FACTORS INFLUENCING USE AND EXTENT OF USE OF STORAGE SYSTEMS AMONG SMALLHOLDER RICE FARMERS" IN KYELA DISTRICT, TANZANIA

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Award of a Master of Science Degree in Agribusiness Management of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

I declare that this thesis is my original work and has never been submitted to this or any other university for the award of a degree.

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Recommendation

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DEDICATION

I dedicate this thesis to my beloved parents Alphonce and Bertha, my brother Patrick, and my sisters Atuganile, and Debora for their love, support and encouragement that helped make this possible.

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ABSTRACT

Rice is the second staple food and cash crop produced in Tanzania after maize, it contributed to national economic growth, food security and source of employment for millions of populations. However, smallholder farmers lack knowledge of the proper postharvest management; thus, they become unaware and unknowledgeable decisions on the storage technique to use and as a result a lot of their produce are wasted. Therefore, assessment of factors influencing use and extent of use of crop storage system in Kyela district is needed. The specific objectives of this study are: to characterise the smallholder rice farmers based on the storage systems they use, to determine the factors that influence the use of storage systems in Kyela district, and to determine the factors that influence the extent of storage of rice among the smallholder rice farmers in the Kyela district. A survey of a sample of 267 smallholder rice farmer in Kyela district from three wards of Katumba songwe, Makwale, and Mwaya was conducted using semi-structured questionnaire. Descriptive and inferential statistics analysis (i.e., the double hurdle model and Logit model) were conducted using STATA software. Descriptive statistics indicated that users of the storage system had higher on-farm income, more education, participate more in group membership, had more access to extension service, training and credit than non-users. The Double Hurdle Model (DHM) revealed that the male household head, household size, access to training, access to agricultural extension services, and on-farm income were found to have a positive and significant effect on smallholder farmers' use of a storage system. In addition, the extent of smallholder farmers' use of storage systems was positively influenced by male household head, access to training, access to agricultural extension services and on-farm income, while negatively influenced by farm size. Finally, the Logit model revealed that the choice of storage system type was significantly and positively influenced by age, marital status (married), access to training, and quantity of rice harvested, while household size, total storage cost, and on-farm income had a negative influence. This study recommends that smallholder farmers need training on how to use storage systems effectively because rice farming predominates in the research area. Also, more effort should be directed to promoting post-harvest storage systems at various levels (home, community, and national), through agricultural extension services by private/international institutions, and governments.

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LIST OF ABBREVIATIONS AND ACRONYMS

BI	Behavioural Intention
CSB	Choice Supportive Bias
DHM	Double Hurdle Model
FAO	Food and Agriculture Organization
GDP	Growth Domestic Product
HSTs	Hermetic storage technologies
IFAD	International Fund for Agricultural Development
IRRI	International Rice Research Institute
JICA	Japan International Cooperation Agency
KATC	Kilimanjaro Agricultural Training Centre
NBS	National Bureau Statistics
NGOs	Non-Government Organizations
NRDS	National Rice Development Strategy
PBC	Perceived Behavioural Control
PICS	Purdue Improved Crop Storage
SAGCOT	Southern Agriculture Growth Corridor of Tanzania
SDG	Sustainable Development Goals
TARI	Tanzania Agricultural Research Institute
TIC	Tanzania Investment Centre
TNC	Tanzania National Census
TPB	Theory of Planned Behaviour
TZS	Tanzanian Shilling
URT	United Republic of Tanzania
WRS	Warehouse Receipt System

CHAPTER ONE

INTRODUCTION

1.1 Background information

One of the major grain foods in Tanzania is rice, which is produced and consumed by the majority of people, second only to maize (Kulyakwave et al., 2020). Tanzania's economy and food security depend heavy on rice cultivation, which also directly supports a number of Sustainable Development Goals (Magubika et al., 2025). IRRI (2024) reports that rice consumption increasing at a pace of 6% annually, Africa is one of the rice markets with the quickest rate of growth. The subcontinent's rice value chain is in danger of being disrupted by climate change, variability, and economic globalization, which would undermine their crucial role in promoting growth in the economy, ensuring food security, as well as decreasing poverty (Terdoo & Feola, 2016)

According to IRRI (2024) Traditionally, rice farmers in Tanzania have depended on local landraces such as the Supa variety. Within the Bagamoyo Irrigation and Development Project (BIDP) area, many farmers continue cultivating Supa primarily due to limited awareness of improved rice varieties and restricted access to high-quality seed. A study by Ardhi & Mungwabi (2022) revealed that, the majority of farmers obtain market information predominantly through informal networks, including relatives, friends, community meetings, traders, and radio broadcasts. Sandy et al. (2024) argues that in about 70% of the smallholder farmers were not accessible to the reliable agricultural data and 96% were knowledgeable however they could not properly get farming information in Mvomero district.

Tanzania's government, through the Tanzania Investment Centre (TIC), has been calling for investment projects and partnerships to stimulate growth in agriculture and agro-processing, including value chain development, as part of its efforts to create employment and boost economic development. Farming activities are being conducted by using poor implements such as hand hoes, and it is family labour based which results in low yields (Mnenwa & Maliti,2010). Most of rice farmers are smallholders who cultivate paddy for domestic use and sell remaining grains directly to the customer or through farmers' cooperatives where there are storage systems in operation. Approximately 90 percent of rice gets produced using the small-scale farming system on farms that range in size from 0.9 to 3 hectares, with a mean of 1.3 hectares (Mauki et al., 2023)

One of the policies issued by the government in the agricultural sector is to increase rice production by tariff protection of its rice industry from cheap imported rice subsidies (Ires, 2022). Uniquely, in this storage facilities system, farmers do not need to rush to sell their crops because farmers can store their crops first at storage facilities and sell them when the market price starts to stabilize. SAGCOT (2024), examines the functionality of the Warehouse Receipt System (WRS), highlighting how the storage of agricultural commodities allows farmers to use their crops as collateral to secure access to financial services. In Tanzania, the systems were launched under Act no 10 of 2005 which is an act established for regulatory framework in order to provide licensing guidelines of warehouses by using warehouse receipts. In 2007, the warehouse receipt system was introduced in Tanzania (William & Kaserwa, 2015).

