

**DETERMINANTS OF PROFIT EFFICIENCY OF SMALLHOLDER DAIRY
PRODUCTION SYSTEMS IN GULU CITY AND GULU DISTRICT, UGANDA**

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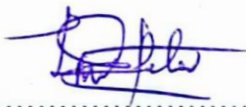
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ENTERPRISESDEVELOPMENTOFGULUUNIVERSITY**

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DECLARATION

To the best of my knowledge, I **Oyoo Peter Okello**, hereby certify that this research thesis is an entirely original work of mine and it has never been submitted for certification at this University or any other college or university. Any materials used have been cited and properly acknowledged throughout the research thesis.

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APPROVAL

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DEDICATION

I dedicate this research to my father John and Late mother Olga for their unwavering support and sacrifice to my studies.

To my devoted wife Margret and our kids Norine, Austin, and Esther. They made a sacrifice, but I believe their lives will become better in the years to come with God's mercy.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
CAO	Chief Administrative Officer

CTC	City Town Clerk
DDA	Dairy Development Authority
EAC	East African Community
EE	Economic Efficiency
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GM	Gross Margin
GUCD	Gulu Uganda Country Dairy
GUREC	Gulu University Research Ethics Committee
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MCCs	Milk Collection Centre
MoFPED	Ministry of Finance Planning and Economic Development
MVP	Marginal Value Product
NAADS	National Agricultural Advisory Services
NARO	National Agricultural Research Organization
NGOs	Non-governmental organizations
OPM	Office of the Prime Minister
ROI	Return on Investment
SFA	Stochastic Frontier Approach
SSA	Sub-Saharan Africa
WHO	World Health Organization

ABSTRACT

Dairy production systems in Uganda are still plagued by yield gaps, post-harvest losses, inadequate coordination, and ineffective marketing strategies. This has resulted in inefficiency and low productivity, even though this sector has been strategically invested in to increase income and food security. The study estimated profit efficiency, characterized dairy production systems, and determined the factors influencing profit efficiency. The maximum likelihood process was used in conjunction with a one-step stochastic profit frontier approach to estimate the profit efficiency and causes of profit inefficiency for 191 smallholder dairy farmers. Results show that the profit efficiency of smallholder dairy production systems is driven by land size, vet cost, costs of feed, cost of equipment, and the cost of labor. Findings further indicate that the inefficiency of smallholder dairy production systems is driven by age, years of experience, family size, gender, marital status, access to extension service, access to credit, group membership, and Friesian breed type. The study thus urges the development of labor-saving technology, the provision of farmers with inexpensive local feed, and the enhancement of extension services. The disparities in profit efficiencies among dairy production systems necessitate benchmarking among top performers and intervention tailored to those systems.

Keywords: *Dairy, smallholder, stochastic frontier Approach, Profit efficiency, Production systems, Gross margin, Return on investment*

CHAPTER ONE:INTRODUCTION

1.1.0: Background

Livestock supports more than 750 million of the world's poorest people (FAO, 2020) and more than 80 per cent of the world's population, or about 6 billion people, regularly consume liquid milk or other dairy products (FAO, 2019). The dairy sector plays a key role in ending poverty, especially for rural communities. Nearly one billion people worldwide earn their livelihood from dairy (European Dairy Authority, 2018). The dairy sector is a major pillar in the socio-economic standing of sub-Saharan Africa (SSA); functioning in both food security and income generation roles, particularly at the small household level (Mubiru & Tenywa, 2007) and (Chagunda et al., 2016).

As the top exporter of dairy goods in the East African Community (EAC), Uganda is one of the largest producers of dairy products in Africa (MoFPED, 2023). The performance of the dairy industry has greatly increased over time, reaching US\$102.6 million in exports in FY2021/22 and having dairy products available in 16 countries (MoFPED, 2023). Kenya buys most of these, purchasing more than 80% of Uganda's exports of dairy. UHT milk, butter, casein powder, milk powder, whey protein, and cheese are some of the most popular dairy product exports (MoFPED, 2023).

Approximately 14.8 million cattle, 16.9 million goats, 43.1 million poultry, 4.4 million pigs, and 4.7 million sheep were kept in Uganda as of 2019 (MoFPED, 2021). Four per cent of Uganda's GDP and 16 per cent of the agricultural sector's GDP were derived from the production of livestock in 2019/20. Nearly 70% of households in Uganda fully or partially derive their income from livestock. The Pork, beef, dairy and poultry sub-sectors are paramount in providing

Ugandans with protein food security (Larive, 2020). In recent years, dairy product consumption has reportedly increased significantly in the country with it now being estimated to be the second most consumed protein product in the country (Larive, 2020).

In Uganda, retail milk prices increased from 1,181 UGX (\$0.32) to 1667 UGX (\$0.45) in FY 2020/2021. The dairy industry now has a value of UGX 3.8 trillion, with increased farmgate and retail milk prices majorly in the northern and northeastern parts of Uganda (DDA, 2023). The overall milk output increased from 2.8 billion to 3.22 billion litres. The northeastern and mid-western Uganda contributed to the increase, with average milk productivity per cow increasing by 4.8 litres(DDA, 2023). Due to the nationwide expansion of milk collecting centres, the nation's milk production grew from 2.5 billion litres in 2018 to 2.8 billion litres in 2020 (MAAIF, 2022). According to the most recent report, there are 483 milk collection facilities across the nation, with a combined installed capacity of 1,938,522 litres(MAAIF, 2022). Dairy cooperatives, businesses, private persons, and processors run these facilities (MAAIF, 2022).

The Lango and Acholi sub-regions in northern Uganda are made up of 17 districts. Over 98 per cent of the cattle are local breeds (Zebu and Ankole), making up 6 per cent of the national herd (DDA, 2023). The national herd is expected to produce 50 million litres of milk annually, with Lango generating 35 million litres and Acholi producing 15 million litres, or less than 2% of the total (DDA, 2023). There is a tremendous potential to produce 150 million litres annually due to the excellent soil and an abundance of grass during the rainy season (DDA, 2023).

There are 22 officially registered cooperative associations, and the Gulu Country Dairy Farm serves as a training ground for cutting-edge technology that adds value to milk by creating yoghurt and ice cream (DDA, 2023). In the surrounding area, there are 23 milk coolers and eight

milk collecting centres (MCCs) owned by the Dairy Development Authority (DDA) located in the districts of Lira, Gulu, Dokolo, and Alebtong (DDA, 2023). In Gulu, there are four small-scale milk processors with a combined capacity of 7,000 litres (DDA, 2023). NAADS, OPM, NARO, district Local Governments, and development partners are participants in Northern Uganda's dairy value chain (DDA, 2023).

According to DDA, (2023), the South-western milk shed contributes 25% to national milk production, followed by the central milk shed with 24%, the Eastern milk shed with 21%, the mid-western shed with 12%, the northern milk shed with 11% and Karamoja shed trailing with 7% of national milk production. The milk sheds with a surplus are central and south-western milk shed which contributes up to 50% of total national milk production, northern shed and eastern shed experience a deficit almost throughout the year and are referred to as milk deficit areas (DDA, 2023).

Table 1: Milk prices at different milk sheds in Uganda by October 2020

Region	Farm gate	Retail
South Western	846	1,312
Central	863	1,646
Eastern	952	1,444
North Eastern	933	1,585
North	1,319	1,876
Mid-western	933	1,600
National Average	984	1,577

Source: Uganda Dairy Development Authority, 2020

Under Zero-grazing system, closed monitoring of animal and appropriate feeding procedures are made possible. This can lead to a more reliable and elevated milk output in contrast to large grazing systems (Dohme-Meier et al., 2014). Infrastructure, such as barns, feeding systems, and

waste treatment facilities, must be significantly invested in initially when setting up a zero-grazing system. Smallholder farmers who have low funding may find this to be a hindrance (Holohan et al., 2021). Farmers can more successfully regulate and control their livestock's diet when they tether them to a certain grazing area. According to Patra et al., (2008) and Mullan et al., (2014), this may result in increased feed utilization and enhanced nutrition for the animals. Cows in zero-grazing systems typically produce more milk than those in tethered and herding systems because they can better control and optimize their feed intake. According to Nalubwama et al., (2016) and Egeru et al., (2015), this is especially true when high-quality forages and supplemental feeds are offered.

Dairy production systems are limited by several factors, including diseases that affect dairy cattle, such as mastitis, tick-borne diseases, access to quality and affordable animal feed, price fluctuations, and post-harvest losses that have a substantial impact on milk production and deter farmers from investing (Ekou, 2014). The government, along with other relevant parties, endeavored to enhance the human resource capacity for the advancement of the dairy subsector using field-based initiatives that foster skill development and training. Encouraging the use of food-grade materials to improve the safety and quality of milk and milk products; renovating the cold chain infrastructure to improve milk marketing and lower post-harvest losses; and bolstering coordination for the dairy subsector's development by keeping an eye on and assessing its operations (DDA, 2018, Ekou, 2014)

1.2.0: Statement of the Problem

Despite being the largest producer of milk in East Africa, Uganda's dairy sector is producing only 3.2 billion liters of milk yet it is anticipated to produce 10 billion liters of milk (FAO,

2023). The supply gap is attributed to disease outbreaks, limited access to quality feeds, limited access to finances, and lack of extension services climate change and weather variability as well as the land tenure system (Wangalwa et al., 2016). As such smallholder dairy farmers are challenged with allocating their resources to optimize their production, thus inefficiency in their production system.

The available research on smallholder dairy production systems shows that inefficiency results in lower incomes for the farmers (Nakanwagi & Hyuha, 2015) on technical efficiency and the study by (Waiswa & Günlü, 2022) on economic efficiency. Such previous research is devoid of information on determinants of profit efficiency of the smallholder dairy production systems. Notably, studies explicitly analyzing the profit efficiency of smallholder dairy production systems are lacking necessitating further research. Therefore, this study sought to examine the determinants of profit efficiency of smallholder dairy production systems to provide insights into how profit efficiency can be enhanced as a strategy for increased incomes for smallholder dairy farmers. Knowledge of determinants of profit efficiency of smallholder dairy production system is useful for policy action in enhancing efficient resource use as well as increased profit margins and improved livelihoods of smallholder dairy farmers.

1.3.0: Objectives of the study

1.3.1: General objective

To investigate the determinants of profit efficiency of dairy production systems in Gulu city and Gulu district.

1.3.2: Specific objectives

- i. To characterize the dairy production systems in Gulu city and Gulu district.
- ii. To estimate the profit efficiency of dairy production systems in Gulu city and Gulu district.
- iii. To determine factors that influence the profit efficiency of smallholder production systems in Gulu city and Gulu district.

1.4.0: Research questions

- i. What are the characteristics of different dairy Production systems in Gulu city and Gulu district?
- ii. What are the estimates of profit efficiency of smallholder dairy production systems in Gulu city and Gulu district?
- iii. What are the factors affecting the profit efficiency of smallholder production systems in Gulu city and Gulu district?

1.5.0: Conceptual framework

Figure 1 shows that household decision-making in dairy production systems is influenced by institutional, socioeconomic, infrastructure, farm and farmer traits. Small-scale dairy farmers' choices are influenced by farm features, input costs, and institutional variables. Factors like education, household size, and farming experience are within the farmer's control, while input costs and institutional factors like financing and extension are not.

Farmers' decision to start a dairy farm depends on market availability, institutional variables like credit access, and input costs. Factors like farm size, education, and experience also impact

investment decisions. The chosen choice impacts the expected yield per cow and production costs.

Institutional, marketing and socioeconomic issues are all independent variables. Intervening variables include the selection of dairy production systems, output level, and production costs. The dependent variable is the profit efficiency.

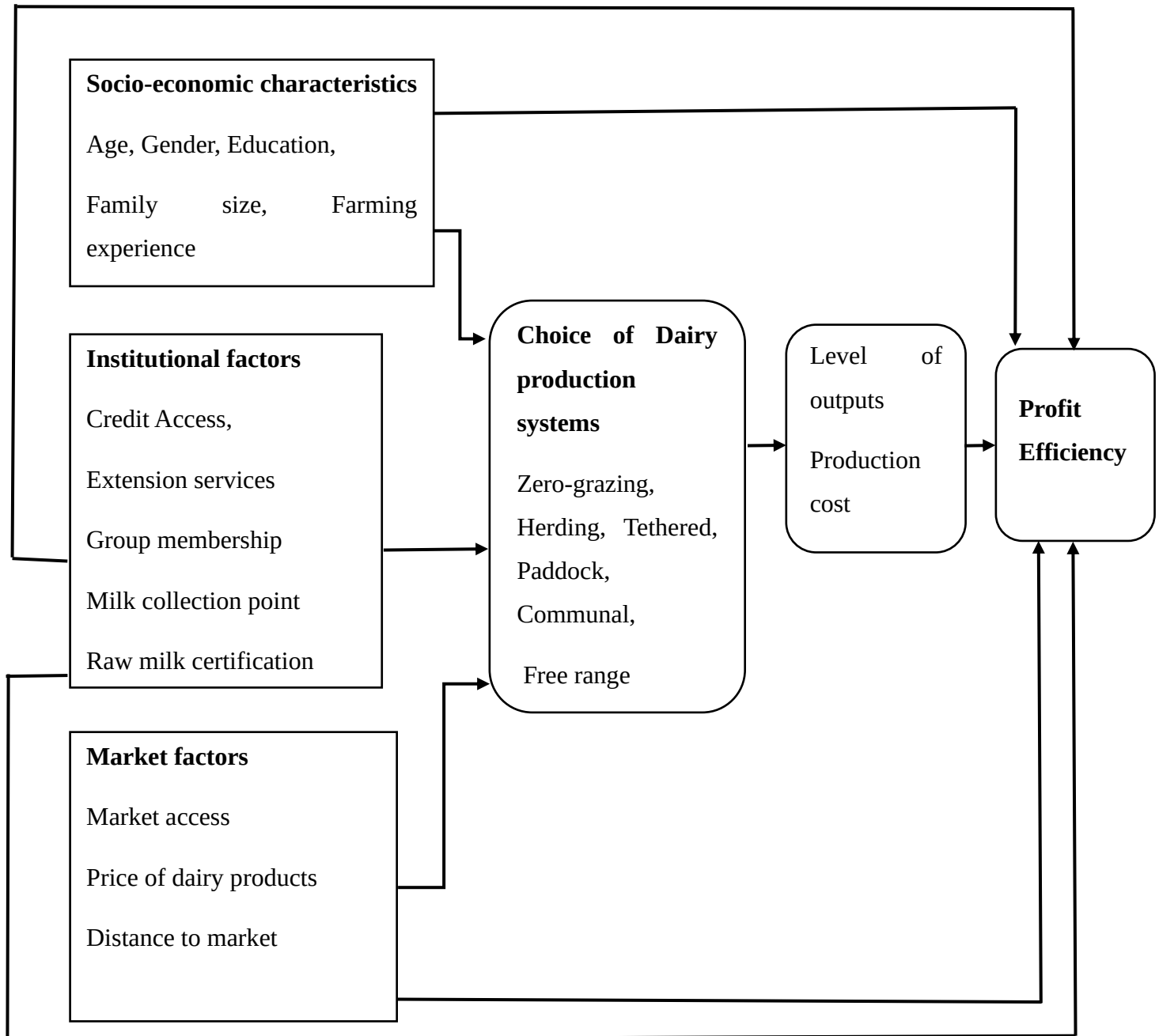


Figure 1: Conceptual framework

Source: Author's own construction, 2023

1.6.0: Justification of the study

The potential for major positive effects on poverty reduction, food security, economic growth, sustainability, and the general well-being of marginalized populations justifies research into the profitability of smallholder dairy farmers in underperforming region of northern Uganda. The focused initiatives and policies that result from this research can help this region and other regions see improvements.

1.7.0: The significance of the study

This study will be beneficial in many ways to a wide range of stakeholders, including farmers, academics, government officials, and NGOs. The dairy sector in Uganda is significant as a source of household income and nutrition. The results of the study will also enable the government and non-governmental organizations to adequately support the nation's dairy industry. The study's findings will help farmers learn more about dairy production so they may increase the effectiveness of their dairy operations. Finally, this work will be referenced by academics in their research articles.

1.8.0: Scope of the study

The study scope was divided in to three namely, contextual, geographical and time scope.

1.8.1: Contextual scope

Conceptually, the study focused on the determinants of economic efficiency of smallholder dairy farmers. Specifically, the study focused on characterizing, estimating profit efficiency and factors influencing profit efficiency of smallholder dairy farmers.

1.8.2: Geographical scope

This study was conducted in Gulu City and Gulu district located in northern Uganda where two divisions of Gulu city and three sub-counties of Gulu district were used in the study.

1.8.3: Time scope

The study was conducted for the period of three months from May to August 2023 using 191 smallholder dairy farmers as study respondents.

CHAPTER TWO: LITERATURE REVIEW

2.1.0: Dairy sector in Uganda

Income levels and household nutrition are significantly influenced by Uganda's dairy industry (FAO, 2022). In Uganda, the industry accounts for 6.5% of the country's agricultural GDP (FAO, 2022). Only around 20% of milk is processed into higher-value products in the dairy industry, which is dominated by rural small-scale farmers of various quality (FAO, 2022). The Dairy Development Authority (DDA) reports that Uganda's income from the export of dairy products has increased significantly, by 63 percent in three years (2018-2020). Currently, 8% of the overall export value comes from the dairy subsector. It's time to support the industry in realizing its full potential (FAO, 2022). The current effects of trade and market policies have led to milk producers earning prices around 7% below international equivalents since 2013, but down from around 50% less in 2005 (FAO, 2022).

In light of the country's expected increase in raw milk output from 1.9 billion litres in 2014 to 2.8 billion in 2021, fresh country support for Uganda's dairy industry (FAO, 2023). Despite this impressive growth, the dairy industry faces difficult times ahead because raw milk supplies are subject to large seasonal fluctuations, processing capacity is underutilized, informal trade is still prevalent, quality concerns restrict international trade, and exports are heavily dependent on demand from some important East Africa export markets, such as the neighboring country of

Kenya (FAO, 2023). Ugandans only consume roughly 2 out of every 3 servings of the necessary amount of milk, which is two-thirds less than what FAO and WHO recommend (FAO, 2023).

