

**DETERMINANTS OF UTILIZATION OF RECOMMENDED FORAGES AND  
CONCENTRATES AMONG SMALLHOLDER DAIRY FARMERS IN NAKURU  
COUNTY, KENYA**

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for the Master of Science Degree in Agricultural and Applied Economics of Egerton  
University**

**EGERTON UNIVERSITY**

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## DECLARATION AND RECOMMENDATION

### DECLARATION

I declare that this thesis is my original work and has not been presented in this University or any other for the award of a degree.



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### RECOMMENDATION

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## **DEDICATION**

This thesis is dedicated to my lovely parents, siblings and friends for their support and prayers.

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May God the Almighty be favorable and kind to all of you.

## ABSTRACT

The dairy industry was an important part of the Kenyan agro economy. It contributed about 4 per cent to the national GDP and it supports more than 1.5 million smallholder farmers. This is because milk production among dairy farmers in Nakuru County was low as a result of the low quality scarce pasture and also their high prices, which were unaffordable in the dry season. This led to unstable production, reduced economical returns and the difficulty in the sustainability of the dairy farming in the long run. Through these obstacles, the research made a broad contribution to no poverty and zero hunger through enhancing profitability and milk output in smallholder dairy farmers. The objectives of the particular study were i) to establish the factors that influence the decision to use recommended forages and concentrates, ii) to establish the degree of technical efficiency of using recommended forages and concentrates and iii) to establish the profitability of the use of recommended forages and concentrates by the smallholder dairy farmers in Nakuru County in Kenya. The research was anchored on the information that was gathered in a sample of 225 small holder dairy farmers in Njoro and Molo Sub-Counties in Nakuru County, Kenya. The respondents were selected by a multistage sampling method and semi-structured questionnaires were used to collect the cross-sectional data. The results of the Probit model revealed that female gender, type of breed, land tenure, live weight of cows, credit utilization, membership of a group, production system, herd size and production contacts with the concerned extension agent, education and experience had a significant ( $P < 0.05$  and  $P < 0.1$ ) influence on decision to use the recommended forage and concentrates by smallholder dairy farmers. The Stochastic frontier model findings demonstrated that smallholder dairy farmers that used both forages and concentrates were more efficient (0.636) compared to those who used only forages (0.364). The average technical efficiency was 34.85 percent amongst the ones using both feeds, 24.07 percent among the ones using forages only. This showed that farmers who fed on both feeds generated milk yield increased by 75.93 percent and farmers who fed on forages only, increased by 65.15 percent. Gross margin analysis showed that a combination of forages and concentrates ( $P < 0.1$ ) was very beneficial in raising gross margins among the smallholder dairy farmers (KES 89,745.77) than when forages were used only (KES 57,619.25). The average gross margin of all feed levels of quality was 78,037.43. The averages of changes in the level of feed quality were statistically

significant at the 10 percent level of significance, which implies that the level of feed quality influences the level of gross margin significantly.

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The quality of the feed was positive and statistically significant at 5% probability level. This meant that the increment of quality of the feed by 1% increased milk yield by 80.5%. This result conformed to that of Akintan *et al.* (2025), which showed that high-quality feeds rich in proteins, carbohydrates, vitamins, and minerals were crucial for efficient milk synthesis. Water intake and herd size were both positive and statistically significant at 1%. This meant that the increment of water intake and herd size by 1% increased milk yield by 42.3% and 59.7%, respectively. This result was consistent with that of Kebede and Guja (2024), who found that adequate hydration was essential, as milk was largely composed of water; dehydration led to reduced milk yield and health issues. Also, Akintan *et al.* (2025), found that larger herds benefited from improved genetics and feeding systems, which enhanced overall milk production..... 61

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## LIST OF ABBREVIATIONS & ACRONYMS

<b>AASR</b>	Annual Agricultural Sector Review
<b>CAGR</b>	Compound Annual Growth Rate.
<b>CBA</b>	Cost-Benefit Analysis
<b>CDLP</b>	County Directorate of livestock production
<b>CIDP</b>	County Integrated Annual Development plan
<b>CGN</b>	County Government of Nakuru
<b>DM</b>	Dry Matter
<b>EU</b>	European Union
<b>GDP</b>	Gross Domestic Product
<b>GM</b>	Gross Margin
<b>GMA</b>	Gross Margin Analysis
<b>GVR</b>	Global Value Research
<b>IOFC</b>	Income Over Feed Cost
<b>IUCEA</b>	Inter University Council for East Africa
<b>KARI</b>	Kenya Agricultural Research Institute
<b>KCC</b>	Kenya Co-operative Creameries
<b>KDB</b>	Kenya Dairy Board
<b>KES</b>	Kenyan Shilling
<b>KIPPRA</b>	Kenya Institute for Public Policy Research and Analysis
<b>KPHC</b>	Kenya Population and Housing Census
<b>KRA</b>	Kenya Revenue Authority
<b>LBY</b>	Liquid Brewers' Yeast
<b>MLE</b>	Maximum Likelihood Estimation
<b>MoALFC</b>	Kenya's Ministry of Agriculture, Livestock, Fisheries, and Cooperatives
<b>MoLD</b>	Ministry of Livestock Development
<b>NAVCDP</b>	National Agricultural Value Chain Development Project
<b>NGOs</b>	Non-Governmental Organizations
<b>RUE</b>	Resource Use Efficiency
<b>SCAO</b>	Sub-county Agricultural Office
<b>SDGs</b>	Sustainable Development Goals of the United Nations
<b>SDL</b>	State Department of Livestock

<b>STATA</b>	Statistics and Data
<b>TE</b>	Technical Efficiency
<b>TMR</b>	Total Mixed Ration
<b>TR</b>	Total Revenue
<b>TVC</b>	Total Variable Cost
<b>USD</b>	United States Dollar
<b>WB</b>	World Bank

## **CHAPTER ONE**

### **INTRODUCTION**

#### **1.1 Background Information**

Agriculture was a proven pathway to prosperity, with most of the regions in the world developing diverse, modern economies by first establishing a robust agricultural foundation (AGRA, 2019). Agriculture played a critical role in economic growth, contributing 4% to the global GDP. In some of the least-developed countries, this contribution exceeded 25% (World Bank, 2024). The global dairy production has grown, and underdeveloped nations have demonstrated minor yields in their portion of dairy production mainly because of an increase in the quantity of producing animals as opposed to the productivity per cow (Kozacka *et al.*, 2023). The dairy industry is well endowed with 133 million farms housing 363 million cattle around the world covering 20 percent of the total farmland in the world (Balem *et al.*, 2022). Agriculture was a major economic activity in Kenya, it provided 24 percent of the GDP worth around 342 billion dollars and the sector also accounted 65 percent of the total export and 70 percent of the total population in the rural areas was employed. The smallholder farmers significantly contributed to the production of up to 80 percent total milk production in the dairy industry, which was a rural-based sector that contributed 14 percent of the GDP of the agriculture industry, 40 percent of the livestock sector GDP, and 4-8 percent of the overall GDP (CBK, 2024).

Central, Rift Valley, and Coastal lowlands were mainly used in dairy farming and it provided good agro-climatic conditions to produce dairies (MoLD, 2010). Some of the central regions that were essential were Kiambu, Nyeri, Murang'a, and Nyandarua. Uasin Gishu, Nakuru, Kericho and Bomet were the regions in Rift Valley that exhibited dairy farming. In the Coastal lowlands, there were major kilifi and kwale (MoALFC, 2022).

Dairy farming as an economic activity was identified as an important economic activity to farmers in Nakuru County which includes dairy keepers. County was ranked as 6<sup>th</sup> Kalahari in Kenya by the value of milk yield (SDL, 2024). The success of dairy farming in the county was due to the conducive climate, which is moderate and has evenly distributed rainfall (Munyua *et al.*, 2023). Not only was dairy farming an important source of income and employment, but it was also vital to the local nutrition and livelihoods of the community, with the necessity to be sustainable towards the environment (Fagundes *et al.*, 2024). The average milk

production in Nakuru County was 300 million litres per year which is more than 25% of what it was since 2019 until 2023. This saw the county become the third-best devolved unit in the production of milk in Kenya, having 381,600 dairy cattle following Kiambu and Nyandarua Counties (Musyoka *et al.*, 2023).

Smallholder dairy farmers in Nakuru County mostly raise high-yielding dairy breed such as Holstein-Friesian and Ayrshire, but they can be crossbred with the local Zebu cattle in order to adapt to localized conditions (Alaru *et al.*, 2022). The dairy animals used by farmers were fed on a mixture of different feed materials that included indigenous grasses, Napier grass, maize and crop residues (bean, maize and sorghum), maize silage, commercial and farm formulated concentrates, and total mixed rations (TMR). Nutritional compositions of such feeds are varied with commercial concentrates containing the highest concentration of crude protein ranging between 109 and 506 g/kg of dry matter (DM) and maize stover (DRM) containing the lowest concentration of crude protein between 40 and 71.4 g/kg of dry matter (DM) (Terler *et al.*, 2019). Moreover, some factors contributed to the adoption of agricultural technologies by the smallholder dairy farmers in Kenya such as education level, livestock type, availability of credit, and dairy cooperative membership (Nyokabi *et al.*, 2022).

Basal feeds and supplements were very important in the nutritional content of livestock feeds that optimized the livestock productivity. Indigenous grasses, Napier grass, maize stover and maize silage were the major basal feeds, but commercial concentrates and total mixed ration (TMR), were commonly used as supplements. These feeds significantly influenced the performance of the animal with commercial concentrates having the highest crude protein at  $17.4 \pm 3.9\%$  dry matter (DM) and maize stover the lowest at  $8.7 \pm 3.3\%$  DM. The spread of ME values was  $7.0 \pm 0.8$  MJ/kg DM in the case of maize stover and  $8.9 \pm 0.8$  MJ/kg DM in the case of dairy meal (Kiura *et al.*, 2024).

In the Nakuru County, the best dairy cow feeds are recommended to include nutritious forage like Napier grass, Brachiara and local grasses in addition to good quality concentrates such as commercial dairy meat and Total Mixed Ration (TMR). These feeds were adapted to the local weather and aid in milk production. Non-recommended feeds One of them was moldy forages, which included the harmful mycotoxins and low-quality concentrates without the necessary nutrients that damaged the health of animals and the safety of milk (Maweu *et al.*, 2023).

The most significant factors influencing the potential of the animal in a positive or negative way were the quality and quantity of feeds (Morsy *et al.*, 2018). Having access to the recommended feeds proved to be a challenge to the smallholder dairy farmers, who faced a significant expense (60-80% of the total production costs) relative to the productive and reproductive performance of dairy cows unless the feeds were supplemented adequately to the animals, especially during the dry seasons (Vilar and Rajala-Schultz, 2020).

During the dry season, milk output declines by 15-30 percent with smallholder farmers being the most affected since they relied on the natural pasture. Smallholder farmers were also more affected by the lack of resources to provide additional feeding than big farms (Mudavadi *et al.*, 2020). Quality of pasture dropped by 40 percent during dry season, also had an impact on nutritional values of forage. To keep the levels of milk production, farmers had to use silage (60-70% usage) and concentrates (30-40% usage) during this period. The quality of pastures began to increase in the wet season, with the potential of the milk production per cow increasing by 20% (Nyokabi *et al.*, 2022). In this context, the authors of this study were measuring the determinants of recommended forages and concentrates use among smallholder dairy farmers in Nakuru County in Kenya.

## **1.2 Statement of the Problem**

The Nakuru County dairy farmers have experienced a lot of difficulties in the dry season because there was a drastic reduction in the milk production given the low quality and quantity of pasture. As the pasture was dwindling and was less nutritious, then farmers would depend on some supplementary feeds to supplement the nutritional needs of their cows. Nevertheless, such feeds were mostly expensive and not necessarily easily available particularly to the smallholder farmers who had limited resources. On top of their high price and scarcity, the quality of these feeds was not consistent with most of the feeds being of low nutritional quality. Consequently, a lot of farmers were unable to feed their animals well, and the milk production was reduced. Although the wet season provisional enhanced the quality of pastures and increased milk production, the constant challenges of the dry season interfered with the year-round production. This variation in production led to low economic performance and financial losses of farmers since most of them would not use the recommended forages and concentrates. After all, the lack of ability to

maintain satisfactory feeding rates during dry season negated the profitability and long-term sustainability of dairy farming in the area.

### **1.3 Objectives of the Study**

#### **1.3.1 General Objective**

To contribute to no poverty (SDG 1) and zero hunger (SDG 2) by improving milk yield and profitability for smallholder dairy farmers in Nakuru County, Kenya, through enhanced utilization of the recommended forages and concentrates.

#### **1.3.2 Specific Objectives**

- i. To determine the factors influencing the choice of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya.
- ii. To determine the level of technical efficiency of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya.
- iii. To determine the profitability of utilizing recommended forages and concentrates for smallholder dairy farmers in Nakuru County, Kenya.

#### **1.3 Research Questions**

- i. What are the factors influencing choice of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya?
- ii. What is the level of technical efficiency of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya?
- iii. What is the profitability of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya?

### **1.5 Justification of the Study**

The study helped to inform targeted agricultural policies and interventions to encourage more efficient feeding practices because it identified the determinants that had an impact on feeding. These will not only yield dairy productivity, but also stabilize household incomes, as well as make a contribution to local and regional food security. Also, the cost-benefit analysis will be useful in assisting farmers to determine the financial gains of nutritious feeding, and the evaluation of technical efficiency would help in determining the best practices in enhancing productivity. At

the end, the results will inform policy-makers to come up with specific interventions and sustainability of dairy farming.

The study will contribute to Vision 2030 in Kenya and national dairy Master Plan (DMP) by working towards productivity and profitability of the dairy farms by improving feeding management. Through encouraging the use of recommended forages and concentrates, the study was to increase milk yield and help in food security and economic recovery. The vision 2030 of Kenya is to ensure that the country becomes a middle income nation that has high living standards among its citizens. This research helps to achieve such target, as it will lead to more profitable and productive dairy farming (with the help of improved feeding). The research aids in economic growth, rural development, and poverty alleviation, which are major agenda of Vision 2030, since it assists farmers to produce more milk and earn more incomes by improving their feeding. Also, the research met the Sustainable Development Goals, especially no poverty (SDG 1) and zero hunger (SDG 2), in enhancing food and nutrition security and increasing the rural incomes.

#### **1.6 Scope and limitations of the Study.**

The study was aimed at identifying the determinants of consumption of recommended forages and concentrates by the smallholder dairy farmers in Njoro and Molo Sub-counties in Nakuru County in Kenya. It included the different attributes in regards to the purchase of feed such as availability, prices and the logistics of acquiring the suggested feeds and supplies. It also involved studying the impacts of feed use on dairy production and economic results of farmers within the County.

The research was faced with a number of limitations. Variability in data availability and reliability was one of the weaknesses because not all smallholder dairy farmers kept detailed records of their feed purchasing behaviors. Besides, there was the problem of language barrier, whereby survey tools and communication have been translated into local languages to facilitate proper understanding by all the participants. In addition, recent taxations by the Kenya Revenue Authority (KRA) encouraged farmers to under-declare dairy revenue.

In order to overcome these shortcomings, the research used the local enumerator who understand the local languages so as to be able to communicate properly during the surveys. In order to overcome the limitation of variation in data collection on the availability and reliability of the data used in the data collection

process, the study also utilized structured interviews involving the use of a pre-prepared checklist, which will direct the farmers to recall certain information about the way they purchase their feed. Specific questions concerning purchases in the recent past, quantities and sources of feed were posed. Also, the visual aides, including the pictures of typical types of feed, were employed to refresh the memory of the farmers and to confirm correct answers. Also, anonymous reporting systems were adopted in order to ease the fears that might be caused by the fear of under-reporting due to tax enforcement to favor more candid feedback on the subject of income and feed usage.

### **1.7 Definition of Terms**

**Concentrates:** Complete diets, high-energy and protein-rich products (i.e. dairy meal, wheat bran, and maize germ), provide essential energy, proteins, and minerals.

**Feed:** Dairy animals are fed on forages and on concentrates.

**Forages:** Plant materials consumed by the dairy animals such as crop residues such as maize stover, wheat straw, bean haulms, silage, hay and Napier grass.

**Gross margin:** This represents the variance between the total revenue (TR) obtained through production of milk and total variable cost (TVC) that encompassed feed costs, labor, and veterinary expenditure.

**Milk yield:** This is the total milk produced by a cow during a specific time frame which could be per day, per month or per lactation cycle.

**Recommended feeding:** This is the use of climate adapted forages as well as safe and nutritionally suitable concentrates as recommended by research institutions and through extension services to ensure uniform dairy productivity among the smallholder farmers in the Nakuru County.

**Small holder dairy farmers:** Owners and operators of less than 5 dairy cows that have less than 1 hectare of land, and use in most cases zero grazing systems.

**Utilization:** This is a process of using forages and concentrates to satisfy the nutritional requirements of dairy cows.



## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Overview of the Dairy Sector in Kenya

In Kenya, the dairy industry contributes significantly to the agricultural GDP of Kenya that is estimated to be 14 percent and the smallholder dairy farmers produce 56 percent of the entire milk. This was an approximation of 1.8 million farmers, and this was about 80 percent of the total producers. On the other hand, the other 44 percent of the milk production in the industry was composed of large commercial farmers (CBK, 2024).

Kenya was a major dairy producing nation and the milk production and its market gains were boosted by the introduction of policies such as the 2004 Kenya dairy policy change. The dairy industry had undergone transition to the control of major players in the industry with the participation of large processors such as the New Kenya Co-operative Creameries (KCC), Brookside Dairy Limited and Githunguri Dairy Farmers Cooperatives and Processors being significant in this sector. Small farmers produce approximately 80 percent of the total milk, and the production is done through different production systems depending on agro-climatic conditions and land yield (Ndung'u *et al.*, 2023).

Kenyan dairy industry though it is an important contributor of the national economy is faced with numerous technical, economic and institutional issues in production, processing and marketing of milk. The constraining variables were seasonality in production process, lack of sufficient quantity and quality of the feeds, poor infrastructure, and lack of participation of farmers in the output market which slowed the process of milk production (Florez *et al.*, 2024).

Kenyan government had realized the problems in the dairy industry over the last 10 years. Through the encouragement of the private sector and the donor agencies, several interventions were spearheaded to examine the factors that limit the competitiveness of the smallholder dairy farmers and policies and institutions influenced the dairy sub-sector among others. He had made the dairy industry a priority in government policies such as the Agricultural Sector Transformation and Growth Strategy and the Big Four Agenda, and Kenya had a dairy master plan to develop the industry up to 2030 to overcome the challenges and improve productivity (Hellen *et al.*, 2024).