The main aim of establishing the Storage Systems was to promote the actions of the government to formalize the available marketing system, focusing to minimizing various challenges hindering effective production and marketing of the agricultural crops (SAGCOT, 2024). Finance play a role in the use of storage systems because enables the smallholder famers to maintain all costs associated with storage. Price increase after the storage period enables farmers to engage more on the storage, increase income and able to recover all costs incurred during storage. The government should provide continue to provide good environment for farmers by ensuring sustainable policies and programs which motivate them to use storage system.

1.2 Statement of the problem

Rice plays a role to improve the national economy and increase income among the people in the country, and rice produced by households is about 30% on average consumed (FAO, 2015). However, losses due to unfavourable weather conditions, moisture, rodents, birds, insects, and micro-organisms affect the rice enterprise. This could be reduced by the use of traditional polypropylene bag storage systems. The systems absorb surpluses to increase output and avoid post-harvest losses through access to storage facilities and credits, which allows producers to maximize their profits by providing them with the choice of when to sell and whom to sell. Different storage systems offer different benefits and opportunities to smallholder rice farmers. Due to the postharvest losses farmer can trade their crops immediately after harvest due to the lack of appropriate storage systems. Smallholder farmers face challenges of generating low income because of selling their produce at lower price at harvesting time compared to the higher price after storage. During the storage system the farmers starts to buy grains because of the food insecurity. Access to storage-efficient technology remains a challenge throughout the post-harvest chain, and there is important for storage because it is more valuable to sell milled rice compared to paddy. One way of addressing this problem is to focus on developing farmers' storage capacity. Therefore, smallholder farmers lose the income generated after the storage due to the higher price compared to price at the time of harvesting.

1.3 Research objectives

1.3.1 General objectives

The main objective of this study was to evaluate the use of storage systems among smallholder rice farmers in the Kyela District in Tanzania.

1.3.2 Specific objectives

i. To characterize smallholder rice farmers in Kyela district based on the storage systems they use.
ii. To determine the factors that influence the use and extent of use (stored quantity) of storage systems among the smallholder rice farmers in Kyela District.
iii. To determine the factors that influence the choice of type of storage system among the smallholder rice farmers in Kyela District.

1.4 Research questions

i. What is the nature and characteristics of smallholder rice farmers in Kyela district based on the storage systems they use?
ii. What are the factors that influence the use and extent of use of storage systems among the smallholder rice farmers in Kyela District?
iii. What are the factors that influence the choice of a type of storage system among the smallholder rice farmers in Kyela District?

1.5 Justification

The study at hand advances the global agenda by supporting the United Nations Sustainable Development Goals (SDGs), especially SDG 2 on Zero Hunger and SDG 12 on responsible consumption and production by 2030 (United Nations, 2015). Therefore, effective crop storage systems are important in reducing post-harvest losses, ensuring food security, and encouraging sustainable food utilization. In addition to addressing the storage issue, the study supports global efforts to strengthen resilient agricultural systems and contribute to global food sustainability.

Similarly, the government of Tanzania boosts rice production to enhance economic growth, national income, food security and improving the livelihood of households through

National Rice Development Strategy (NRDS). This can be attained through the use of modern storage systems and will help the producers to take the essential efforts against the undesirable effects of using local methods of storing gains and increasing profitability among users of the storage systems, and attracting non-users of the storage systems. The income effects of the storage systems will help producers and buyers to ensure market accessibility, access to credit, and appropriate storage facilities for their rice products, and ensure food security.

This research will provide policymakers in the government of Tanzania with new evidence about the determinants of the income effect of different storage systems. Furthermore, this study will help make investment decisions for the investors as it will shed light on the positive effects of investing in storage systems and attract farmers to farm higher yields, and make them investors to sell on the profitability of the intended firm. Lastly, this study is important for conducting other studies in the study area, academics in the agriculture field and researchers can develop various theories through this study.

1.6 Scope and limitations of the study

This study was carried out in three wards of Kyela District, which are Katumba Songwe, Makwale, and Mwaya. The language barrier was one of the challenges likely to be experienced in the field because most of the Nyakyusa in rural areas in the Kyela district are not fluent in Kiswahili. To solve this problem, a local translator was used to translate from the local language (Nyakyusa) to Kiswahili. Also, getting the current Storage systems on rice primary data for different seasons from the whole district was another challenge likely to be encountered; in that case, secondary data from the Tanzania Agricultural Research Institute (TARI) and the District Agricultural Department were used. This study was limited to smallholder rice farmers in Kyela district. The analysis was restricted to farm-level profitability as a proxy for improved incomes. Since most smallholder farmers do not keep records, the study was relying heavily on farmers' memory recall to collect the needed data, which may compromise the accuracy of the estimates."

1.7 Definition of terms

Extent – Refers to the amount of rice stored by the particular storage system.

Income – This is the amount of money received by the smallholder rice farmers after investing in producing and storing the rice.

Non-users of rice storage systems – Are smallholder rice farmers who do not use storage systems.

Post-harvest loss – refers to the quantitative and qualitative reduction in agricultural produce that occurs between the time of harvest and the point of final consumption.

Smallholder farmers – are small rice farms operating under a small-scale agriculture model, assumed to have a landholding of around 1 – 10 acres and often using very little to no expensive technologies.

Storage system – Refers to the process of keeping rice for future use as food or sale, and to maintain its original state.

Users of rice storage systems–Are smallholder rice farmers using storage systems.

CHAPTER TWO

LITERATURE REVIEW

2.1 Rice production in Tanzania

Rice (*Oryza sativa*) ranks as the second greatest significant food produce in Tanzania, following maize in terms of importance to national food security and livelihoods. Tanzania produces approximately 2.2 million metric tons of rice annually, positioning it as the leading rice producer by volume in the East African region (URT, 2019). During the 2022/2023 cropping season, Tanzania produced an estimated 2.4 million metric tons of rice, with the majority of this output contributed by smallholder agricultural households. The total cultivated area covered approximately 1.7 million hectares (Magubika et al., 2025). According to SAGCOT (2024), over 70% of Tanzania's rice production is concentrated in six regions, namely Shinyanga, Tabora, Mwanza, Mbeya, Rukwa, and Morogoro.