Northern Uganda is recovering from a civil war that lasted 25 years. This region is fertile with numerous palatable grasses for raising livestock. During dry seasons several livestock die due to lack of feed as the farmers lack the skill to preserve and store the grass for their livestock (GUCD, 2023). Smallholder dairy farmers in Gulu City and the surrounding Gulu district are still having trouble expanding their businesses because they lack adequate knowledge of dairy production, despite the interventions of the Ugandan government and other stakeholders, including the Diocese of Northern Uganda and Heifer International, to supply cattle and provide farmers with affordable training on dairy production (Tumwesige. A, Aug 19, 2020). The majority of smallholder farmers keep one to three dairy cows, but they are underfed (Tumwesige. A, Aug 19, 2020). Most of the time, these farmers don't adequately care for the sick cows, and because they don't have much money, they are compelled to use less-efficient spraying methods instead of spray dips, which decrease milk production, such as knap snack spray, which is less expensive (Tumwesige. A, Aug 19, 2020). The amount of milk produced may vary depending on the stage of nursing, but to increase yields, cows need to be fed roughly 75 kg of feed and 40 litres of water each day to produce an average of 18 litres of milk per cow. However, some farmers in the area do not do this (Tumwesige. A, Aug 19, 2020). The market for dairy products is easily accessible in Gulu City and Gulu district as a result of the expanding urban population, nearby hotels, schools, and other organizations. There is a high demand for dairy products as a result of a drop in milk supply (Tumwesige. A, Aug 19, 2020).

2.2.0: Dairy Production Systems in Uganda

The most intense production method is zero-grazing. This method requires a high degree of external inputs, including purchased food, and significant spending on livestock and veterinary services. Improved dairy cattle are housed in stalls with no access to free grazing. Farms are close to towns, have a small size, and have a high level of productivity. Even though the farm's cropped area is relatively modest, a sizable amount of the land is planted for crops since the cattle are confined. About a quarter of farms fall into this category, and the majority of those are in the central and southwestern regions (Wozemba and Nsanja, 2008), (Nalubwama et al., 2019). Pastoral groups commonly engage in herding or communal grazing, which entails pastoral grazing on communal land controlled by clan. Despite being prohibited, this technique is still used in northern and eastern Uganda. This community has a strong connection to its historical agropastoral or pastoralist culture (Wozemba and Nsanja, 2008).

Free-range grazing is when cattle are moved around the grassland to graze. In the vast grasslands of southern Uganda, it is a customary practice. The boundaries are fenced with local hedgerow species, although the farmland is frequently not divided into paddocks (Wozemba and Nsanja, 2008). When the land holding is small, farmers often use fenced or paddock grazing, which entails grazing cattle in paddocks and supplementing their diet with feed concentrates. Land clearing and improved pasture are needed for this kind of grazing. Farmers of hybrid and cross-breed cattle primarily engage in it (Wozemba and Nsanja, 2008). Tethered grazing; mostly indigenous cattle breeds are grazed off farms, freeing up area for farming; cow density is often high. Tethered farms frequently coexist with fenced, zero-grazing, or semi-intensive farms. The

Western region is where tethered farms are most prevalent, accounting for around one-third and one-fifth of all farms, respectively (Baltenweck, 2007) and (Nalubwama et al., 2019).

2.3.0: Characteristics of smallholder dairy farmers

The obligations, and duties of smallholder dairy farmers are substantially influenced by their gender. This improves the sustainability and efficiency of smallholder dairy farming operations. Kataike et al., (2018) discovered that the male gender dominates dairy production with 79 per cent compared to the female gender and their study contradicted the study of Rantlo et al., (2020) and Kiggundu et al., (2021) revealing female' gender are more in dairy farming with the reason that women take charge of dairy production and marketing while men go for urban jobs.

Age is a multidimensional trait of smallholder dairy farmers that affects their traditional knowledge, openness to innovation, physical capacities, financial planning, and role in generational transitions. The survival and expansion of smallholder dairy farmers depend on effective cooperation between different age groups of farmers. Kataike et al., (2018), Jadav & Pandya, (2014) and Balirwa & Waholi, (2018) study demonstrated that the most active age group in dairy farming ranges from 36 to 50 years which is the middle age group this was disputed by the study conducted by Omondi et al., (2017) with the mean of 51 years.

Educated smallholder dairy farmers are better equipped to manage their farms and increase their income in many ways, including through modern technology, financial literacy, sustainable farming techniques, and market dynamics. According to Kataike et al., (2018), 74% of dairy farmers have attained primary education which equipped them with basic knowledge to run the dairy farm and this concurred with the finding of Omondi et al., (2017) but contradicts the

findings of Rantlo et al., (2020) and Jadav & Pandya, (2014) who reported only 27% of the dairy farmers attended primary education and Jadav & Pandya, (2014) categorized further by revealing that 23% out this educated dairy farmers can read and write.

Smallholder dairy farmers that have off-farm income have more stable incomes, access to resources, and a wider variety of revenue sources. It is essential for guaranteeing the viability and sustainability of small-scale dairy farming businesses. The study conducted by Kataike et al., (2018) and Jadav & Pandya, (2014) asserted that the majority of the dairy farmers belong to the middle-income group with 64% and 79% respectively.

According to Kataike et al., (2018), the milk output per cow per day ranges from 10 to 20 litres constituting the greater percentage, with the herd size ranging from 6 to 10 accounting for the highest percentage. This coincides with the findings of Jadav & Pandya, (2014) but contrary to the finding of Mawa et al., (2014) with the mean herd size of 3 cows. Jadav & Pandya, (2014) revealed that 72% of the smallholder dairy farmers owned crossbreed cows but their observation was at odds with those of Raval&Chandawat, (2011), who suggested only one breed dominating.

Family size is a very important characteristic of smallholder dairy farmers that impacts labor availability, resource management and the overall household livelihood. Rantlo et al., (2020)in their study confirmed the mean house size was 9 persons. According to Rantlo et al., (2020), large household size impacted negatively on dairy production and marketing. This contradicts the findings of Kataike et al., (2018) and Jadav & Pandya, (2014) of 3 to 5 persons in a household which was very close to the findings of Omondi et al., (2017) with a mean family size of 6 persons.

Smallholder dairy farmers who have experience are highly prized. It is an expression of the wisdom, knowledge, and experience gained through many years of managing farms and dealing with dairy cattle. Kiggundu et al., (2021) revealed that the majority of dairy farmers had less than 11 years of dairy farming experience this was disputed by Omondi et al., (2017) revealing 21 years of dairy farming experience. Distance travel to the market contributes significantly to dairy farming, Somda et al., (2005) reported a study that the mean distance travelled to the market by smallholders is 6 kilometres and the sales of unprocessed or fresh milk dominate the market with 56% of the farm households.

The mean gross margin of smallholder dairy farmers ranges from US \$911 to US \$1111 and the net income obtained from the sale of milk ranges from US \$640 to US \$1030 between the resource-poor and the medium group smallholder dairy farmers (Somda et al., 2005). The study on characteristics and economic viability of milk production in smallholding dairy in Gambia by Somda et al., (2005) indicated that estimated returns on investment range from US \$28 to US \$33 between the resource-poor and the medium group smallholder dairy farmers (Somda et al., 2005).

2.4.0: Efficiency measurement

Gross margin analysis of profit efficiency can be a helpful strategy for smallholder dairy farmers whose fixed assets are little. Profit efficiency in this situation measures how well these farmers are making use of their inputs to produce gross margins while taking into account the limited availability of fixed assets (Datta et al., 2019) and (Migose et al., 2018).

Gross Margin= Total Revenue - Variable Costs equals

Where:

Total Revenue is the sum of income from milk sales.

Variable Costs: The expenses that are directly related to producing dairy products, such as feed, veterinary services, labor, and other variable costs.

2.4.1: Stochastic Frontier Approach (SFA)

Farrell's 1957 work led to the development of the stochastic frontier approach (SFA). Later, Aigner et al., (1977) proposed the stochastic frontier approach based on Aigner's (1968) translation of Farrell's frontier into a production function (SFA), which has been widely used in econometrics to estimate cost functions, revenue functions, and distance functions. The SFA is a parametric method that divides error terms into inefficiency and measurement error components, capturing random error impacts and inefficiency consequences. Estimating frontier models requires assuming the inefficiency parameter's probability density function is either half-normal, exponential, normal-gamma, or truncated normal distributed.

The SFA uses a parametric model to estimate the upper limit of the production frontier in agricultural production systems. The stochastic frontier production function has a regression type with a composite disturbance term. The likelihood function accommodates the variance parameters, with values between 0 and 1, indicating noise or technical inefficiencies. This model is recommended for farm-level data analysis when measurement errors, missing data, and risk variables significantly impact output (Battese and Coelli, 1995).

The SFA approach assesses inefficiencies in specific production units using distributional hypotheses based on technical and economic scores. Deterministic models cannot be used for standard error estimation or hypothesis testing, but SFA models allow for maximum likelihood methods (Ali & Flinn, 1989). The model's main drawback is the need for a specific parametric functional form and distributional assumption for inefficiency factors (Chiona et al., 2014). Therefore, there is no *a priori* reason to justify choosing a specific functional form for the inefficiency component (Coelli, 1998).

2.5.0: Determinants of profit efficiency

The "One-step" and "Two-step" methods assess efficiency, with the "Two-step" method focusing on estimating the frontier function's distance function, computing technical inefficiency, and returning the influencing factors. This approach leads to skewed conclusions and diverging function distributions (Wang & Schmidt, 2002). Coelli & Battese, (1996) introduced the "One-step" method, which involves estimating the stochastic frontier function and profit efficiency models simultaneously, allowing for more precise prediction of technology inefficiency. Efficiency estimation is limited without understanding socioeconomic, demographic, and institutional variables. This makes it difficult to identify appropriate policy interventions based on predicted producer efficiency. Investigations have been conducted to identify causes of variances in agricultural technical, allocative, and economic efficiency. Improved estimation power and sophisticated modifications to efficiency assessment are needed (Wang et al., 2017; Anyaegbunam et al., 2016; Abate et al., 2019; Milkessa et al., 2019).

Gender influences farmers' productivity, with male farmers being more productive due to social norms, religious beliefs, and conventions, as reported by Alston et al., (2017), this was at odds with the findings of Masunda & Chiweshe, (2015) and Zirham & Palomba, (2016) but moderate to the findings of Musliu et al., (2014) who reported that dairy production is technically efficient for both men and women.

Singh et al., (2023), and Ongwech et al., (2020) found out that education level and farm size significantly impact technical efficiency. Higher education improves administrative and technical abilities, boosting farmers' capacity to use current technologies (Coelli, 1995). Owuor and Shem, (2009) and Turinawe et al., (2012) found a negative correlation between farmers' technical efficiency and education, with technical inefficiency rising after five years due to a reduced desire for farming and focus on salaried employment.

Furthermore, accessibility to extension services is a significant issue that influences efficiency. The acceptance of recommended production standards and the practical application of current technology are made easier by a farmer's constant contact with extension officers. Nakanwagi & Hyuha, (2015) looked into the technical efficiency of milk producers in the Kiboga district of Uganda's Cattle Corridor. According to the authors, regular use of extension services boosted technical efficiency as confirmed by Yadav et al., (2021) and Warriach et al., (2019). This was disputed by Mawa et al., (2014), according to these authors extension services paid for by dairy farmers increase the cost of dairy production resulting in a decreased milk gross margin and consequently the profit efficiency. According to Nganga et al., (2010), Maina et al., (2020), Hansen et al., (2020) and Teklewold et al., (2013) dairy farming experience influenced profit

efficiency positively. This implies that more years of experience result in the accumulation of knowledge and understanding of dairy farming.

The age of the dairy farmers significantly influences their profit efficiency, the study on profit efficiency by Nganga et al., (2010) confirmed that age negatively impacted profit efficiency. Authors argued that old age reduced the mobility of the farmers, adoption of new technology and increased reliance on hired labor. Balirwa & Waholi, (2018) added that age affects the decision to adopt a new breed type which produces more milk and negatively affects the quantity of milk produced.

According to a common argument in development theory, access to finance increases liquidity and increases the use of agricultural inputs. Guadu & Mengistie, (2016) noted that technological efficiency is positively impacted by loan availability. According to the authors, this lessens the financial challenges that confront farmers at the start of dairy production, allowing them to purchase inputs. The amount of credit gained and utilized, in addition to formal education, experience, and access to extension services, was proven by Addai & Owusu, (2014) to be a significant element that can improve technical efficiency. Contrarily Turinawe et al., (2012) and Ongwech et al., (2020) reported that due to the short grace period, inadequate loan size, and change in the loan's intended use from farming to non-farming activities, dairy producers regarded loan payback as a restraint. Family size is yet another element that affects how productive farmers are. Large family sizes place additional strain on farm income for food and clothes, although Kumar et al., (2017), Girma, (2019); Bekele, (2021) noted that they can occasionally ensure the availability of sufficient family labor to ensure dairy tasks are completed on time.

Empirical evidence reveals mixed influences on education, age, credit access, market access, extension services and dairy experience. This study uses the stochastic frontier approach (SFA) to evaluate the profit efficiency of the sampled farms in Gulu City and Gulu district, aiming to close the knowledge gaps on existing efficiency levels.

2.6.0: Research gaps

From the literature reviewed, little information is available on smallholder dairy production systems profit efficiency compared to economic and technical efficiency. The study carried on dairy production in Uganda (Nakanwagi & Hyuha, 2015; Waiswa & Günlü, 2022) concentrated on technical and economic efficiency of smallholder dairy farmers. Most research focus on marketing and production of dairy products (Egeru et al., 2015; Nalubwama et al., 2016).

The determinants of profit efficiency of smallholder dairy production systems have not been given focus by the previous studies in the country. It is therefore necessary to investigate the determinants of profit efficiency of smallholder dairy production systems. This will provide a ground for a comprehensive study to inform development of appropriate research and policy interventions to enhance smallholder dairy production in Gulu city and Gulu district. The study therefore characterized dairy production systems, estimated profit efficiency and determined the factors influencing profit efficiency.

CHAPTER THREE: METHODOLOGY

3.1.0: Study area

Smallholder dairy farmers made up the research population, which was conducted in two divisions of Gulu City and three sub-counties of Gulu District. Northern Uganda's Gulu City is located close to the coordinates 2°46'54.03 N and 32°17'57.0 E. The largest and capital city of Uganda, Kampala, is located about 333 kilometres from Gulu City. The two divisions are Pece-Laroo division and the Bardege-Layibi division were selected for this study. The study location was selected because it has a significant concentration of dairy farming populations and are influenced by various factors including electricity, an expanding urban population, access to dairy inputs, extension services and milk collection centres include the Gulu Women Dairy, Gulu Uganda Country Dairy, and Nozomi. Gulu City is the leading milk producer among the cities in Northern Uganda.

The Gulu district is situated in northern Uganda between latitude 02°4°N and longitude 30°32°E. The districts of Amuru and Nwoya share borders with the districts of Gulu in the west and southwest, Lamwo in the northeast, Pader in the east, Lira in the southeast, and Oyam in the south.

Gulu District occupies 3,428.42 sq. km of land or 1.44 per cent of Uganda's total area. Open water covers 96.9 sq. km (0.8%) of the area. The Great North Road connects Sudan and the Democratic Republic of the Congo, and it is 332 kilometres from Kampala to the district headquarters. The study focused on the three sub-counties of Paicho, Awach and Patiko. These three sub-counties were selected because of a greater number of dairy farmers due to support from Good Partners a non-governmental organization providing dairy cows cheaply to farmers, providing extension services at subsidized prices and sourcing markets for these dairy farmers. Map of the study area is as shown in (Figure 2).

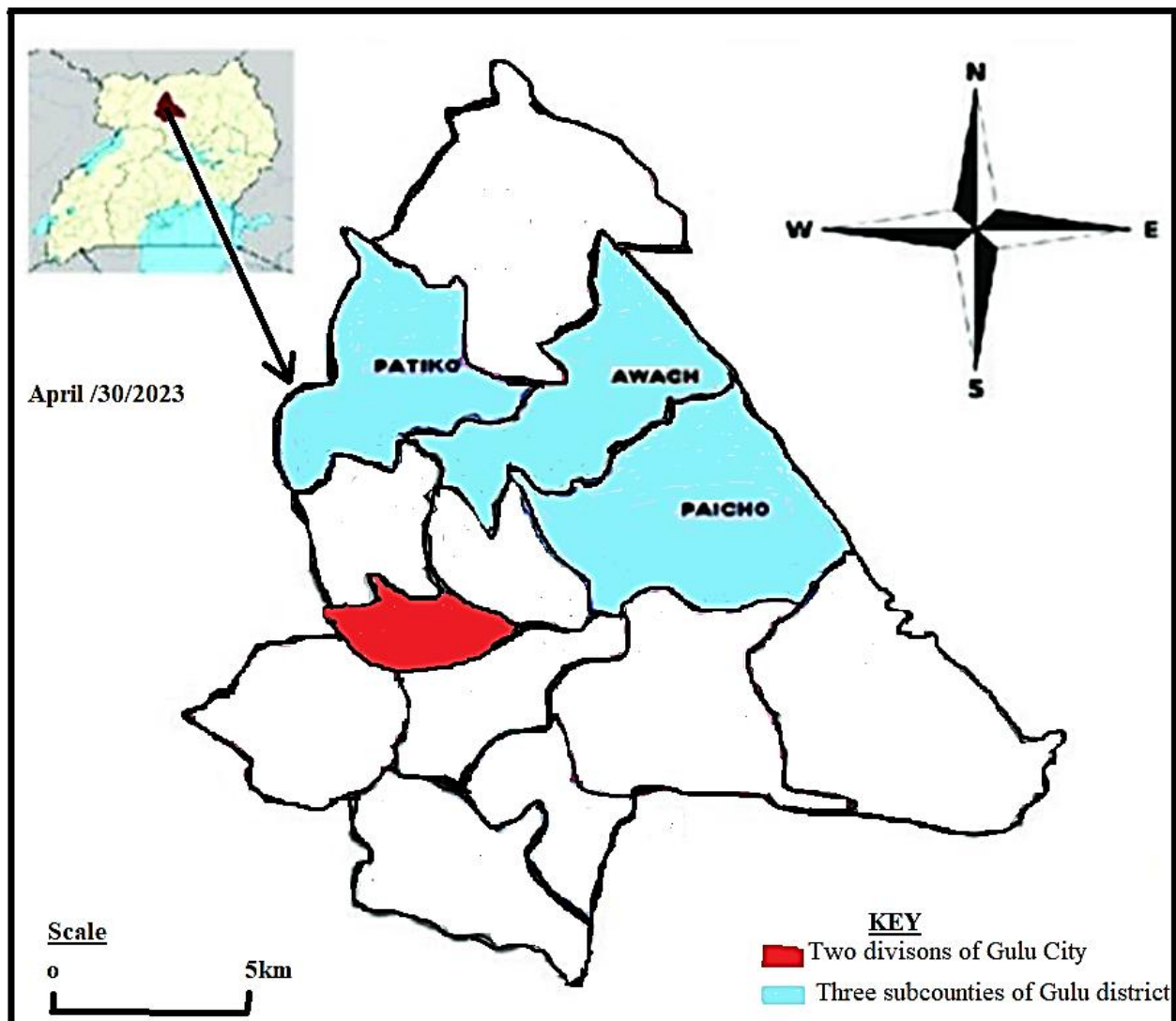


Figure 2: Map showing the study area

3.2.0: Study design

This study applied a cross-sectional study design. A cross-sectional study design is an observational study that analyses data collected at a specific point in time from the population or a sample of the population (Sekaran, 2003). Since this study intended to collect data in a short period, therefore cross-sectional was the most appropriate research design or study design. Many scholars have used this study design in a similar discipline or study (Kemitare & Kabuye, 2018; Yan, 2017)

3.3.0: Sample size determination and sampling procedure

3.3.1: Sample size determination

Smallholder dairy farmers were the study's intended population from northern Uganda particularly Gulu City and Gulu districts. Based on the data taken from the district veterinary officer in Gulu city and Gulu district, the population of smallholder dairy farmers were 380 farmers. Using the Krejcie and Morgan table of 1970 of sample size determination, a sample of 191 respondents was used for this study as shown in appendix I

3.3.2: Sampling Procedure

The study targeted smallholder dairy farmers in Gulu City and Gulu district, who were exposed to dairy farming. A representative sample was selected using multistage sampling, with Gulu City and Gulu district being chosen purposively in the first stage while the two divisions and three sub-counties were also chosen purposively in the second stage. In the final stage (stage

three), a total of 191 respondents were finally chosen using simple random sampling with the aid of a sampling framework. The sampling framework was constructed with the help of area extension staff and it was a global listing of all dairy farmers in the study areas.