Milk production in Kenya was seasonal owing to various factors such as rainfall, accessible nutrients among others hence, there were high production seasons that made the local markets saturated. The Kenya Cooperative Creameries (KCC) is a large buyer of milk at

these peak periods but has been restricted in capacity of plants, leading to dumping of excess milk because of alleged poor quality. This scenario had necessitated the involvement of additional companies in the dairy processing and distribution business to reduce the pressure exerted on KCC and had delivered transparent milk consumption, processing as well as the distribution. Nonetheless, the liberalization of the marketing was perceived as a long-term measure to overcome these obstacles and optimize the industry within the dairy market in Kenya, in general (Berut, 2020).

The importance of having dairy farming in the area was noted with Nakuru County being the third biggest milk producer in Kenya after Kiambu and Nyandarua Counties, which helps in supplying the area and the country with milk (SDL, 2024). A large variety of dairy activities was involved in the county: production, processing, and consumption. This involvement in the dairy industry on a large scale emphasized the value of milk as a basic foodstuff in the local economy and diet. Local cattle in Nakuru was reported to be at KES 54,075 which was very high when compared to the same in Nyandarua. The County had a greater reliance on farming since it was the main occupation of 86.1% of the households in Nakuru County (Otieno *et al.*, 2021).

Dairy rearing is a source of about 8 per cent of Kenya GDP and the production currently stands at 3.43 billion litres per annum. The mean litres of milk picked up at the local centres each day was around 36,870 litres, which implies that Nakuru County has a strong supply chain of milk (Ndungi *et al.*, 2021). The total milk production per cow is, however, low at 6-7 litres per day that was significantly lower than the international standards. Milk production was much less than the global averages, which indicates inefficiency in production (Bett *et al.*, 2021).

Nakuru had the greatest processed dairy product, which was pasteurized milk, accounting 48 percent of the production, then followed by fermented milk and yogurt. The dairy industry of Nakuru County with about 381,600 dairy cattle and 300 million litres of milk yearly engaged more than 6,000 dairy farmers (Ndungi *et al.*, 2021). The county targeted 15 litres per cow per day with the enhancement of the management practices such as climate-resistant agriculture and enhanced breeding. Nakura was estimated to have a potential of the dairy sector at US 169.3 million (Mutai and Kussaga, 2023).

## **2.2 Factors Affecting Decision of Using Recommended Forages and Concentrates**

The smallholder dairy farmers in different parts of the globe used a wide variety of feed types and sources to feed on their dairy cows. Additionally, a dairy cow feed formula

was developed in China that used cassava flour, alfalfa, cotton seed meal, and other powders such as pine needle and seaweed to offer balanced nutrition and improve palatability, which later accelerated the production of milk and improvement of diseases (Krizsan *et al.*, 2014).

To deal with the problems of feed shortage, farmers tend to use a mixture of conventional and unconventional feeds, such strategies as free grazing, zero grazing, use of alternative feed sources during the times of lack of feeds. In addition, other substitutions such as silage on sweet potato vine that were supplemented with wheat bran had been considered as viable options that were relatively cheaper to keep the smallholder dairy farming systems producing milk (Akintan *et al.*, 2022).

African dairy producers feeding their cattle on natural pastures, crop residues, green feeds, hay, non-conventional feeds such as brewery by-products and liquid brewers yeast were using agro-industrial by-products and combine them with other concentrate mixes (Duguma & Janssens, 2016). The significance of investigating inexpensive and nutritious inexpensive feed resources, such as the use of liquid brewers yeast (LBY) as a nutrient dense protein supplement in the production of dairy products, contributed to the increase in the productiveness of dairies and the management of the problem of scarce feeds and the effects of climate change. Such sources and types of feed significantly contributed to the achievement of nutritional requirements of dairy cows, and this was in the context of delivering the necessary nutrients to produce milk at its best (Duguma *et al.*, 2017).

The methods that these farmers used to resolve the feed shortage included the enhancement of storage capacity, molasses, the purchase of shredding machines, and the use of non-traditional feeds in times of deficiency like local brew waste, bean and pea hulls, and sugarcane tops (Simone *et al.*, 2024).

The implementation of dairy feed technology bundles had been proven to positively affect the production of milk, which illustrates the importance of the technological solutions in increasing the feed sources among the smallholder dairy farmers (Akzar *et al.*, 2023). Further, various interventions, like modification of wheat straw with urea and yeast culture, had also been tried to enhance nutritional value of the feed resources that dairy cattle consumed to demonstrate all the attempts being made to achieve optimal use of the feed resources in smallholder dairy farming systems (Kashongwe *et al.*, 2017).

The small dairy farms in Kenya relied on the pasture based diets, grass and crop residues formed the key sources of the feeds and the milk production of the lactating cows. As much as these pasture-based diets were cheaper than the imported grains which were then being used in the production of dairy in the developed world, they were in most occasions

less nutritious and they produced An inadequate amount of milk in contrast to mixed ration diets (Florez et al., 2024). To replenish the amounts that were lacking in roughages, there were some attempts of adding the concentrates such as maize bran, cotton seed cake, sunflower seed cake, leaf meals, and mineral-vitamin premixes in the smallholder dairy cows feed mixture in Kenya (Nyokabi *et al.*, 2022).

Dairy farmers in the Nakuru County applied a wide range of feed varieties to maximize the cow wellness and milk formation, especially when there was a lack of feed. The feeding plans were adjusted to the climate and availability of resources in the region and as such the dairy cows obtained sufficient feeding during the year round. Some of the major types of feeds used were Indigenous grasses, Napier grass, Brachiaria, Rhodes grass, Kikuyu grass, fodder sorghum, lucerne, and other types of supplementary feeds, which played a vital role in ensuring that milk was produced at a steady rate. The diet was improved with Commercial Concentrates and TMR, which have a higher content of crude protein as commercial concentrates (Boniface *et al.*, 2019; Nyokabi *et al.*, 2022).

Other methods like preserving hay and silage were critical in mitigating a shortage of feeds (Hussain *et al.*, 2023). Drought-tolerant grasses such as Brachiaria were introduced that boosted the milk production and domestic earnings (Kabirizi *et al.*, 2013). The County Government of Nakuru, the Department of Livestock Production, extension services and other service providers were important in advising the farmers about the feed sources and improving the dairy farming practices to increase the productivity. The entities had guidelines and supports depending on the needs and conditions of the region, which allowed farmers to get the best possible type of feed and approaches to ensure that their dairy cattle had optimal health and high production of milk (Mucoki *et al.*, 2022).

There are multiple factors that were facing smallholder dairy farmers in the world, which affected their usage of suggested animal feed and livestock productivity and livelihoods. Decisions in regard to smallholder farmers were influenced by the quality and the availability of recommended animal feed. Poor quality of feed caused inadequate nutrition to livestock, which led to the reduction in milk production and health problems (Paul, 2019).

Economic reasons as the price of the recommended feeds were important determinants of adoption. Smallholder farmers are also operating under constrained financial limits making it difficult to afford feeds of a better quality. The cost of inputs was instrumental in the adoption of recommended feeding practices by the farmers. Information and agricultural extension services were also necessary to promote the use of recommended animal feeds. The farmers were provided with the effective training programs that assisted them in learning

about the advantages of the enhanced feeding practices and how to achieve them (Shanthararaju *et al.*, 2024).

Accessibility of infrastructure, e.g., transportation and storing facilities, was critical in the capacity of the farmers to obtain and employed the recommended feeds. The lack of infrastructure resulted in the inefficiencies of the supply chain, which caused the inability to obtain quality inputs in time (Alaru *et al.*, 2022). Climate change had an impact on the supply and quality of forages, and this affected the choice of farmers on the use of feeds. The quality and the amount of the available feed were affected by seasonal changes, including droughts, which affected overall productivity (Shanthararaju *et al.*, 2024).

Market forces such as availability of markets of dairy products and demand of quality milk also played a significant role in determining the decisions of farmers in terms of feeds. The higher the demand of producing high-quality milk was, the more likely farmers were to invest in suggested feeds (Maleko *et al.*, 2018). The reason behind low adoption was insufficient knowledge on the benefits of recommended feeds and the ways of managing them. Understanding of nutritional benefits of better feeds or the best practices that could be applied by many farmers was not known to most of them (Opoola *et al.*, 2019). More farmers face the problem associated with the lack of quantity and quality feed and are forced to experience an imbalance in metabolizable energy and crude protein in their feed, which affect the milk output and the overall well-being of livestock (Paul, 2019).

### **2.3 The Costs and Benefits of Using Forages and Concentrates to Smallholder Dairy Farmers**

Farmer profitability was pegged on the minimization of milk losses (Bach, 2023). The strategic use of certain feed sources in the world also gives smallholder dairy farmers the economic benefits and productivity increase. Implementation of forage technology in Cambodia decreased women and children labour loads on farms, improved household income, and had a promising future of livelihoods among smallholder cattle farmers. The profitability of dairy production depended on efficiency in feed-to-milk ratio as the costs on feed accounted a substantial percentage of the total costs of production, which was up to 70 percent given the volatility of milk and feed prices at the moment (Chagwiza, 2022).

Animal agriculture had been working towards increased production efficiency to ensure an adequate supply of food and fiber at a profitable position to the producer. The cost of milk production and financial performance was a vital indicator of sustainable dairy farming and economic competitiveness and the measurements such as feed cost per day and

income over feed cost would help farmers make informed decisions about their feeding regime and possible financial profitability (Balem *et al.*, 2022).

The consumption of milk per capita among the Africans had greatly increased over the years and was estimated to keep on increasing steadily over the years (Nirmala *et al.*, 2023). The use of particular feed sources was helpful to the smallholder dairy farmers. The study in Ethiopia showed that the implementation of a better forage-based system of feeding resulted in a 36 percent higher milk yield with 26 percent higher advantage relative to the conventional methodology (Simone *et al.*, 2024). Moreover, the use of multipurpose forage legumes and non-conventional protein sources in diet development also led to cost-effective feeding solutions of smallholder dairy production, saving up to 30 percent of the expenses in comparison with traditional-based concentrates (Dey *et al.*, 2022).

Diets based on multipurpose forage legumes were vital in the Sub-Saharan Africa because of the production of small dose dairy by small scale farmers as alternative to commercial protein concentrates (Chakeredza *et al.*, 2008). As well, in Tanzania technical efficiency analysis found that the cost of feed constituted a large portion of the smallholder dairy cost center highlighting the importance of strategies such as group organization of input purchased to minimize costs and improved profitability (Mbilu, 2015).

The dairy industry in Kenya used to raise Friesian, Guernsey, Ayrshire, Jersey cows, and their crossbreeds, but in this case, they were mostly crossbred with the native East African Zebu to maximize the milk production potential (KNBS, 2019). Although Kenyan indigenous cattle had high genetic capacity regarding milk production, better management and diet increased productivity further (Graham *et al.*, 2024). The benefits of nutrient-dense feed resources such as liquid brewers yeast (LBY), climate-smart Brachiara grass, agroforestry with Calliandra calothyrsus and Sesbania sesban shrubs had been demonstrated to have positive effects on dairy farming including increased productivity per cow, improved income, and livelihoods as indicated by higher profits, lower feeding costs and better knowledge on dairy cow nutrition by the farmers. Nonetheless, their introduction to feed sources had some factors, such as the level of awareness, age, experience, herd size, type of breed, and provision of extension services, and more awareness and support should be provided towards their large-scale adoption by smallholder dairy farmers in Kenya (Alaru *et al.*, 2022).

Also, wheat bran sweet potato vine silage as a GM supplement had proven economically efficient and matched grain-based concentrates in milk production, providing an alternative to dairy farming systems in Kenya that are sustainable (Gakige *et al.*, 2020).

Furthermore, the application of agricultural technologies, such as the use of better feeds, such as hay and silage played a critical role in productivity and income growth in the dairy smallholder farmers, and the factors such as education level, type of livestock, land, access to credit, and dairy cooperative membership affected the probability and severity of technology adoption (Okello *et al.*, 2021).

#### **2.4 Feed Supply and Effect on the Health, Milk Yield and Economic Return of the Dairy Cattle**

The world animal feed market was growing in a steady manner with the growth in demand of meat, dairy products and other related animal products. As of 2022, the animal feed market size in the world was estimated at USD 463 billion and was projected to increase at a compound annual growth of approximately 4.5% between 2023 and 2030 (GVR, 2022).

United States was the largest producer at about 220 million metric tons of animal feeds mostly of the corn and soy bean meal whereas Canada had about 8 million metric tons of animal feeds mostly of the barley and corn. Production in the EU was about 150 million metric tons of which the main grains were wheat and barley. China led the world at 230 million metric tons in the Asia-Pacific with 30 million metric tons of India. The drought conditions had proven to lower the yield and digestibility of the forage maize that is a major source of dairy cow feed, which directly influenced the milk production. In a meta-analysis, the increased drought and high levels of Carbon dioxide resulted in reduced forage quality, and the crude protein content reduced by 19.7 because of drought pressure (Liu *et al.*, 2023).

The severe weather increased the volatile feed costs, forcing dairy farmers to find more homegrown forage, which were difficult to find without reducing quality (Liebert *et al.*, 2023). Food and feed crops have arable land competition that will restrict the supply of good-quality forage, putting additional pressure on the dairy production (Milenković *et al.*, 2023).

The feed production/consumption environment in Africa was highly regionalized and it depended on traditional sources of feed. As of 2023, the production of total compound feed is about 40 million metric tons, including large contributions by such countries as South Africa (4 million metric tons) and Nigeria (2 million metric tons) (Alimi *et al.*, 2024). Approximately 7 million metric tons of feeds, mostly soybean, are imported in Africa every year. The feed per capita consumption is low and has an average of 0.5 metric tons per unit of livestock in Sub-Saharan Africa, which is equivalent to 1.5 metric tons in Europe and North America (Van der Poel *et al.*, 2020).

In Sub-Saharan Africa, the nutritional deficiencies of animals caused by a lack of adequate feed are estimated at about 60 percent (Baris, 2023). The lack of minerals and vitamins resulted in metabolic disorders and diseases, including rickets and anemia, which also worsened the state of animals (Kokolova *et al.*, 2024). In Ethiopia, the milk production per feed was boosted by 15% with the use of improved feed management which resulted in more milk production with less feed (Andrighetto *et al.*, 2023). Better feeding procedures increased the milk production by 20-30 percent and high-quality feed enabled dairy cows to yield up to 15 litres of milk per day. In Uganda, the economic value of high-quality feed was reported after farmers who embraced the use of improved feeding methods realized a 25 percent increase in net returns. Nevertheless, the price of quality feed was an obstacle, as was observed in Zambia, where the prices of commercial feed were up to 500 USD per ton (Baris, 2023).

In Kenya, the feed sector was developing with the current production of about 1.2 million metric tons of animal feed in 2023, but there are significant challenges in the sector. The major sources of feed were forages, crop residues and commercial feeds and local production had to be supplemented with imports. Natural pastures and developed ones such as Napier grass were very important. Wheat by-products like maize stover and wheat straw were important. The local mills were used to produce concentrates, yet 500,000 metric tons of ingredients, such as soybean meal, had to be imported (Masese *et al.*, 2022). Diets that had high quality are known to increase milk production tremendously; farmers who feed with high-quality feeds test yield up to 15 litres per cow per day with a number of 10 litres per cow recorded by farmers who feed with low-quality feeds. A higher level of feed efficiency increased milk production by up to 20 percent by improving feeding habits to optimize the utilization of available feed (Olorunkoya *et al.*, 2024).

The production of forage and feeds in Nakuru County was marked by tremendous inputs made by different sources and Napier grass was the dominant forage. In 2023, the County yielded about 200,000 metric tons of forage, of which approximately 120,000 metric tons were Napier grass: ordinary and super (Pakchong) (Ambaw *et al.*, 2024). Local feed mills added an extra 50,000 metric tons of commercial animal feed annually, the average cost of macronutrients that played a major role in livestock health indicated that the prices of protein and lipids have a significant effect on overall feed costs, with protein shadow prices averaged at 0.4373 Ksh/g (Kappes & Marsh, 2020). The forage availability was affected by seasonal variation, especially when it was dry, and the decrease was usual (30-40) (Tlahig *et al.*, 2024).

The quality of the diets fed to the cattle in Nakuru County was also found to have a great influence on the nutritional health of the dairy cattle with 60 percent of the cattle being affected by the quality of diets deficiencies that resulted in negative health consequences to the cattle. The quality of the feeds especially Napier grass that was well maintained improved the health and productivity of the cattle leading to reduced veterinary expenses and bigger milk production. Poor quality of feeds leads to low weight gain, low fertility, and increased vulnerability to diseases (Baris, 2023). The cattle on the napier grass and commercial feeds will see their mastitis rates cut down by 30% and other related health complications (Islam *et al.*, 2024).

The cattle that were fed on quality feed gave 12-15 litres of milk per day as opposed to 8-10 litres of milk per day when fed on low-quality feeds. Improved feed conversion efficiency (20% better) was a result of enhanced feed management (Islam *et al.*, 2024). Farmers claim that even with commercial feed prices ranging at 400-600 per metric ton the net returns would improve by 20-25 percent because of increased milk production and less veterinary bills. Although the advantages of good feed were obvious, the barriers to using them like the availability of extension services or even the affordability of good feeds were still a problem to most of the farmers in Nakuru County (Ogola *et al.*, 2023).

## **2.5 Critical Analysis and Research Gaps**

The available literature on the subject of smallholder dairy farming in Nakuru County Kenya mainly discussed general issues relating to milk production, animal health, and access to markets among others but did not give much information on the type and amounts of forage and concentrates cows should get in a specific locality. This loophole did not allow the researcher to have a thorough perception on the effects of feeds types and quantity on milk output and profitability. Although extensive research was often written on the general feeding practices, it did not carry out a thorough and analytical analysis of the specific nature and amount of forages and concentrates employed and the direct impacts of the same on profitability and productivity among smallholder dairy farmers. This lack of particular data restricted the possibility to evaluate the economic impact of different types of feed and different levels, which revealed the necessity to carry out additional studies in the field. Thus the study addressed this gap as recommended forages and concentrates applied by smallholder dairy farmers at Nakuru County were studied and the study resulted in determination of milk yield and profitability.



Particularly, it examined the effects of change in the number of feeds fed and consumed on the yield and profitability of milk. Using the production theory, the study determined the efficiency of the smallholder farmers in converting inputs (including forages and concentrates) into outputs (milk yields) and factors that influenced their capacity to comply with the recommended amount of feed to maximize profit.