Rain-fed lowland, irrigation, and upland rice are the three main ecosystems in which rice is produced in Tanzania (Busungu, 2023). Each of these types has a very low but changing maximum output level that depends on different conditions of soil and climate (Rugumamu, 2014). In Tanzania rain-fed lowland ecosystem signify the most predominant rice cultivation system. It main relies on natural rainfall, with minimum or no additional irrigation. Production in this system is normally undertaken using basic farming tools, and input levels remain comparatively low. 1.4 and 2.1 tonnes per hectare is an average outputs range produced in rain-fed lowland (Busungu et al., 2023). Upland rice is usually cultivated in well-drained soils, commonly on sloping or elevated terrain. This production system is identified by low input use, restricted mechanization, and depend on traditional farming methods. As a consequence, productivity is inclined to be low, with produces commonly ranging from approximately 0.8 to 1.2 tonnes per hectare in most areas (Busungu et al., 2023). The irrigated rice ecosystem is defined by a consistent and managed water supply, promoted through developed irrigation infrastructure such as canals, pumps, or reservoirs. This system typically facilitates higher mechanization levels and the use of modern agricultural factors of production. Consequently, it attains significantly higher outputs contracted to other rice production systems, usually ranging from 3.2 to 4.5 tonnes per hectare (Busungu et al., 2023).

National rice production improved by the Government of Tanzania through National Rice Development Strategy (NRDS) with the aims to increase rice production, improve value chains, and attain food and economic growth. NRDS phase I strategy focused to increase level of production from approximately 0.9 million metric tons to 2.2 million metric tons (Ministry of Agriculture, 2019). NRDS Phase II, launched in 2019 for further progress with the aim to increase more production to approximately 4.4 million tons by 2030 (Ministry of Agriculture, 2019). Capacity building through and training, reinforcement of agricultural extension services, distribution of advanced rice varieties and escalation of irrigated paddy production are main interventions under NRDS II. Coordination of the Tanzania Agricultural Research Institute (TARI) and the International Rice Research Institute (IRRI) shows an effort in enhancing the rice seed system through projects focusing on access to high seeds value and advanced rice varieties (TARI, 2023). These initiatives focus on the distribution of newly released rice varieties appropriate for both rain-fed and irrigated lowland ecosystems, promoting the registration and launch process of improved varieties, and strengthening the collectively quality of seed available to farmers. Development stakeholders such as the Japan International Cooperation Agency (JICA) with the aid of the Tanrice projects, the Tanzania Agricultural Research Institute (TARI), and agency like the Kilimanjaro Agricultural Training Centre (KATC), executes training programmes targeted at strengthening agricultural capacity (JICA, 2022). These programs target extension officers, irrigation technicians, and farmers, focusing on the adoption of modern cultivation techniques, efficient irrigation management, gender-responsive approaches, and improved agronomic practices.

2.2 Storage systems of farmers in developing countries

Post-harvest grain losses involve all losses and reduction of grains produced starting from harvesting period upon the time needed for consumption or other purposes (Nath et al., 2024). The main causes of postharvest losses in Sub Saharan Africa like Tanzania are insects, rodents, termites, birds and high-water contents in the grains at the time of storage (Ngowi & Selejio 2019). Rice and maize farmers lose about 25% of their produces because of improper crop handling and lack of appropriate storage resources (Rutta, 2024). Postharvest loss constitutes a significant challenge for numerous agricultural producers in Tanzania, jeopardizing their means of living and access to adequate food, while resulting in an annual loss of approximately 30 to 40 percent of the country's harvested crops (Bisheko & Rejikumar, 2024). The storage systems used by smallholder farmers in developing countries includes traditional storage systems such as polypropylene bags, traditional granaries and jute sacks as well as improved storage systems such as metal silos and hermetic bags (Manandhar et al., 2018). Smallholder farmers faces challenges such as rodents' infestations and fungal contaminants to their grains after harvesting and thus results to postharvest losses at farm based and market stage of storage (Manandhar et al., 2018). Also, a study by Adikaram & Kulatunga (2018) shows that smallholder farmers frequently rely on storage facilities that are locally constructed using readily available natural materials. Common examples include granaries made from thatch, mud, wood, bamboo, straw, and cow dung. Although traditional gunny bags and woven or polypropylene bags are inexpensive, they are more prone to moisture fluctuation, insect infestation, and greater loss of seed or paddy quality compared to hermetic storage systems (Ngoma et al., 2023).

Rice smallholder farmers in Kenya predominantly rely on conventional storage methods such as polypropylene sacks and wooden bins; however, these systems are highly susceptible to pest infestation and moisture-related deterioration (Muriuki et al., 2017). A study conducted by Baributsa et al. (2017), show that increasing attention is being directed toward the adoption of improved storage systems, including hermetic storage solutions such as Purdue Improved Crop Storage (PICS) bags and metal silos, as effective measures to reduce postharvest losses and enhance crop value. Farmers use inappropriate postharvest facilities such as mud and wooden silos which increase high postharvest losses and cause them to sell their produces immediately after harvest to escape from rodents and insects' invasions (Gitau et al., 2024). A study carried out by Maina et al. (2016) examined that farmers use polypropylene bags and sisal bags for 83.3% and 16.7% respectively to reduce postharvest losses. polypropylene bags observed as most common methods used by smallholder farmers to reduce postharvest losses although PICs is appropriate and effective method to store maize (Arthur et al., 2022). Smallholder farmers they can adopt the storage systems, but they face challenges such as inadequate knowledge, insufficient capital and constrained to the access of such storage system (Bisheko & Rejikumar, 2023).

To support small-scale rice farmers in reducing post-harvest losses, Merekit in Eastern Uganda formed a group-based drying and storage center covering roughly 5, 600-meter square. The services provided by center comprising labor facilitation for drying and winnowing, drying, storage without charge, and water capacity inspection. Through these services, the community can adopt the storage technologies and strengthening facilities, as a result to the improvement of post-harvest management technology in the area (Katongole, 2019). While the most of small-scale farmers in Northern Uganda continue to rely on traditional storage methods, there is a noticeable increase in awareness of hermetic storage technologies (HSTs) for grain preservation. In a study involving 306 farmers, approximately 53.3% were familiar with HSTs; however, only 17.6% had adopted their use. 73% of smallholder farmers in Uganda use polypropylene storage method in storing their produce, although is not efficient for postharvest management (Okori et al., 2022).