3.4.0: Data Collection

3.4.1: Pre-testing of the questionnaire

Pretesting was done in Omoro district, similar to Gulu districts and Gulu City, allowing researchers to rephrase questions, assess data consistency, and measure questionnaire delivery time. Research assistants were chosen based on Acholi language proficiency and advanced education qualification in Uganda (Uganda advanced certificate of education).

3.4.2: Data collection instrument

Face-to-face interviews were used to administer semi-structured questionnaires to gather data. The questionnaire had both closed-ended and open-ended questions for gathering data. In contrast to open-ended questions, which allows respondents to come up with their responses, close-ended questions let respondents choose a response from a list of possible ones. The questionnaire had the following sections:

The respondents' socioeconomic characteristics including the respondents' age in complete years, education level in years, size of their farms in terms of herds, travel distance to the market in kilometers (km), group membership, employment, experience in years, gender, income from secondary occupation and size of their households.

From a technical standpoint, this part of the questionnaire concentrated on the number of lactating cows, bulls, castrates, and calves, the milking cycle, the calving interval, the amount of milk produced by each cow per day, the average amount of milk sold, the average amount of milk consumed, the number of crosses or exotic-breed cows, the amount of water (Ltr), feeds (Kg), veterinary supplies and services, human labor (person-days) land size (acres).

The costs and profitability of the smallholder dairy business. To calculate the costs and returns for smallholder dairy producers, this component of the questionnaire looked at the price of labor, transportation, feeds, transactions, legal fees, equipment, and veterinary goods and services. The characteristics of dairy production systems, such as free-range, zero-grazing, tethered, paddock, and herding systems, were also examined in this section of the questionnaire.

The questionnaire used both closed-ended and open-ended questions to gather information from farmers. A team of specialists from the Department of Rural Development and Agribusiness Faculty of Agriculture evaluated the instrument's content validity, ensuring measurements complied with specifications, items were clearly labelled, and claims were unambiguous. A pretest with 30 smallholder dairy farmers confirmed its validity.

The information was gathered from primary sources, and primary field surveys of a sample of smallholder dairy farmers were carried out using a questionnaire to learn about their socioeconomic traits, dairy production, levels of inputs and outputs, farm management techniques, and income from dairy farming.

3.5.0: Data analysis

Data were entered into SPSS V25 software, cleaned, edited, and coded for consistency, uniformity, and accuracy. The data were then exported to STATA V13 for further processing and analysis.

3.5.1: Analytical framework

3.5.2: Objective one: Characteristics of dairy production systems in Gulu city and Gulu district.

The categorical chi-square test of association was used to determine whether dairy production systems (Zero-grazing, Tethered, Herding) were associated with the categorical farmers' characteristics (Gender, extension services, group membership, credit access, market access, marital status and form of milk sold). The one-way ANOVA test was performed to compare continuous or numerical farmers' characteristics (Age in years, experience in years, distance to the market in kilometres, education in years, Off-farm income, land size in acres, herd size, quantity of milk in litres per cow per day, labor cost in Ugx, cost of veterinary service in Ugx, feed cost in Ugx quantity of feed in kilograms) by dairy production systems (Zero-grazing, Tethered, Herding).

3.5.3: Objective two: Estimation of profit efficiency of smallholder dairy production systems in Gulu city and Gulu district.

The profitability of smallholder dairy production systems in the research area was estimated for this purpose using gross margin analysis. Analysis of gross margins (GM) is a method for estimating small enterprises' profitability. It is a helpful planning tool for farming operations

where fixed capital is a small component of the agricultural enterprises in this instance of smallholder dairy farming (Datta et al., 2019) and (Migose et al., 2018).

$$GM_{jk} = TR_{jk} - TVC_{jk} \dots \dots \dots (1)$$

Where k represents the k^{th} observation while j represents the j^{th} dairy farmer.

Equation (2) calculates the total revenue (TR) from milk sales in Uganda shillings, while equation (3) determines the total variable cost (TVC) in Uganda shillings. GM is the gross margin in Uganda shillings.

$$TR_{jk} = \sum PQ \dots \dots \dots (2)$$

Where Q is the quantity of milk sold in litres, and P is the price per litre of milk.

$$TVC_{jk} = H_{Feedj}N_{Feedj} + H_{Vetj}N_{Vetj} + H_{Labourj}N_{Labourj} + \dots + H_nN_n \dots \dots \dots (3)$$

N is the quantity of variable inputs, and H is the price of the variable inputs.

The Return on Investment (ROI) was calculated as suggested by (Ojiakor et al., 2018) to determine the level of profitability. As the ROI rises, profitability rises as well. ROI is depicted as follows in equation (4):

$$ROI = GM/TVC \dots \dots \dots (4)$$

Formulation of a stochastic model

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} e^{\varepsilon_{ij}} \dots \dots \dots (5)$$

As illustrated below, the profit function was linearized by applying natural logarithms to both sides.

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \varepsilon_{ij} \dots \dots \dots (6)$$

$$\varepsilon_{ij} = v_{ij} - u_{ij}$$

ε_{ij} = composite error term, v_{ij} = random error, and u_{ij} = technical inefficiency

Where Y represents the unit profit from milk production (UGX/Litre), X_1 represents the size of the land (a fixed input), X_2 represents the unit cost of feeds (UGX/Kg), X_3 represents the unit cost of veterinary services (UGX/Man-day), X_4 represents the unit cost of labor (UGX/Man-day), and X_5 represent cost of equipment for milking and drinking (UGX/Man-day).

Using the inefficiency effects model stated in equation (7), the profit inefficiency is estimated

$$u_{ij} = \delta_0 \sum_{z=1}^n \delta_z \delta X_{zj} \dots \dots \dots (7)$$

Where δ_0 stands for the constant term, δ_z represents the parameters to be estimated, u_i stands for profit inefficiency, and δX_{zj} represents the vector of z^{th} independent variables of the j^{th} dairy farm. These variables include dairy farming experience (years), family size (number), education level (years), land size (acres), gender (male or female), access to credit, access to extension service, farmers' group membership, age (years), breed type and quantity of water (Litres/cow).

To account for the two variance parameters, $\delta^2 = \delta_u^2 + \delta_v^2$ and $\gamma = \delta_u / \delta_v$ in the stochastic frontier production function, Aigner et al., (1977) advise employing a likelihood function.

Gamma (γ) values must fall between 0 and 1, with values of 0 indicating that all deviations from the frontier are solely caused by noise and values of 1 suggesting that all deviations are caused by technical inefficiencies.

3.5.4: Objective three: Determine the factors affecting the profit efficiency of smallholder dairy production systems in Gulu city and Gulu district.

The factors affecting profit inefficiency were computed simultaneously in equations 2 and 6. For the specification, equation 7 was employed.

Table 2: The list and descriptions of the variables used in profit efficiency analysis

Variables	Measurement units	<i>A priori</i> expectation
Household characteristics		
Age	Years	+/-
Gender	Female=1 and Male=2	+
Farmers' education level	Years	+/-
Farming experience	Years	+/-
Family size	Number of persons	+
Marital status	Single, married, divorced, widow, widower	+
Income level	UGX	+
Production and market variables		
Land size	Acres	+/-
Herd size	Number of herds	+/-
Lactating cows' size	Number of lactating cows	+/-
Quantity of water provided	Quantity of water per cow in litres	+/-
Capital	UGX	+
Price of feeds	UGX/kg	+/-
Cost of veterinary services	UGX/man-day	+/-
Human labor	UGX/man-day	+
Cost of equipment	UGX/man-day	+/-
Quantity of output	Ltr/cow	+
Quantity of output sold	Ltr	+/-
Total cost of production	UGX	+/-
Total revenue for product	UGX	+/-
Total profit	UGX	+
Institutional variables		
Market access	Dummy (Yes =1, No=0)	+
Credit access	Dummy (Yes =1, No=0)	+
Group membership	Dummy (Yes =1, No=0)	+

3.6.0: Ethical Consideration

The researcher obtained introductory letters from the district Chief Administrative Officer (CAO) or city town clerk (CTC) after approval from the Gulu University Research Ethics Committee (GUREC), directing him to the district veterinary officer (DVO) for information on dairy farmers. Assistant veterinary officers connected the researcher and his team to local councils. The researcher was introduced to respondents at their homes or farms, and only family members aged 18-65 with a dairy farming history were selected for the study by lottery.

CHAPTER FOUR: PRESENTATION OF RESULTS

4.1.0 Socio-economic Characteristics of dairy farmers

The results in Table 3 compare the socio-economic characteristics of dairy farmers by the dairy production systems used. The results in Table 3, reveal that 39% of farmers used a zero-grazing system, 36% used a tethered system, and the other 25% used a herding production system. The age of dairy farmers varied among dairy production systems, with an average age of 47 years. The study also revealed that farmers using a herding system, as opposed to zero-grazing and tethered grazing systems, had an average of nine years of dairy experience. Dairy farmers' average length of education was eight years, which indicates that all of them had completed at least the primary level of education. The results also showed that across all dairy production systems, the average family size was 8 people.

The average land size for the herding system was 3 acres, which was significantly higher than the other two production systems ($p < 0.01$). The farmers under the herding system had the largest

average size of total land owned, up to ten acres, while those under zero-grazing had the smallest average size of all owned land, just five acres.

The study found that herding systems had statistically significant ($p < 0.01$) herd sizes compared to the other two dairy production systems probably because they had access to more acres of land. The mean number of lactating cows in the herding production system was three times more than those in the other two dairy production systems. The results also showed that zero-grazing systems produced significantly more milk per cow than the other two dairy production systems ($p < 0.01$) probably due to increased care and management.

The mean milking circle was up to eight months under zero grazing less under the tethered system. The mean calving interval was twelve months across all the dairy production systems. The mean quantity of water provided per cow was 28 litres which was significantly more under a zero-grazing production system. The mean distance travelled to the market was two kilometres under a tethered system which is significantly less compared to the other two production systems.

Table 3: Continuous socio-economic characteristics of dairy farmers in Gulu city and Gulu district

	Overall (N=191)	Zero-grazing (n=75)	Tethered (n=69)	Herding (n=47)	F-test	P-value
Numerical Variables	Mean (SD)					
Age (years)	46.91(12.03)	47.59(11.46)	43.99(11.49)	50.13(12.92)	3.959**	0.021
Dairy Experience (years)	6.53(4.76)	5.67(4.24)	6.06(4.84)	8.60(4.94)	6.325***	0.002
Education level (years)	8.49(5.36)	10.03(5.74)	6.64(4.79)	8.77(4.77)	7.779***	0.001
Family size	7.82(2.91)	7.81(3.14)	7.51(2.41)	8.30(3.18)	1.032	0.358
Land size under dairy (acres)	1.43(3.42)	0.92(1.09)	1.11(2.38)	2.69(5.97)	4.494**	0.012
Total land size owned (acres)	6.93(12.00)	4.81(5.52)	7.14(14.05)	10.02(15.40)	2.788**	0.064
Herd size	5.56(4.58)	4.21(3.20)	3.87(2.20)	10.19(5.82)	47.766***	0.000
Number of lactating cows	1.95(1.46)	1.49(0.76)	1.59(0.75)	3.19(2.23)	29.294***	0.000
Qty of milk per cow per day (litre)	6.88(4.46)	10.40(3.72)	4.94(3.59)	4.13(2.71)	65.010***	0.000
Milking circle	7.10(1.44)	7.95(0.90)	6.17(1.50)	7.11(1.20)	38.166***	0.000
Calving interval	12.17(1.25)	12.19(1.39)	12.04(0.21)	12.32(1.80)	0.693	0.502
Qty of water per cow per day (litre)	25.70(8.45)	27.92(8.16)	25.51(8.96)	22.45(7.06)	6.445***	0.002
Distance to market (Km)	2.72(1.80)	3.17(1.78)	1.96(1.53)	3.11(1.86)	10.564***	0.000

The figures in parentheses represent mean & standard errors. *, ** and *** indicate level of significant at 10%, 5% and 1%

Source: Author, 2023

The comparison of categorical dairy farmers' characteristics by dairy production systems used is illustrated in Table 4. The results revealed that among these dairy production systems, 64% of zero grazers were female, 81% were married, and that gender was statistically significant ($p < 0.01$). While marital status did not differ across dairy production systems.

The study results also showed that these dairy production methods relied heavily on market access and financial availability, both of which had statistically significant values ($p < 0.01$) and ($p < 0.05$), respectively. While group membership was statistically significant ($p < 0.05$) with higher group membership under zero grazing, extension services were not statistically significant across the dairy production systems.

In addition, the study found that 62% and 93% of farmers in tethered production system employed hired labor and/or had a second job, both of which had statistically significant effects ($P < 0.01$) on the three dairy production systems.

Additionally, the findings confirmed that 96%, 53%, and 96% of dairy producers using zero-grazing systems used boreholes, had Friesian cattle breeds, and sold raw milk, all of which were statistically significant at ($P < 0.01$) across the dairy production systems.

Table 4: Categorical characteristics of dairy farmers compared by production system

Categorical Variables	Category	Overall	Zero-grazing	Tethered	Herding	χ^2	P-valve
		(N=191)	(n=75)	(n=69)	(n=47)		
Frequency (%)							
Gender	Male	88(46.1)	27(36.0)	29(42.0)	32(68.1)	12.832***	0.002
	Female	103(53.9)	48(64.0)	40(58.0)	15(31.9)		
Marital status	Marred	153(80.1)	61(81.3)	55(79.7)	37(78.7)	134	0.935
	Otherwise	38(19.9)	14(18.7)	14(20.3)	10(21.3)		
Market access	Yes	131(68.6)	61(81.3)	39(56.5)	31(66.0)	10.782***	0.005
	No	60(31.4)	14(18.7)	30(43.5)	16(34.0)		
Credit access	Yes	116(60.7)	53(70.7)	35(50.7)	28(59.6)	6.084**	0.048
	No	75(39.3)	22(29.3)	34(49.3)	19(40.4)		
Extension services	Yes	185(96.9)	74(98.7)	66(95.7)	45(95.7)	1.492	0.474
	No	6(3.1)	1(1.3)	3(4.3)	2(4.3)		
Group membership	Yes	147(77.0)	64(85.3)	53(76.8)	30(63.8)	7.394**	0.025
	No	44(23.0)	11(14.7)	16(23.2)	17(36.2)		
Breed type	Friesian	95(49.7)	72(96.0)	17(24.6)	6(12.8)	126.637***	0.000
	Cross-breed	96(50.3)	3(4.0)	52(75.4)	41(87.2)		
Secondary occupation	Yes	171(89.5)	61(81.3)	64(92.8)	46(97.9)	10.333***	.006
	No	20(10.5)	14(18.7)	5(7.2)	1(2.1)		
Source of labor	Family	104(54.5)	44(58.7)	26(37.7)	34(72.3)	14.705***	0.001
	Hired	87(45.5)	31(41.3)	43(62.3)	13(27.7)		
Source of water	Tap	21(11.0)	18(24.0)	2(2.9)	1(2.1)	58.745***	0.000
	Borehole	79(41.4)	40(53.3)	33(47.8)	6(12.8)		
	Stream	91(47.6)	17(22.7)	34(49.3)	40(85.1)		
Form of milk sold	Raw	170(89.0)	72(96.0)	52(75.4)	46(97.9)	20.408***	0.000
	Processed	21(11.0)	3(4.0)	17(24.6)	1(2.1)		

The figures in parentheses represent frequency & percentages. *, ** and * indicate level of significant at 10%, 5% and 1%**

Source: Author, 2023

4.2.0 Costs and returns across dairy production system

For the three dairy production systems, the results in Table 5 summarize the findings on costs and returns on dairy production. During the study, the revenue and expenses were assessed based on the prices that were in effect the year prior, 2022. The results showed that the overall mean cost of feeds under zero-grazing was UGX 983,800 and considerably ($p<0.01$) higher than in the other two dairy production systems. The average veterinary cost across the dairy production systems was also statistically significant ($p<0.01$) at UGX 222,202. The average cost of the equipment was UGX71, 255, with the herding system significantly ($p<0.10$) costing more than the other two dairy production systems. Tethered grazers significantly ($p<0.01$) used the least amount of labor for milking, feeding, or grazing the animals compared to zero-grazers, who spent an average of UGX608,330 on labor costs total. The amount of milk sold on average under a zero-grazing system was fourteen litres, whereas the amount under a tethered system was considerably ($p<0.01$) lower. In contrast, the average selling price of milk was higher under tethered systems and significantly ($p<0.1$) lower under zero-grazing systems. The annual transport cost had no discernible impact on dairy production systems.

With a notable ($p<0.01$) difference between the dairy production systems, the overall cost was greater under the Zero-grazing system and lower under the tethered system. Additionally, the results showed that the Zero-grazing system had the highest average revenue across all dairy production systems, with statistical significance ($p<0.01$). Comparing zero-grazing systems to the other two grazing methods, the average profit is UGX3, 374,447. Different dairy production systems had different gross margins that were statistically significant. For the two dairy production systems, the gross margin (GM) obtained was considerably ($p<0.01$) smaller. Overall, the results

showed that dairy production was lucrative, with a return on investment (ROI) of 2.0678 on average, with the zero-grazing system having a considerably ($p < 0.01$) lower ROI than the other two systems.

Table 5: Summarizes information on cost and return on dairy production.