### **2.6.2 Resource Use Efficiency (RUE) Theory**

Resource use Efficiency (RUE) Theory was described as the correlation between the elasticity of resource use and economic production, which focused on non-linear approach to resource dynamics (Marchenko, 2024). RUE Theory emphasized the relevance of effective resource deployment to attain greater productivity, especially in small and marginal farmers, where the inefficient application caused large output losses (Narayanan *et al.*, 2023).

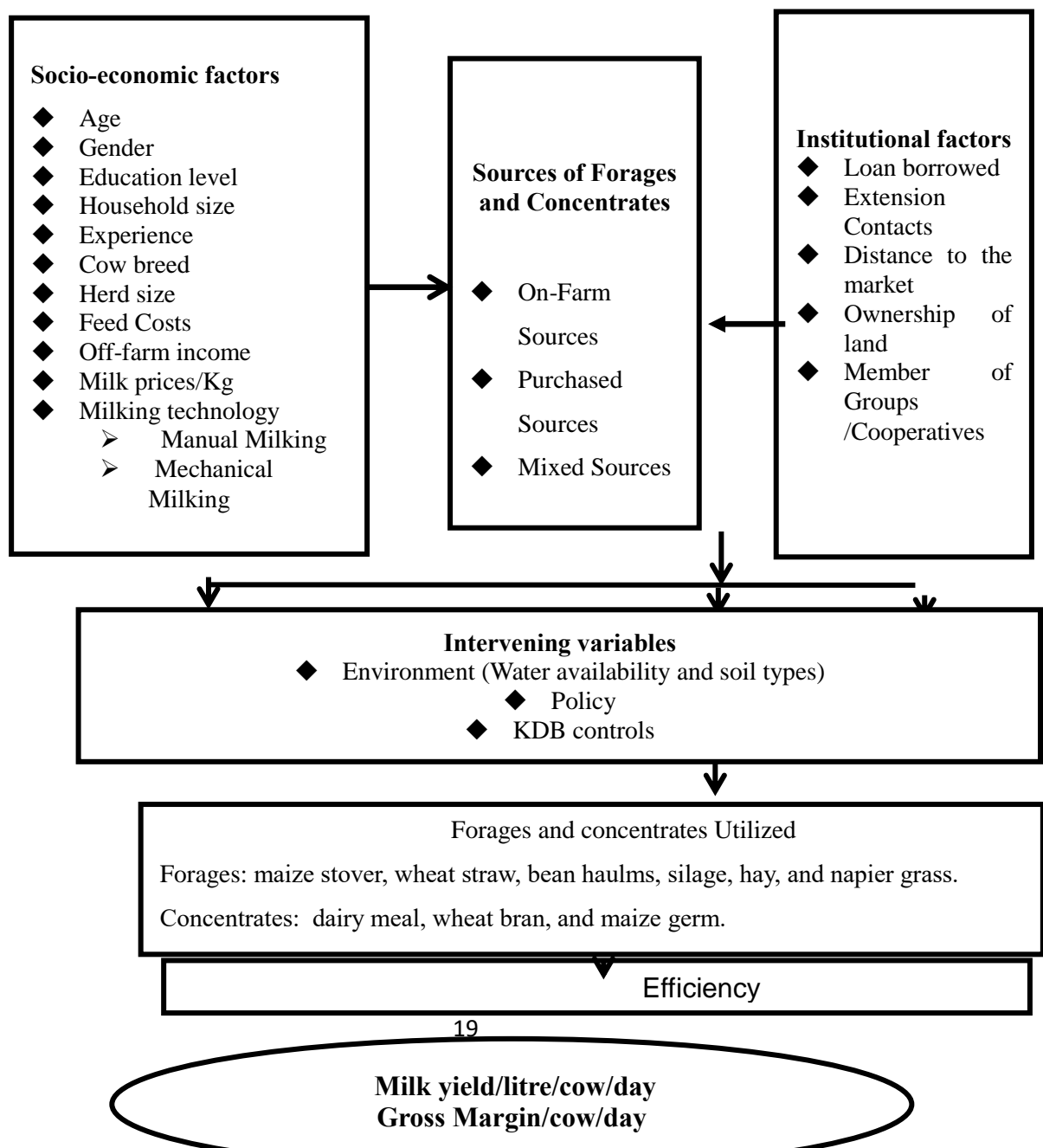
The Resource Use Efficiency (RUE) Theory was applicable in the research of smallholder dairy farmers in Nakuru County, Kenya as it focused on the most efficient use of resources such as forages and concentrates to increase the dairy farmers in terms of milk production and profitability. This theory emphasized on the significance of utilizing inputs making the best possible output with minimum wastes. Through emphasizing the effective application of recommended forages and concentrates by the Smallholder dairy farmers, the study sought to see which strategies resulted to the increased milk production, at the lowest input cost. Moreover, approximating expenses and profit of applying suggested forages and concentrates provided an opportunity to include a clear-cut evaluation of whether the investment in these resources provides considerable returns, which validates the applicability of RUE Theory in advancing the smallholder dairy farmers to sustainable and profitable business.

### **2.7 Conceptual Framework**

Theoretical framing of the study in the determinants of utilization of the recommended forages and concentrates by smallholder dairy farmers in Nakuru County, Kenya, was conceivable to get a chance to model the dependence and independent variables. Age, gender, education level, household size, dairy farming experience, cow breed, feed costs and off-farm income among others were the socio-economic factors that cause the use of the recommended forages and

concentrates. These were the factors which influenced the decision of the farmers regarding the sourcing and usage of feeds.

The institutional factors were also known to be important and some of these factors were access to loans, market contacts, and distance to markets, land ownership, cooperative or group membership among others. These factors determine the capacity of farmers to make good use of the suggested forage and concentrates. It was assumed that those farmers who optimize the application of the recommended feeds would have increased milk yields and better gross margins because of better nutrition of their cattle. Therefore, the knowledge of these determinants played an important role in coming up with measures that improved dairy farming practices and economic performances in Nakuru County, as shown in Figure 1.





**Figure 1: Conceptual Framework**

## **CHAPTER THREE**

### **RESEARCH METHODOLOGY**

#### **3.1 Introduction**

The different procedures of data collection and analysis were outlined in this chapter. It started with an elaboration of the study area and the research design, it talked about the sample size, sampling procedure, and data collection methods. Lastly, it also gave a detailed analytical framework of each objective, which defined the modeling and econometric methods applied.

#### **3.2 Study Area**

Nakuru County, situated in Kenya's Rift Valley region, covering approximately 2,543 square kilometers. It shares borders with Baringo, Laikipia, Nyandarua, Narok, Kajiado, and Kericho Counties. The County's diverse economy include agriculture (maize, horticulture, and floriculture), livestock rearing, and industrial activities. The County's population of approximately 2.4 million comprises both rural and urban communities, indicating a blend of lifestyles and economic activities (KPHC, 2019).

The County lies between Latitude 0° 18' 11.156" N and Longitude 36° 4' 48.094" E, approximately 300km Northwest of Nairobi, with an area of 1997.9 km<sup>2</sup>. The temperature of the County is 20 o C per annum with monthly precipitation of 1100mm to 1500mm in two rainy seasons long rains of March to May and short rains of August to October. Nakuru County has a significant dairy sector alongside its main economic activity of maize production, with common livestock-rearing practices involving cattle, goats, sheep, and poultry (Nakuru County CIDP, 2020).

Smallholder dairy farming is vital in the Sub-Counties of Njoro, Molo, Rongai, Subukia, and Naivasha within Nakuru County. Njoro led with approximately 3,500 smallholder farms, producing around 15 million litres of milk annually, with each farm averaging a herd size of 3 to 5 cows. Following closely, Molo hosted about 3,200 smallholder farms that contributes roughly 12 million litres of milk each year, averaging 2 to 4 cows per farm. Rongai, with nearly 2,800 smallholder farms, produced approximately 14 million litres of milk annually, maintaining a similar herd size of 3 to 5 cows. Subukia features around 2,500 smallholder farms, yielding about

10 million litres of milk per year, with an average herd size of 2 to 4 cows. Lastly, Naivasha, primarily known for horticulture, also supports around 2,000 smallholder dairy farms, producing approximately 8 million litres of milk annually, with an average herd size of 2 to 3 cows (Nakuru County CIDP, 2020).

This was researched in the Njoro and Molo Sub-Counties of the Nakuru County in Kenya (Figure 2). Mauche, Lare, Kihingo, Nessuit, Mau Narok, and Njoro are the wards that constitute Njoro Sub-County and it has an area of 713.3 square kilometers and a population of about 238,773 (KPHC 2019). Njoro Sub-County is located at a longitude of 35° 45 0 to 36 10 0 East and a latitude of 0 15 0 to 0 42 30 South and an altitude of 1,800 above the sea level. The major economic activities are barley, wheat, potato farming, dairy and horticulture. One of its major environmental resources is the Mau Forest occupying 885 square kilometers contributing to the 1700mm of the rainfall each year in the region, the Mau Forest was selected specifically to make the study relevant since dairy farming was among the primary economic activities of the Sub-County. The rural dairy farmers in the Sub-County have 2 to 5 cattle with a farm size of approximately 1 to 2 hectares (Smollo *et al.*, 2016).

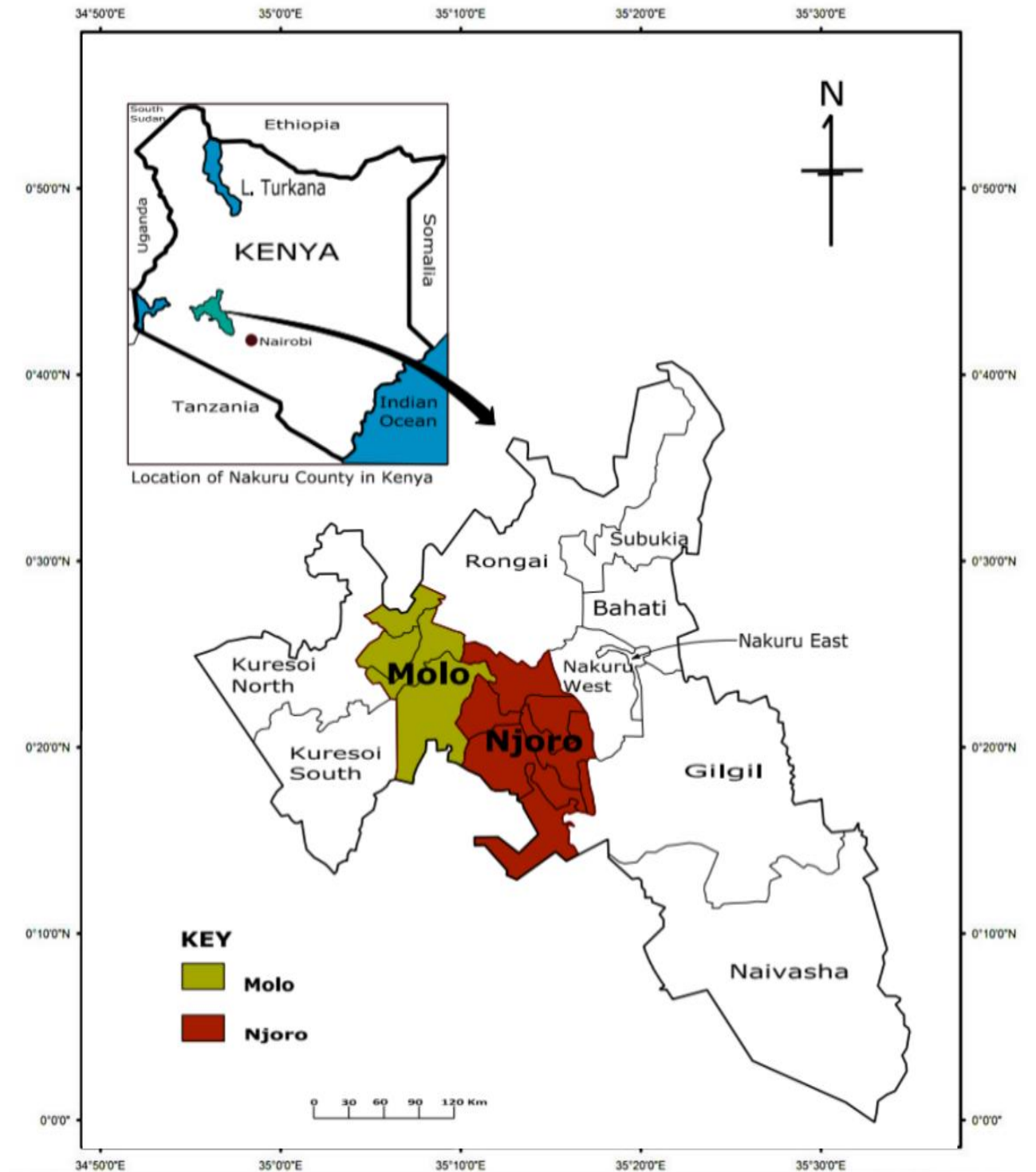
Molo Sub-County is 478.7 sq.km, out of which 69.6 percent of the area is arable. The average rainfall is 800-1681mm/ year, and the temperatures are 9-28C. The households and the farm families constitute 30,783 and 27,375 respectively with the average landholding of 1.3 ha. The different soils in Molo, including sandy loams, sandy clay, clay loams and mollic andosols are favorable to the cultivation of various crops like wheat, maize, beans among others that were rotated with fodder crops that sustained dairy farming. Njoro and Molo Sub-Counties, which are found in Nakuru County, have similar agro-ecological attributes as the County, as they enjoy the benefits of good agricultural and livestock production. The dairy industry in the Njoro and Molo Sub-Counties is also a major contributor to livelihoods of the local population and is also a source of overall economic growth of the area (Nakuru County CIDP, 2020).

The two Sub-Counties within the Nakuru County have a lot of potential in the dairy sector because of the favorable climatic conditions and the soil fertility. The difference in altitude and temperature in Sub-County Njoro has provided a unique environment to dairy farming, which is flourishing throughout the year. High quality

milk production is possible because the volcanic soils are very good in terms of drainage and nutrient content to support growth of pasture. The slightly larger average landholdings in the Molo Sub- County and the variety of the soil types enable a larger variety of fodder crop to be grown there. The relatively more precipitations received in certain regions would guarantee sufficient supply of water to crops and livestock, which is essential in keeping dairy herds healthy. Nakuru County, Njoro and Molo Sub-Counties have favourable soils and sufficiently high rainfall amounts, which allows the country to cultivate nutritious dairy-fodder to boost the productivity and sustainability of the dairy industry in the regions (Nakuru County CIDP, 2020).

The two Sub-Counties selected purposely in Nakuru County to be incorporated into the study based on their distinctiveness especially their geographical position, the level of milk production, the variety of dairy activities and the presence of small scale dairy production. The two Sub-Counties undertook the greatest concentration of dairy related activities in the country that included production, processing and consumption.

The map (Figure 2) showed the study area which was Njoro and Molo Sub-Counties of Nakuru County, Kenya.



**Figure 2: Map of the Study Area**

**Source:** Geography Department, Egerton University (2024)

### 3.3 Research Design

Research design denoted the general plan adopted by the researcher in combining diverse aspects of the research in responding to the research problem (Gogo & Musonda, 2022). The present survey was based on a survey design to assess the factors that could determine the adoption of recommended forage and concentrates by smallholder dairy farmers in the study location. It was cross-sectional and it involved a one-year recall of the survey. The design that was applied in the description of the characteristics of a population or a phenomenon under study was termed as descriptive design (Ahlstrom *et al.*, 2013). Data on the sampled population was used to make generalization when it came to the rest of the population.

### 3.4 Sample Size Determination

The population of interest constituted about 17, 000 smallholder dairy farmers in Njoro Sub-County. What appears to be the estimated number of smallholder dairy farmers in Molo Sub-County was about 11,159 (CDLP, 2023). Smallholder farmers in this case were large scale dairy farmers. They usually had less than 5 dairy cows and they work on less than 1 hectare of land usually using zero-grazing production methods. The target population was equal to the accessible population of the study.

The formula to be used in determining the sampling size required was derived by Nassiuma (2001), as highlighted in **Equation (2)** below:

$$n = \frac{NC^2}{C^2 + (N-1)e^2} \dots\dots\dots (2)$$

Where: n = the necessary sample size; N = target population; C = coefficient of variation and e = the standard error value.

In the majority of surveys, Nassiuma (2001) argued that a coefficient of variation of between 21% 2 C and 30% and a standard error of between 2% and 5% were acceptable. A coefficient variation of 30% and a standard error of 2 were used, therefore, in the study. The maximum value of the coefficient of variation was set to the lowest possible value and the minimum value of standard error was set to be low so that the variability and the error can be low.

The sample size was estimated in the following way:

$$n = \frac{28,159 \times (0.3)^2}{(0.3)^2 + (28,159-1)(0.02)^2} \dots\dots\dots$$

(3)

$n = 224.68 \approx 225$ . In this way, the sample size of the smallholder dairy farmers in Njoro and Molo Sub-Counties of the Nakuru County, Kenya was 225.

### 3.5 Sampling Procedure

The small holder dairy farmers sampled in each of the study areas were selected through proportionate random sampling. In this approach, all subgroups in the sample were proportional to the real representation of the sample in the overall population. Proportionate random sampling also made sure that all the sub-populations were not excluded in the sample and also prevented overloading of some sub-populations (Borg & Gall, 1984).

The respondents were selected using a multistage sampling method to the study. On the larger scale, the research was done on the dairy farming in Kenya, and purposely chosen at the first stage the Nakuru County based its importance on dairy farming activities. The second stage involved purposive selection of Njoro and Molo Sub-Counties in Nakuru County due to the large number of smallholder dairy farmers in the two Sub-Counties. The third and last stage was the selection of smallholder dairy farmers of individual Sub-Counties by systematic random sampling. A known population of the smallholder dairy farmers of Njoro and Molo Sub-Counties was used to select the final list of 225 households using agricultural offices list, Systematic sampling technique was used.

First, the sampling interval (n) was calculated by dividing the total number of households in the population (28,159) by the desired sample size (225). where a sampling interval of approximately 126 was obtained. Therefore, 126<sup>th</sup> farmer was selected as the first respondent. From there, the next 125 farmers were skipped and selected the 126th farmer as the second respondent. and the process continued, until the target of 225 respondents were obtained. Table 1 shows that 225 out of the known population (smallholder dairy farmers) in Njoro and Molo Sub-Counties were selected as the sample used to study the population.