Majority of smallholder farmers in Nigeria use traditional storage system such as jute sacks, granaries to store their grains at home (Adebayo, 2020). Smallholder farmers have a chance to access loans through collateral offered by the Warehouse Receipt System (WRS) due to the storage of their grains at the warehouses (Mapunda et al., 2018). A study comparing the storage of *Swarna* paddy in IRRI Super Bags and conventional gunny bags revealed that the hermetic Super Bags preserved seed viability more effectively, maintaining a germination rate of approximately 91.7%, while the germination rate in gunny bags declined to around 68.2% after six months (Sivashankari & Khandai, 2025).

According to Admire et al. (2014), Zimbabwe stores grain in polypropylene bags, jute bags, cotton wool packs, poles, dagga/mud granaries, and silos. Also, it is observed that farmers trade their grains immediately after harvest due to the shortage of appropriate storage methods and lack of postharvest management tools (Admire et al., 2014). In Egypt, grain is stored in jute or cloth bags in these shouna, and the quality of stored grain, particularly rice, is determined by factors such as the type of storage bag used, water content levels, temperature conditions, and the duration of the storage period (Saleh et al., 2020). 25% of the quantity of rice produce in Bangladesh is wasted along the value chain channels such as production, processing and storage (Hossain et al., 2021). A study by Gope et al. (2022) shows that hermetic cocoons with a storage capacity of 30 tons effectively preserved paddy seed without the need for repeated chemical treatments and maintained slightly higher germination rates compared to traditional gunny bags (approximately 92.94% versus 91.47%). It is about 85% of Purdue Improved Crop Storage and GrainPro bag being used as replacement and appropriate storage methods to store rice in Bangladesh (Hossain et al., 2021).

2.3 Storage methods for smallholder farmers in Tanzania

Traditional and modern storage techniques are both used to store crops in Tanzania (Kotu et al., 2019). As reported by Chidege et al. (2024), there are various traditional storage methods in Tanzania including woven polypropylene bags, traditional granaries, and other non-hermetic containers and appropriate storage methods like hermetic bags e.g., PICS, and metal silos. In Tanzania, smallholder farmers predominantly rely on traditional non-hermetic storage methods, including bamboo baskets, plastic or polypropylene sacks, and rudimentary wooden granaries. These storage systems offer limited protection against moisture, insect pests, and mold, often resulting in post-harvest grain losses estimated between 15% and 25% during storage (Muroyiwa et al., 2020; Rutta, 2024). According to Mwageni et al. (2022), majority of smallholder farmers in Tanzania use traditional storage methods like polypropylene bags and jute sacks to store their grains. Smallholder farmers use more traditional storage methods because of their affordability and availability in relation to modern storage (Swai et al., 2019). Smallholder farmers in Tanzania preferred to use Hermetic storage technologies from 2014 after promotion and assessed as good technologies for postharvest management (Zacharia et al., 2024). As smallholder farmers sell their grains later after storage they benefit from selling at higher price compared to the time of harvest (Mutungi et al., 2023).

2.4 Farmers' perceptions on the use of storage system

Awareness among the farmers plays a critical role in influencing them to make decision in the use of storage system. Social, economic and cultural factors can determine the perception of the farmers to use storage system. Farmers who access training and extension services which expand the knowledge on the storage systems and enable them to reduce postharvest loss, but other farmers fail to do so.

Traditional storage system such as jute sacks, granaries are main traditional storage systems used among the smallholder farmers due to the awareness, cost and accessibility (Kumar et al., 2019; Tesfaye et al., 2021). Although, these traditional storage systems are not effective in postharvest management because it allows the fungal contamination, pest infestation and moisture contents (Ojo et al., 2020).

Perceptions of using storage systems among the smallholder famers are important in adopting appropriate and improved storage systems. Factors such as education level, extension services and capital are most challenges facing smallholder farmers to be aware in using improved storage systems such as metal silos, hermetic bags and chemical treatments (Adeyemi & Ojo, 2018; Mwangi et al., 2022). For example, Mwangi et al. (2022) observed that smallholder farmers were able to use modern storage systems due to the training accessibility and awareness of improved storage systems. Most of smallholder farmers scared to use improved storage systems because of losses due to unawareness and high cost associated with such storage systems (Singh et al., 2017). Mgale & Yunxian (2021) assess the perceptions of price changes and their influences on the adoption of risk management initiatives such as the use of storage facilities.

The decision to use improved storage systems among the smallholder farmers is difficult due to the traditional and cultural practices (Chigoverah et al., 2020). Uncertainty avoidance, shortage of capital and different market challenges is crucial reasons for smallholder farmers to trade their grain without delay after collected from the farm. Farmers do not involve in the use of storage systems because they fear from risk and can't tolerate for a long time without selling their grains (Gilbert et al., 2020). For instance, Tibaingana et al. (2018) found that cost, accessibility and cultural factors contributed to the use of eight different storage systems among the smallholder maize farmers in eastern Uganda. Despite this diversity, many farmers opted to sell their produce soon after harvest to minimize potential losses associated with unreliable or unsafe storage conditions. Smallholder farmers have positive altitude that, the use of storage system increase income (Tibaingana et al., 2018). However, many expressed concerns about the safety and reliability of existing household storage systems, which they believed contributed to significant losses. As a result, some farmers opted to trade their produce instantly after harvest to avoid potential storage-related risks.

A study by Baributsa & Njoroge (2020) found that awareness is among the factor influencing to use improved storage system (hermetic storage) among the smallholder farmers in eastern Kenya. Also, modern storage system such as metal silos and hermetic technologies can be available in the area, while there no adoption due to the lacking of awareness and training among the smallholder farmers (Nakoma-Ngoma, 2025).

2.5 Factors determining the use of storage system

The use and effective use of storage systems by smallholder farmers are influenced by a complex interplay of socioeconomic, institutional, and cultural factors. Postharvest management, food security and income growth can be enhanced after understanding the various factors that determine the use of storage system at family level. Social and economic factors are main crucial for determining the use of storage systems among the smallholder farmer. Smallholder farmers who generate higher income are more significant to use appropriate storage methods, because they are capable to use their capital to invest in all costs concerning the use of such systems (Twilumba et al., 2020). Smallholder farmers sell their grains immediately after harvest or they use unimproved storage systems due to the shortage of capital, thus such systems cause postharvest losses and food insecurity.