	Overall (N=191)	Zero-grazing (n=75)	Tethered (n=69)	Herding (n=47)	F-test	P-value
Numeric variables	Mean (SD)					
Feed cost	483441.36(728384.25)	983800.00(867235.25)	128985.51(291737.01)	205368.09(424272.73)	41.902***	0.000
Vet Cost	222201.57(177027.50)	313633.33(179964.46)	126811.59(130287.84)	216340.43(157905.21)	25.140***	0.000
Equipment cost	57937.17(68494.00)	61160.00(76735.07)	45362.32(38486.43)	71255.32(85324.31)	2.160*	0.118
Labor cost	608329.84(370540.35)	741826.67(419062.06)	420623.19(226146.37)	670872.34(350850.43)	16.781***	0.000
Transport cost	260261.78(655978.53)	351333.33(477457.61)	182608.70(900025.58)	228936.17(435431.99)	1.263	0.285
Selling price	1683.51(448.98)	1573.33(306.83)	1783.33(552.58)	1712.77(440.66)	4.200**	0.016
Qty of milk sold (litres)	10.48(8.56)	13.99(8.57)	6.63(5.56)	10.54(9.84)	15.252***	0.000
Total cost	1371909.95(1019556.89)	2100420.00(1053163.99)	721782.61(521080.07)	1163836.17(751229.54)	52.761***	0.000
Total Revenue	4122840.31(3830941.39)	5474866.67(3908906.66)	2479644.93(2448572.08)	4377702.13(4480932.61)	12.464***	0.000
Gross Margin	2750930.37(3188338.70)	3374446.67(3380517.04)	1757862.32(2073198.64)	3213865.96(3862387.95)	5.528***	0.005
Return on investment	2.0678(1.81)	1.66(1.340)	2.31(2.12)	2.36(1.89)	3.168**	0.044

The figures in parentheses represent mean & standard errors. *, ** and * indicate level of significant at 10%, 5% and 1%**

Source: Author, 2023

4.3.0 Stochastic frontier analysis of smallholder dairy production systems profit efficiency

Table 6 provides the important variables affecting dairy production systems as determined by the stochastic profit frontier. Feed, veterinary, and equipment costs all showed statistically significant ($p < 0.01$) effects on the profitability of smallholder dairy production systems. These explain why a unit increase in the price of these inputs in Ugandan shillings was linked to a decline in the profit efficiency of these dairy farmers using different production techniques, but the case was different under the herding production system where veterinary cost had a positive significant relationship with profit efficiency.

Overall, land had positive significant ($P < 0.05$) impacts on profit efficiency under these dairy production systems implying that a unit increase in an acre of land was linked to an increase in the profit efficiency of smallholder dairy producers under various production systems. But this was not the case under the tethered system and herding system which had a negative significant relationship with profit efficiency.

The profit efficiency of smallholder dairy production systems, on the other hand, was positively impacted by the cost of labor. This relationship was significant ($p < 0.01$), indicating that a rise in the value of labor by one Uganda shilling was linked to a rise in the profit efficiency of smallholder dairy production systems though it was not statistically significant under zero-grazing production system.

4.4.0 Determinants of profit efficiency of smallholder dairy production systems

The findings in Table 6 revealed a negative statistically significant coefficient of education, extension services, the Friesian breed, and farming experience implying an inverse relationship

with profit inefficiency. In other words, a unit increase in those variables reduces profit inefficiency by the same unit. Whereas credit access, market access, female gender, age, and group membership had a positive relationship with profit inefficiency. Implying that a unit increase in those variables increases profit inefficiency by the same unit.

A statistically significant ($p < 0.01$) negative coefficient of education suggests that farmers with higher levels of education are better equipped to make informed decisions, manage resources effectively, and operate their dairy farms more efficiently. The negative significant ($p < 0.1$), ($p < 0.05$) and ($p < 0.01$) coefficient indicate that extension services are effectively transferring valuable knowledge and skills to smallholder dairy farmers. This might lead to better management practices, improved animal health, increased milk production, and ultimately higher profits. The statistically significant ($p < 0.05$), (0.01) negative coefficient of the Friesian breed indicates that smallholder farmers using Friesian breeds are likely to experience higher productivity in terms of milk production per unit of input, leading to more efficient profit generation. The negative significant ($p < 0.01$), ($p < 0.01$) coefficient suggests that, on average, as the number of years of farming experience increases, profit inefficiency tends to decrease. In other words, farmers with more experience are associated with higher efficiency in generating profits.

Credit access can provide farmers with funds to invest in their operations, the positive significant ($p < 0.01$), and (0.05) coefficient indicate that the cost of borrowing (interest rates, fees, etc.) could be relatively high. The additional costs associated with credit use may offset the potential benefits, leading to higher inefficiency in profit generation. The positive statistically significant ($p < 0.1$), and ($p < 0.05$) coefficients of market access imply that smallholder farmers may incur costs related to marketing activities, such as transportation, storage, and meeting quality

standards. The positive coefficient may indicate that these costs, relative to the benefits gained from market access, contribute to higher profit inefficiency. Statistically significant ($p < 0.1$) positive coefficient of female gender, indicates that women often play multiple roles within and outside the household. Time constraints related to domestic responsibilities, caregiving, and other activities might affect the time and effort that female farmers can dedicate to their dairy operations, potentially leading to higher inefficiencies. The positive statistically significant ($p < 0.1$), (0.01) coefficient of age implies that aging farmers may experience health challenges that impact their ability to actively manage and operate their dairy farms. Health-related issues could contribute to higher inefficiencies in farm management and productivity. Group membership can provide access to collective resources, the positive statistically significant ($p < 0.01$), ($p < 0.01$), and ($p < 0.01$) coefficients may suggest that, on average, farmers in groups face challenges in effectively utilizing resources to improve their dairy production efficiency.

Table 6: Results of the Stochastic Profit Frontier for Dairy production systems.

Variables	Overall (N=191)		Zero-grazing (n=75)		Tethered (n=69)		Herding (n=47)	
	Coefficients	Standard error	Coefficients	Standard error	Coefficients	Standard error	Coefficients	Standard error
Profit efficiency								
Constant	-2.098	1.928	10.424***	2.455	-2.749	3.184	-2.380	1.682
Land size	0.162**	0.069	0.314***	0.098	-0.005**	0.144	-0.257**	0.094
Cost of feeds	-0.080***	0.013	-0.687***	0.077	-0.069***	0.024	-0.026	0.018
Vet cost	-0.119***	0.027	-0.029	0.091	-0.144***	0.031	0.099***	0.034
Cost of equipment	-0.043***	0.013	-0.036***	0.011	-0.048*	0.027	-0.018	0.017
Cost of labor	0.472***	0.156	0.089	0.154	0.558**	0.263	0.278**	0.141
Inefficiency model								
Constant	-1.463*	0.853	11.335***	2.112	-0.383	1.820	2.003	5.142
Age of dairy farmer	0.039***	0.011	-0.016*	0.009	0.026**	0.012	-0.050***	0.017
Education level	-0.101***	0.034	-0.015	0.019	0.018	0.082	-0.071	0.050
Years of dairy experience	-0.203***	0.048	-0.025*	0.015	0.043	0.052	0.261	0.060
Family size	0.072**	0.032	-0.015	0.029	0.012	0.054	0.240***	0.042
Gender	0.402*	0.233	-0.201	0.152	-0.876**	0.483	-1.228**	0.449
Marital status	0.061	0.300	0.196	0.263	-0.966**	0.454	-1.377**	0.555
Extension services	-0.861*	0.459	-8.131***	1.475	-2.133**	0.900	-3.408***	1.004
Credit access	1.005***	0.301	0.410**	0.161	0.988**	0.436	-1.212***	0.354
Group membership	0.097	0.395	0.965***	0.268	1.033*	0.606	1.724***	0.511
Market access	0.377*	0.193	-0.151	0.157	0.843**	0.397	0.246	0.347
Breed type	-0.716**	0.286	-0.902***	0.260	-1.627**	0.759	2.362***	0.657
Quantity of water(ltr)	0.012	0.012	-0.002	0.007	-0.034*	0.020	0.002	0.042
Variances parameters								
Usigma constant	-3.655***	0.603	-5.302***	1.087	-3.331***	0.926	-3.448***	0.793
Vsigma constant	-0.426***	0.125	-1.372***	0.166	-0.796***	0.152	-1.656***	0.216
Sigma-u	0.161***	0.048	0.071*	0.038	0.189**	0.088	0.178**	0.071
Sigma-v	0.808***	0.051	0.504***	0.042	0.672***	0.051	0.437***	0.047
Lambda	0.199***	0.069	0.140**	0.051	0.281***	0.099	0.408***	0.082
Log-likelihood	-231.1690		-54.3127		-74.1524		-34.6366	

The figures in parentheses represent coefficients & standard errors. *, ** and *** indicate level of significant at 10%, 5% and 1%

Source: Author, 2023

A likelihood ratio (LR) test was used in Table 7 to examine the null hypothesis for profit efficiency ($\gamma=0$). The variance of the parameter gamma (γ), which was also determined to be 0.0382 with statistical significance ($p<0.01$), indicated that 4% of the technical, allocative, scale inefficiency and the remaining 96% of the inefficiency was due to random error brought on by weather changes and other external factors not taken into account by the model. However, this is not a convincing argument against the null hypothesis ($\gamma=0$). The most acceptable test statistic, however, according to (Kumbhakar et al., 2015), is the likelihood ratio (LR) test statistic [$LR = -2(L_R - L_U)$], where, L_R , L_U are the log-likelihood values calculated from the restricted (OLS) model. Alternatively, it is a Cobb-Douglas production function and the unrestricted stochastic frontier model. This statistical value is contrasted with the crucial value for mixed distribution from the chi-square table by Kodde and Palm (1986) in Appendix II at a particular degree of freedom reflecting the number of inefficient variables with a given level of significance. The results showed that profit inefficiency existed in smallholder dairy farms with a variety of dairy production systems, and the null hypothesis was strongly rejected at ($p<0.01$) level of significance with LR statistics $37.413 > X^2_{(1,0.01)}=5.412$.

Table 7: The null hypothesis for profit efficiency

Variable	Parameter	Coefficient	P>|z|
$\sigma^2=\sigma_u^2+\sigma_v^2$	σ^2	0.678785	0.000
$\gamma=\sigma_u^2/(\sigma_u^2+\sigma_v^2)$	γ	0.038187	0.000
Log-likelihood		-231.1690	
$LR=-2(L_R - L_U)$	LR	37.41319	0.000

The figures in parentheses represent coefficients & p-values

Source: Author, 2023

The findings in Table 8 showed how profitable the sampled smallholder dairy producers were under various dairy production techniques. With a mean efficiency score of 0.853, the overall profit efficiency ranges from 0.765 to 0.996. The typical smallholder dairy farmer in the sample could only improve production by $((0.996-0.853)/0.996)$ or 14.36 per cent to reach the profit efficiency level of the most efficient farmers. The least effective smallholder farmer can improve production by 78.21% $((0.996-0.217)/0.996)$ to match the most effective smallholder dairy farmer's needed profit efficiency. 5.76 per cent of dairy producers who are smallholders operate at an efficiency level of 0.81 to 0.90.

Table 8: Profitability of the sampled smallholder dairy producers under various dairy production systems.

	Overall (N=191)	Zero-grazing (n=75)	Tethered (n=69)	Herding (n=47)
Efficiency score	Frequency (%)			
<0.30	11(5.76)	10(13.33)	9(13.04)	9(19.15)
0.30-0.50	15(7.85)	31(41.33)	10(14.49)	5(10.64)
0.51-0.60	5(2.26)	9(12.00)	3(4.35)	2(4.26)
0.61-0.70	5(2.26)	4(5.33)	2(2.90)	0(0.00)
0.71-0.80	5(2.26)	0(0.00)	4(5.80)	0(0.00)
0.81-0.90	11(5.76)	3(4.00)	6(8.70)	4(8.51)
>0.90	139(72.77)	18(24.00)	35(50.72)	27(57.45)
Total	191(100)	75(100)	69(100)	47(100)
Mean	.8530679	.5546627	.7384135	.7359985
Std. Dev	.2341258	.272167	.294839	.3361363
Minimum	.2165003	.1276326	.0739365	.0127245
Maximum	.9957359	.99812	.9949807	.9953479

The figures in parentheses represent frequency & standard percentages.

Source: Author, 2023

CHAPTER FIVE: DISCUSSION OF RESULTS

5.1.0 Smallholder dairy farmers' characteristics under different production systems.

This study results summarized the respondents' responses and described smallholder dairy farmers in the study area. With an average age of about 47 years, smallholder dairy farmers were mostly middle-aged, which does not limit their ability to embrace contemporary farming practices like precision farming and automated milking systems, which increase output. These findings were at odds with the study on the Socio-Economic Profile and Constraints of Dairy Farmers in the Cuddalore District of Tamil Nadu, India (Gopi et al., 2020), (Nganga et al., 2010; Balirwa & Waholi, 2018). Supportively, Chandrasekar et al., (2017) findings indicated that middle age was increasingly dominating the dairy farming industry.

The results of this study also revealed that smallholder dairy producers have in-depth knowledge of farm management, animal care, nutrition, breeding, and health. This expertise enables efficient production, resource allocation, moral breeding, and health management, these findings agreed with the findings of (Hansen et al., 2020). The years of experience were a little less than what Maina et al., (2020) reported for the research on the Socio-economic Determinants and Impact of adopting climate-smart Brachiaria Grass among dairy farmers in Eastern and Western Regions of Kenya.

Family size is a proxy for the dairy farming labor force, as larger families assist with daily tasks like feeding, milking, cleaning, and infrastructure, improving farm productivity and efficiency the study revealed that on average the family size was about 8 people per household and

statistically significant which was in agreement with the findings of (Gopi et al., 2020), (Girma, 2019); (Bekele, 2021)

Education is essential for smallholder dairy producers because it introduces them to research, technology, and industry best practices while encouraging animal care. With an average age of 8.49 years, the smallholder dairy farmers had considerable education levels, indicating that the majority of them had completed primary school. The results of this study are consistent with those of Chandrasekar et al., (2017) and Karki & Ansari, (2023).

The results also showed that land size was significant, indicating that dairy cows need enough grazing pasture for a balanced diet to have access to enough feed, improve the availability of that feed, maintain good health, and produce milk. Gopi et al., (2020) however, confirmed that the average land size in acres was roughly 6.9 acres.

The statistical significance of herd size demonstrated that bigger herd sizes with more lactating cows often yield more milk. With more cows, a greater volume of milk is produced overall. This is particularly true if the extra cows are well-managed and given access to a nutritious diet and medical attention. If a dairy farmer produces more milk overall, they could make more money. The results are consistent with the research by Kumar et al., (2020) on Food security and safety regulations for small-scale dairy farmers in Bihar, India and the study of Nganga et al., (2010) on profit efficiency.

The amount of milk produced per cow was statistically significant, indicating that smallholder farmers' capacity to access markets and be commercially viable depends on daily milk output, which raises their appeal to customers, processors, and cooperatives. These findings were

supported by Kalaivani et al., (2017) and Jagadeeswary et al., (2010), who found that this increases prices, client base, and bargaining leverage.

Distance to market was statistically significant, supporting the idea that transportation costs and market distance have an impact on the profitability of smallholder dairy producers by lowering income and reducing overall profitability. The results of this study concurred with those of Rantlo et al., (2020) on Institutional Factors Influencing Dairy Farmers' Participation in Formal and Informal Milk Markets in Maseru Urban, Lesotho, South Africa and Benti et al., (2021)

Due to its dependence on the birth-weaning period, the length of the milking cycle has an impact on the time and labor management of smallholder farmers. According to Mulliniks et al., (2020) and Bjorklund et al., (2013), a shorter cycle enables efficient resource utilization and provides greater freedom in agricultural tasks.

Calving interval has an impact on the reproductive efficiency of cow herds; shorter intervals lead to quicker conception and delivery of calves. This boosts milk production and makes it possible for smallholder farmers to keep up a consistent supply. The results were consistent with those (Ettema & Santos, 2004).

The availability of water affects the amount of dry matter and feed consumed by cows, which affects milk production and helps them consume the driest matter, according to the fact that the water source was also statistically significant. These results concurred with Benti et al., (2021) on the Assessment of Dairy Cattle Production, Handling and Marketing Systems of Milk and Milk Products in the BakoTibe District of West Showa Zone, Ethiopia and Castanheira et al., (2010).

Women's ability to invest is constrained by gender inequities, which also affect access to land, finance, technology, and extension services. This lowers dairy production among smallholder farmers. However, these results showed that, on average, females outnumbered their male counterparts. This conclusion was consistent with that of Gopi et al., (2020), but it was at odds with that of Jagadeeswary et al., (2010), who found that more men worked in the dairy industry.

Marital status was not statistically significant, but with an average of 80.1 per cent of married smallholder dairy farmers, it is consistent with claims made by (Ongwech et al., 2020) and (Ume et al., 2018) that a higher proportion of livestock farmers were married.

Market access was statistically significant, indicating that smallholder dairy farmers can expand their products and investigate value-added solutions through improved market access. This will allow them to connect with processing facilities, cooperatives, and direct consumer marketplaces, increasing their capacity for cash generation. These studies concurred with the findings of (Rantlo et al., 2020).

According to Gopi et al., (2020), smallholder dairy farmers have access to crucial knowledge and information about the best methods in dairy production due to extension programs. On average, most smallholder dairy farmers were receiving extension services.

With an average of 60.7%, credit access was statistically significant, showing that smallholder dairy farmers who have access to credit benefit from working capital for managing farm costs, cash flow fluctuations, and operational expenses, assuring stable dairy output and dependable financing. This was consistent with the findings of Maina et al., (2020) who observed comparable lower numbers.

The findings on group membership were significant which indicates that smallholder dairy producers benefit from group membership, access to inputs and services, bargaining power, market connections, technical assistance, and extension services, leading to better dairy products as confirmed by the study on Socio-Economic and Psychological Characteristics of Dairy Contract Farmers in Namakkal district of Tamil Nadu by Kalaivani et al., (2017) and as well as the study by Rantlo et al., (2020).

The significance of breed type suggests that it influences milk quality and content, with some breeds providing milk with higher protein and butterfat contents. Smallholder farmers choose particular breeds for value-added dairy products depending on how profitable and valuable their milk is to the market. The results collaborate with those of (Benti et al., 2021).

The secondary occupation was statistically significant as well, suggesting that smallholder dairy farmers can increase their dairy output by learning new skills through agricultural or entrepreneurial activities, improving sustainable farming methods, marketing, and business management, which will increase output and profit, as it was also confirmed by Gopi et al., (2020) and Chandrasekar et al., (2017).

Given that labor was statistically significant, it follows that the expansion of smallholder farmers' dairy businesses depends on the availability of labor as well as on factors like responsibility, diversity, and the opportunity to expand. The potential for dairy production can be limited by a labor shortage and management difficulties. These results corroborated the research conducted by Mawa et al., (2014) on the Profit Efficiency of dairy farmers in Kenya.

The water source was significant, suggesting that the production of dairy products depends on the availability of clean, untainted water for the health and welfare of the cows. Health issues, a

reduction in feed intake, and a reduction in milk production can all result from poor water quality. To ensure that the water is safe to drink, regular testing and safeguards are crucial. This was consistent with the findings of Huang et al., (2014).