**Table 1:** Sample Size Distribution of the Respondents in the Area of the Study

<b>Sub-ounties</b>	<b>Number of the dairy farm households</b>	<b>Proportion</b>	<b>Sample size</b>
Njoro	17,000	60.371%	136
Molo	11,159	39.629%	89
<b>Total</b>	<b>28,159</b>	<b>100%</b>	<b>225</b>

**Source:** (CDLP), 2023

### 3.6 Data Collection and Analysis

Primary data was on the interview basis through interviewing the respondents and personally administering the questionnaires to the smallholder dairy farmers. The primary data were collected using semi-structured questionnaires that contained both closed and open ended questions. To examine the validity and reliability of the questionnaire, a pilot study was carried out before the real data collection was made. The questionnaire had been pre-tested using a sample of 25 smallholder dairy farmers. Analyses of the data obtained were done using the Probit Model, Cobb-Douglas Stochastic frontier model and Gross Margin Analysis. The data were analyzed with the help of STATA software.

### 3.7 Analytical Framework

The data collected were analyzed to align with the specific objectives.

#### **Objective One: To determine the factors influencing the choice of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya**

The different types of feed and forage concentrates and types of forages applied on the smallholder dairy farms in Nakuru County, Kenya were recorded using a descriptive statistic. This analysis categorized the feed sources into two main groups: On-Farm Sources and Purchased Sources. To measure if the forages and concentrates were recommended or not, the study assessed farmers' usage based on established guidelines from agricultural extension services and the County Government of Nakuru. Common recommended forages included Napier grass (*Pennisetum purpureum*), Brachiaria (*Brachiaria ruziziensis*), fodder oat (*Avena*

*sativa*), lucerne (*Medicago sativa*), leucaena (*Leucaena leucocephala*) and indigenous grasses like Kikuyu grass (*Pennisetum clandestinum*), African stargrass (*Cynodon plectostachyus*), Couch grass (*Cynodon dactylon*) and African foxtail grass (*Cenchrus ciliaris*) among others.

The recommended concentrates were commercial products with high crude protein content such as oil seed cakes-cotton seed, sunflower, canola and maize germ, high energy content like molasses, wheat and maize bran, high mineral content in the form of mineral licks. These commercial products were fed individually or in combination either in Total Mixed Ration (TMR) or dairy meal in the different farms. Farmers' choices were compared to these recommendations based on the types of forages and concentrates they use and whether they meet the nutritional and environmental suitability criteria for the region. Farmers were surveyed to identify which specific forages and concentrates they were utilizing, and their compliance with the recommended options recorded.

The recommendations are done through research-KALRO, Universities and any other research organizations that conduct forage and dairy cattle research. These trickle down to the farmers by way of extension officers. By selecting the recommended forages, farmers were able to produce adequate forage round the year by conserving the excess during the wet season for use in the dry season and also by having forages that are drought-tolerant hence produce forage during the dry spell.

For concentrates, the perspective is nutritional quality and safety. From the nutritional point of view, concentrates are used as supplements-to correct a deficiency or deficiencies in the main feed. Therefore, the use of concentrate (quality and quantity) recommended based on the deficiency of the main feed.

From the safety point of view, it is recommended that feed should be safe-not harmful to the animals and humans who consume the products e.g milk. The feed should not impart off-flavour in the milk e.g feeding mouldy feed (silage/hay) leads to aflatoxins in milk. This will cause ill-health to the cattle and humans who consume the milk. Similarly, there are certain forages that cause ill-health to cattle, hence decline in productivity. These recommendations are generated from animal nutrition and food science research, which reaches farmers via extension agents.

The data were summarized and presented by applying descriptive statistics in the mean, percentages, frequencies and standard deviations. Chi-square and T-tests were used to make a comparison between the household

and farm characteristics of the farmers who used various ratios of types of feeds. Those were presented in the form of tables and charts to explain a full picture of the recommended types and sources of feeds and how they are used by the farmers in the study area. The t -test compared the difference in mean difference in continuous variables between groups of farmers who applied various combinations of feed types (e.g., farm size, household income, or milk production). This aided in establishing whether there were any significant differences in factors like performance of the farms or household attributes depending on feed mixes applied. The Chi-square test was employed to determine the relationship between variables that are categorical. It determined the presence or absence of significant relationships between the choices of feed types and such factors as institutional, or demographic.

In order to examine the determinants that affect the decision to utilize the recommended forages and concentrates among the smallholder dairy farmers, the research adopted a Probit model. Such a probabilistic model as the logistic, linear probability model and probit models were suitable in the analysis of the factors that affect the decision by the smallholder dairy farmers to use recommended forages and concentrates. The independent variable was the decision of the farmer to utilize the suggested forages and concentrates. The response variable was binary in nature and hence, the three models were suitable. Nevertheless, the research employed the probit model due to the fact that it assumed that the data was normally distributed, which was in line with the underlying assumption of the probit model, which was the existence of a normal cumulative distribution.

Although both the logistic and probit models were good in working with binary outcomes where they usually yielded similar results, the probit model was more applicable as a result of the data being normally distributed. The linear probability model also had no restrictions on the predicted probability rates of 0-1; hence it was not applicable in this analysis (Wooldridge, 2008). This predisposed the probit model as more appropriate to test the issue that determined the decision of the smallholders dairy farmers to use the recommended forages and concentrates. According to Nielsen and Pedersen (2020), farmers will always be rational given the resources and

technology at their disposal in case of traditional farming. Since nothing was given away freely, then the reproduced the prices of the feeds, and assuming that the household income equated to the household expenditures, then the total income ( $Y$ ) was modeled as shown below:

$$Y = p_1X_1, p_2X_2, \dots, p_nX_n \dots \dots \dots (4)$$

The reliance on the recommended feeds however, was based on not only observable characteristics of the farmer, but on some non-observable characteristics, which, without balancing, it over-estimated, under-estimated, and claimed to be affecting where it actually had no effect whatsoever. Socioeconomic, demographic, institutional, financial, and market factors formed the variables that limited the ability of the farmer households to decide how to use the recommended forages and concentrates (Thirunavukkarasu & Jothilakshmi, 2023). Thus, the farmers were divided into two groups: those who fed their cows with both forages and concentrates and those who feed their cows with forages only. Then, was stated as follows:

$$P_{it} = f(X_1, X_2, \dots, X_n) \dots \dots \dots (5)$$

where  $P_{it}$  is 1 where a farmer used both forages and concentrates to feed their cows, and  $P_{it}$  is 0 where a farmer used forages only to feed their cows.  $X_1, X_2, \dots, X_n$  was the household characteristics of a farmer and other factors that were used in establishing whether a farmer will choose to use the recommended forages and concentrates. We can see the values 0 and 1 of the variable, and the latent non-observable continuous variable that controls the binary censoring, i.e., the benefit that the smallholder farmer gains by using the recommended forages and concentrates is represented as follows, as  $P^*_{it}$  represented the critical point of the decision for a farmer to use the recommended forages and concentrates.

$P^*_{it}$  was specified as follows:

$$P^*_{it} = \beta_0 + \beta_1X_1 + \beta_2X_2 + \dots \dots \dots + \beta_nX_n + \varepsilon_{it} \dots \dots \dots (6)$$

and that  $P_{it} = 1$  if  $P^*_{it} > 0$  (if a farmer used both forages and concentrates)

$P_{it} = 0$  if  $P^*_{it} \leq 0$ , (if a farmer used only forages)

From (6)  $P_r(P = 1) = P_r(\beta_0 + \beta_1X_1 + \beta_2X_2 + \dots + \beta_nX_n + \varepsilon_{it} > 0 \dots\dots\dots)$   
 (7)

Farmer *i* used both forages and concentrates if  $P_{it} > P^*_{it}, P^*_{it} > 0$ ;  
 Farmer *i* used forages only if  $P_{it} < P^*_{it}, P^*_{it} \leq 0$ ; The error term was assumed to be normally distributed so probability that  $P_{it} \leq P^*_{it}$  was calculated by use of the cumulative normal probability function. In this way, the empirical model of the probit model will look like:

$P^*_{it} = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 \dots\dots\dots + \beta_nX_n + \varepsilon_{it} ..$   
 (8)

$P^*_{it}$  portrayed the propensity of the farmer to use the suggested forages and concentrates,  $X_1, X_2, \dots, X_n$  were explanatory variables which were the factors influencing utilization of the recommended forages and concentrates, coefficients  $\beta_1, \beta_2, \dots, \beta_n$  the consistent estimations of the explainable variables, and  $\varepsilon_{it}$  portrayed the error term that was normally distributed with equal variance.

**Table 2:** Description and Measurement of Variables Used in the Probit Model

Variable Code	Description	Types	Unit of Measurement	Expected Sign
<b>Dependent Variable</b>				
$P_{it}$	Utilization of the recommended feeds only=0		Categorical Forages and Concentrates=1 Forages	
<b>Independent Variables</b>				
Age	Age of household	Continuou s	Years	+/-
Gender	Gender of household	Categorica l	0= female 1= male	+/-
Educl	Education	Continuou s	Years of	+

		s	schooling	
Dfex	Dairy farming experience	Continuou s	Number of years	+
Cw	Cow live weight	Continuou s	kg	+/-
Ncbmc	Number of cross bred milking cows owned	Continuou s	Number	+
Mp	Milk production	Continuou s	Kg	+/-
Cf	Costs of feeds	Continuou s	Kenyan Shillings per Kg	+/-
Dtm	Distance to the market	Continuou s	Kilometers	+/-
Oi	Off-farm income	Continuou s	Kenyan Shillings	+/-
Exc	Extension contacts	Dummy	1=yes, 0=no	+
Mdco	Membership in dairy cooperatives or groups	Dummy	1=member, 0=non member	+/-
Lb	Loan Borrowed	Continuou s	Kenyan Shillings	+/-

Table 2 outlined the description, measurement method, and expected influence on the model of the variables used in the Probit Model. As a result, the implicit functional form which predicted the factors that affected the decision to use recommended forages and concentrates by smallholder dairy farmers took the following form:

$$\ln P_i = \beta_0 + \beta_1 \text{Age} + \beta_2 \text{Gender} + \beta_3 \text{Educl} + \beta_4 \text{Dfex} + \beta_5 \text{Cw} + \beta_6 \text{Ncbmc} + \beta_7 \text{Lb} + \beta_8 \text{Mp} + \beta_9 \text{Oi} + \beta_{10} \text{Cf} + \beta_{11} \text{Dtm} + \beta_{12} \text{Mdco} + \beta_{13} \text{Exc} + \epsilon_i$$

.....  
 ..... (9)

Where;  $\beta_2$  represented choice of utilizing the recommended feeds

$\beta_0$  was a constant,  $\beta_1$  to  $\beta_{13}$  were coefficients,

$\epsilon_i$  was the error term

**Objective Two: To determine the level of technical efficiency of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya**

A Cobb-Douglas stochastic production frontier model was used to determine the extent of efficiency of using the recommended feeds (forages and concentrates) to smallholder dairy farmers, providing a robust framework for measuring technical efficiency and the relationship between input use and milk yield. This approach quantified how variations in utilization of forages and concentrates influenced milk yield.

According to Battese and Coelli (1988), the stochastic frontier production model incorporated a composite disturbance term that included two error components: a stochastic error captured random shocks to production and a non-negative term represented technical inefficiency. This was mathematically represented as follows:

$$\ln Y_j = \ln f(X_{ij}; \beta) + V_j - U_j \quad .$$

..... (10)

$$U_j = \delta_{z_j} + \epsilon_j \quad \dots \dots \dots (11)$$

In this context,  $\ln Y_j$  referred to the natural logarithm of milk output for the  $i^{th}$  dairy farm, and  $\ln X_{ij}$  represented the logarithm of various inputs employed by farm j (forages and concentrates). The parameters  $\beta$  and  $\delta$  were vectors of unknown coefficients that were estimated using maximum likelihood estimation (MLE). The term  $V_j$  captured random variations, were assumed to have a zero mean and an unknown variance while  $U_j$  represented the technical inefficiency affected the milk yield on farm j. Thus, the total error term in the model for farm j for equation 10 was  $\beta_2 = \beta_2 - \beta_2$  (random shock +

inefficiency in milk output). while the Error term for equation 11 was  $\eta_{2j} = \eta_{1j} + \mu_{2j}$  (random shock + inefficiency in profitability).

Two simultaneous equations (10) and (11) were estimated to assess the production function's parameters and the inefficiency effects. The technical efficiency (TE) of production was expressed as follows:

$$TE_j = \frac{Y_j}{Y_j^*} = \frac{Y_j}{Y_j + \mu_{2j}} \quad \dots\dots\dots (12)$$

This model allowed for a thorough examination of how various inputs influenced milk yield and the extent to which inefficiencies exist. The Cobb-Douglas production function was not linear, meant that as the quantity of feed for dairy animals increased, the additional output (milk production) initially rose but eventually reached a point of diminishing returns. At this stage, further increase in feed resulted in progressively smaller gains in milk output. In this study, adopting a Cobb-Douglas stochastic production function aligned with its well-documented virtues of simplicity and widespread application (Bravo-Ureta & Evenson, 1994).

Efficiency was classified into three categories: low efficiency (0% – 49%), indicating significant room for improvement. Moderate efficiency (50% – 79%) reflected a reasonable level of performance, while high efficiency (80% – 100%) indicated optimal use of resources and near-maximal output (Johnes, 2006). This study opted for a truncated-normal distribution for estimating the stochastic frontier, as it provided a more realistic modeling approach for technical inefficiency effects by allowing for a non-zero mode, contrary to the half-normal distribution. This choice was supported by Kumbhakar & Lovell (2003), emphasizing the robustness of the truncated-normal distribution in capturing the intricacies of technical inefficiency in agricultural production.

According to the research of Farrell (1957), Charnes *et al.* (1978) came up with Data envelopment analysis as an empirical method of frontier analysis. Data Envelopment Analysis was a non-parametric effectiveness examination approach that used linear programming to determine the optimal practice or the most efficient production frontier. As a result, the decision-making units that were at the frontier were called technically efficient, a score of 1 and the ones underneath the frontier were considered to be ineffective,

less than 1. All efficiency scores in data envelopment analysis scaled between 0 and 1 and lower scores demonstrated lesser efficiency.

The technical could have been evaluated by means of Data Envelopment Analysis (DEA) efficiency of smallholder dairy farmers yet it had a number of limitations that rendered it less appropriate to this particular end. DEA made an assumption of a deterministic frontier where all were treated as equal breakages of the frontier as inefficiency that does not take into consideration random variations like weather or fluctuations in the market. It did not also distinguish between inefficiency and random shocks to production, which led to inaccurate efficiency scores. These limitations made the Stochastic Frontier Model (SFM) a better choice, as it accounted for both inefficiency and random variation, provided statistical inference, and handled measurement errors more effectively.

**Table 3:** Description and Measurement of Variables Used in a Regression Model

<b>Variable Code</b>	<b>Description</b>	<b>Types</b>	<b>Unit of Measurement</b>	<b>Expected Sign</b>
<b>Dependent Variable</b>				
$Y_i$	Milk yield	Continuous	litres	
<b>Independent Variables</b>				
Age	Age of household	Continuous	Years	+/-
Gender	Gender of household head	Categorical	0= female 1= male	+/-
Educl	Education	Continuous	Years of schooling	+/-
Dfex	Dairy farming experience	Continuous	Number of years	+/-
Afu	Amount of feed utilized	Continuous	kg	+/-
Hs	Herd size	Continuous	Number	+/-
Mt	Milking technology	Categorical	Manual Milking, Mechanical Milking	+/-
lc	Input costs	Continuous	Kenyan Shillings per Kg	+/-
Exc	Extension contacts	Dummy	1=yes, 0=no	+/-
la	Information access	Dummy	1=yes, 0=no	+/-
Wi	Water intake	Continuous	gallons	+/-

Table 3 outlined the description, measurement method, and expected influence on the model of the variables that were used in the Stochastic

Frontier Model. Consequently, the implicit functional form estimating the level of technical efficiency in utilizing the recommended forages and concentrates for smallholder dairy farmers was as follows:

$$\ln \hat{Y}_i = \beta_0 + \beta_1 \ln \text{Age} + \beta_2 \ln \text{Gender} + \beta_3 \ln \text{Educl} + \beta_4 \ln \text{Afu} + \beta_5 \ln \text{Dfex} + \beta_6 \ln \text{Hs} + \beta_7 \ln \text{Mt} + \beta_8 \ln \text{Ic} + \beta_9 \ln \text{Exc} + \beta_{10} \ln \text{Ia} + \beta_{11} \ln \text{Wi} + V_i - U_i \dots \dots \dots$$

(13)

where;  $\ln \hat{Y}_i$  represented the natural logarithm of milk output and profitability,  $\beta_0$  was a constant,  $\beta_1$  to  $\beta_{11}$  were the parameters estimated, and  $V_i - U_i$  was the error term.

**Objective Three: To determine the profitability of utilizing recommended forages and concentrates for smallholder dairy farmers in Nakuru County, Kenya**

To determine the costs and benefits of using recommended forages and concentrates to smallholder dairy farmers in Nakuru County, Kenya, a Gross Margin Analysis (GMA) was used to estimate the costs and benefits of the recommended forages and concentrates. Gross Margin Analysis (GMA) was a methodical process of approximating the strengths and weakness of alternative options. Gross Margin Analysis (GMA), in this instance, was used to determine the economic feasibility of smallholder dairy farmers in Nakuru County Kenya, who started using recommended forages and concentrates.

GMA was explained as the variance between the revenue obtained after selling milk and variable costs of production. The method generated an explicit index in assessing the profitability of agriculture and was known to be accurate and simple (Shi *et al.*, 2021). Farmers calculated the gross margins to find out which of the two feed will be more beneficial than the costs the feed will incur, providing a complete analysis of the milk yield and profitability. The positive gross margin meant that the advantages exceed the expenses and the investment is worth the game and the other way round. It also helped GMA to compare different types of feeds, and allowed the farmers to find the most cost-effective and advantageous ones (Janković *et al.*, 2013). Finally, GMA was a convenient instrument of assessing financial performance, showing how the improvement of sales profits was achieved through efficient management (Mittei, 2021).

Gross margin was obtained as follows:

$$GM=TR-TC.....$$

(14)

where GM was the Gross Margin, TR was the Total Revenue of the milk produced and TVC was the Total Variable Costs of forages, concentrates and veterinary services. In the Gross Margin Analysis (GMA) of smallholder dairy farmers in Nakuru County, the adoption of recommended forages and concentrates bore pertinent costs of the direct as well as the indirect costs. Direct costs include feed costs (forages and concentrates), farm operation costs labour costs (feeding, milking, and herd management), water costs, veterinary health costs and any machinery/equipment required to produce forage or feed.