Agricultural extension services are crucial factor that determine the smallholder farmers to make decision in the use of storage system. Such extension services enable to disseminate skills, knowledge and awareness that helps then to choose appropriate storage methods (Chirwa et al., 2019). Farmers who acquired extension services are more likely to use storage system because they are able to mitigate postharvest losses due to the awareness enhanced.

Also, the presence and affordability of the storage system in the region can be a factor that influence farmers to use or not use of such system. Sub Saharan Africa, usually in rural areas faces a challenge of poor infrastructure and limited access to markets for storage resources, thus they fail to use. Smallholder farmers can have willingness to use improved storage methods, but infrastructure challenge and the absence of storage resources limit them to adopt (Adetunji et al., 2020).

Additionally, Non-Government Organizations, government programmes and farmers organizations are key factor determining the use of storage system. These organizations enable the use of appropriate and modern storage system among the smallholder farmers due to the supporting of subsidies like storage facilities and provision of training on the reduction of postharvest losses. Most of smallholder farmers use the local storage systems like granaries because of their traditional and native's knowledge disseminated in the area. Also, these traditional cultures enable to determine the awareness for farmers to use new storage systems and those used frequently. Smallholder farmers continue to use local storage methods like granaries and underground pits because of the perceptions, traditional factors and their understanding although appropriate and improved methods are accessible (Obeng et al., 2021).

Moreover, smallholder farmers decide to use the storage systems by considering several factors such as infrastructures, financial level, information availability, traditional practices and institutional assistance. To ensure these works, there is important for policymakers and development stakeholders to support the use of improved storage systems that enhance postharvest management.

2.6 Factors determining the extent of use of storage system

The factors determining the intensity level to use storage among the smallholder farmers are discussed by different literature. Farm size, credit accessibility, access to market, reliability of storage infrastructure, awareness and knowledge of reducing postharvest loss can determine the amount of grains to be stored.

Quantity of agricultural grains stored by the smallholder farmers can be determined by the size of land farm. Large farm size usually produces higher level of grains which can accommodate the consumption needs of the households and surplus. Farmers can be able to store the greater quantity of their harvest grains due to the surplus. Smallholder farmers with higher farm size in Western Kenya have higher possibility to store larger quantities of maize compared to those farmers with smaller farm size (Munyua et al., 2017). The risk of food insecurity and strategic market engagement due to favorable price after storage can be enhanced through the ability of the smallholder farmers to store their grain surplus.

Smallholder farmers are capable to use appropriate and improved storage systems due to the access of credit and capital resources which can enhance the larger quantity of agricultural grains to be stored. Mungai & Masese (2019) ague that Smallholder farmers were capable use improved storage systems such as metal silos and hermetic bags due to the accessibility of credit at lower cost. Modern storage systems it is more important because have ability to preserve the higher amount of grains for a long period of time. In contrast, Smallholder farmers with inadequate financial resources are usually use local storage systems which are not capable to store the large quantity of grains and fail to improve postharvest management due to fungal and pests, hence food insecurity and low income.

Also, the decision to use storage system can be influenced by market factors such as price variation, access to reliable market which can determine the intensity level of storage. Most of the smallholder farmer decide to use storage system in order to increase income, especially when higher prices are expected in the future market period. Ndiritu et al. (2018) found that Smallholder farmers in Central Kenya increases the amount of grains to be stored due to the seasonal price fluctuations, hence enable them to sell their produce at higher price. Additionally, limited access to market information and poor infrastructure usually limit smallholder farmers to use storage system. As result, majority of smallholder farmers decide to store the small quantities of grains for household consumption rather than for trade purposes.

Notably, the intensity level of storage among the smallholder farmers is greatly determined by their consciousness, knowledge and their capability to reduce postharvest losses. As examined by Minde et al. (2020), Farmers who access skills and knowledge on the use of improved storage systems have more possibility of reducing postharvest losses and being able to store lager amount of grains. This shows the importance of agricultural extension services and training programmes in ensuring such knowledge are distributed among the farmers. By improving farmers' technical ability, these programmes helps directly to enhance the positive outcome of using storage systems such as food security and postharvest management in agricultural systems.

Significantly, availability of infrastructure such as warehouses, storage centers, and silos are important factor in influencing smallholder farmers to store their produce at large quantity. As noted by Mwangi & Kariuki (2021), Smallholder farmers in rural area of Kenya limited to store the large quantity of their produces because of lacking and accessibility of reliable storage facilities. Conversely, when such infrastructure is present and located nearby, it reduces logistical challenges such as transportation costs and post-harvest losses thereby encouraging farmers to increase the quantity of grains stored for future use or commercial purposes.

Furthermore, government initiatives, financial subsidies, and programs are institutional factors which considered as important in determining the intensity level for smallholder farmers to involve in using storage system. These initiatives frequently offer critical resources, including support for the construction of storage infrastructure, subsidies for the skills and knowledge of storage systems. Collectively, such actions serve to motivate increased storage quantity among farmers (FAO, 2017). Also, policies that promote market integration through mechanisms such as warehouse receipt systems and value chain linkages further enhance farmers' ability to store grains properly and access markets more efficiently.

2.7 Challenges facing grain storage practices

A study by Maina et al. (2016) found that limited access to storage bags, insects, mold and rodents are major constraints facing smallholder farmers in Kenya. Dzahan (2025) found that postharvest losses and food losses are main caused by improper storage facilities, limited access to knowledge and information. In many developing countries, the absence of advanced storage infrastructure, including silos and climate-controlled warehouses, remains a critical challenge.

Consequently, farmers predominantly depend on conventional storage techniques, such as mud granaries and jute sacks, which are highly susceptible to pest infestations, moisture accumulation, and subsequent deterioration. These vulnerabilities contribute substantially to post-harvest losses, thereby diminishing both the availability of food and the economic returns for farmers (Kumar & Kalita, 2017). Smallholder farmers face a challenge of limited drying methods and high moisture contents in the storage of their grains, this result to the development of mold and fungi contamination, hence postharvest loss (FAO, 2019). Postharvest loss and food insecurity become a problem among the farmers because of the limitation of improved storage systems which can store properly and manage the amount of moisture in their produce.