Sales of different types of milk were statistically significant. 89% of smallholder dairy farmers sold their raw milk directly to consumers or markets, providing a convenient and economical option. To ensure client safety, though, high quality and hygiene standards are required. Farmers are required to frequently test their milk for safety, maintain clean equipment, and employ suitable handling procedures. Market demand and product pricing may be impacted by consumer preferences and regulatory compliance. This was in contrast to van der Lee et al., (2020) findings, which said that 76% of the tested dairy producers sold processed milk products in Ethiopia on average.

5.2.0 Profitability of smallholder dairy producers across diverse dairy production systems.

In Gulu city and Gulu district, zero-grazing is the most widely used and effective dairy production technique, having the largest gross margin of the three methods (tethered, herding, and zero-grazing) These results corroborated a study on the Economic assessment of small-scale mountain dairy farms in South Tyrol depending on feed intake and breed by (Kühl et al., 2020), which found that zero-grazing is more profitable.

The efficiency and productivity of the feed are impacted by feed costs. By enhancing management, optimizing the formula, and investigating alternate feed sources, farmers can boost feed efficiency. This boosts dairy profitability and decreases expenses per unit of milk produced, however, the average feed cost under the zero-grazing system was UGX 983800, which was

consistent with studies by Chand et al., (2017) and (Kühl et al., 2020) revealed high feed costs increase milk yield.

Significant veterinary expenditures suggest that smallholder dairy farmers are having trouble remaining profitable as a result of increased veterinary expenses, necessitating effective cost control to maintain the health and productivity of the animals. These results were in direct opposition to those of Gopi et al., (2020).

It was clear from the equipment (milk cans, water buckets, milking buckets, hoof trimmers, chaff cutters, stools and ropes) cost that smallholder dairy producers confront difficulties with equipment costs, which affect farm profitability without raising milk prices or output. Effective management guarantees increased productivity, decreased labor requirements, and improved cow well-being as these findings concurred with Chand et al., (2017).

Although the influence of transportation on feed prices was not statistically significant, smallholder dairy farmers frequently buy forage and animal feed from suppliers. Transport costs may rise, impacting the profitability of farms, milk production, and cow health.

However, on average gross margin was statistically significant and was in line with the findings of Kaur et al., (2012), Savage & Lewis, (2005) and Hennessy & Heanue, (2012). Smallholder farmers can invest in environmentally friendly farming techniques with a healthy gross margin, improving animal welfare, and resource management, and reducing environmental impact, ensuring long-term profitability and resilience.

Return on investment (ROI) was statistically significant implying that sustainable farming methods adoption is influenced by ROI, as upfront fees for resource-saving techniques, animal

care, and environmentally friendly technologies boost output and profitability for smallholder farmers, these finding was in agreement with the study on Dairy farm financial performance: firm, year, and size effects Wolf et al., (2016).

5.3.0 Determinants of profit efficiency of smallholder dairy production systems

Stochastic profit frontier analysis reveals 14 significant variables impacting smallholder dairy profitability in Gulu.

By increasing production efficiency, both gross margin and profit efficiency can be positively improved. Concentrating on factors like feed conversion efficiency, reproductive performance, and general herd health management would help farmers increase milk yields while minimizing variable costs per unit of milk produced. As noted by (Turinawe et al., 2012) and the study on Determinants of Milk Production Profitability of Dairy Farms in the EU member states (Gołaś, 2017), increased manufacturing efficiency results in higher gross margins by increasing sales while minimizing costs.

Dairy cows need sufficient grazing acreage and high-quality feed for good nutrition and milk production, as shown by the statistical finding that land was a positively significant factor impacting profit efficiency. These results concur with those of Latruffe & Piet, (2014) who stated that land fragmentation decreases efficiency and profitability. Larger land also maximizes profit efficiency by improving grazing conditions, feed availability, cow health, and milk output.

The cost of feeds, equipment, and veterinary services were all statistically significant negative expenses, which showed that high input costs in dairy farming can make it less profitable, especially if they are not offset by rising productivity or market prices. These results conflicted

with the research on Economic analysis of dairy farming in dry farming areas of Tamil Nadu (Perumal, 2016).

The relationship between labor cost and efficiency was positively significant, which suggests that the positive cost coefficient encourages smallholder farmers to focus on product and value growth. By using more expensive inputs or advancing technologies, farmers can produce unique or superior goods that command greater prices in the market. In contrast to a negative coefficient of cost, where the opposite is true, this distinction enables increased profit margins, which ultimately improve profit efficiency. These results were in agreement with Singh et al., (2023) concluded that increasing labor input boosts productivity and also Deming et al., (2019).

Farmers may experience physical limitations as they age, making it difficult for them to do labor-intensive tasks or complex farm tasks. A decrease in productivity, reliance on contract workers, and possibly higher labor costs could result from this. Physical restrictions may make it more difficult for farmers to optimize their activities, which may have an impact on how profitably they can earn income. The results agreed with Turinawe et al., (2012) and Hansen et al., (2020) however, disagreed with Singh et al., (2023) who hypothesize that milk yield efficiency increases as dairy farmer age increases by one year.

Farmers with greater education can better understand market dynamics, consumer behavior, and the possibility of producing goods with value-added value. Higher-educated farmers are more likely to identify niche markets, increase the scope of their product offerings, and develop goods with higher market value. Businesses can run more profitably if they have a stronger understanding of the market and the ability to seize opportunities that provide value. The results

of this study also agreed with those of (Singh et al., 2023), and (Ongwech et al., 2020) but did not agree with those of Turinawe et al., (2012).

Since experience had a statistically significant positive impact on profit efficiency, it was concluded that smallholder dairy farmers with more experience were better equipped to identify and eliminate bottlenecks, reduce waste, and make other adjustments that would boost profit efficiency. Farmers are taught how to enhance resource allocation, streamline processes, and put best practices into practice to boost productivity, which helps them manage their dairy operations more efficiently and productively as they gain experience. These results corroborate those of Maina et al., (2020), Hansen et al., (2020) and Teklewold et al., (2013), who hypothesized that older farmers are more likely to adopt new agricultural technologies because they are perceived as having more experience than younger farmers.

The statistically negative significant relationship between family size and profit efficiency suggests that having more children may result in higher costs for housing, healthcare, education, and other responsibilities associated with raising a family. These additional costs could strain the farm's finances and reduce the amount that can be allocated for dairy industry investments. Insufficient investments in infrastructure, technology, or inputs can reduce productivity and limit profit efficiency. This was at odds with (Kumar et al., 2017) findings, which claimed that an increase in the number of people living in a household could result in the adoption of food safety procedures (FSM).

These findings showed that, on average, the female gender was greater than the male gender and that gender was significantly having a negative influence on profit efficiency. Suggesting that women frequently perform domestic and caregiving tasks without compensation, taking away

from their time and resources for dairy farming. Caregiving and work-life balance can result in lower productivity and fewer income-generating opportunities, which can hurt profit efficiency. These results contradicted the study on Female Agriculture in the Short Food Supply Chain: A New Path Toward Sustainability Empowerment (Zirham & Palomba, 2016) and the findings of (Masunda& Chiweshe, 2015).

Statistics showed that credit availability had a large negative impact on profit effectiveness. These results suggest that smallholder farmers' ability to effectively manage credit may be constrained by a lack of financial literacy and inadequate understanding of the terms, interest rates, and repayment plans associated with loans. Lack of financial literacy may cause farmers to make poor choices, forget payments, or fail to understand the full cost of loans, all of which can reduce the effectiveness of their profit margins. The results of the study on Socio-Economic Evaluation of Improved Forage Technologies in Smallholder Dairy Cattle Farming Systems in Uganda by (Turinawe et al., 2012) and the claim stated by (Ongwech et al., 2020)that because of the condensed grace period, insufficient loan size, and change in the loan's intended usage from farming to non-farming activities, dairy producers perceived loan repayment as a constraint.

The coefficient of market access was negatively significant, suggesting that smallholder farmers' ability to successfully access markets may be constrained if they experience difficulties utilizing transportation services or deal with inadequate infrastructure for product transportation. Due to excessive transportation costs, delays, or product degradation during transit, profit margins may be reduced and profit efficiency may be impacted. The study supported van der Lee et al., (2020)findings but disagreed with those of Kumar et al., (2020).

The fact that extension services had a favorable, significant impact on profit efficiency suggests that smallholder dairy farmers who make use of them have access to crucial knowledge, technical know-how, and training opportunities. By disseminating knowledge about modern agricultural practices, animal health management, feed formulation, breeding techniques, and business management, extension services help farmers acquire the necessary skills and knowledge to boost productivity and profitability. The study on Constraints and Way Forward for Boosting Income from Dairy Farming in India and the study Impacts of improved extension services on awareness, knowledge, adoption rates, and perceived benefits of smallholder dairy farmers in India by Yadav et al., (2021) and study on Impacts of improved extension services on awareness, knowledge, adoption rates and perceived benefits of smallholder dairy farmers in Pakistan by (Warriach et al., 2019) both confirmed the importance of knowledge and skill acquisition for increasing profit efficiency but contrary to the findings of (Mawa et al., 2014).

The profitability of the smallholder dairy farmers was statistically significantly influenced by breed type. This suggests that dairy cow breeds with disease-resistant genetics can decrease medical costs, improve herd health, and increase profitability for smallholder dairy farmers by lowering illness risks and veterinary expenses. These results supported the conclusions of other research by Yadav et al., (2021), Khan et al., (2016) and Ojango et al., (2016) as well as the study by Dal Zotto et al., (2007) on the Effect of crossbreeding on the market value of calves from dairy cows.

Group membership was statistically significant, the negative elasticity of the coefficient went against the expectation that farmer organizations and cooperatives would frequently represent the needs of their members in discussions of public policy, including those about agriculture, dairy

farming, and rural development. By advocating for the interests of smallholder dairy farmers as a whole, these organizations can have an impact on public policy, get access to government aid programs, and advance greater infrastructure, market access, and loan accessibility. Such advocacy activity may assist in fostering the conditions required for smallholder dairy farmers to produce milk and make a profit as confirmed by (Kalaivani et al., 2017) and (Rantlo et al., 2020).

Marital status was statistically significantly influencing profit efficiency positively under the tethered system and herding system, implying that marriage can open doors to a larger network of resources, including money, knowledge, and social connections. These resources could be crucial for financing agricultural improvements, obtaining loans, and getting technical support, which can increase farm profitability. These findings were contrary to the findings of (Ironkwe & Ajayi, 2008), the authors suggested that marital status reduces the positive impacts of extension services such as the adoption of new technological innovation initiated by extension agents.

The amount of water provided to each cow was statistically significant and had positive coefficients that increased profit efficiency under the tethered system. This was because water intake by dairy cows helps in the digestion of the driest matter which results in the production of more milk, this was also confirmed by (Benti et al., 2021) and (Castanheira et al., 2010).

CHAPTER SIX: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1.0 Summary of results

The main objective of this study was to investigate the determinants of profit efficiency of dairy production systems in Gulu city and Gulu district. The specific objectives were (1) to characterize the dairy production systems in Gulu city and Gulu district, (2) to estimate the profit efficiency of dairy production systems in Gulu city and Gulu district and (3) to determine factors that influence the profit efficiency of smallholder production systems in Gulu city and Gulu district. A sample size of 191 dairy farmers was sampled using a multi-stage sampling technique. Data was collected using a semi-structured questionnaire with a focus on dairy farmers' household heads.

The gross margin and return on investment were calculated to ascertain the most profitable dairy production systems (Zero-grazing, Tethered and Herding) in the study area. The stochastic frontier model was used to estimate the profit efficiency levels and the factors influencing the profit efficiency of the three dairy production systems.

One-way ANOVA and Chi-square were used to characterize the dairy production systems. The result revealed that the female gender dominates dairy production with an overall percentage of 53.9%. The study also confirmed that the average dairy output per cow per day was 10.4 litres under Zero-grazing, 4.94 litres under Tethered and 4.13 litres under Herding.

The average years of dairy farming experience were 5.67, 6.06 and 8.60 respectively under Zero-grazing, Tethered and Herding. On average all the smallholder dairy farmers under the three different production systems had completed the primary level of education. The study also consented that the overall average age and the family size were 46.91 years and 8 people in the household.

The results also indicated a fair percentage of farmers' access to (market, credit and group membership) with overall percentages of (68.6%, 60.7% and 77.0%) across the three dairy production systems respectively. The main source of water for cows was the stream with an overall percentage of 47.6, raw milk dominates the sale of the smallholder dairy farmers with 89.0 per cent.

The study also confirmed that labor cost, feed cost and cost of veterinary services were tremendously high under Zero-grazing with an average of UGX741,827 UGX 983,800 and UGX313,633 respectively. On average milk was sold at UGX1, 684/litre across the dairy production systems.

The gross margin on average was UGX3374, 447 under Zero-grazing, UGX1757, 862 under Tethered and UGX3213, 866 under Herding, with a return on investment of 16.6%, 23.1% and 23.6% respectively.

The overall minimum, mean and maximum efficiency scores across the dairy production systems were 0.217, 0.853 and 0.995 respectively. This implies that the least efficient smallholder farmer can increase production by 78.21% $((0.996-0.217)/0.996)$ to achieve the required profit efficiency of the most efficient smallholder dairy farmers. The efficiency of all dairy production systems is displayed in Table 8.

Furthermore, nine factors were found to be significantly influencing profit efficiency, namely age, education level, dairy experience, family size, gender, extension services, credit access, market access and breed type. The findings revealed that variables like years of experience, education level, extension services and breed type have a negative influence on the inefficiency model, implying a positive influence on profit efficiency. Education level was significant at 1%, years of experience was significant at 1%, extension services were significant at 10% and breed type was significant at 5%.

The variables gender, family size, age, credit access and market access all had a positive influence on the inefficiency model, indicating a negative impact on the profit efficiency. Gender was significant at 10%, family size was significant at 5%, age was significant at 1%, credit access was significant at 1% and market access was significant at 10%.

6.2.0 Conclusions

The study findings reveal that there was a significant difference in age, years of dairy farming experience, years of education, land size owned, herd size, number of lactating cows, the quantity of milk per cow per day, milking circle, the quantity of water per cow per day, distance to market, female gender, market access, credit access, group membership, Friesian breed, family labor, stream water, and raw milk. It can therefore be concluded that age, years of dairy farming experience, years of education, land size owned, herd size, number of lactating cows, the quantity of milk per cow per day, milking circle, the quantity of water per cow per day, distance to market, female gender, market access, credit access, group membership, crossbreed, family labor, stream water, and raw milk greatly varies between dairy farmers who rely on Zero-grazing system, Tether system and herding system.

On the other hand, the results show that feed costs and veterinary costs, equipment costs, labor costs, and land were significant predictors of profit efficiency. It can therefore be concluded that feed cost, veterinary cost equipment cost labor cost, and land are critical in measuring the profit efficiency of smallholder dairy farmers under varied dairy production systems and none of the dairy farmers had unit profit efficiency.

Regarding factors influencing profit inefficiency, the study establishes that education level, years of dairy experience, age, family size, female gender, extension services credit access, group membership, market access, and Friesian breed significantly influence profit inefficiency. It can therefore be concluded that profit inefficiency is driven by education level, years of dairy experience, age, family size, female gender, extension services credit access, group membership, market access, and Friesian breed.

6.3.0 Recommendations

6.3.1 Policy recommendations

The strategic role of dairy in increasing food security and income necessitates that information about profit efficiency to be sufficiently available to development agents and farmers to inform strategic development of dairy sector and improve farmer's livelihoods.

In order to increase profit efficiency of dairy farmers the study recommends development of programs that focus profit tailored extension system, inputs system and infrastructural development

Furthermore, the study suggests the need to develop and adopt cost effective and labor-saving technologies like automated milking machine and refrigerator to reduce labor cost associated with production and post-harvest losses.

6.3.2 Recommendation for further study

The study should be conducted to comprehend the transition of dairy products from farm to market and conduct a thorough investigation of the dairy value chain. Find inefficiencies, value-adding possibilities, and bottlenecks, such as those in processing and marketing. To make sure that farmers obtain fair prices, look into the actions of different players in the value chain, such as processors, intermediaries, and retailers.

Research the effects of climate change on local small-scale dairy farming. Analyze how the availability of feed, water supplies, and animal health are impacted by shifting weather patterns, severe occurrences, and temperature changes. Create farming methods and coping mechanisms that are climate-resilient.

Examine the availability and cost of supplies and services required for dairy farming, such as good feed, veterinarian care, and breeding services. Describe the obstacles farmers must overcome to access these resources and offer solutions.

Examine the risk management techniques used by the area's small-scale dairy farmers. Determine typical risks, such as epidemics, price changes, and natural disasters, and evaluate the efficiency of current risk-reduction strategies. Offer cutting-edge risk management tools and insurance choices.

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APPENDICES

Appendix I: SampleSize Determination Table

TABLE 1
Table for Determining Sample Size from a Given Population

<i>N</i>	<i>S</i>	<i>N</i>	<i>S</i>	<i>N</i>	<i>S</i>
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	100000	384

Note.—*N* is population size.
S is sample size.