Other types of indirect costs were the opportunity costs, which were represented as the income that could be earned by utilising the land and labour in dairy farming as opposed to other forms of agriculture. Feed quality was also taken into account based on the gross margin as the amount of feed is not enough to be used without focusing on its quality as well. Although the increase in the amount of feed is critical to satisfy the livestock nutrition, the quality of the feed played the key role in awarding cows with the appropriate proportion of nutrients required to produce a lot of milk and increase economic returns (Petrova *et al.*, 2022). Feed quality was categorized into three levels: low quality (0% – 49%), moderate quality (50% – 79%), and high quality (80% – 100%), based on data from KALRO (2020).

## **CHAPTER FOUR**

### **RESULTS AND DISCUSSIONS**

#### **4.1 Introduction**

This chapter presented the results and discussions of the findings of the study. It presented and discussed the results from descriptive statistics, probit model, stochastic frontier model, and gross margin analysis, all aligned with the objectives of the study.

#### **4.2 Descriptive Statistics and Inferential Statistics**

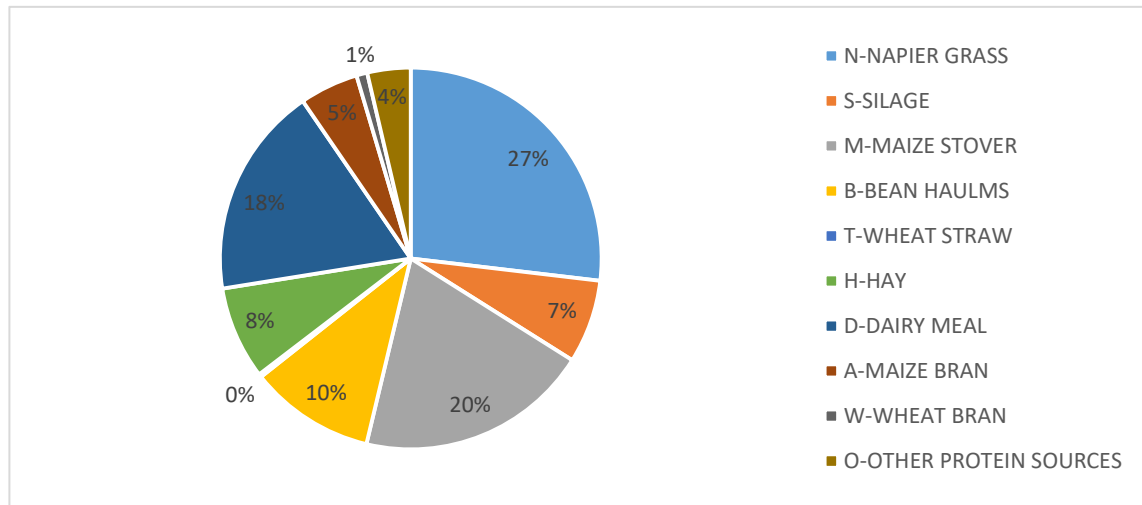
Figures 3 and 4 presented the research findings and provided a detailed discussion of the findings through a descriptive analysis of the feed types and feed sources utilized by smallholder dairy farmers in Nakuru County, Kenya, respectively.

Figure 3 illustrates the average composition of feed ingredients in the diets of dairy cattle. The percentages represent the relative contribution of each feed type to the overall ration across all sampled farms. For instance, Napier grass accounts for 27% of the total diet, followed by maize stover (20%) and hay (8%) provide fiber and bulk, silage (7%) adds moisture and energy, and dairy meal (18%) serves as a commercially balanced concentrate that provides a combination of protein, energy, and minerals.

The nutritional profile is further supplemented by bean haulms (10%), wheat straw (0.009%), maize germ (5%), wheat bran (1%) and other sources of protein (4%) including lucerne, calliandra and sunflower seed cake among others. This figure represents the collective percentage of these ingredients on the farms and not the feeding behavior of a specific farmer.

Bean haulms (10%), wheat straw (0.009%), maize germ (5%), wheat bran (1%), and other protein sources (4%) such as lucerne, calliandra, and sunflower seed cake among others further enrich the nutritional profile. The figure captures the aggregate

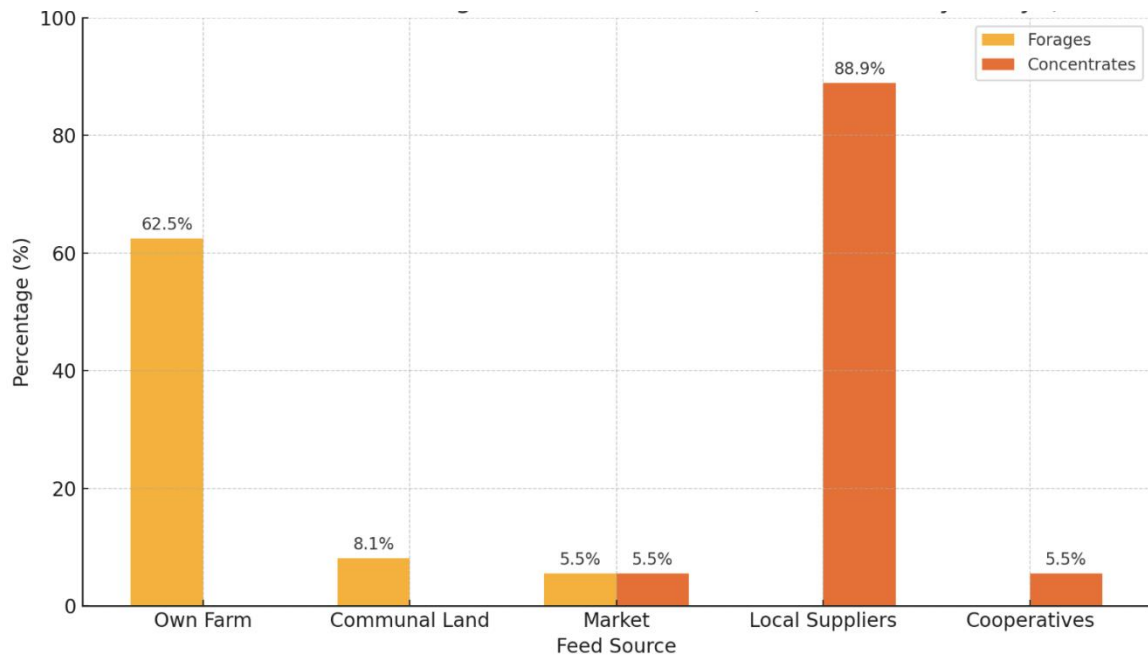
proportions of these ingredients across farms, not the feeding practices of individual farmers.



**Figure 3:** Average Proportion of Feed Ingredients in Dairy Cattle Diets among Smallholder Farmers in Nakuru County, Kenya

Figure 4 illustrated the information about the sources of feed, showed that smallholder dairy farmers in Nakuru County, Kenya have a heterogeneous method of sourcing forages and concentrates to the dairy cows. The own farm was the main source of forage, which was 62.5% out of the total, which means that they are highly dependent on self-produced feed. Conversely, the local suppliers played a major role in the concentrates with a significant share of 88.94% which confirms the significance of local markets in supplying the critical components of feeds.

The data also showed minimal contributions from communal land and cooperatives, with communal land providing only 8.14% for forages and cooperatives contributing 5.53% for concentrates. Market sources for both forages and concentrates were also minimal, with only 5.52% and 5.53%, respectively, which implied that the farm was less dependent on external markets for its feed needs.



**Figure 4:** Feed sources utilized by smallholder dairy farmers in Nakuru County, Kenya

### 4.3 Socio-demographic and Economic characteristics of smallholder dairy farmers in Nakuru county, Kenya

A household's socioeconomic characteristics mattered in feed utilization decisions. Tables 4 and 5 presented the farm and farmer attributes for continuous and categorical variables, respectively.

The age of the sampled households was between 20-98 years. The overall age of the smallholder dairy farmers using both forages and concentrates to feed the dairy cows was about 46.44 years and the average age of the smallholder dairy farmers using forages only to feed the dairy cows was about 41 years.

The statistics demonstrated that communal land and cooperatives also had little to contribute as the communal land only contributed 8.14 percent towards forages and the cooperatives contributed 5.53 percent towards concentrates. This demonstrated the fact that, smallholder dairy farmers who only used the forages to feed their dairy cows were younger than the farmers who used both forages and concentrates. The relationship between age and the utilization choice of the recommended forage and concentrates was accepted as statistically significant at 1% level.

Another important factor in feed decisions was age whereby older farmers were more experienced and therefore would be more willing to use a more balanced diet,

both forages and concentrates to maximize milk production. This was in line with Odhiambo *et al.* (2019) who believed that older farmers tended to be more informed on local feed resources and management practice which allowed them to make informed decisions regarding feed formulation.

Measured years of formal education were used to measure the level of education. The mean years attained by the farmers through formal learning were 9.94. The comparison between smallholder dairy farmers, who fed their dairy cows using both forages and concentrates (average number of years of formal schooling was 10.43 years), and those using forages only (average number of years of formal schooling was 9.07 years) had a significant number. The significance of the difference between the means of the number of years spent in schooling was significant at 5% level.

This was to imply that the smallholder dairy farmers who fed their dairy cows using both concentrates and forages were better educated than those that fed their dairy cows using forages alone. According to Paul (2019), advanced feeding technologies were also more utilizing by the more educated farmers as a result of which more milk was produced and herd management was better as compared to the less-educated farmers.

The labour force and dependency ratio of households was a proxy variable of household size. The findings showed that the average family size of the sampled households was 4.84. Smallholder dairy farmers that only used forages had the mean of 4.95 household members whereas the smallholder dairy farmers that used both forages and concentrates to feed their dairy cows had the mean of 4.78 household members. The statistical significance of mean difference in the household size was not significant at any level. This opinion did not coincide with that of Jafri *et al.* (2024) who stated that bigger households tended to focus on the basic needs such as food and education which limited their dairy feed budget. This perspective was also incompatible with the report of Banda *et al.* (2021) which showed that the size of a household affected the resource distribution which also concerned feed usage.

The herd size must have been smaller among smallholder dairy farmers who used only forages (1.57) as opposed to those who used both forages and concentrates (1.80). The correlation between the herd size and her decision on the utilization of the

suggested forage and concentrates was statistically significant at 10 percent level. This was attributed to the fact that farmers with smaller herd size had less resources to accommodate many cows with good feed and contrary, farmers using both forages and concentrates had a larger herd to sustain them due to the fact that they could provide them a better-balanced diet that could meet the nutritional requirements of more cows. This perception was in line with Sova *et al.* (2013), who established that the size of the herd in farmers using both forages and concentrates was bigger. The use of concentrates by farmers enhanced cow nutrition resulting in the increase of milk quality and quantity. This enhanced their milk sales hence they were able to invest in their farms and slowly build their herds.

The rural areas depended on land as a factor of production, which was usually a measure of wealth (Fan *et al.*, 2024). According to the survey, 83.11 of the households indicated that they owned land, 63.4% of these households fed the dairy cows with both forages and concentrates, 36.36% of such households fed dairy cows exclusively on forages. Interestingly, only 4.44 per cent of the households rented land (Table 5). Smallholders dairy farmers had an average of 0.51 hectares (Table 6). The individuals who fed their cows both with forages and concentrates had a slightly higher average land size of 0.52 hectares than those who utilized only forage as they had a mean land size of 0.49 hectares.

The estimated cow live weight which was determined by use of weight band was lower in farmers who only fed on forages (291.6 kg) than in farmers who fed on forages and concentrates (327.95 kg). The correlation between the cow live weight and the utilization of the recommended forages and concentrates choice was found to be statistically significant at 1% level. It was also observed by the Madilindi *et al.* (2022) study that the cow live weight and nutritional requirement also varied at different lactation stages, which affected the feeding strategy. The heavier cows were a sign of better health and increase in productivity which motivated the farmers to invest in forages and concentrates to maintain and enhance their performance.

The average number of years that the farmers had worked in dairy farming is 14.34. The length of farming experience (15.39) of smallholder dairy farmers who fed their dairy cows on both forages and both forages and concentrates were longer compared to smallholder dairy farmers who only fed their dairy cows with forages (12.5). Dairy farming experience and use of the recommended forages and

concentrates were statistically significant at 10 percent level. This meant that the longer the farming experience, the higher the chances of using the recommended forages and concentrates since the farmers were able to acquire more experience, perfect their feeding habits and an understanding of the nutritional requirements of the livestock. This was in line with Stelwagen *et al.* (2024) who discovered that a greater farming duration provided the opportunity to explore different feeding methods, improving the overall farm management.

The price of milk to farmers who fed their dairy cows with forages alone (49.91) was lower than that of farmers who fed their cows with both forages and concentrates (51.16). When farmers added concentrates to the forages, more milk (17.27) with higher fat and protein content was produced and on most occasions this milk was highly valued in the market, hence it attracted a high price compared to when a cow is fed on forage alone (10.54). The correlation between milk production and the use of the recommended forages and concentrates was significant at 1 percent level. According to the study conducted by Velarde-Guillen *et al.* (2018), it was also discovered that the use of concentrate supplementation increased the milk composition, especially the fat and protein composition that was extremely marketed.

Smallholder dairy farmers who fed their cows on both forages and concentrates had a slightly higher rating of credit use of 0.202 as compared to those who used forages only who had a score of 0.09. This disparity implied that farmers who applied a more balanced feeding method, which involved concentrates, had better chances of accessing and utilizing credit which could be based on costs involved in using concentrates and the extra financial support. The relationship between credit use and use of the recommended forages and the utilization of concentrates was found to be statistically significant at 5% level and postulated that credit availability was an important factor in helping farmers invest in the recommended feed practices which were corroborated by Ashagrie *et al.* (2023).

Smallholder dairy farmers that applied both means yielded 17.27 liters per day of milk, whereas those that applied only forages had a mean yield of 10.54 liters per day. The milk production between the two groups was statistically significant at the 1% level. This meant that higher yield of milk is achieved through the combination of both the forage and the concentrates. This observation was in line with research by Sairanen and Huhtanen (2023) who revealed that feeding the diets on protein sources

in addition to forages enhanced the overall intake of dry matter and production of milk.

The mean distance to the feed market was 3.8 kilometers. Farmers adding forages and concentrates recorded a marginally higher distance (4.0 kilometers) as compared to the farmers who added forages only (3.8 kilometers) to feed their dairy cows. This meant that the farmer who was much far off the feed market had little chance of using both the forages and the concentrates. This could have been explained by the fact that longer distance was linked to an increase in cost of transportation and this deterred farmers to obtain different sources of feed. On the same note, Migose *et al.* (2018) reported that the use of the recommended feeds reduced as the distance to the nearest feed market increased.

**Table 4:** Descriptive Statistics of Farm and Farmer Characteristics of Continuous Variables

Variables	Forages and Concentrates	Forages	t-value
	Mean	Mean	
Age (Years)	49.32	41.43	4.023***
Education (Schooling years)	10.43	9.07	2.4529**
Household size (number)	4.78	4.95	-0.591
Herd size (number)	1.80	1.57	1.864*
Land size (Hectares)	0.52	0.49	0.441
Cow live weight (Kgs)	327.95	291.6	4.7443***
Dairy farming experience (Years)	15.39	12.5	1.711*
Milk Prices (KES)	51.16	49.91	1.566
Credit use (Yes, No)	0.202	0.09	2.0597**
Milk yield (litres)	17.27	10.54	3.267***
Distance to the nearest market (Km)	4.0	3.8	1.006

Note: \*\*\*, \*\*, and \* denoted statistical significance at 1%, 5%, and 10%, respectively.

The majority of the participants were men (52.89%), and 47.11% of the participants were female. Out of this sub-population, 68.91% smallholder dairy farmers who were male and 57.55% female feed their cows on forages and concentrates. The average difference in gender average had a statistically significant value at 10% level of probability. Male played a key role in using suggested feeds over female since they had greater rights to own land (Paul, 2019). Smallholder dairy farmers 78.67% reported that their main activity was farming. Out of these farmers, 80.5% gave their cows a blending of forages and concentrates. Conversely, 77.6% of reported the use of forages alone.

There were wide services in dissemination of information to the farmers. Out of the smallholder dairy farmers, who gave their cows both forage and concentrates, 76.52% of them had access to extension services. Comparatively, the smallholder dairy farmers who accessed only forages became the 37.35 percent of all farmers who had access to the extension services. There was a statistically significant mean difference between the two means at the statistically significant level of 1%. Access to information was greater among small holder dairy farmers who fed their cows with both forages and concentrates (83.33) than with small holder dairy farmers who only fed their cows with forages only (66.27). The average difference between the two means was statistically significant even at 10% level. According to Mburu *et al.* (2024) agricultural extension service played a critical role in educating and swaying farmers, particularly on the way to adopt advised feeding use of practices.

Among the sampled households 59.09% of the smallholder dairy farmers belonged to agricultural groups. In this sub-population, 66.42% of them used both forages and concentrates to feed their cows and 60.89% used forages only. Conversely, most of the non-member group households that used only forages (39.11), and those with foraging and concentrates (33.58) comprised the majority of households that used forages. An average difference between the membership averages in the groups was also found to be statistically significant at 5 percent probability level.

The benefits of using the improved feeds are the sharing of information in the groups. when they joined agricultural groups. they were able to receive a network of peers, agricultural specialists, and groups or cooperatives. extension services that helped in sharing of knowledge and best practices. This result was similar to that of Zhu and Wang (2024) who observed that group membership was necessary because

helps in which making feeds cheaper for smallholder farmers boosting its collective purchasing power.

Access to training was also greater in smallholder dairy farmers who used both forages and concentrates (87.36) than those farmers who used forages to feed their dairy cows only (42.17). The correlation between the access to training and the utilization (choice of utilization) of the recommended forages and concentrates was found to be statistically significant at 1% level. This observation was in line with the research by Kashongwe et al. (2017), who established that training enabled farmers to have the information concerning balanced diets, effective feed formulations, and effective feeding schedules. This subsequently improved the nutritional status of dairy cows resulting in improved health, large production of milk, and milk quality.

As far as off-farm jobs are concerned, households had a low percentage in other jobs. In particular, 78.67% said that their main income was dairy farming, 3.56% of the households had permanent employment, and 17.78% of them were self employed. These figures suggested that very few smallholder dairy farmers engaged in off-farm activities, with the majority focused solely on dairy farming as their main source of income. A number of households reported having off-farm income. With 42.44% engaged in such activities, while a larger proportion of 75.56% did not rely on activities outside of farming. This reinforced the notion that the majority of smallholder dairy farmers depended primarily on dairy farming, with limited participation in additional income-generating activities, which matched the results of Banda *et al.* (2021).