In developing countries, most of smallholder farmers fail to use appropriate and improved storage systems because of the limited access to capital which can help them to afford the all costs associated with such system. Most of the smallholder farmers in rural area constrained with low income level and limited access to credit, due to this, improved storage systems like hermetic storage systems, metal silos and climate managed warehouses are not adopted (Kumar & Kalita, 2017). Poor financial supports and lack of collateral observed as a challenge among smallholder farmers in the use of improved storage systems, because it results to the limited access to credit which enhance farmers fails to reduce postharvest losses. (Affognon et al., 2015). Farmers usually continue to depend more on local and unimproved storage systems due to the limited financial support, for that reason postharvest losses increase (World Bank, 2023).

Inadequate knowledge and training are challenges hinder smallholder farmers in developing countries to use improved storage systems. A finding by Ngoma et al. (2025) show that, limited awareness and training identified as key non-technical barriers to the use of improved postharvest storage methods. In addition, Ariong et al. (2023) traditional storage practices frequently do not maintain appropriate moisture content, and emphasizes poor handling and lack of training as significant factors leading to losses. Kansiime et al. (2022) and Wekesa et al. (2025) studies found that extension service significantly limits the adoption of improved grain storage systems.

In accordance with a study by Shabani et al. (2015), about 50% and 40% of rodents and insects respectively observed as a major challenge among the smallholder farmers in storage periods. Poor storage practices among the smallholder farmers in Ethiopia increase postharvest losses from 11% up to 19% (Mezgebe et al., 2016).

2.8 Theoretical framework

Theoretical framework for this literature is choice supportive bias theory, the theory of planned behaviour of Storage Systems and Diffusion of Innovation Theory. The theoretical bases are explained in the following sub-theories.

Choice Supportive Bias Theory: This theory is a cognitive bias where individuals tend to attribute more positive features to choices they have made in the past, while downplaying or ignoring the negative aspects (Mather et al., 2000). This psychological phenomenon plays a significant role in decision-making processes, including agricultural technology adoption. Among smallholder farmers, CSB can influence how they evaluate, justify, and remain committed to the use of a particular storage system**,** regardless of its actual performance. Mather et al. (2000) show that, memory is involved in this bias, as memory of the various options is changed, which results in remembering the positive aspects of choosing to use a particular storage system, and likewise also tends to forget its negative aspects. The memory of refusing to use a particular storage system is also modified, as the smallholder farmer remembers the negative aspects rather than their positive ones. This gives the smallholder rice farmers the illusion of a greater gap between their choices and their other alternative storage systems that are available to them.

After selecting a storage method such as hermetic bags, metal silos, or traditional granaries farmers could exhibit a tendency to emphasize the benefits of the system they chose, minimize shortcomings, even if the technology has not performed optimally, rationalize their decision to avoid cognitive dissonance or regret. This can lead to continued use of suboptimal storage systems or reluctance to switch to potentially better alternatives, especially when they have already invested time, money, or effort into the current method.

The choice of storage system has many potential effectiveness side effects. The smallholder farmers will focus on the effectiveness of storage systems, such as the reduction of household pest infestation, maintaining good quality of grain, preventing grain exposure to physical damage, and reducing incidents of grain theft. By understanding this bias, stakeholders in agricultural development can better design communication and support strategies that address not only informational gaps but also the emotional and cognitive factors that shape technology adoption.

Diffusion of Innovations Theory: This theory gives an outline on how new systems or technologies are distributed and adopted within a community through social systems Rogers et al. (2008). In order for the farmers to use new storage systems must passes through the different stages of adoptions such as awareness, persuasion, decision, implementation and continuation. This theory helps smallholder farmers to make decision on the use of modern storage systems such as metal silos, hermetic bags and cold storage methods. Food security, market access and sustainability of agricultural being enhanced due to the use of modern storage systems for the postharvest management. Also, through this theory, smallholder farmers can be aware, and understandable on the use of appropriate storage systems due to the various modes of communication such as farmer organizations, Social media, NGOs and extension services. As well, time has been identified by this theory as essential in the dissemination process, and finding the way how storage systems are used within a given community. Through time, smallholder farmers use new storage systems and other factors that determine the period and the development of the use such as institutional factors, education, income and farmers cooperatives. Also, smallholder farmers can accept and widely use an improved storage system through the application of this theory by policymakers, development agencies and extension services.

The Theory of Planned Behaviour (TPB): This theory developed by Ajzen (1991), as psychological model that explains human’s intention to involve in a certain behaviour. The theory outlines three factors that determine the intention to engage in that behaviour such as attitude toward the behaviour**,** peer pressure to implement or not implement the behaviour, and ability to implement the behaviour**.** The factors that determine smallholder farmers on the intensions and decision to make use of improved storage systems can be assessed through TPB. Most of the smallholder farmers can have their personal details on the storage systems, through this enhance them to avoid in using a certain storage system (George, 2004). Through the Theory of Planned Behaviour (TPB), a study examines factors that determine farmers ‘intentions to use storage systems. This theory suggests that attitude towards the storage system, peer pressure to implement or not implement the use of storage system, ability to implement the use of storage system, and their decomposed belief structure can assist in predicting and explaining smallholders' storage system intention.

Attitude toward the behaviour refers to the farmer's overall evaluation either positive or negative of employing improved storage systems, such as hermetic bags or metal silos. When farmers perceive these innovations as beneficial particularly in terms of reducing post-harvest losses, enhancing income, or contributing to household food security they are more likely to develop a favorable ambition to use and apply them in their farming practices. Subjective norms pertain to the perceived social pressures or influences exerted by significant others, such as peers, family members, community leaders, or agricultural extension agents**.** When key figures within a farmer's social network endorse and actively promote the use of improved storage technologies, individuals may feel compelled to conform to these expectations, thereby increasing their likelihood of adopting such innovations in response to prevailing social norms. Perceived Behavioural Control (PBC) refers to an individual's assessment of the ease or difficulty involved in performing a particular behaviour, which is influenced by factors such as prior experience**,** availability of resources, and external constraints**.** In the context of smallholder farming, if individuals perceive limitations such as insufficient capital, inadequate technical knowledge, or lack of institutional support their perceived control over adopting improved storage technologies may be diminished. This reduced perception of control can hinder adoption, even when attitudes are positive and social influences are supportive.

