendix 4: Interview schedule.**

#### **Introduction**

This interview schedule aims to collect data on uptake of improved dairy farming technologies and productivity among smallholder farmers in Meru County. The information provided herein will be treated with the utmost confidentiality.

**INTERVIEW SCHEDULE**  **NO:**

#### **GENERAL INFORMATION**

Enumerator:	Sub-County
Division	Ward
Sub-location	Village

## SECTION A: SOCIO-ECONOMIC INFORMATION

This section will record information on socio-demographic information of smallholder

A1 household head gender	1=male 2=female
A2 Marital status of the household head	1= married 2=window 3=single 4= single 5= widower
A3 Household head age in years	
A4. i) household head Education level	1= primary 2=secondary 3=college 4= university
Number of years spent in school	.....
ii) Household years spent in school	
A5. Household head occupation	1= farming 2= business 3=employment
A6. Household income per year/ month in KES	.....
A7. The off-farm income per year/month in KES	.....
A8. Sources of off-farm income	1= self-employment 2= salaried jobs 3= pension 4=wages 5 others specify.....
A9.No. of years spent in dairy farming	

dairy farmers

## SECTION B ADOPTION OF IMPROVED DAIRY FARMING TECHNOLOGIES

- 1) Please indicate if you are aware of the following dairy farming technologies (1= Fodder establishment technologies 2= Exotic cows 3= Artificial insemination, 4=Feed conservation technologies 5= Others specify.....)
  - a) which technology are you using.....
  - b) When did you started using the technology.....
- 2) Which of the following fodder have you established in your farm (1= Sweet potato vines 2= Improved variety Nappier grass 3= Lucern 4= Boma Rhodes

- grass) Others  
specify.....  
.....
- 3) Which method do you use in milking your cows (1= use of free hands 2= Use of machinery)
  - 4) Which equipment do you use in your dairy farm.....
  - 5) How often do you treat your dairy cows.....?
  - 6) Which are the sources of treatment to your cows (1= Government Veterinary officer 2= Private 3= Dairy cooperative)
  - 7) Which of the following dairy cows do you have on your farm (1= Exotic Fresian 2= Cross bred cows 3= indigenous cows 4= mixed of all) Others specify.....
  - 8) Which of the following feed conservation do you have in your farm (1= Hay 2= silage) Others specify.....
  - 9) Which method do you use to breed your dairy cows (1=Artificial insemination 2= Natural mating) other specify.....
  - 10) Where did you get dairy farming technology from?.....
  - 11) Which income do you use to invest in dairy farming technologies (1=sale of milk 2=sale of cows 3= sale of other crops in the farm 4= sale of milk and other enterprise on the farm) others specif.....
  - 12) Which of the following feed storage do you use in your farm (1= Hay 2=silage 3 Both) others specify.....
  - 13) In your own view, what are determinants of adoption of dairy farming technologies?.....
  - 14) Who provides labour in performing the dairy farming technologies (1= family labour 2 Hired labor 3= Both family and hired labour)
  - 15) How much is the cost of labour in Mandays (Men----- 2 Women-----

-- Children-----)

**SECTION C ADOPTION OF IMPROVED DAIRY FARMING TECHNOLOGIES ON PRODUCTIVITY**

- 16) How many times do you milk your cow per day.....?
- 17) What is the average yield of milk per day per dairy cow.....?
- 18) From the amount of milk produced in a day what amount is used (1= Household consumption..... 2 Amount taken to the dairy company..... 3 Amount sold in direct market 4 Amount sold to brokers 5. Amount sold to the neighbors 6 Others specify.....
- 19) What is the amount of income obtained per month from the sale of milk.....?
- 20) Indicate the inputs you use in dairy farming and their respective costs

Inputs	Cost (KES)
Labour	
Land	
Water	
Feed	
Others specify	

**SECTION D SUPPORT SERVICES ON ADOPTION OF DAIRY FARMING TECHNOLOGIES**

- 21) In dairy production, do you receive any extension service anytime (1= yes 0= No)
- 22) If YES, from where do you get the extension information? (1 = County extension officer 2 = Farmer Groups 3 = Non-Governmental Organization 4 = Television 5 = Radio 6 = Newspapers/ magazine 7 = Others (specify).....
- 23) In a year how many times do you receive the extension service.....
- 24) Do you have access to any farm credit? (1 = YES 2 = NO)
- 25) If YES, provide the information required in the table below;

B1. Sources of credit	1=Banks 2= SACCO 3= Government 4= Merry go round 5=Others specify.....
B2.Amount of credit borrowed in KES	
B3. Purpose of credit	1= dairy farming 2=school fees 3= medical 4=others specify.....
B4. Activities carried out	1= dairy farming 2= school fees 3= medical 4= others specify.....
B5. Constraints in obtaining credit	1= fear of risk 2= high-interest rate 3=lack of collateral 4= others specify.....

26) Do you attend any training with regard to dairy farming technologies (1=yes, 0=no?)

27) Do you access market information on the farm milk produce? (1=YES 2=NO)

28) If (YES) What are your means of accessing market information (please indicate with a tick)

Means	Response
Radio	
Television	
Extension services	
Seminars	
Ministry of Agriculture	
Newspapers	
Phone	
Any other ( please specify)	

29) Where do you sell your milk? (1 = Local market 2 = Farmer cooperatives 3 = Institutions/schools 4 = Brokers Others (specify.....)

- 30) What is the distance from your farm to the nearest motorable road?  
..... kilometers
- 31) How do you rate the road referred to in 10 above in terms of accessibility?
- 32) (1 = Highly accessible 2 = Less accessible 3 = Not accessible)

**GROUP MEMBERSHIP**

- 33) Are you a member of any group (1= Yes 0=No)
- 34) If yes, which group do you belong to. (1= diary group= 2 Society group 3 =  
Other specify)--
- 35) Which are some of the services offered in the group.....

**Thank you**