For both smallholder dairy farmers who feed their cows a combination of forages and concentrates, as well as those who relied solely on forages, 99% still used hand milking methods, while only 1% used machine milking methods. In terms of feeding systems, 50.22% of farmers practiced extensive grazing, 29.78% used semi-zero grazing, and 20% adopted zero grazing. The mean difference between production system average was statistically significant at 1% probability level.

**Table 4:** Inferential Statistics of Farm and Farmer Characteristics for Categorical

Variables

Variables		All	Forages and Concentrates	Forages	$\chi^2$
		%	%	%	
<b>Farmer characteristics</b>					
Gender	Male	52.89	68.91	57.55	3.124*
	Female	47.11	31.09	42.45	
Occupation	Dairy Farming	78.67	80.5	77.6	1.406
	Permanent employment	3.56	4.9	2.8	
	Self-Employment	17.78	14.6	19.6	
Off-farm income	Yes	24.44	30.91	38.24	0.9629
	No	75.56	69.09	61.76	
Land tenure	Owned	83.11	84	83	10.917**
	Leased	4.44	1	10	
	Both	12.44	15	7	
Rented-in land	Yes	4.44	63.72	60	0.057
	No	95.56	36.28	40	
<b>Institutional factors</b>					
Information access	Yes	76.74	83.33	66.27	8.318*
	No	23.26	16.67	33.73	
Extension access	Yes	61.40	76.52	37.35	32.980***
	No	38.60	23.48	62.65	
Training access	Yes	69.30	86.36	42.17	46.785***
	No	30.70	13.64	57.83	
Group membership	Yes	59.09	66.42	60.89	30.749**
	No	40.91	33.58	39.11	
Milking method	Manual milking	98.67	99	99	0.91
	Mechanical milking	1.33	1	1	
Production system	Extensive grazing	50.22	36	74	34.887***
	Semi-zero grazing	29.78	34	22	
	Zero grazing	20	29	4	

Note: \*\*\*, \*\*, and \* denoted statistical significance at 1%, 5%, and 10% level.

Table 6 results indicated the socio-economic indicators of smallholder dairy farmers in Nakuru County, Kenya. The average age of respondents was approximately 46 years. This youthful age implied that they were useful and productive and this allowed them to operate their farms efficiently and they introduced suggested feeding habits.

Most of the respondents were of medium literacy as most of them reported having between 10 years of formal education on average. This helped the farmers reach, learn and adopt the suggested feeding practices, which had a positive effect on production efficiency and yield.

The smallholder dairy farmers were averagely 14 years in dairy farming, which shows that they have a good amount of experience and knowledge in the dairy farming. This extensive experience contributed probably to their skill in surmounting the obstacles of dairy farming and resolving the knowledgeable choices on farming methods. Each household had an average of five members and this was necessary to provide farm labour. This implied that the availability of multiple family members could help in addressing labour issues in agricultural tasks and hence enhance productivity and efficiency in agricultural production.

The average size of land of the respondents was approximately 0.51 hectares. According to the research by Migose (2020), in the Nakuru County, the common land tenure of the smallholders was about 0.77 hectares, which is around 1.9 acres. This size was characteristic of a small scale agricultural work such as dairy farming. The small size of the land would in many instances require effective utilization of resources and amalgamation of methods such as zero- grazing systems in order to achieve maximum productivity. With regard to yield, the findings indicated that the mean milk yield was about 8 litres in each cow per day. This poor production was also attributed to factors like inaccessibility of good feeds, inaccessibility of extension services and financial resources where the dairy farming production was not enhanced.

**Table 6:** Smallholder Dairy Farmers in Nakuru County, Kenya Socio-economic Factors

<b>Variables</b>	<b>Mean (N=225)</b>	<b>Std. Dev.</b>	<b>Min.</b>	<b>Max.</b>
Age (Years)	46.44	14.62	20	98
Education (Schooling years)	9.94	4.05	0	20
Dairy Farming experience (Years)	14.34	12.25	1	70
Household size (Number)	4.84	2.13	1	13
Land size (Hectares)	0.51	0.49	0.5	6
Milk Yield (litres)	7.89	0.89	2	35

#### 4.4 Factors influencing the choice of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya.

##### 4.4.1 Post estimation test results

##### 4.4.1.1 Multicollinearity test

Table 7 presented the results of multicollinearity test. Multicollinearity was tested by the use of variance inflation factor (VIF). The mean of VIF was 1.47 with a range of 1.05-2.43. According to the level of 10, the research concluded that no multicollinearity was present, and this implied that the strong linear relationship between the explanatory variables was not present. Multicollinearity also resulted in the estimation of the regression coefficients with incorrect signs that made the wrong inferences (Mijena, 2011).

**Table 5:** Variance Inflation Factor (VIF) Multicollinearity Test Results for the Probit Model

<b>Variable</b>	<b>VIF</b>	<b>1/VIF</b>
Age (Years)	2.43	0.411398
Milk/day (litres)	2.17	0.459983
Experience (Years)	2.13	0.470104
Herd size (Number)	1.86	0.538617
Cow live weight (Kgs)	1.52	0.656727
Production system (2=Extensive)	1.51	0.663625

grazing, 1=Zero grazing, 0=Semi-zero grazing)		
Number of years of education (Number)	1.37	0.728460
Group membership (Yes, No)	1.37	0.729762
Land size (Hectares)	1.33	0.754597
Breed types (1=local breed, 0=other breed types)	1.32	0.758282
Extension contacts (Yes, No)	1.19	0.837214
Household size (Number)	1.17	0.857601
Off farm income (Yes, No)	1.16	0.858953
Credit use (Yes, No)	1.16	0.860115
Gender (1=male, 0=female)	1.15	0.870926
Land tenure (Yes, No)	1.09	0.914255
Distance to the nearest market (Km)	1.05	0.953207
<b>Mean VIF</b>	<b>1.47</b>	

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#### 4.4.1.2 Test for Heteroscedasticity

The Breusch-Pagan and White heteroscedasticity tests were employed to test the relationship between the variance of the disturbance and the independent variables without necessarily knowing that they were related. The Breusch-Pagan / Cook-Weisberg test was carried out to determine the heteroscedasticity of the regression equation. As the results of the test showed that  $\text{prob} > \chi^2 = 0.1489$ , which was greater than 0.05, it was implied that heteroscedasticity was not an issue. We were therefore not able to reject the null hypothesis that the variance was homoscedastic.

#### **Breusch-Pagan / Cook-Weisberg test of heteroscedasticity.**

H0: Constant variance

$$\chi^2 (1) = 2.08$$

$$\text{Prob} > \chi^2 = 0.1489$$

The White test was also used next to the Breusch-Pagan / Cook-Weisberg test of heteroscedasticity and the data was presented in Table 8 where a p-value of 0.2790 was also found to be larger than 0.05 (5% level of significance) was obtained. This

affirmed the lack of heteroscedasticity and the error terms were the same among observations.

**Table 6:** White Test of Heteroskedasticity

<b>Source</b>	<b>Chi2</b>	<b>df</b>	<b>p-value</b>
Heteroscedasticity	166.92	157	0.2790
Skewness	48.14	17	0.0001
Kurtosis	0.43	1	0.5115
<b>Total</b>	<b>215.49</b>	<b>175</b>	<b>0.0201</b>

#### **4.4.2 Factors Influencing the Choice of Utilizing Recommended Forages and Concentrates**

##### **4.4.2.1 Pairwise Correlation Test for Categorical variables**

Table 9 showed the pair wise correlation test of the categorical variables in the probit model. The value of the pair-wise correlation of both the categorical variables was between 0.3121 and 0.0065, which was lower than the allowable cut-off of 0.5. This meant that the categorical variables that were used in the model were not strongly related.

**Table 7:** Pairwise Correlation Test for Categorical Variables

<b>Variables</b>	Gender	Extension access	Information access	Training access	Off-farm income	Group membership	Land tenure	Milking method	Production system	Credit use
Gender	1.0000									
Extension access	0.0174	1.0000								
Information access	0.0065	0.3121	1.0000							
Training access	-0.0065	0.0368	0.0488	1.0000						
Off-farm income	-0.0559	0.1217	0.0134	0.0776	1.0000					
Group membership	-0.1191	0.2386	0.2647	0.0941	-0.0956	1.0000				
Land tenure	-0.0877	-0.0524	0.0745	0.0189	-0.0633	0.0834	1.0000			
Milking method	0.0270	0.1437	0.0661	-0.0591	-0.0240	0.0932	-0.0505	1.0000		
Production system	0.1658	0.1218	0.1733	0.1222	-0.0956	0.1786	-0.0941	0.1168	1.0000	
Credit use	-0.0094	0.1070	0.1965	-0.0137	0.0570	0.2573	0.0507	-0.0516	-0.0340	1.0000

#### 4.4.2.2 Empirical Results

The findings of the probit models in factors that determine the decision of using the prescribed forages and concentrates in smallholder dairy farmers in Nakuru County in Kenya were given in table 10.

The gender of household head was highly significant to propensity of using the recommended forages and concentrates at the level of significance of 1%. Households with males as their heads were 90.82 percent probable to use the suggested feeds. This result was consistent with the results of Njiru *et al.* (2023), who discovered that men had a higher propensity to deal with the suppliers and financial institutions, increasing their power to get quality feeds.

The options of using the recommended forages and concentrates had a positive significant level of 10% in education. Households with greater years of education had more chances of implementing the suggested forages and concentrates. The years of formal education to the household members increased the probability of using the prescribed forages and concentrates by 9.69. This implied that better educated members in the household were better placed to put the recommended forages and concentrates into practice. With this information at hand, the farmers were also favorably placed to increase the bargaining power on their food supplies to get a better market and meet the quality of feeding standards that were enforced. The results of Schoenleben *et al.* (2020), also indicated that education enabled the farmers to be capable of staying conscious of the existing nutritional techniques such as the use of good quality feeds.

The experience of the households on dairy farming positively and significantly affected the decisions of application of the recommended forages and concentrates at 5 percent level of probability. This translated to the fact that, experience positively affected farmers when it came to them making a decision whether to use the recommended feeds. The marginal effects revealed that experience of a year enhanced the chances of using proposed forages and concentrates. The age as a proxy variable dependent on experience also indicated that the older farmers had less probability to use the recommended forages and concentrates as compared to the young farmer. It also supported the finding of Akintan *et al.* (2025), who discovered that the more experienced farmers employed data-driven decisions when various sources are integrated to achieve the highest level of production and quality in the feed formula.

The probability of negative values of 5 per cent were negative and statistically significant in the size of herds. The possibility of employing the recommended forages and concentrates decreased by 24.26 with a unit change in the size of the herd. The additional feeds were not paid off in proportion in bigger herds and therefore less of the suggested forages and concentrates were consumed. Continuing on the same note, Scasta and Furquim, (2025) also indicated that the greater workload of large herd shifted the focus on the intensive methods of feeding the animals to the simplicity of their maintenance.

The growth of the herd also implied the need to adjust the simpler feeding programs in controlling the labor and the resource thus reducing the use of recommendable feeds. The level of control of the ownership of land positively and significantly at the level of 5 percentage level of significance influenced the usage of the recommended forages and concentrate. Ownership of land by the smallholder dairy farmers increased the probability of utilizing the recommended concentrates and forages by 62.13. Most of the land owners diversified and expanded the recommended forages and concentrates that acted as an alternative to fall back position in case of the shocks rather than just a few who utilized the family/communal land. Additionally, the ownership of land reduced the risk and unpredictability of investments; thus, encouraging farmers to invest in their business on a long-term scale (Akber *et al.*, 2024). This was consistent with Chavula and Turyisingura (2022) who found that tenure security was a hindrance to the implementation of risk management practices and farmers were prone to external shocks.

The usage of the suggested forages and concentrates registered an unfavorable and statistically significant group membership at 10 percent degree. By 50.24% the farmers, who belonged to an agriculture group, were less likely to utilize the recommended forages and concentrates. This was attributed by the fact that, smallholder dairy farmers were not ready to defy the group norms by social pressure or belonging to the community. To the extent that other members of the group were not applying such new suggestions, then an individual farmer was not discouraged to apply them even when he or she realized that they would be helpful. It was also in accordance with the outcomes of Kamakaula (2024), who stated that farmers did not feel the necessity to change to new methods since they were considered either unnecessary or too costly, which also contributed to the lack of motivations to change.

However, the same result was anomalous concerning the findings of Ayesha *et al.* (2024), who also found that in the vast majority of the cases, the Agricultural groups were undergoing training sessions and discussions that exposed farmers to enhance feeding strategies and practices and led to the increase in the degrees of adoption of recommended feeds. They were positive and significant at a level of 0.05 percent on the use of the recommended forages and concentrates. It was observed that small holder dairy farmers who were extending their services would consume both the recommended forage as well as concentrates by 13.22. The extension agents provided the advisory services to farmers and, therefore, raised the ability of farmers to consume the recommended feeds such as forage and concentrates. Similarly, Ahikiriza *et al.* (2025) mentioned that the extension agents sensitized the farmers about the benefits of improved feed and nutrition which was demonstrated through best practice through on-farm trials. They could also introduce quality inputs and this mattered in the implementation of new ways.

There was positive and significant use of credit at 10% level and this involved the use of recommended forages and concentrates. The increase in the use of the recommended forages and concentrates was the result of one unit change in the use of credit. This might be explained by the fact that credit allowed farmers to invest in the recommended feeds that they would not have been able to acquire without the credit due to the financial limitation. Being able to access credit and its application, smallholder dairy farmers emerged of the transitional difficulties in the cash flow and began to concentrate on the transformative change in the farming practice with a long-term perspective. Due to this, they were easily influenced to adopt the modernized techniques of increasing the production of milk. This was in line with the one by Prah *et al.* (2025) who pointed out that the combined delivery of credit access and credit extension services was a significant push towards using inputs in the most effective way, and this served in guiding the farmers towards the best practices.

The results of cow live weight showed that there was positive and significant effect on use of recommended forages and concentrates at 10 percent level of significance. This disclosed that the heavier the live weight of cows the higher the probability of using the recommended forages and concentrates 59.62.

Cow live weight results depicted that there was a positive and significant impact on the use of recommended forages and concentrates at 10 percent level of significance. This revealed that the greater the live weight of cows the greater the chances of using the recommended forages and concentrates was 59.62. this meant that the more the live weight of a cow, the more the energy and protein to support the body weight to produce milk especially during lactation. The NASEM model proposed by Waddell *et al.* (2023) proposed that cows in the lactation phase had heavy energy needs that were body-weight-dependent.

There was also elevated DM consumption (DMI) and metabolizable protein requirements of the big cows especially during lactation. The breed type showed positive and significant effect on the use of recommended forages and concentrates at 5 percent level of significance. This implied that local breeds were more likely to effectively use the recommended forages and concentrates by 80.53 percent because they were normally adapted to the local conditions besides being more adapted to the traditional, nutrient rich feeds, which was normally present in the area. According to Shiddieqy *et al.* (2023), the local breeds were adequately suited to transform the nutrients of the local feeds into enhance their performance on the local feeds.

The indicated results of the production system showed that there was a positive and significant impact on the use of recommended forage and concentrates at 10 percent difference and therefore there was a high probability that cows in the zero grazing production systems utilized the recommended feeds effectively as compared to the other production systems that represented 43.29 percent. This meant that the amount of feed taken was more controlled with zero-grazing and cows were made to eat a regulated, balanced and managed diet of high quality forages as well as concentrates that matched the nutritional demand of the cows. Zero-grazing systems provided a constant source of good-quality feeds, leading to the improved DMIs and the high milk production. According to Holohan *et al.*, (2022) and Lavery *et al.* (2023), big and semi-intensive grazing systems failed to produce milk in the same measure as Zero-grazing system had.

**Table 8:** Probit Estimates for Factors Influencing the Choice of Utilizing Recommended Forages and Concentrates Among Smallholder Dairy Farmers in Nakuru County, Kenya

	Forages and Concentrates		Forages	
	Coef.	Std. err.	Coef.	Std. err.
Age (Years)	-0.0015595	0.0134481	-0.0027643	0.0032164
Gender (1=Male,0=Female)	0.9081995***	0.2260364	0.4076219***	0.2079327
Education (Schooling years)	0.0968335*	0.0367703	-0.1217515*	0.1643732
Experience (Years)	0.0333596**	0.0119346	0.0264184**	0.1173285
Household size (Number)	0.0303624	0.0525844	0.0534842	0.1238512
Off farm income (Yes, No)	-0.00000764	0.0000096	0.00000021	0.0000014
Herd size (Number)	-0.2426088**	0.1082972	-0.0964218**	0.0715476
Land size (Hectares)	-0.0630105	0.1792773	-0.2485318	0.3111764
Milk prices (KES per ltr )	0.0169444	0.0140793	0.0175321	0.1165328
Land ownership (Yes, No)	0.6213267**	0.1907694	0.5492201***	0.1485361
Group membership (Yes, No)	-0.5024774*	0.2683308	0.2031356	0.4351281
Extension contacts (Yes, No)	0.1322252**	0.0573863	0.1932174**	0.3105421
Distance to the nearest market (Km)	0.0291742	0.0676847	0.3507734***	0.0812864
Credit use (Yes, No)	0.5490943*	0.3268324	0.6932174*	0.2225451
Cow live weight (Kgs)	0.5962631*	0.2964578	0.4595215*	0.1442315
Breed types (1=local breed, 0=other breed types)	0.8053476**	0.3727718	0.5075632**	0.2073265
Milking method (1=Manual, 0=Mechanical)	0.4328728*	0.2511537	0.3261321	0.2253167
Constant	-6.013237	1.116625	-5.0003217	1.0033591

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Number of observations=225	Pseudo R2 = 0.3904
Prob > chi2 = 0.0000	Log likelihood = -88.18917
LR chi2 (17) = 112.94	

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Note: The asterisk \*\*\*, \*\* and \* represented 1%, 5%, and 10% significant levels, respectively.

#### **4.5 Level of Technical Efficiency of Utilizing Recommended Forages and Concentrates Among Smallholder Dairy Farmers in Nakuru County, Kenya**

##### **4.5.1 Description of Variables/Regression Production Factors**

Table 11 presented the factors that affected milk yield among smallholder dairy farmers in Nakuru County, Kenya. It showed the different variables (factors) that influenced how much milk a smallholder dairy farmer could produce.