Figure 2.1 shows the smallholder rice farmers' intention to engage in using a particular storage system. For TPB, attitude on the storage system and subjective norms about involving in using the storage system are insight to determine intention, and TPB intails perceived behavioral control over engaging in using the storage system as a factor determining intention. Based on TPB, the smallholder farmer's efficiency in using a particular storage system is determined by his or her intent to use that storage system. Intent is independently informed by attitudes toward the use of the storage system, subjective norms on engaging in using the storage system, and perceptions about whether the smallholder farmer will be able to engage successfully in using the storage system.

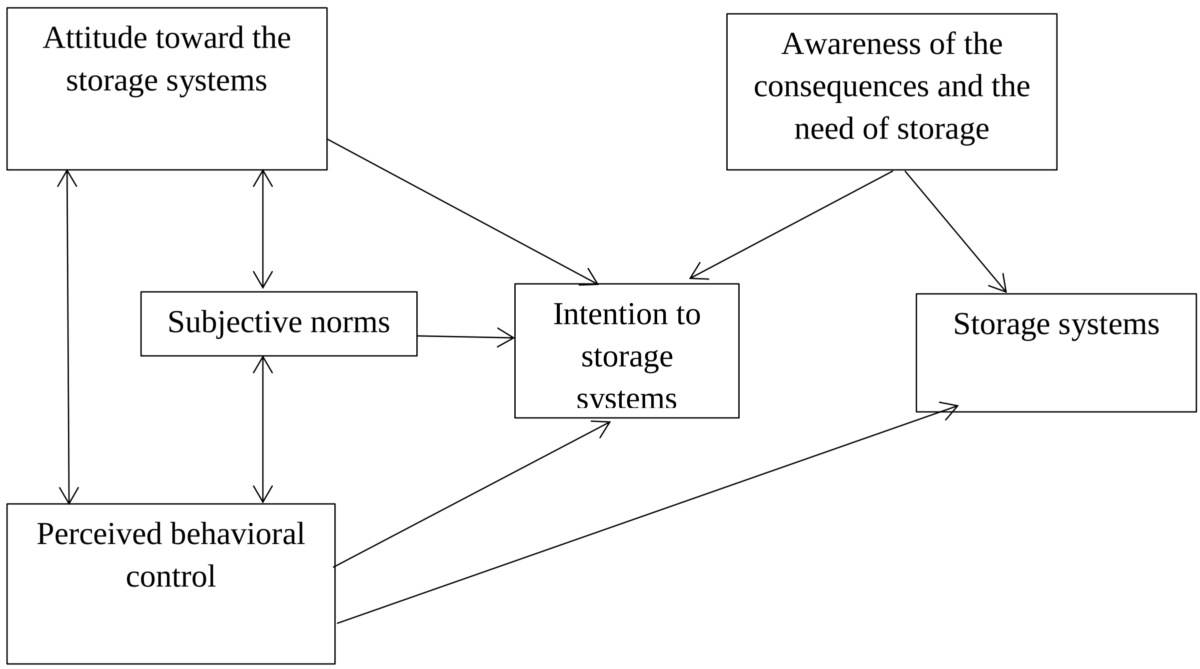

Figure 2.1: Theory of Planned Behaviour

2.9 Conceptual framework

The conceptual framework focused on the use and extent of use of rice storage systems among smallholder rice farmers. The study examined the relationship between the use of rice storage systems and factors that influence. Figure 2.2 represents the relationship between factors determining smallholder rice farmers' use of storage systems. The variables of interest assumed to influence the use of rice storage system include the socio-economic factors and institutional factors. These variables are assumed to determine smallholder rice farmers to use storage systems. Therefore, socio-economic factors and institutional factors such as access to market, access to credit, access to training, farmers' engagement in group activities, and access to information are crucial factors to strengthen farmers' use of the storage system. The expected outcome of the use of the rice storage systems is increased quantity of rice stored by smallholder farmers which could results in household food security, farmers' well-being, sales of production, and post-harvest management.