Source: Krejcie & Morgan, 1970

Appendix II: Koddeand Palm Critical Value Chi-Square Table

1246

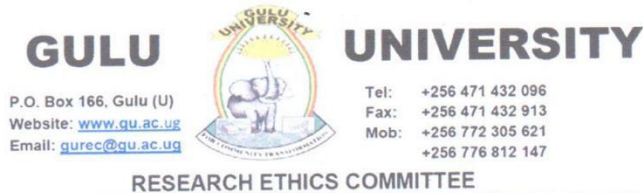
DAVID A. KODDE AND FRANZ C. PALM

TABLE I
UPPER AND LOWER BOUNDS FOR THE CRITICAL VALUE FOR JOINTLY TESTING EQUALITY
AND INEQUALITY RESTRICTIONS^a

df	α .25	.10	.05	.025	.01	.005	.001
1	0.455	1.642	2.706	3.841	5.412	6.635	9.500
2	2.090	3.808	5.138	6.483	8.273	9.634	12.810
3	3.475	5.528	7.045	8.542	10.501	11.971	15.357
4	4.776	7.094	8.761	10.384	12.483	14.045	17.612
5	6.031	8.574	10.371	12.103	14.325	15.968	19.696
6	7.257	9.998	11.911	13.742	16.074	17.791	21.666
7	8.461	11.383	13.401	15.321	17.755	19.540	23.551
8	9.648	12.737	14.853	16.856	19.384	21.232	25.370
9	10.823	14.067	16.274	18.354	20.972	22.879	27.133
10	11.987	15.377	17.670	19.824	22.525	24.488	28.856
11	13.142	16.670	19.045	21.268	24.049	26.065	30.542
12	14.289	17.949	20.410	22.691	25.549	27.616	32.196
13	15.430	19.216	21.742	24.096	27.026	29.143	33.823
14	16.566	20.472	23.069	25.484	28.485	30.649	35.425
15	17.696	21.718	24.384	26.856	29.927	32.136	37.005
16	18.824	22.956	25.689	28.219	31.353	33.607	38.566
17	19.943	24.186	26.983	29.569	32.766	35.063	40.109
18	21.060	25.409	28.268	30.908	34.167	36.505	41.636
19	22.174	26.625	29.545	32.237	35.556	37.935	43.148
20	23.285	27.835	30.814	33.557	36.935	39.353	44.646
21	24.394	29.040	32.077	34.869	38.304	40.761	46.133
22	25.499	30.240	33.333	36.173	39.664	42.158	47.607
23	26.602	31.436	34.583	37.470	41.016	43.547	49.071
24	27.703	32.627	35.827	38.761	42.360	44.927	50.524
25	28.801	33.813	37.066	40.045	43.696	46.299	51.986
26	29.898	34.996	38.301	41.324	45.026	47.663	53.403
27	30.992	36.176	39.531	42.597	46.349	49.020	54.830
28	32.085	37.352	40.756	43.865	47.667	50.371	56.248
29	33.176	38.524	41.977	45.128	48.978	51.715	57.660
30	34.266	39.694	43.194	46.387	50.284	53.054	59.064
31	35.354	40.861	44.408	47.641	51.585	54.386	60.461
32	36.440	42.025	45.618	48.891	52.881	55.713	61.852
33	37.525	43.186	46.825	50.137	54.172	57.035	63.237
34	38.609	44.345	48.029	51.379	55.459	58.352	64.616
35	39.691	45.501	49.229	52.618	56.742	59.665	65.989
36	40.773	46.655	50.427	53.853	58.020	60.973	67.357
37	41.853	47.808	51.622	55.085	59.295	62.276	68.720
38	42.932	48.957	52.814	56.313	60.566	63.576	70.078
39	44.010	50.105	54.003	57.539	61.833	64.871	71.432
40	45.087	51.251	55.190	58.762	63.097	66.163	72.780

^a The values in the table are obtained by solving the equation $\alpha = \frac{1}{2} \Pr[\chi^2(df-1) \geq c] + \frac{1}{2} \Pr[\chi^2(df) \geq c]$ for c , given α and df .

Appendix III: Approval letter from the Research Committee (GUREC)



12/05/2023

To: Peter Oyoo

Gulu University
0785523949

Type: Initial Review

Re: GUREC-2023-525: DETERMINANTS OF ECONOMIC EFFICIENCY OF SMALLHOLDER DAIRY PRODUCTION SYSTEMS IN NORTHERN UGANDA: A CASE STUDY OF GULU CITY AND GULU DISTRICT

I am pleased to inform you that at the **98th** convened meeting on **24/03/2023**, the Gulu University REC, committee meeting voted to approve the above referenced application.

Approval of the research is for the period of **12/05/2023** to **12/05/2024**.

As Principal Investigator of the research, you are responsible for fulfilling the following requirements of approval:

1. All co-investigators must be kept informed of the status of the research.
2. Changes, amendments, and addenda to the protocol or the consent form must be submitted to the REC for re-review and approval **prior** to the activation of the changes.
3. Reports of unanticipated problems involving risks to participants or any new information which could change the risk benefit: ratio must be submitted to the REC.
4. Only approved consent forms are to be used in the enrollment of participants. All consent forms signed by participants and/or witnesses should be retained on file. The REC may conduct audits of all study records, and consent documentation may be part of such audits.
5. Continuing review application must be submitted to the REC **eight weeks** prior to the expiration date of **12/05/2024** in order to continue the study beyond the approved period. Failure to submit a continuing review application in a timely fashion may result in suspension or termination of the study.
6. The REC application number assigned to the research should be cited in any correspondence with the REC of record.
7. You are required to register the research protocol with the Uganda National Council for Science and Technology (UNCST) for final clearance to undertake the study in Uganda.

The following is the list of all documents approved in this application by Gulu University REC:



No.	Document Title	Language	Version Number	Version Date
1	Informed Consent forms	Acholi	3	2023-05-10
2	Informed Consent forms	English	3	2023-05-10
3	PROTOCOL	English	2	2023-05-01
4	COVID-19 MEASURE	ENGLISH	2	2023-05-01
5	Data collection tools	English	1	2023-02-19

Yours Sincerely

Julaina A. Obika

Julaina A. Obika (PhD)

For: Gulu University REC



Appendix IV: Informed Consent Form (ACHOLI)

Version 3.0

DOCOMEN MER PENYO TWERO NI MER GAMO LAPENY IKOM KWAN MAN

WI LOK MADONGO ME KWAN MAN: NENO KERO PA LUGWOK DYANGI CAK NI WOK KI IKOM KWONE PUR MA PAT-PAT MA GIN LUPUR DYANGI CAK GIN PURU WEK WA NEN MENE MA YILO KERO PA LUPUR MA BER KI TUNG KUMALO ME UGANDA (GULU CITY KACEL KI GULU DISTRICT).

Lakwed man: Oyoo Peter Okello

Gang Pwonye: Gulu University

Nyute

An Oyoo Peter Okello latin kwan me gang kwan me pur ki kadedo ma orumu wa, Gulu University. An atye katimo kikweda na ikom neno kero pa lugwok dyangi cak ni wok ki ikom kwone pur ma pat-pat ma gin lupur dyangi cak puru wek wa nen mene ma yilo kero pa lupur ma ber ki tung Kumalo me Uganda (Gulu city kacel ki Gulu district). An ayero in wek ikonya ikwan man. Dong alegi ni imii lagam ikom lapeny man. Omyero ibed ki ngec ni kit lagam mo kiken ma ibimino ne pe wa bikobo ne ka mo wa ki acel kono do wa bi tic kwede pi kwan eni kiken.

Wiye wiye ikom dul ma tye ka tyelo kor kwan man

Kwan man dul ma oculu pire aye obedo Regional University Forum for Capacity Building in Agriculture (RUFORUM) iter Mastercard foundation cohort 5.

Pi ngo kwan man

Kwan man tye mer yenylo lok ikom kero pa lugwok dyangi cak ni wok ki ikom kwone pur ma pat-pat ma gin lupur dyangi cak puru wek wa nen mene ma yilo kero pa lupur ma ber ki tung Kumalo me Uganda (Gulu city kacel ki Gulu district). Kwan man bi cung ma calo gin maber mer timo kikweda ikom puru lee ki bene obi konyo lupur dyangi cak matino tino mer nongo ngec maber ikom kit dul pur mene maber me gwoko dyangi cak kun yilo kero pa lupur dyangi cak malo niwok ki gin acama, ki cente. Ki bene bi weko lupur gwoko dyangi cak ma komgi yot dok madowong ki bene kelo luwil mapol. Kwan man bene bikelo lukwed madwong, ki bene bipoko ngec ikin lukwan mapol, konyo bene lumok cik ki bene lupur lee weng.

Anga gi ma bibedo ikwan man

Dano mo kiken ma tye ka puru pur mer gwoko dyang cak ika bedo ma kwan tye ka time iyee. Dong lapeny man pe bitero kare ma pol, romo oo dakika pyera adek onyo ma tidi dong ikin jo (180) miya acel ki pera aboro ni in itye ikin gi.

Ongongola onyo gin matwero keto kwoni kama rac ikere mer kwan man

Peko ma romo bedo tye aye nya pa COVID-19 ikare mer kwed man, dong wa romo gengo man ki lubu cik ma kiketo mer gengo COVID-19 macalo tic ki sabun, laduny cing ma pige, ruku labor wum ki dong bedo ma kin wa bor bor ki luwot wa ikere mer kwan man.

Ber pa kwan man



Kwan man abyeko ni obikonyo medo ngec pa lapur, ki bene lapur romo tic ki ngec man mer yubu puru dyangi cak wek obed ma ber dok ma monya ma yilo rwom pa gin apura gi malo. Ngec ma ononge ikwan man bii dok cen bot lupur kun wok ki cing lutela gi. Lupur weng ma obedo ikwan man gibii nongo obalkere ma romo sukari kilo acel ki cabun bar acel.

Gwoko mung ma imiyo ikwan man

Lok komi mo kiken pe wabimiyo woko ki bene wan wabitiyo ki nukuta (namba) mer ngeno wun lumi ngec botwa. Ngec ma wan wa noo ki bot wun lukwan man kiken aye bibedo ki ngec iye. Wa bi gwoko ngec man ican duk ma ki pungo doge apunga. Ngec ma pire tek lakwed madit aye bingeyo ne.

Yoo mukene ma twero kwanyo

Pe twero timo kwan man ka cer cwiny pe iye. Gin mo kiken marac peke kaccer pe timo kwed man.

Acara

Acara mo ma in ibinongo ne ni wok ki ikom kwan man bibedo pee wa ki acel.

Lapeny mo ma itye kwede ikom kwan man

Dong ka itye ki lapeny mo kiken ikom kwan man ma lube ki twero macalo lakony kor kan man, itwero gono cim bot lakwed ma dit **Oyoo Peter Okello** inama cime **0785523949** onyo iromo wok ki email: **oyoopeterokello059@gmail.com**.

Lok ma dok ikom mine pi kwan man

Yee mer mino ngec ikom kwan man aa ki cwinyi piri keni labong dic mo kiken. Itye ki twero mer weko mino ngeci icawa mo kiken labong pwod mo kiken bene.

Kacer itye ki koko mo kiken ma lube ki twero ni mer mino ngec ikom kwan man, goo cim bot latela madit maloyo wi Gulu University Research Ethics Committee (GUREC), **Dr. Gerald Obai** inama cime **0772305621**; iromo cwele email: **lekobai@yahoo.com/lekobai@gmail.com** onyo iromo kupe ki Uganda National Council for Science and Technology on plot 6 Kimera Road, Ntinda, Kampala inama cim: **0414705500**.

Ka iye mer mino ngec ikom kwan man, ki woro madit dong alegi ni inyut yeyo ni ki keto cingi /diyo twon nyig cingi acuc kabedo ma pinyi

Name Sign/Thumb print of the participant..... date.....

Name Sign/Thumb print of the witness..... date.....

Name Sign/Thumb print of the interviewer..... date....



Appendix V: Informed Consent Form (ENGLISH)

Version 3.0

INFORMED CONSENT DOCUMENT

Title of the study: DETERMINANTS OF ECONOMIC EFFICIENCY OF SMALLHOLDER DAIRY PRODUCTION SYSTEMS IN NORTHERN UGANDA: A CASE STUDY OF GULU CITY AND GULU DISTRICT

Invigilator(s): Oyoo Peter Okello

Institution(s): Gulu University

Introduction

I am **Oyoo Peter Okello** from the Faculty of Agriculture and Environment, Gulu University. I am conducting a study on determinants of economic efficiency of smallholder dairy production systems in northern Uganda: a case study of Gulu city and Gulu district. You have been selected as a study participant. We kindly request you to respond to our questions. For your assurance, this information shall not be shared with any organization or institution but shall only be used for this study.

A brief Description of the Sponsors of the Project

This study is funded by Regional University Forum for Capacity Building in Agriculture (RUFORUM) under Mastercard foundation cohort 5.

Purpose

The study seeks to investigate the determinants of economic efficiency of dairy production systems in northern Uganda. The study will serve as a suitable tool for agricultural researchers and it will enable smallholder dairy farmers gain adequate knowledge needed on which dairy production systems is more economically efficient that would make them generate more income and food. This will in turn enhance the quality and quantity of the dairy products produced to improve the farmers and consumer experience of dairy products. The discoveries of the study will attract the attention of researchers, and promote awareness among scientists, policymakers, and producers.



Procedures

Your participation in this study will involve answering the questions while filling in the questionnaires as requested.

Who will Participate in the Study?

Any individual who deals in dairy farming in the selected study area. The interview will last for thirty minutes or less and the participants will be 180 with you inclusive.

Risks/Discomforts

The only risk that could be faced in the course of this survey is the risk of the spread of COVID-19 during the research period shall be mitigated by adhering to COVID-19 SOP measures such as ensuring the use of hand sanitizers and nose masks and keeping social distancing.

Benefits

The study is expected to improve on the knowledge of the smallholder dairy farmers, which could be used to improve on the quality of dairy production. I will also ensure that feedback on the findings is made available to the respondents through their leaders. The respondents shall be compensated for their time with one kilogram of sugar and one bar of soap.

Confidentiality

Your identity will not be revealed to anyone as we shall only use codes to identify participants. Information obtained will only be accessible by the research team. Soft copies of the data will be protected by password and hard copy files will be kept under lock and key. Confidential information will only be accessed by the principal investigator.

Alternatives

You do not have to participate in this study if you are not interested. You will not lose any benefit in case of no participation.



Costs

There will not be any additional cost incurred as a result of participating in this study.

Inquiries

If you have any questions related to the study or your rights as a research participant, you can contact the principal investigator, Oyoo Peter Okello on telephone 0785523949 or via email at oyooopeterokello059@gmail.com

Statement of Voluntaries

Participation in the research study is voluntary and you may join at your own free will. You have a right to withdraw from the study at any time without penalty.

If you have any issues pertaining to your rights and participation in the study, please contact the Chairperson, Gulu University Research Ethics Committee (GUREC), Dr. Gerald Obai Tel: No., 0772305621; email: lekobai@yahoo.com/lekobai@gmail.com; or the Uganda National Council for Science and Technology on plot 6 Kimera Road, Ntinda, Kampala on Tel 0414705500.

If you consent to participate in the study, kindly indicate by signing/thumb print in the space below;

Name Sign/Thumb print of the participant.....date.....

Name Sign/Thumb print of the witness..... date.....

Name Sign/Thumb print of the interviewer..... date....



Appendix VI: Covid-19 Measures

Version 2.0

Measures for the Prevention and control of risk of spread of COVID-19 during the implementation of research

Study Title: Determinants of Economic Efficiency of Smallholder Dairy Production Systems in Northern Uganda: A Case Study of Gulu city and Gulu district
Principal Investigator (s): Oyoo Peter Okello

Introduction:

The novel Coronavirus is transmitted from human to human through droplets and direct or close personal contact with an infected individual

Novel Coronavirus signs of infection include respiratory symptoms, fever, cough, shortness of breath and breathing difficulties. In more severe cases, the infection can cause pneumonia, severe acute respiratory syndrome, kidney failure and even death

Implementation of the prevention and control measures

In the implementation of the research activities, the investigators are committed to ensuring the safety of the research team, research participants and communities where the study will be conducted. The study team undertakes to comply with the Standard Operating Procedures issued by the Ministry of Health, and presidential directives to mitigate against the risk of infection of COVID-19, rapidly detect and effectively respond to any COVID-19 case that may occur in the process of carrying out the study, screening, face covering, physical distancing, and good hand hygiene.

Procedures to be followed during the implementation of the research.

Prior to data collection and Training

1. **Health guidance:** There will be training sessions dedicated for COVID-19 sensitization and awareness, to equip the research team with knowledge of signs and symptoms of the COVID-19, and preventive measures such as hand hygiene before placing and removing the mask, as well as storage of the mask, social distancing. The research team will circulate notices, posters, charts on common signs and symptoms of COVID-19 as provided by the Ministry of Health, and develop and/or use existing plan for the appropriate referral pathway for identified and/or suspected cases.
2. **Personal Screening:** All researchers, research assistants, research participants and any other individuals engaged in research activities will screen temperature daily for fever. Screening for temperature will be carried out during planning meetings, trainings, community outreach. Any individual found with COVID 19 symptoms will be withdrawn and referred to the COVID – 19 task force for further assessment and management. The withdrawn individual will be allowed to return only if they present a valid certification of their COVID-19 status showing negative result



3. **Wearing face coverings:** All researchers and research assistants and any other individuals engaged in research activities that require interaction with fellow researchers or research participants or the community member will have to wear a face mask that fully covers the mouth and nose at all times. The study will provide face masks for individuals who do not have.
4. **Physical Distancing:** There will be social distancing during the training, meetings, community outreach of at minimum of 2 metres. During breaks, the team will not be allowed to congregate in common areas.
5. **Good hygiene:** All team members will be required to wash their hands or use hand sanitizers before and after entering the training room, and other common areas. Hand washing equipment shall be supplied and made available at all times. All surfaces and equipment shall be sanitised frequently.

During data collection

1. **Personal Protective Equipment (PPE):** All research assistants involved in tracing of respondents and in in-person interviews and research participants will use PPE including a properly fitted face mask. Enumerators/Researchers and research participants will wash hands with soap and water or use hand sanitizer prior to the interview. Handshakes and hugging are prohibited. Physical distancing of at least 2 metres in all research related activities shall be observed.
2. **Consent Process:** The Researcher /Research assistants will observe social distancing when taking consent (while 2 metres apart) upon arrival to the participant. Enumerators/Researchers and research participants will wash hands with soap and water or use hand sanitizer prior to the interview. Participant will then be sensitized on covid-19 and presented with preventive measures.
3. **Equipment sanitization:** shared devices used to record or capture data shall be sanitized regularly.

During Dissemination/Community engagement

1. **Community Engagement:** The research team shall carry educational materials on the prevention of COVID-19 in a language understood by the participants. These materials shall also have visual images to support understanding. Enumerators/Researchers and research participants will wash hands with soap and water or use hand sanitizer prior to the interview. Screening for temperature will be carried out prior to conducting community engagements.
4. **Equipment sanitization:** shared devices used during community engagements to shall be sanitized regularly.

The preventive and control measures will continuously be reviewed based on new information and guidelines communicated by the Ministry of Health



Appendix VII: Introductory Letter



GULU

P. O. BOX 166
Gulu-Uganda



UNIVERSITY

TEL.: +256 471 432518
FAX: +256 471 432094
Email: fac@gu.ac.ug
URL: www.gu.ac.ug

FACULTY OF AGRICULTURE & ENVIRONMENT

Date: 21st April 2023

The Chief Administrative Officer,
Gulu District

Dear Sir/Madam,

RE: INTRODUCTION OF MR. OYOO PETER OKELLO

I would like to introduce the bearer of this letter (Mr. Oyoo Peter Okello) who is a student of Gulu University Pursing a Master of Science in Agri-Enterprises Development registration number: 21/U/3383/MAE/PS.

He is conducting academic research on the topic: **"DETERMINANTS OF ECONOMIC EFFICIENCY OF SMALLHOLDER DAIRY PRODUCTION SYSTEMS IN NORTHERN UGANDA"**. He will be meeting dairy farmers in your district to obtain information on dairy production.

All information obtained will majorly be used for academic purposes and as well, it may help policy makers and programme designers to select and tailor new interventions and innovations in improving dairy production in the rural and urban areas of this country.

All the necessary support rendered to him Shall be highly appreciated.

Thank you.

Assoc Prof. Mugonola Basil

Head of Department Rural Development and Agribusiness

Tel. +256-772459745,

Email: basil.mugonola@gmail.com



Noted and No objection.

1051023.