The average milk yield of 3,066.844 litres per year across smallholder dairy farms in Nakuru County, Kenya, served as a crucial benchmark for assessing farm productivity. On average, farms utilized 8,610.15 kg of forage. The quality and type of forage greatly influenced the nutritional intake of the cows, which directly affected their milk yield. The average use of concentrates was 270.12 kg per cow per year. This quantity of energy-dense feed complemented forage and was vital for enhancing milk yield. The balance between forages and concentrates was crucial for achieving optimal productivity. An average of 15,806.93 litres of water was used across the farms.

The average herd size was approximately two cows, indicating that these farms operated on a smaller scale, and it was found that smaller herd sizes limited the overall milk production capacity. The average feed quality score was 30.94, suggesting variability in feed standards across different farms. This medium-quality feed was associated with moderate health and productivity in dairy cows, which led to increased milk yields. Most farms tend to use a single breed of dairy cows, which influenced the consistency of milk production. Different breeds had varying milk production capabilities, and the choice of breed significantly impacted the overall farm productivity. These factors collectively highlighted the complexities of dairy farming in Nakuru County, Kenya, and underscored the importance of effective management practices to enhance milk yield and farm efficiency.

**Table 9:** Description of Variables/Regression Production Factors

<b>Variables</b>	<b>Mean</b>	<b>Stand. Dev.</b>	<b>Min</b>	<b>Max</b>
Milk Yield (litres)	3,066.844	1,975.259	210	94,500
Forages (Number)	8,610.151	12,605.67	0	136,500
Concentrates (Number)	270.1174	356.234	0	3250
Feed quality component (percentages)	30.937	28.350	0.099	96.473
Water intake (litres)	15,806.93	5,607.334	5,475	25,550
Herd size (Number)	1.72	0.899	1	5
Breed types (Number)	1.12	0.320	1	2

#### 4.5.2 Stochastic Regression for Factors Influencing Technical Efficiency

Table 12 showed the Maximum likelihood estimates of parameters of frontier production/efficiency and inefficiency functions. The accumulation of the partial elasticity (function coefficient) was the indicator of the size of production. The constant return to scale was revealed by a function coefficient of one. A coefficient of functions that were both less than one and greater than one predicted decreasing and increasing returns to scale respectively. The summation of the estimates of the coefficients of the coefficients of the estimated model was 2.674 which indicated that the production frontier was on the increasing scale of returns i.e. the farmers were in the rational part of the production process i.e. stage I of the production region. Such an outcome meant that the farmers increased their milk production by 2.674% with a one-percent rise in the inputs.

The variables that had a significant influence on the production of the milk among small-holder dairy farmers in Nakuru County, Kenya, were the inputs including forages and concentrates. Their coefficients were significant at a 5 percent level and 1 percent level respectively. The positive value of forages was 0.674. This implied that the amount of more forage by 1% raised milk yield by 67.4 percent. On the other hand, concentrates also presented a positive value of 0.223, meaning that the increment of a concentrate by 1% increased milk yield by 22.3%. This result

agreed with that of Chen *et al.* (2024), who suggested that a medium forage-to-concentrate ratio optimized milk yield and nutrient digestibility.

The quality of the feed was positive and statistically significant at 5% probability level. This meant that the increment of quality of the feed by 1% increased milk yield by 80.5%. This result conformed to that of Akintan *et al.* (2025), which showed that high-quality feeds rich in proteins, carbohydrates, vitamins, and minerals were crucial for efficient milk synthesis. Water intake and herd size were both positive and statistically significant at 1%. This meant that the increment of water intake and herd size by 1% increased milk yield by 42.3% and 59.7%, respectively. This result was consistent with that of Kebede and Guja (2024), who found that adequate hydration was essential, as milk was largely composed of water; dehydration led to reduced milk yield and health issues. Also, Akintan *et al.* (2025), found that larger herds benefited from improved genetics and feeding systems, which enhanced overall milk production.

In the inefficiency function, education, experience, off-farm income, extension access, and information access significantly affected the level of milk production, while age, gender, household size, and credit use were not significant.

The education level of the household head was not found to be positive and the coefficient of the dummy was negative indicating that higher education level led to low technical inefficiency. It was significant at the probability level of 5%. It was a negative experience which was statistically significant at 10% level. This meant that the greater the experience, the lower the technical inefficiency in dairy farming. Experienced farmers made better feeding decisions, ensuring proper nutrition for their cows and ultimately improving milk yield. This finding was in line with that of Ameer *et al.* (2024), who found that experienced farmers demonstrated higher technical efficiency due to better decision-making regarding feed and herd management.

The coefficient for the dummy for off-farm income had a positive sign and was statistically significant at 5% probability level, showing that the more off-farm income, the higher the technical inefficiency. This was due to sub-optimal resource utilization, as some farmers became less motivated to maximize efficiency in dairy farming when their off-farm income was stable or higher. This finding corroborated with that of Chang *et al.* (2022), who stated that when off-farm employment exceeded a certain threshold, it negatively impacted agricultural production efficiency.

The coefficient for the dummy for both access to extension services and access to information had negative signs and were both statistically significant at 5% probability level, showing that the greater the access to extension services and information, the lower the technical inefficiency in dairy farming. This presented similar findings as those reported by Ali and Byerlee's (1991), that when farmers had access to extension services, there was a negative influence on inefficiency.

The sigma-squared parameter was within the range of 0-1. The value of 0 meant that there was no technical inefficiency and the ordinary least squares estimation was a sufficient representation. A value of 0.9 or nearer meant that the frontier model fitted (Piesse & Thirtle, 2000). The sigma square value showed the goodness of fit and validity of the given assumption of the distribution of composite error terms. The result of the parameter value of lambda ( $\lambda$ ) was 0.002 and it was significant at 5% level which meant that 2% of the output changes could be explained by the inefficiency.

**Table 10:** Stochastic Regression for Factors Influenced Technical Efficiency

<b>Variables</b>	<b>Parame ter</b>	<b>Coefficient</b>	<b>Stand. Err.</b>
Constant	$\beta_0$	4.586	0.552
Ln_forages	$\beta_1$	0.674**	0.330
Ln_concentrates	$\beta_2$	0.223***	0.052
Ln_feed quality	$\beta_3$	0.805**	0.031
Ln_water intake	$\beta_4$	0.423***	0.106
Ln_herdsize	$\beta_5$	0.597***	0.092
Ln_breed types	$\beta_6$	-0.048	0.192
<b><i>Inefficiency factors that influenced milk yield</i></b>			
Constant	$\alpha_1$	7.648	0.583
Age (Number)	$\alpha_2$	-0.002	0.006
Gender (1=male, 0=female)	$\alpha_3$	0.041	0.139
Education (Number)	$\alpha_4$	-0.059**	0.018
Household size (Number)	$\alpha_5$	-0.011	0.008
Experience (Number)	$\alpha_6$	-0.059*	0.032
Off-farm income (Yes, No)	$\alpha_7$	0.392**	0.166

Extension access (Yes, No)	$\alpha_8$	-0.064**	0.030
Information access (Yes, No)	$\alpha_9$	-0.357**	0.143
Credit use (Yes, No)	$\alpha_{10}$	-0.121	0.172

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***Variance Parameters***

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$\mu = -0.19$ ,  $\ln\gamma = -6.45$ ,  $\sigma^2 = 0.34$ ,  $\gamma = [\sigma^2 / (\sigma_u^2 + \alpha_v^2)] = 0.002$ ,  $\alpha_u^2 = 0.00055$ ,  $\alpha_v^2 = 0.35$ ,  
 $\ln\sigma^2 = -1.06$

\*\*\*, \*\* and \* represented 1%, 5%, and 10% significant levels, respectively.

Technical efficiency frequency distribution was shown in table 13. It was noted that the smallholder dairy farmers in Nakuru County experienced the least efficiency levels that ranged between 0.40 and below with the lowest percentage of the same (71.11) but at the same time the highest percentage was at 0.60 and above at 12.44. Generally, smallholder dairy farmers who used both forages and concentrates to feed their cows had higher efficiency levels of 0.636 compared to those who relied solely on forages (0.364). The mean technical efficiency of 34.85% and 24.07% indicated that there was potential to increase milk yield by 75.93% and 65.15% for smallholder dairy farmers who used both forages and concentrates to feed their cows and those who relied solely on forages, respectively.

**Table 11:** Frequency Distribution of Technical Efficiency (TE)

TE Score	Forages and concentrates (143)		Forages (82)		Total Percentage
	No. of farmers	Percentage	No. of farmers	Percentage	
TE < 40	90	40	70	31.111	71.111
$40 \leq TE \leq 60$	33	14.667	4	1.778	16.444
$60 \leq TE \leq 100$	20	8.889	8	3.556	12.444
Mean	0.349		0.241		
Minimum	0.313		0.199		
Maximum	0.384		0.283		
Std. Dev.	0.217		0.191		

#### **4.6 Gross Margin for Utilizing Recommended Forages and Concentrates Among Smallholder Dairy Farmers in Nakuru County, Kenya**

To find out the profitability of various suggested forages and concentrates by smallholder dairy farmers in Nakuru County in Kenya, the Gross Margin Analysis (GMA) was applied. Table 14 presented the GMA results. The average gross production of the milk in terms of gross margin per year was KES 78, 037.43. Smallholder dairy farmers who relied solely on forages to feed their cows had an average gross margin of KES 57,619.25, while those who used both forages and concentrates to feed their cows recorded a notably higher average of KES 89,745.77. This suggested that using both forages and concentrates significantly improved the gross margin in milk yield compared to relying solely on forages. The difference in gross margins between the two groups was statistically significant at the 10% level (Table 14). The average variable cost for farmers who utilized both forages and concentrates was higher than that for those using forages only. This was attributed to the higher costs associated with purchasing concentrates. However, the increased returns from higher gross margins more than offset the higher costs for those who used both forages and concentrates.

Furthermore, the total yield was higher for farmers utilizing both forages and concentrates, which was explained by the superior nutrition provided by concentrates, leading to increased milk production. This was also attributed to the fact that farmers using both types of feed used better feed varieties and typically managed larger herds compared to those relying solely on forages, further contributing to the higher yields observed. This result was consistent with the findings of Cowley *et al.* (2020), who reported that dairy farmers with higher production levels were more likely to achieve better financial outcomes compared to those with lower production. Similarly, farmers utilizing both forages and concentrates reported higher gross margins, probably due to the increased milk yield associated with this feeding strategy.

**Table 12: Gross Margin for Different Dairy Feed Types**

Variables	Forages and concentrates (143)	Forages (82)	t-value	P-value
	Mean	Mean		
Milk Yield (per litre)	3,429.755 (165.421)	2,433.963 (195.215)	3.7436	0.0002***
Total revenue (TR)	145,434.8 (16274.92)	91,888.22 (8986.776)	2.3735	0.0185**
Total Variable Costs (TVC)	55,689.03 (4068.096)	34,268.5 (5592.081)	2.5655	0.0110*
Gross margin (KES per litre per year per cow)	89,745.77 (13930.69)	57,619.72 (5632.786)	1.6998	0.0906*

The asterisk \*\*\*, \*\*, and \* represented 1%, 5%, and 10% significant levels, respectively.

Table 15 showed the relationship between feed quality levels and gross margin. High-quality feed resulted in a gross margin of KES 115,034.4, medium-quality feed produced KES 82,695.56, and low-quality feed generated KES 63,186.38. The overall average gross margin across all feed quality levels was 78,037.43 KES. The mean differences in feed quality levels were statistically significant at the 10% significance level, indicated that feed quality levels had a meaningful impact on gross margin. High-quality feed led to the highest gross margin, followed by medium and low-quality feed. This result corroborated with what was found by Baris (2023) that low-quality feed led to stunted growth and lower production rates; better feed quality correlates with increased weight gain, higher milk yields, and improved reproductive performance.

**Table 13: Feed quality levels on gross margin**

Feed Quality levels	Mean	Std. dev.	Freq.
Low	63,186.377	16,0092.36	125
Medium	82,695.556	88,194.585	57
High	115,034.4	10,9531.4	43
<b>Total</b>	<b>78,037.434</b>	<b>137,015.26</b>	<b>225</b>

## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### 5.1 Conclusions

The study conclusions made on each of the objectives are as follows;

- i. Among the smallholder dairy farmers in the Nakuru County, gender, breed types, land ownership, cow live weight, use of credit, group membership, production system, herd size, extension contacts, education and experience were the key issues that influenced the decision to use the recommended forages and concentrate.
- ii. The average efficiency in technical of 34.85 and 24.07 percent was a good indication that there was a potential market to increase the yield of milk by 75.93 percent and 65.15 percent of the milk of smallholder dairy farmers who feed their cows on both forages and concentrates and those who feed their cows on forages only, respectively.
- iii. Gross margin is significantly higher for smallholder dairy farmers who use both forages and concentrates to feed their cows (KES 89,745.77), compared to the gross margin of those who rely solely on forages (KES 57,619.25).

#### 5.2 Recommendations

The recommendations based on the results of the study are as follows;

- i. Gender, types of breeds, ownership of lands, live weight of cows, use of credit, group membership, production system, herd size, extension contacts, education and experience are key factors influencing the choice of utilizing recommended forages and concentrates, they will be adequately addressed by way of training and require the interventions of the national and county government.
- ii. It is recommended that farmers should be provided with resources to offer nutrition specifically tailored to their cows' needs, to enhance milk yield efficiency and maximize productivity.
- iii. Immediate actions to provide training on dairy best practices, such as proper feed management, clean milk production and handling, and herd health. This will equip farmers with practical skills to improve milk yield and quality, and enhance overall farm productivity.

### **5.3 Further research**

Further research is needed on the evaluation of milk yield efficiency from feeds formulated using locally available forages, including grasses and legumes, with particular attention to their nutritional content.

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## APPENDICES

### **Appendix 1: Questionnaire Smallholder Dairy Farmer in Sub-Counties Molo and Njoro.**

#### **Introduction**

My full name is Flora Gash KAMBABAZI, I am pursuing MSc in Agricultural and Applied Economics in Egerton University, Kenya. The proposed research is on the topic of Determinants of utilization of recommended forages and concentrates among Smallholder dairy farmers in Nakuru County, Kenya. This research is purely academic. You are one of the selected stakeholders and who I believe can offer valuable information and support towards this objective of this research.

**Questionnaire Identification**

Questionnaire Number:

County:

Ward:

Date (dd/mm/yy):

Name of the Enumerator:

Name of Respondent (optional):

**INSTRUCTIONS**

- Please tick (✓) only the option(s) that apply to the questions with alternative answers.
- Kindly give brief and precise answers in the blank slots provided in the questionnaire.
- ❖ Thank you for participating in this study. The information you provide will be handled with the **utmost discretion**.

**SECTION A: Demographic Information**

**A1:** Please provide the following details about the household head and household size

Gender	Age (years)	Highest level of education	Primary Occupation	How many years of experience do you have in dairy farming?"

1. Male [ ]		1. No formal education [ ]	1. Permanent employment [ ]	1. Less than 1 year [ ]
2. Female [ ]		2. Adult education [ ]	2. Self-employed [ ]	2. 1–3 years [ ]
		3. Primary education [ ]	3. Dairy Farming [ ]	3. 4–6 years [ ]
		4. Secondary education [ ]		4. 7–10 years [ ]
		5. University education [ ]		5. More than 10 years [ ]

**A2.** How many people living in the household?

Number of people living in the household	Males	Females	Total

**A3.** Are you involved in any other on-farm activities?

1 = Yes  0 = No

**A4.** Are you involved in any off-farm activities?

1 = Yes  0 = No

**A5.** If yes (above A3 & A4) what was the estimated amount of income (KES) received last month?

**a)** From farm production KES .....

**b)** From off-farm KES.....

**c)** Total income (a + b) KES.....

## Section B: Farm Characteristics

<b>B1a.</b> What type of land tenure do	A) Owned [ ]	B) Leased [ ]
---	--------------	---------------

you have? <b>B1b.</b> If you own the land, how many hectares do you own? [            ]	B) Rented [   ]    D) Other [   ]
<b>B2.</b> How many dairy cows do you currently have? (Include all stages: lactating, dry, heifers, etc.)	
<b>B3.</b> What breed of dairy cows do you keep? (Tick all that apply)	1. Holstein Friesian [   ] 2. Jersey [   ]                      4. Guernsey [   ] 3. Ayrshire [   ]                      5. Crossbreed [   ] 6. Other (specify) [                      ]
<b>B4.</b> What type of housing do you provide for your dairy cows?	1 = Zero-grazing [   ] 2 = Semi-zero grazing [   ] 3 = Extensive range [   ] 4 = Other (specify) [                      ]

**Section C: Types, Sources, Quantity, and Utilization of Forages and Concentrates**

**C1.** What types of forages do you use for feeding your dairy cows?

Forages	Yes	No
1 = Napier grass		
2 = Silage		
3 = Hay		
4 = Kikuyu grass		
5 = Wheat straw		
6 = Maize stover		
7 = Bean haulms		

**C2.** What types of concentrates do you use for feeding your dairy cows?

Concentrates	Yes	No
1 = Dairy meal		
2 = Wheat bran		
3 = Maize bran		

<b>C3.</b> What are the main sources of forages for your dairy cows? (Tick all)	1 = Own farm [   ] 2 = Purchased from local suppliers [   ]
---	--

that apply)	3 = Purchased from markets [ ] 4 = Collected from communal land [ ] 5 = Other (specify) [ ]
<b>C4.</b> What are the main sources of concentrates for your dairy cows? (Tick all that apply)	1 = Local agro-dealers [ ] 2 = Cooperative societies [ ] 3 = Market vendors [ ] 4 = Other (specify) [ ]
<b>C5.</b> What is the distance to the nearest market for forages?	
<b>C6.</b> What is the distance to the nearest market for concentrates?	
<b>C7.</b> On average, how much forages do you provide per cow per day (Kg)?	
<b>C8.</b> On average, how much concentrates do you provide per cow per day (Kg)?	
<b>C9.</b> How much do you spend per month on purchasing forages per cow? (KES)	
<b>C10.</b> How much do you spend per month on purchasing concentrates per cow? (KES)	
<b>C11.</b> What is the typical range of labor and/or veterinary costs associated with dairy farming you spend per month ?	A) KES 1,000 to KES 5,000 [ ] B) KES 5,000 to KES 15,000 [ ] C) KES 15,000 to KES30,000 [ ] D) Over KES 30,000 [ ]

**Section D: Factors influencing choice of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya.**

**D1. ACCESS TO EXTENSION SERVICES AND TRAINING**

Have you received any extension service in the last dairy production	1 = Yes [ ] 0 = No [ ]
--	---------------------------

<p>year?</p> <p>If yes, How frequent was the extension service?</p>	<p>1=weekly[ ]                      2=twice a week[ ]</p> <p>3=once a month[ ]    4=once a year[ ]</p>
---	--

**D2. SOCIAL CAPITAL**

<p>Do you belong to any group association?</p> <p>If yes, which type of group association do you belong to?</p>	<p>1 = Yes [ ]</p> <p>0 = No [ ]</p> <p>1=Farmer group [ ]</p> <p>2=dairy cooperative[ ]</p> <p>3=Welfare group [ ]</p> <p>4=Marketing group[ ]</p> <p>5=Merry-go round[ ]</p> <p>6=others (specify).....</p>
---	---

**D3. MILK PRODUCTION**

<p>What is your average daily milk production per cow? (Kilograms per day)</p>	
<p>How do you sell your milk? (Tick all that apply)</p>	<p>1 = Directly to consumers [ ]</p> <p>2 = Through cooperatives [ ]</p> <p>3 = Local markets [ ]</p> <p>4 = Processors [ ]</p> <p>5 = Other (specify) [ ]</p>
<p>On average, What price do you receive</p>	

per kilogram of milk? (KES)	
How many months do you milk your cow per year?	

#### **D4. LOAN BORROWED**

**D4.1** Have you borrowed any loan during the last production season?

1=Yes [ ] 0=No [ ] If yes, continue to **D4.2**,

**D4.2** Please indicate the amount of the loan borrowed and the interest rates.

<b>Source of Loan</b>	<b>Amount received</b>	<b>Interest rates in KES</b>
Cooperative society		
Bank		
Microfinance		
Mobile loan		
Farmer group		
Others (specify)		

**Section E: The level of efficiency of utilizing recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya.**

<b>E1.</b> What is the weight of your cow?	Weight: _____ kg
--	------------------

<p><b>E2.</b> What is the current lactation stage of your cow?</p>	<p>A) Early lactation (0-60 days post-calving) [ ]</p> <p>B) Mid-lactation (61-200 days post-calving) [ ]</p> <p>C) Late lactation (201-305 days post-calving) [ ]</p> <p>D) Dry period (non-lactating phase) [ ]</p> <p>E) Transition period (3 weeks before calving) [ ]</p>
<p><b>E3.</b> What is the typical daily water intake for your dairy cow?</p>	<p>A) 10 to 20 gallons [ ]</p> <p>B) 20 to 30 gallons [ ]</p> <p>C) 30 to 50 gallons [ ]</p> <p>D) 50 to 70 gallons [ ]</p>
<p><b>E4.</b> What type of milking method do you use on your farm?</p>	<p>A) Manual Milking [ ]</p> <p>B) Mechanical Milking (using milking machines) [ ]</p>
<p><b>E5:</b> How do you manage feed shortages during periods of low forage/concentrate availability? (Tick all that apply)</p>	<p>1 = Purchase additional feed [ ]</p> <p>2 = Reduce the number of cows [ ]</p> <p>3 = Use crop residues [ ]</p> <p>4 = Use stored silage/hay [ ]</p> <p>5 = Other (specify) [ ]</p>

**Section F: Costs and Benefits of Utilizing Recommended Forages and Concentrates**

<p><b>F1:</b> Do you consider the use of forages to be cost-effective for your dairy farming?</p>	<p>1 = Yes <input type="checkbox"/></p> <p>0 = No <input type="checkbox"/></p>
<p><b>F2:</b> Do you consider the use of concentrates to be cost-effective for your dairy farming?</p>	<p>1 = Yes <input type="checkbox"/></p> <p>0 = No <input type="checkbox"/></p>

<p><b>F3:</b> On average, how much additional milk do you produce per month due to using recommended forages and concentrates per cow? (litres)</p>	<p>a) 0 - 50 litres [ ]  b) 51 - 100 litres [ ]  c) 101 - 150 litres [ ]  d) 151 - 200 litres [ ]  e) More than 200 litres [ ]</p>
<p><b>F4:</b> On average, how much additional income do you earn per month as a result of the increased milk production per cow from utilizing recommended forages and concentrates? (KES)</p>	<p>a) 0 - 5,000 KES [ ]  b) 5,001 - 10,000 KES [ ]  c) 10,001 - 15,000 KES [ ]  d) 15,001 - 20,000 KES [ ]  e) More than 20,000 KES [ ]</p>
<p><b>F5.</b> What strategies do you believe could enhance the utilization of recommended forages and concentrates among smallholder dairy farmer?</p>	<ol style="list-style-type: none"> <li>1.</li> <li>2.</li> <li>3.</li> <li>4.</li> <li>5.</li> </ol>

***THANK YOU FOR YOUR PARTICIPATION!!!***

## Appendix 2: Roughages Fed to Dairy Cattle and Their Quality

Forage/Fodder	Dry matter (g/kg)	ME Energy (MJ/kg DM)	Crude Protein (g/kg DM)	Calcium (g/kg DM)	Phosphorus (g/kg DM)
Napier grass	180	8.5	88	5.0	3.0
Rhodes grass	280	8.5	90	-	-
Napier silage	280	9.0	75	-	-
Maize cobs	900	7.5	30	1.2	0.4
Fodder sorghum dry	890	8.9	75	4.0	2.1
Maize silage	320	10.5	80	4.0	2.7
Kikuyu grass	200	9.5	120	-	-
Rhodes hay	850	9.2	80	-	-
Lucerne hay	865	8.5	170	14.0	2.4
Sesbania leaves	260	8.5	260	22.1	2.8
Calliandra leaves	260	8.5	240	11.1	1.4
Leucaena leaves	280	8.4	230	15.5	2.1
Sweet potato vines	100	8.0	160	17.9	2.4
Green maize stalks	300	9	80	5.0	2.5
Maize stover	850	7.5	45	3.5	1.9

Source: KALRO, 2020

## Appendix 3: Concentrates and Minerals Supplemented to Dairy Cattle and Their Quality

Concentrate/Mineral	Dry matter (g/kg)	ME Energy (MJ/kg DM)	Crude protein (g/kg DM)	Calcium (g/kg DM)	Phosphorus (g/kg DM)
High yielder dairy meal	920	12.0	180	-	-
Dairy meal	950	12.0	165	6.0	4.0
Calf pellets	920	12.0	180	-	-
Cotton seed cake	920	13.5	350	1.9	2.0
Maize germ	900	15.5	106	1.0	0.5
Maize bran	900	11.5	115	1.0	2.0
Wheat pollard	900	15.1	160	1.3	9.0
Fish meal (Omena)	880	15.0	470	60.0	32.0
Fish meal (Buta)	900	13.4	400	60.0	20.0
Poultry litter	880	10.6	160	-	-
Urea	950	0.0	2600	-	-
Brewers Yeast	930	12.6	340	1.0	14.0
Brewers grains	210	10.5	254	3.3	5.5
Magic protein	900	11.9	480	-	-
Wheat bran	890	11.2	140	1.4	13.8
Maize meal	860	13.8	102	-	-
Cassava tuber meal	840	15.7	30	3.0	3.5
Lupins	860	14.2	342	-	-
Sunflower seed cake	940	12.5	360	3.0	9.0
Soya bean meal	900	12.4	470	-	-
Molasses	750	12.2	35	9.0	1.0
Maclick super	980	-	-	185.1	110.0
Limestone	100	-	-	340.0	0.2
Dicalcium phosphate	970	-	-	220.0	193.0

Source: KALRO, 2020

## Appendix 4: Top 3 Milk Producing Counties in Kenya

County	Milk Production
Kiambu	430 million litres
Nyandarua	380 million litres
Nakuru	300 million litres

Source: Author's conceptualization

## Appendix 5: Ethical Clearance

**EGERTON**

TEL: (051) 2217808  
FAX: 051-2217942



**UNIVERSITY**

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EGERTON

**EGERTON UNIVERSITY INSTITUTIONAL SCIENTIFIC AND ETHICS REVIEW  
COMMITTEE**

**EU/RE/DIR/009**

**Approval No. EUISERC/APP/391/2025**

**19<sup>th</sup> February 2025**

Kambabazi Flora Gash  
P.O. Box 536-20115  
Egerton- Njoro, Kenya  
Telephone +254704412188/+250722103292  
Email: florahgash250@gmail.com

Dear Flora,

**RE: ETHICAL APPROVAL: DETERMINANTS OF UTILIZATION OF  
RECOMMENDED FORAGES AND CONCENTRATES AMONG SMALLHOLDER  
DAIRY FARMERS IN NAKURU COUNTY, KENYA**

This is to inform you that the *Egerton University Institutional Scientific and Ethics Review Committee* has reviewed and approved your above research proposal. Your application approval number is *EUISERC/APP/391/2025*. The approval period is *19<sup>th</sup> February 2025 – 20<sup>th</sup> February 2026*

This approval is subject to compliance with the following requirements;

- i. Only approved documents including (informed consents, study instruments, MTA) will be used.
- ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by *Egerton University Institutional Scientific and Ethics Review Committee*.
- iii. Death and life-threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to *Egerton University Institutional Scientific and Ethics Review Committee* within 72 hours of notification
- iv. Any changes, anticipated or otherwise that may increase the risks or affect safety or welfare of study participants and others or affect the integrity of the research must be reported to *Egerton University Institutional Scientific and Ethics Review Committee* within 72 hours.
- v. Clearance for Material Transfer of biological specimens must be obtained from relevant institutions.

---

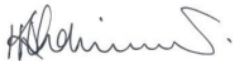
*“Transforming Lives through Quality Education”*

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- vi. Submission of a request for renewal of approval at least 60 days prior to the expiry of the approval period. Attach a comprehensive progress report to support the renewal.
- vii. Submission of an executive summary report within 90 days upon completion of the study to *Egerton University Institutional Scientific and Ethics Review Committee*.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) <https://oris.nacosti.go.ke> and also obtain other clearances needed.

Yours sincerely,



Prof. Kennedy N. Ondimu PhD  
**CHAIRMAN, EUISERC**  
KNO/BK/



---

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**The National Commission for Science, Technology and Innovation**, hereafter referred to as the Commission, was established under the Science, Technology and Innovation Act 2013 (Revised 2014) herein after referred to as the Act. The objective of the Commission shall be to regulate and assure quality in the science, technology and innovation sector and advise the Government in matters related thereto.

**CONDITIONS OF THE RESEARCH LICENSE**

1. The License is granted subject to provisions of the Constitution of Kenya, the Science, Technology and Innovation Act, and other relevant laws, policies and regulations. Accordingly, the licensee shall adhere to such procedures, standards, code of ethics and guidelines as may be prescribed by regulations made under the Act, or prescribed by provisions of International treaties of which Kenya is a signatory to
2. The research and its related activities as well as outcomes shall be beneficial to the country and shall not in any way;
  - i. Endanger national security
  - ii. Adversely affect the lives of Kenyans
  - iii. Be in contravention of Kenya's international obligations including Biological Weapons Convention (BWC), Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), Chemical, Biological, Radiological and Nuclear (CBRN).
  - iv. Result in exploitation of intellectual property rights of communities in Kenya
  - v. Adversely affect the environment
  - vi. Adversely affect the rights of communities
  - vii. Endanger public safety and national cohesion
  - viii. Plagiarize someone else's work
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5. The Commission reserves the right to cancel the research at any time during the research period if in the opinion of the Commission the research is not implemented in conformity with the provisions of the Act or any other written law.
6. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research.
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9. The Commission may monitor and evaluate the licensed research project for the purpose of assessing and evaluating compliance with the conditions of the License.
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14. The Commission shall have powers to acquire from any person the right in, or to, any scientific innovation, invention or patent of strategic importance to the country.
15. Relevant Institutional Scientific and Ethical Review Committee shall monitor and evaluate the research periodically, and make a report of its findings to the Commission for necessary action.

National Commission for Science, Technology and  
Innovation(NACOSTI),  
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Telephone: 020 4007000, 0713788787, 0735404245  
E-mail: dg@nacosti.go.ke  
Website: www.nacosti.go.ke

## Appendix 7: STATA Results

Multicollinearity tests Stata output

```
. vif
```

Variable	VIF	1/VIF
Age	2.43	0.411398
milk_day	2.17	0.459983
Experience	2.13	0.470104
Herdsiz	1.86	0.538617
Cow_weight	1.52	0.656727
Prodsystem~y	1.51	0.663625
numberofye~n	1.37	0.728460
Group_Member	1.37	0.729762
Landsiz	1.33	0.754597
Breedtype_~y	1.32	0.758282
Extensionf~q	1.19	0.837214
Households~e	1.17	0.857601
AmountOfff~e	1.16	0.858953
Credit_Acc~s	1.16	0.860115
Gen	1.15	0.870926
Landtenure~y	1.09	0.914255
Distance_c~t	1.05	0.953207
Mean VIF	1.47	

```
. hettest
```

Breusch-Pagan/Cook-Weisberg test for heteroskedasticity  
 Assumption: Normal error terms  
 Variable: Fitted values of `Feed_types`

H0: Constant variance

chi2(1) = 2.08  
 Prob > chi2 = 0.1489

```
. imtest, white
```

White's test  
 H0: Homoskedasticity  
 Ha: Unrestricted heteroskedasticity

chi2(157) = 166.92  
 Prob > chi2 = 0.2790

Cameron & Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	166.92	157	0.2790
Skewness	48.14	17	0.0001
Kurtosis	0.43	1	0.5115
Total	215.49	175	0.0201

dy/dx wrt: Age Gen numberofyearsofeducation Experience Householdsize AmountOfffarm\_income  
 Landsize Herdsize milk\_day Landtenure\_binary Group\_Member Extensionfreq  
 Distance\_conceMarket Credit\_Access Cow\_weight Breedtype\_Binary Prodsystem\_Binary

	dy/dx	Delta-method std. err.	z	P> z	[95% conf. interval]	
Age	.0075358	.0023606	3.19	0.001	.0029091	.0121624
Gen	.2051572	.046644	4.40	0.000	.1137367	.2965777
numberofyearsofeducation	.0218741	.0074929	2.92	0.004	.0071884	.0365599
Experience	-.0003523	.0024592	-0.14	0.886	-.0051723	.0044677
Householdsize	.0068587	.0119362	0.57	0.566	-.0165358	.0302533
AmountOfffarm_income	-1.73e-06	2.19e-06	-0.79	0.430	-6.01e-06	2.56e-06
Landsize	-.054804	.0235283	-2.33	0.020	-.1009187	-.0086893
Herdsize	-.0142337	.0351387	-0.41	0.685	-.0831044	.0546369
milk_day	.0038276	.0026162	1.46	0.143	-.0013	.0089553
Landtenure_binary	.2593649	.1186545	2.19	0.029	.0268064	.4919234
Group_Member	-.1135069	.0530287	-2.14	0.032	-.2174411	-.0095726
Extensionfreq	.0298689	.0169709	1.76	0.078	-.0033933	.0631312
Distance_conceMarket	.0065903	.0151197	0.44	0.663	-.0230437	.0362243
Credit_Access	.1240374	.0735058	1.69	0.092	-.0200314	.2681061
Cow_weight	.0010483	.0005011	2.09	0.036	.0000662	.0020305
Breedtype_Binary	.1819236	.0760652	2.39	0.017	.0328385	.3310087
Prodsystem_Binary	.0977836	.051674	1.89	0.058	-.0034956	.1990628

. oneway GM\_Cow\_Year Quality\_level2 , tab

Levelsd1	Summary of GM NEW		
	Mean	Std. dev.	Freq.
high	115034.4	109531.4	43
low	63186.377	160092.36	125
medium	82695.556	88194.585	57
Total	78037.434	137015.26	225

Source	Analysis of variance				
	SS	df	MS	F	Prob > F
Between groups	8.7663e+10	2	4.3832e+10	2.36	0.0965
Within groups	4.1175e+12	222	1.8547e+10		
Total	4.2052e+12	224	1.8773e+10		

Bartlett's equal-variances test: chi2(2) = 26.6572 Prob>chi2 = 0.000

```
. ttest TR_Cow_Year, by ( Feed_types)
```

Two-sample t test with equal variances

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf. interval]	
F	82	91888.22	8986.776	81378.72	74007.35	109769.1
C	143	145434.8	16274.92	194619.8	113262.3	177607.2
Combined	225	125920	10969.26	164538.9	104303.9	147536.2
diff		-53546.55	22559.99		-98004.6	-9088.512

diff = mean(F) - mean(C) t = -2.3735  
H0: diff = 0 Degrees of freedom = 223

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0  
Pr(T < t) = 0.0092 Pr(|T| > |t|) = 0.0185 Pr(T > t) = 0.9908

```
. ttest TVC_Cow_Year, by (Feed_types)
```

Two-sample t test with equal variances

Group	Obs	Mean	Std. err.	Std. dev.	[95% conf. interval]	
F	82	34268.5	5592.081	50638.45	23142.01	45394.98
C	143	55688.68	5446.993	65136.56	44921	66456.35
Combined	225	47882.21	4068.096	61021.43	39865.58	55898.84
diff		-21420.18	8349.377		-37873.95	-4966.404

diff = mean(F) - mean(C) t = -2.5655  
H0: diff = 0 Degrees of freedom = 223

Ha: diff < 0 Ha: diff != 0 Ha: diff > 0  
Pr(T < t) = 0.0055 Pr(|T| > |t|) = 0.0110 Pr(T > t) = 0.9945

```
. sum GM_Cow_Year
```

Variable	Obs	Mean	Std. dev.	Min	Max
GM_Cow_Year	225	78037.43	137015.3	240	1771500

## Appendix 8: Cow Live Weight Measurement Using Weight Band



**Appendix 9: Publication Abstract**



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## Determinants of utilization of recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya

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### Abstract

This paper examined the factors influencing the choice of utilizing the recommended forages and concentrates among smallholder dairy farmers in Nakuru County, Kenya. The study was based on data collected from a sample of 225 smallholder dairy farmers from Nakuru County, Kenya. The statistical programme STATA was used to analyse the data. Probit model result showed that factors including gender, breed types, land ownership, cow live weight, credit use, group membership, production system, herd size, extension contacts, education, and experience significantly affected the choice of utilizing recommended forages and concentrates. The average milk yield is approximately 8 litres per cow per day. This low yield is attributed to challenges such as limited access to quality feeds, limited extension services and financial resources. Therefore, the study recommends the need to improve access to quality feed, agricultural training, and extension services to help smallholder dairy farmers enhance feed efficiency and productivity.

**Keywords:** Recommended forages, recommended concentrates, smallholder farmers and probit model