Please AMO Anash,

V/O Pakko, V/O Paicho

Handle Mr Student.

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Appendix VIII: Plagiarism Check

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DETERMINANTS OF ECONOMIC EFFICIENCY OF SMALLHOLDER DAIRY
PRODUCTION SYSTEMS IN GULU CITY AND GULU DISTRICT, UGANDA

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☐ Moderate
☐ Serious

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Appendix IX: Data Fitness Test Result (STATA Output)

```
. regress lnP_Profit lnF_Feedcost lnL_Labourcost lnV_Vetcost lnO_Othercost lnL_Land Ex_Experience A_Age S_Sex Market_Access QW_
> Qtywater Extensionservices AC_Accesscredit GM_Groupmembership Ed_Education Fa_Familysize Breed_Type Marital_Status
```

Source	SS	df	MS	Number of obs = 191		
Model	64.2596162	17	3.77997742	F(17, 173) = 4.67		
Residual	140.075207	173	.809683279	Prob > F = 0.0000		
				R-squared = 0.3145		
				Adj R-squared = 0.2471		
Total	204.334823	190	1.07544644	Root MSE = .89982		

lnP_Profit	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
lnF_Feedcost	-.0763409	.0183227	-4.17	0.000	-.1125058	-.0401761
lnL_Labourcost	.4730248	.138579	3.41	0.001	.1995015	.7465481
lnV_Vetcost	-.0818704	.0301062	-2.72	0.007	-.1412932	-.0224475
lnO_Othercost	-.0387301	.0160371	-2.42	0.017	-.0703837	-.0070765
lnL_Land	.1627154	.0790533	2.06	0.041	.0066823	.3187486
Ex_Experience	.0163677	.0163611	1.00	0.319	-.0159253	.0486607
A_Age	-.0029482	.0065815	-0.45	0.655	-.0159386	.0100421
S_Sex	.173738	.165208	1.05	0.294	-.1523448	.4998208
Market_Access	-.1624606	.1765033	-0.92	0.359	-.5108377	.1859164
QW_Qtywater	.0067217	.008563	0.78	0.434	-.0101796	.0236231
Extensionservices	.2516241	.451071	0.56	0.578	-.6386869	1.141935
AC_Accesscredit	-.1858372	.1990009	-0.93	0.352	-.5786195	.2069451
GM_Groupmembership	-.0179408	.2045596	-0.09	0.930	-.4216948	.3858131
Ed_Education	.0444868	.0161004	2.76	0.006	.0127082	.0762654
Fa_Familysize	-.0048981	.0241582	-0.20	0.840	-.0525808	.0427846
Breed_Type	-.1658223	.1871863	-0.89	0.377	-.5352853	.2036406
Marital_Status	.0315109	.1864072	0.17	0.866	-.3364143	.3994361
_cons	-3.334972	1.784553	-1.87	0.063	-6.857272	.1873277

AppendixX: Multicollinearity Test Result (STATA Output)

```
. corr lnF_Feedcost lnL_Labourcost lnV_Vetcost lnO_Othercost lnL_Land Ex_Experience A_Age S_Sex Market_Access QW_Qtywater Extens
> sionservices AC_Accesscredit GM_Groupmembership Ed_Education Fa_Familysize Breed_Type Marital_Status
(obs=191)
```

	lnF_Fe~t	lnL_La~t	lnV_Ve~t	lnO_Ot~t	lnL_Land	Ex_Exp~e	A_Age	S_Sex	Market~s	QW_Qty~r	Extens~s	AC_Acc~t
lnF_Feedcost	1.0000											
lnL_Labour~t	0.4066	1.0000										
lnV_Vetcost	0.4585	0.5065	1.0000									
lnO_Otherc~t	-0.0493	-0.1157	0.0125	1.0000								
lnL_Land	-0.0657	0.0507	0.0672	0.0773	1.0000							
Ex_Experie~e	-0.1221	0.1081	0.1817	0.1152	0.1270	1.0000						
A_Age	0.0130	0.1231	0.0261	-0.0032	0.0069	0.3195	1.0000					
S_Sex	-0.0061	-0.0584	-0.0821	-0.0125	-0.1024	-0.1204	-0.1067	1.0000				
Market_Acc~s	0.1476	0.0208	0.0113	0.0699	0.0690	-0.1811	-0.0774	0.0759	1.0000			
QW_Qtywater	0.1650	0.0301	-0.0018	0.0322	-0.1077	-0.2391	0.0680	0.0969	0.0028	1.0000		
Extensions~s	0.2297	0.2318	0.3797	-0.0724	0.2231	0.0327	-0.1865	0.0744	0.0721	0.0506	1.0000	
AC_Accessc~t	0.2061	0.0489	0.0948	0.1094	0.2059	-0.1376	-0.0539	0.1349	0.5662	-0.0365	0.1821	1.0000
GM_Groupme~p	0.0898	-0.2482	-0.1067	0.1244	0.0359	-0.2008	-0.1958	0.1678	0.4066	-0.0209	0.1153	0.5358
Ed_Education	0.3779	0.3597	0.3384	0.0274	0.0421	-0.0813	-0.1785	-0.3726	0.1192	-0.0828	0.0615	0.0471
Fa_Familys~e	0.0775	-0.0303	0.0825	-0.0623	0.0669	0.0816	0.1641	-0.1616	-0.0609	0.0646	0.1130	0.0343
Breed_Type	0.5858	0.3695	0.3690	-0.1089	-0.1754	-0.1283	-0.0101	0.2473	0.1769	0.2329	0.1191	0.2485
Marital_St~s	0.0890	-0.0358	0.0403	-0.0344	0.0270	-0.1212	-0.1961	-0.3291	0.0018	0.0104	-0.0898	-0.1465
	GM_Gro~p	Ed_Edu~n	Fa_Fam~e	Breed_~e	Marita~s							
GM_Groupme~p	1.0000											
Ed_Education	-0.0589	1.0000										
Fa_Familys~e	0.0650	-0.0237	1.0000									
Breed_Type	0.0469	0.1943	-0.0833	1.0000								
Marital_St~s	-0.0546	0.1906	0.0869	-0.0288	1.0000							

. vif

Variable	VIF	1/VIF
AC_Accessc~t	2.13	0.470048
Breed_Type	2.07	0.483956
lnF_Feedcost	2.02	0.494631
lnV_Vetcost	1.85	0.540759
GM_Groupme~p	1.75	0.571398
Ed_Education	1.75	0.571885
lnL_Labour~t	1.74	0.573387
S_Sex	1.60	0.625125
Market_Acc~s	1.58	0.631569
A_Age	1.47	0.679937
Extensions~s	1.46	0.684756
Ex_Experie~e	1.43	0.701544
Marital_St~s	1.31	0.765505
QW_Qtywater	1.23	0.814822
lnL_Land	1.22	0.817504
Fa_Familys~e	1.16	0.861738
lnO_Otherc~t	1.13	0.888610
Mean VIF	1.58	

Appendix XI: Normality Test Result (STATA Output)

```
. predict residuals
(option xb assumed; fitted values)

. jb residual
Jarque-Bera normality test:  2.249 Chi(2)  .3249
Jarque-Bera test for Ho: normality:
```

Appendix XII: Heteroscedasticity Test Result (STATA Output)

```
. imtest, white

White's test for Ho: homoskedasticity
    against Ha: unrestricted heteroskedasticity

      chi2(152)    =    168.73
      Prob > chi2  =    0.1674

Cameron & Trivedi's decomposition of IM-test
```

Source	chi2	df	p
Heteroskedasticity	168.73	152	0.1674
Skewness	16.07	17	0.5191
Kurtosis	0.59	1	0.4433
Total	185.39	170	0.1986

Appendix XIII: Stochastic Profit Frontier and the Inefficiency Term Result (STATA Output)

Overall dairy production systems

```
. sfcross lnP_Profit lnF_Feedcost lnL_Labourcost lnV_Vetcost lnO_Othercost lnL_Land ,dist(tn) ort(o) vce(robust) emean( Ex_Experi  
> ence A_Age S_Sex Market_Access QW_Qtywater Extensionservices AC_Accesscredit GM_Groupmembership Ed_Education Fa_Familysize Br  
> eedtype Marital_Status )
```

```

initial:      Log likelihood = -24832.031
Iteration 0:  Log likelihood = -24832.031 (not concave)
Iteration 1:  Log likelihood = -363.73978 (not concave)
Iteration 2:  Log likelihood = -306.25639 (not concave)
Iteration 3:  Log likelihood = -265.61372 (not concave)
Iteration 4:  Log likelihood = -261.47227 (not concave)
Iteration 5:  Log likelihood = -241.90457 (not concave)
Iteration 6:  Log likelihood = -238.20054
Iteration 7:  Log likelihood = -237.36545
Iteration 8:  Log likelihood = -236.08962 (not concave)
Iteration 9:  Log likelihood = -236.05957
Iteration 10: Log likelihood = -235.97506 (not concave)
Iteration 11: Log likelihood = -234.78859
Iteration 12: Log likelihood = -233.21981
Iteration 13: Log likelihood = -231.20418
Iteration 14: Log likelihood = -231.17794 (backed up)
Iteration 15: Log likelihood = -231.17147 (backed up)
Iteration 16: Log likelihood = -231.16985 (backed up)
Iteration 17: Log likelihood = -231.16905 (backed up)
Iteration 18: Log likelihood = -231.169 (backed up)
Iteration 19: Log likelihood = -231.16897 (backed up)
Iteration 20: Log likelihood = -231.16897 (backed up)
Iteration 21: Log likelihood = -231.16897 (backed up)
Iteration 22: Log likelihood = -231.16897 (backed up)
Iteration 23: Log likelihood = -231.16897 (backed up)
Iteration 24: Log likelihood = -231.16897 (backed up)
Iteration 25: Log likelihood = -231.16897 (backed up)
Iteration 26: Log likelihood = -231.16897 (backed up)
Iteration 27: Log likelihood = -231.16897 (backed up)
Iteration 28: Log likelihood = -231.16897 (backed up)
Iteration 29: Log likelihood = -231.16897 (backed up)
Iteration 30: Log likelihood = -231.16897 (backed up)
Iteration 31: Log likelihood = -231.16897 (backed up)
Iteration 32: Log likelihood = -231.16897 (backed up)
Iteration 33: Log likelihood = -231.16897 (backed up)
Iteration 34: Log likelihood = -231.16897 (backed up)
Iteration 35: Log likelihood = -231.16897 (backed up)
Iteration 36: Log likelihood = -231.16897 (backed up)
Iteration 37: Log likelihood = -231.16897 (backed up)

```

Iteration 38: Log likelihood = -231.16897 (backed up)
Iteration 39: Log likelihood = -231.16897 (backed up)
Iteration 40: Log likelihood = -231.16897 (backed up)
Iteration 41: Log likelihood = -231.16897 (backed up)
Iteration 42: Log likelihood = -231.16897 (backed up)
Iteration 43: Log likelihood = -231.16897 (backed up)
Iteration 44: Log likelihood = -231.16897 (backed up)
Iteration 45: Log likelihood = -231.16897 (backed up)
Iteration 46: Log likelihood = -231.16897 (backed up)
Iteration 47: Log likelihood = -231.16897 (backed up)
Iteration 48: Log likelihood = -231.16897 (backed up)
Iteration 49: Log likelihood = -231.16897 (backed up)
Iteration 50: Log likelihood = -231.16897 (backed up)
Iteration 51: Log likelihood = -231.16897 (backed up)
Iteration 52: Log likelihood = -231.16897 (backed up)
Iteration 53: Log likelihood = -231.16897 (backed up)
Iteration 54: Log likelihood = -231.16897 (backed up)
Iteration 55: Log likelihood = -231.16897 (backed up)
Iteration 56: Log likelihood = -231.16897 (backed up)
Iteration 57: Log likelihood = -231.16897 (backed up)
Iteration 58: Log likelihood = -231.16897 (backed up)
Iteration 59: Log likelihood = -231.16897 (backed up)
Iteration 60: Log likelihood = -231.16897 (backed up)
Iteration 61: Log likelihood = -231.16897 (backed up)
Iteration 62: Log likelihood = -231.16897 (backed up)
Iteration 63: Log likelihood = -231.16897 (backed up)
Iteration 64: Log likelihood = -231.16897 (backed up)
Iteration 65: Log likelihood = -231.16897 (backed up)
Iteration 66: Log likelihood = -231.16897 (backed up)
Iteration 67: Log likelihood = -231.16897 (backed up)
Iteration 68: Log likelihood = -231.16897 (backed up)
Iteration 69: Log likelihood = -231.16897 (backed up)
Iteration 70: Log likelihood = -231.16897 (backed up)

Iteration 71: Log likelihood = -231.16897 (backed up)
Iteration 72: Log likelihood = -231.16897 (backed up)
Iteration 73: Log likelihood = -231.16897 (backed up)
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Iteration 81: Log likelihood = -231.16897 (backed up)
Iteration 82: Log likelihood = -231.16897 (backed up)
Iteration 83: Log likelihood = -231.16897 (backed up)
Iteration 84: Log likelihood = -231.16897 (backed up)
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Iteration 88: Log likelihood = -231.16897 (backed up)
Iteration 89: Log likelihood = -231.16897 (backed up)
Iteration 90: Log likelihood = -231.16897 (backed up)
Iteration 91: Log likelihood = -231.16897 (backed up)
Iteration 92: Log likelihood = -231.16897 (backed up)
Iteration 93: Log likelihood = -231.16897 (backed up)
Iteration 94: Log likelihood = -231.16897 (backed up)
Iteration 95: Log likelihood = -231.16897 (backed up)
Iteration 96: Log likelihood = -231.16897 (backed up)
Iteration 97: Log likelihood = -231.16897 (backed up)
Iteration 98: Log likelihood = -231.16897 (backed up)
Iteration 99: Log likelihood = -231.16897 (backed up)
Iteration 100: Log likelihood = -231.16897 (backed up)

Stoc. frontier normal/tnormal model

Number of obs = 191
Wald chi2(5) = 86.14
Prob > chi2 = 0.0000

Log likelihood = -231.1690

lnP_Profit		Robust				
		Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]
Frontier						
lnF_Feedcost		-.0804289	.0130263	-6.17	0.000	-.1059599 -.0548979
lnL_Labourcost		.4717649	.1557855	3.03	0.002	.166431 .7770988
lnV_Vetcost		-.1185371	.027395	-4.33	0.000	-.1722302 -.0648439
lnO_Othercost		-.0432428	.0130357	-3.32	0.001	-.0687923 -.0176933
lnL_Land		.161648	.0685301	2.36	0.018	.0273313 .2959646
_cons		-2.098318	1.927641	-1.09	0.276	-5.876425 1.679789
Mu						
Ex_Experience		-.2029323	.0477984	-4.25	0.000	-.2966156 -.1092491
A_Age		.0385773	.0109762	3.51	0.000	.0170644 .0600902
S_Sex		.4020219	.2334295	1.72	0.085	-.0554914 .8595353
Market_Access		.377103	.1928348	1.96	0.051	-.0008464 .7550523
QW_Qtywater		.0119468	.0122114	0.98	0.328	-.0119872 .0358808
Extensionservices		-.8614355	.4590895	-1.88	0.061	-1.761234 .0383633
AC_Accesscredit		1.004731	.3005259	3.34	0.001	.4157109 1.593751
GM_Groupmembership		.097082	.3953123	0.25	0.806	-.6777158 .8718798
Ed_Education		-.1010465	.0339952	-2.97	0.003	-.1676758 -.0344172
Fa_Familysize		.0717493	.0321105	2.23	0.025	.008814 .1346846
Breedtype		-.7158729	.285896	-2.50	0.012	-1.276219 -.1555269
Marital_Status		.0606949	.2999356	0.20	0.840	-.527168 .6485579
_cons		-1.462679	.8529057	-1.71	0.086	-3.134344 .2089856
Usigma						
_cons		-3.654589	.6025771	-6.06	0.000	-4.835618 -2.473559
Vsigma						
_cons		-.426218	.1251772	-3.40	0.001	-.6715609 -.1808752
sigma_u	.1608482	.0484617	3.32	0.001	.0891167	.2903177
sigma_v	.808068	.0505759	15.98	0.000	.71478	.9135313
lambda	.1990528	.0692816	2.87	0.004	.0632634	.3348422

Zero-grazing system

```
. sfcross lnP_Profit lnF_Feedcost lnL_Labourcost lnV_Vetcost lnO_Othercost lnL_Land ,dist(tn) ort(o) vce(robust) emean( Ex_Experi  
> ence A_Age S_Sex Market_Access QW_Qtywater AE_Accessexextension CreditAccess GM_Groupmembership Ed_Education Fa_Familysize Bree  
> d_Type Marital_Status H_Herdsize OF_Otherfarmincome )
```

Stoc. frontier normal/tnormal model

Number of obs = 75
Wald chi2(5) = 90.32
Prob > chi2 = 0.0000

Log likelihood = -54.3128

lnP_Profit		Coef.	Robust Std. Err.	z	P>|z|	[95% Conf. Interval]	
Frontier							
lnF_Feedcost		-.6874685	.0772616	-8.90	0.000	-.8388984	-.5360386
lnL_Labourcost		.0889339	.1540109	0.58	0.564	-.2129219	.3907896
lnV_Vetcost		-.0285746	.0910802	-0.31	0.754	-.2070886	.1499394
lnO_Othercost		-.0362785	.011017	-3.29	0.001	-.0578714	-.0146855
lnL_Land		.3142203	.0976749	3.22	0.001	.1227811	.5056596
_cons		10.42361	2.454901	4.25	0.000	5.612092	15.23513
Mu							
Ex_Experience		-.0245208	.0149543	-1.64	0.101	-.0538307	.0047891
A_Age		-.0161441	.0090591	-1.78	0.075	-.0338997	.0016114
S_Sex		-.2008147	.1518717	-1.32	0.186	-.4984777	.0968483
Market_Access		-.1514887	.1571696	-0.96	0.335	-.4595356	.1565581
QW_Qtywater		-.0022403	.0075	-0.30	0.765	-.01694	.0124594
AE_Accessexension		-8.131291	1.475098	-5.51	0.000	-11.02243	-5.240152
CreditAccess		.410284	.1609757	2.55	0.011	.0947774	.7257907
GM_Groupmembership		.9645162	.2675959	3.60	0.000	.440038	1.488995
Ed_Education		-.0151247	.0190048	-0.80	0.426	-.0523734	.022124
Fa_Familysize		-.0153442	.0294477	-0.52	0.602	-.0730605	.0423722
Breed_Type		-.9019169	.2598474	-3.47	0.001	-1.411208	-.3926253
Marital_Status		.196177	.2633184	0.75	0.456	-.3199177	.7122717
H_Herdsize		-.3029539	.0522912	-5.79	0.000	-.4054427	-.2004651
OF_Otherfarmincome		-.469419	.2382005	-1.97	0.049	-.9362834	-.0025545
_cons		11.33517	2.112205	5.37	0.000	7.19532	15.47501
Usigma							
_cons		-5.302297	1.08778	-4.87	0.000	-7.434307	-3.170287
Vsigma							
_cons		-1.371943	.1659149	-8.27	0.000	-1.69713	-1.046756
sigma_u	.0705701	.0383824	1.84	0.066	.024303	.2049184	
sigma_v	.5036008	.0417774	12.05	0.000	.4280287	.5925158	
lambda	.1401311	.0508163	2.76	0.006	.0405329	.2397293	

.

Tethered system

```
. sfcross lnP_Profit lnF_Feedcost lnL_Labourcost lnV_Vetcost lnO_Othercost lnL_Land ,dist(tn) ort(o) vce(robust) emean( Ex_Experi  
> ence A_Age S_Sex Market_Access QW_Qtywater AE_Accessexextension CreditAccess GM_Groupmembership Ed_Education Fa_Familysize Bree  
> d_Type Marital_Status H_Herdsize OF_Otherfarmincome )
```

Stoc. frontier normal/tnormal model

Number of obs = 69
Wald chi2(5) = 44.28
Prob > chi2 = 0.0000

Log likelihood = -74.1524

lnP_Profit		Coef.	Robust Std. Err.	z	P>|z|	[95% Conf. Interval]	
Frontier							
lnF_Feedcost		-.0693452	.0237815	-2.92	0.004	-.115956	-.0227343
lnL_Labourcost		.5580163	.2625606	2.13	0.034	.0434069	1.072626
lnV_Vetcost		-.144464	.0312469	-4.62	0.000	-.2057069	-.0832211
lnO_Othercost		-.0477963	.0267943	-1.78	0.074	-.1003121	.0047195
lnL_Land		-.0051377	.1435779	-0.04	0.971	-.2865451	.2762698
_cons		-2.748939	3.183998	-0.86	0.388	-8.989461	3.491582
Mu							
Ex_Experience		.0427987	.0522794	0.82	0.413	-.0596671	.1452645
A_Age		.0257402	.0122946	2.09	0.036	.0016433	.0498372
S_Sex		-.8761409	.4831534	-1.81	0.070	-1.823104	.0708223
Market_Access		.8433545	.3965112	2.13	0.033	.0662068	1.620502
QW_Qtywater		-.0339628	.020053	-1.69	0.090	-.0732659	.0053404
AE_Accessexension		-2.132517	.9003705	-2.37	0.018	-3.897211	-.3678229
CreditAccess		.9883396	.4358266	2.27	0.023	.1341353	1.842544
GM_Groupmembership		1.032936	.6057187	1.71	0.088	-.1542509	2.220123
Ed_Education		.0176132	.0820672	0.21	0.830	-.1432355	.178462
Fa_Familysize		.0120607	.0543322	0.22	0.824	-.0944285	.1185499
Breed_Type		-1.626508	.7586299	-2.14	0.032	-3.113395	-.1396203
Marital_Status		-.9659013	.4538722	-2.13	0.033	-1.855474	-.0763282
H_Herdsize		-.5475379	.3508554	-1.56	0.119	-1.235202	.140126
OF_Otherfarmincome		3.096452	1.519259	2.04	0.042	.1187591	6.074146
_cons		-.3827311	1.820355	-0.21	0.833	-3.950562	3.1851
Usigma							
_cons		-3.331042	.9256826	-3.60	0.000	-5.145346	-1.516737
Vsigma							
_cons		-.7955399	.152297	-5.22	0.000	-1.094037	-.4970433
sigma_u		.1890922	.0875197	2.16	0.031	.0763312	.4684301
sigma_v		.6718166	.0511578	13.13	0.000	.5786727	.779953
lambda		.281464	.098647	2.85	0.004	.0881194	.4748086

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Herding system

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. sfcross lnP_Profit lnF_Feedcost lnL_Labourcost lnV_Vetcost lnO_Othercost lnL_Land ,dist(tn) ort(o) vce(robust) emean( Ex_Experi  
> ence A_Age S_Sex Market_Access QW_Qtywater AE_Accessexextension CreditAccess GM_Groupmembership Ed_Education Fa_Familysize Bree  
> d_Type Marital_Status H_Herdsize OF_Otherfarmincome )
```

Stoc. frontier normal/tnormal model

Number of obs = 47
Wald chi2(5) = 27.31
Prob > chi2 = 0.0000

Log likelihood = -34.6366

lnP_Profit		Robust				
		Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]
Frontier						
lnF_Feedcost		-.0259267	.0180079	-1.44	0.150	-.0612216 .0093682
lnL_Labourcost		.2777587	.1413628	1.96	0.049	.0006928 .5548247
lnV_Vetcost		.0990986	.0344877	2.87	0.004	.0315039 .1666933
lnO_Othercost		-.0183471	.0173941	-1.05	0.292	-.0524389 .0157448
lnL_Land		-.2573078	.0944379	-2.72	0.006	-.4424027 -.0722128
_cons		-2.380232	1.681985	-1.42	0.157	-5.676861 .9163983
Mu						
Ex_Experience		.2614092	.0600614	4.35	0.000	.1436911 .3791274
A_Age		-.0502134	.0168547	-2.98	0.003	-.083248 -.0171787
S_Sex		-1.227891	.4485352	-2.74	0.006	-2.107003 -.3487778
Market_Access		.2459841	.3471383	0.71	0.479	-.4343946 .9263627
QW_Qtywater		.0015354	.042407	0.04	0.971	-.0815809 .0846517
AE_Accessexension		-3.407731	1.004311	-3.39	0.001	-5.376145 -1.439318
CreditAccess		-1.212461	.3541587	-3.42	0.001	-1.906599 -.5183222
GM_Groupmembership		1.72389	.5113005	3.37	0.001	.7217596 2.726021
Ed_Education		-.0713915	.0501809	-1.42	0.155	-.1697444 .0269613
Fa_Familysize		.2396444	.0416286	5.76	0.000	.1580538 .321235
Breed_Type		2.362427	.6574841	3.59	0.000	1.073782 3.651072
Marital_Status		-1.376662	.5545985	-2.48	0.013	-2.463655 -.289669
H_Herdsize		-.2422186	.0627372	-3.86	0.000	-.3651812 -.119256
OF_Otherfarmincome		1.830216	4.683265	0.39	0.696	-7.348815 11.00925
_cons		2.002623	5.142329	0.39	0.697	-8.076157 12.0814
Usigma						
_cons		-3.447549	.7932765	-4.35	0.000	-5.002342 -1.892755
Vsigma						
_cons		-1.655724	.2161128	-7.66	0.000	-2.079298 -1.232151
sigma_u		.1783916	.0707569	2.52	0.012	.0819889 .3881445
sigma_v		.4369825	.0472188	9.25	0.000	.3535788 .5400597
lambda		.4082351	.0818165	4.99	0.000	.2478776 .5685925

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Appendix XIV: Questionnaire

Title of the study: Determinants of Economic Efficiency of Dairy Production Systems in Gulu city and Gulu district, Uganda.

Introduction:

Dear respondents I am **Oyoo Peter Okello** conducting a study on the **Determinants of Economic Efficiency of Small holder Dairy Production systems in Gulu city and Gulu district, Uganda**. You have been selected to participate in this study and all the information provided shall be kept confidential, I am now seeking for your positive response toward this study.

Questionnaire No Date of Interview.....

Name of District Name of Ward/Village.....

Name of Interviewer Phone No.

Section A: Socio-Economic characteristics of dairy farmers

A₁ :Are you the household head?	1. Yes 2. No
A₂ :If no , what is your relationship with the household head?	1. Spouse 2. Son 3. Daughter 4. Others specify.....
A₃ :Age	Years
A₄ :Sex of the household head	1=Male ☐ 2=Female ☐
A₅ :Experience of the dairy farmer	 (Years),
A₆ :Education level of the dairy farmer	 (Years)
A₇ :Major secondary occupation	1=Farming, 2=Livestock keeping, 3=Employed, 4=Trader, 5=Others, Specify
A₈ : Marital status	1. Single 2. Married 3. Divorced 4. Widowed
A₉ : Family size	.....
A₁₀ : Number of dependents	1. Aged 15 below..... 2. Aged above 65 years.....
A₁₁ :Land size owned (bought and rented)	(acres)
A₁₂ :Land size owned (bought and rented) under dairy farming	(acres)
A₁₃ :Agricultural enterprises other than dairy	.....

Section B: Cow information on productive performance

B₁ :How did you acquire the knowledge of dairy production?	1=Apprenticeship, 2=Vocational training, 3=Others (Specify).....
B₂ : Herd size	.....
B₃ :Name of the dairy breed	1. Local (Zebu, Ankole) 2. Friesian 3. Jersey 4. Guernsey 5. Ayrshire 6. Others

	(specify.....
B₄ : Number of lactating cows	
B₅ : Number of in-calving cows	
B₆ : Number of bulls	
B₇ : Number of calves	
B₈ : Number of castrates	
B₉ : The quantity of milk obtained per cow in litres per day	
B₁₀ : The average quantity of milk obtained per day in litres	
B₁₁ : The quantity of milk consumed per day in litres	
B₁₂ : The quantity of milk sold per day in litres	
B₁₃ :How many days do you milk the cow from birth to the time the milk get dried?	
B₁₄ : What is your calving interval in months	
B₁₅ :Who provide information on dairy production practices?	Tick all that apply 1. NGOs 2. Government 3. Workshops and seminars 4. Neighbors 5. Own knowledge 6. Others specify
B₁₆ :Where do you make your farm purchases	Tick all that apply 1. Agro-vet store 2. Local shop 3. Farmer groups 4. Government supply 5. Others (specify).....

Section C: Information on production systems

C₁ :Name of the production systems	Tick the most appropriate 1. Zero-grazing 2. Free-range 3. Fence 4. Herding 5. Tethered
C₂ :What are the major problems facing the named production system?	Tick all that apply 1. Inadequate land

	2. Labor availability 3. Unreliable rainfall 4. High price per unit of forage 5. Others (specify)
C₃ :What is the source of your forage	Tick the most appropriate 1. Own production 2. Buy 3. Others specify.....
C₄ :For own production what source of forages do you grow?	Tick all that apply 1. Napier grass 2. Rhodes grass 3. Desmodium 4. Sweet potato vines 5. Grass silage 6. Maize silage 7. Hay 8. Others (specify).....
C₅ :Size of land under forage	(acres)
C₆ :Land size under specified production system	(acres)

Section D: Bought forages

D₁ : Forage type purchase (tick all that apply)	The unit measure	Quantity purchase	Per unit price
Napier grass			
Rhodes grass			
Desmodium			
Sweet potato vines			
Grass silage			
Maize silage			
Hay			
Napier grass			
Rhodes grass			

D₂ :Are these amounts similar to other in other months	1. Yes 2. No
D₃ :If no, please describe the differences in the months	.....

	
D₄ :If yes what are the major problem with the with the forage feeding?	Tick all that apply 1. Inadequate land 2. Labor availability 3. Unreliable rainfall 4. High price per unit of forage 5. Others (specify)

Section E: Concentrates

E₁ : Type of concentrates (tick all that apply)	Number of time fed/day	Quantity fed to lactating cow at one moment	Cost of feed	
			Unit measure	Price (Ugx)
Dairy meal				
Wheat bran				
Maize jam				
Vitamin/mineral powder				
Vitamin/mineral block				
Others (specify)				

E₂ :Are these amounts similar to other in other months	1. Yes 2. No
E₃ : If no, please describe the differences in the months	..... ..... .....
E₄ : If yes what are the major problem with the forage feeding?	Tick all that apply 1. High cost of concentrates 2. Inadequate availability 3. Inconsistence supply 4. Others (specify)

Section F: Water sources and consumption

F₁ :Type of water sources	Tick all that apply 1. Tap water 2. Bore hole 3. Stream
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	4. River 5. Others (specify).....
F₂ :How many times a day do you provide water to animals?	(number)
F₃ :What quantity of water do you provide your cow?	 (litre/cow)
F₄ :What materials do you use for watering the animals?	Tick all that apply 1. Bucket 2. Cemented water trough 3. Others (specify).....

Section G: Labor cost

G₁ :Do you always hire labor?	1. Yes 2. No
G₂ : If yes what types of labor?	Tick all that apply 1. Family members 2. Hired workers 3. Both
G₃ : Hours worked Per day by the labor?	
G₄ : How much you pay them per day?	
G₅ : What activities does this labor do?	

G₆: How many people are normally involved?

Individual	Number of individuals
Male	
Female	

G₇ : If hired workers, how many do you hire?	
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G_8 : What is the average pay for each labor?	 (UGX)
G_9 : Do you hire labor seasonally?	1. Yes 2. No
G_{10} : If yes , what month do you hire labor?	.....

Section H: Veterinary cost

H_1 : In the last, 12 months, have you accessed veterinary services?	1. Yes 2. No
H_2 : If yes, what services were you looking for?	Tick all that apply 1. Vaccination 2. Mastitis treatment 3. AI services 4. Deworming 5. Spraying 6. Others (specify).....
H_3 : Number of times you have received veterinary services	

H_4 : How much in (Ugx) did you spend on vet services in the last 12 months				
Services	Cow#1	Cow#2	Cow#3	Cow#4
Vaccination				
Mastitis treatment				
AI services				
Deworming				
Spraying				
Others (specify)				

How much on average did you spent on veterinary services in the last 12 months?	
H_5 : How often do you deworm your cow?	.....
H_6 : Did you meet other expenses apart from veterinary services, feeding and labor in the last 12 months?	1. Yes 2. No

H₇ :If yes, what expenses are they?	..... .....
H₈ :How much did it cost you in Ugx?	.....

Section I: Milk marketing

I₁ :Location of the farm	1. Main road (km)..... 2. Market centre (km).....
I₂ : Do you have milk collection centres?	1. Yes 2. No
I₃ : If yes , how far is the milk collection centre from the farm?	 (Km)
I₄ :Type of the nearest main road	1. Tarmac 2. Murram 3. Earth 4. Others (specify).....
I₅ :Means of transport	1. Private car 2. Public service vehicle 3. Motorcycle 4. Bicycle 5. Walking 6. Others(specify).....
I₆ :What is the current selling price of milk per litre?	(Ugx)
I₇ :What and when was the highest and the lowest selling price you had in the last 12 months?	1. Highest.....Ugx in..... month 2. Lowest.....Ugx in..... month
I₈ :Who are your milk customers?	Tick all that apply 1. Neighbors 2. Local shops/hotels 3. Middlemen 4. Processors 5. Dairy cooperative, 6. Others (specify).....
I₉ :Which market is	.....

your main market for milk selling	
I₁₀ :Main reasons for selling milk in this market	Tick all that apply 1. Better price 2. Direct cash payment 3. NGOs encourage it 4. Closer to the farm 5. Others (specify).....
I₁₁ :Which form of milk do you sell at your farm?	Tick all that apply 1. Raw 2. Fermented 3. Chilled
I₁₂ :What is your average sale of milk per day in litres during the last month?	ltr
I₁₃ :How much is transport cost to the market	 Ugx
I₁₄ :What problem did you face with marketing of milk?	Tick all that apply 1. Low milk prices 2. Long distance 3. Late payment 4. Others (specify).....
I₁₅ :Which items has the highest annual cost in your farm?	1. Feeds 2. Veterinary 3. Marketing 4. Labor 5. Others (specify).....

Section J: Institution and income information

J₁ :Are you a member of any development group (farmer's group)?	1. Yes 2. No
J₂ :If yes, what is the nature of the group?	1. Formal group 2. Informal group
J₃ :What type of group is it?	1. Women's group

	2. Young farmers group 3. Others (specify).....
J₄ :How long have you been a member of this group?	.....
WJ₅ :Which major services is offered by the group?	Tick all that apply 1. Credit services 2. Marketing information 3. Marketing of products 4. Transportation 5. Provide supply 6. Others (specify).....

J₆:In your own opinion how important are the following factors in influencing your decision to join/form a group

Factors	Relative importance		
	1. Very important	2. Important	3. Less important
Market access			
Provide farm supplies			
Organizing learning seminars			
Number of group members			
Leaders who are dedicated to serve			
Fairness of distribution of benefit among members			
Good quality of services offered			
Leader transparency in finance matters			

J₇ :Do you have access dairy extension services?	1. Yes 2. No
J₈ :If yes , who provide dairy extension services to you in the last 12 months	Tick all that apply 1. Government 2. NGO specify..... 3. Private company (bank) 4. Uganda dairy 5. Others (specify).....
J₉ :How many times in the last 12 months did you received dairy extension services?	
J₁₀ :Do you have access to credit for your dairy farming?	1. Yes 2. No

J₁₁ :If yes, what type of loan?	1. Cow/Heifer loan 2. Cash loan 3. Feed loan 4. Others (specified)
J₁₂ :What is the source of loan?	1. Dairy cooperative 2. Bank 3. SACCOs 4. Relative and friends 5. Agricultural finance 6. Others (specify).....
J₁₃ :Have you received loan in the last 12 months?	1. Yes 2. No
J₁₄ :If yes, what amount of loan did you receive?	(Ugx)
J₁₅ :What was the purpose of the loan you received?	1. Buy medicine 2. Buy feed 3. Purchase cow/heifer 4. AI services 5. Others (specify).....
J₁₆ :Did you pay the loan in full?	1. Yes 2. No
J₁₇ :If no, why	..... ..... .....
J₁₈ :What are most important benefits from your dairy farming?	Order of importance 1. 2. 3. 4.
J₁₉ :What are the key challenges in your dairy production?	1. 2. 3. 4.
J₂₀ :Is dairy farming your main source of income?	1. Yes 2. No
J₂₁ : If yes, how much is earned from the dairy enterprise per month	(Ugx)

J₂₂ :Who controls the income from the dairy farming enterprise	Tick all that apply 1. Household heads 2. Spouse 3. Others (specify).....
J₂₃ :Do you have other source of income?	1. Yes 2. No

J₂₄:If **yes**, what are these other sources of income?

Sources	Estimated amount earned in the last month in (Ugx)	Who controls the income from this source?
Other farming activities (specify).....		
Formal employment more than 20 hours per week		
Casual labor 20 or less hour per week		
Self-employed business man/woman		
Remittance (cash transfers from government or NGOs) and gifts		
Others (specify).....		

J₂₅ :Are these amounts similar to other months in last year?	1. Yes 2. No	
J₂₆ :If no, please describe the differences in other months	..... ..... .....	
J₂₇ :Estimate your expenditures in the last month for the following	Expense	Amount (Ugx)
	Dairy enterprise	
	Food	
	School fees	
	Medical care	
	Clothing	
	Entertainment	

	Savings	
	Donations	
	Other (specify).....	
<i>J</i> ₂₈ :Are these amounts similar to other amounts in the last year?	1. Yes 2. No	
<i>J</i> ₂₉ :If no please describe the differences in the other months	1. 2. 3. 4.	

Thank you for your participation.