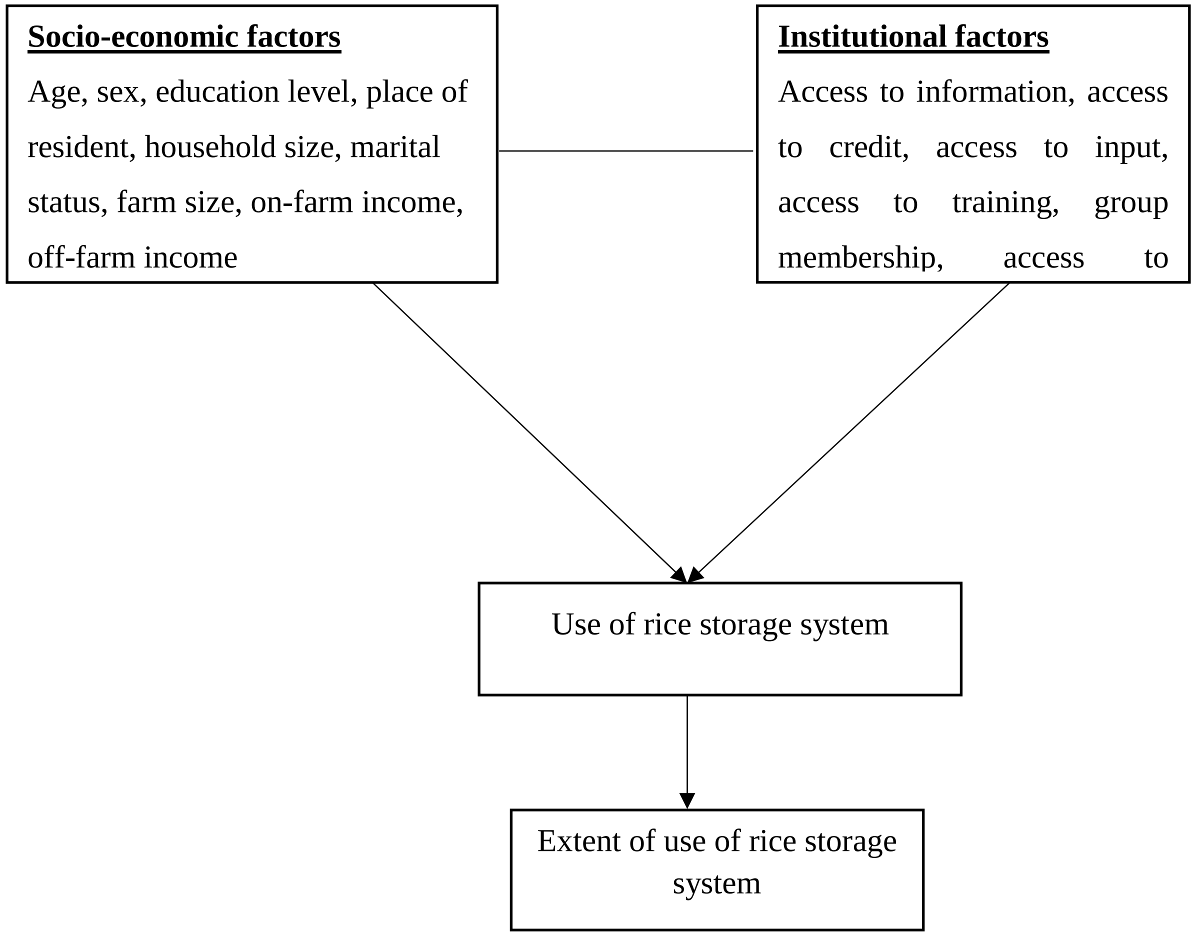

Figure 2.2: Conceptual framework

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

This study was carried out in the three wards of the Kyela district, which are Makwale, Mwaya, and Katumba Songwe, located in the Mbeya region. Kyela is among of the six districts others are Chunya district, Mbarali district, Mbeya district, Mbeya city, and Rungwe district. Kyela district is selected based on the fact that it is the most important for rice production in the Southern Highlands of Tanzania (Ngailo et al., 2016). Kyela district lies between Latitude 9º 25' and 9º 40' South and Longitude 33º 40' and 30º 00' East (Bushesha, 2014). It is bordered to the northeast by Rungwe district, to the east by Iringa region, to the west by Ileje District and to the south and south west by Malawi (Bushesha, 2014). According to the 2012 Tanzania National Census, the population of the Kyela District was 71,968 NBS (2022). The main rainy season in Kyela District is between November and June, with a mean annual rainfall of 2658.8mm (Bushesha, 2014). Majority of households depend more on agriculture activities, and the most produced crops are paddy, groundnuts, maize, and sweet potatoes.

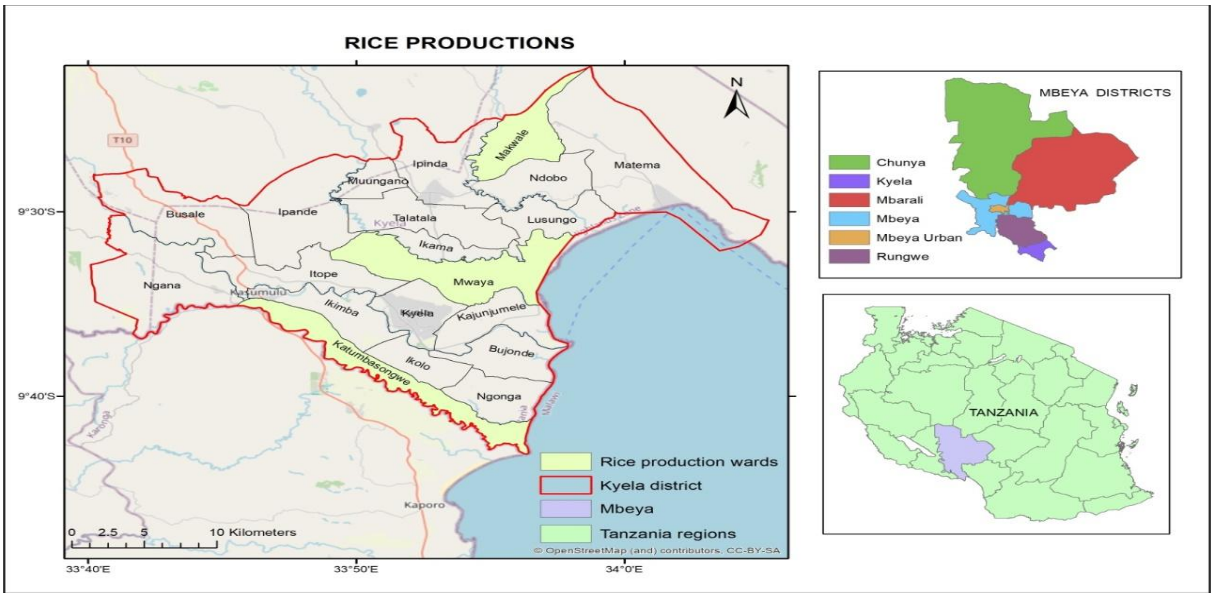

Figure 3.1: Map of Kyela District, Tanzania

3.2 Sample size and sampling technique

3.2.1 Sample size

The Yamane (1977) formula, also referred to as Slovin's formula, which is frequently used in social science research for finite populations, was used to calculate the sample size (see equation 1). The calculation produced a desired sample size of roughly 392 respondents out of a total population of 19,110 at a 95% confidence level and a 5% precision (shown below). We employed a stratified random sample by ward, allocating Katumba Songwe (n=137), Makwale (125), and Mwaya (115) proportionately, to ensure representativeness. However, the actual sample size was 267 (≈68% of the planned sample) with representative respondents from Katumba Songwe (97), Makwale (88), and Mwaya (82) (Table 3.1). The shortfall resulted from a combination of logistical constraints (limited field days and transport) and restricted access to some enumeration areas during data collection. To preserve data quality, we prioritized completing fully valid interviews rather than extending fieldwork with rushed or incomplete questionnaires.

The Yamane/Slovin's formula is as shown in equation 1.

$$n = \frac{N}{1 + NE^2} \quad (1)$$

Where n = desired sample size; N = population size; and E = margin of error (0.05 for 95% confidence).

$$n = \frac{19{,}110}{1 + 19{,}110(0.05)^2} \approx 393 \text{ respondents}$$

3.2.2 Sampling technique

Respondents was selected by using a multistage sampling procedure. The first stage applied a purposive selection of the Kyela district because it was considered to have the best quality of rice (FAO, 2015). In the second stage, the three wards, Katumba Songwe, Makwale, and Mwaya, were purposely selected because they have a large number of farmers. Then, a random sample technique was used to determine respondents from each of the three wards who were farmers. All farmers had equal chances of being included in this study. In Table 3.1, the distribution of the desired sample size by wards is presented and 267 respondents were surveyed.

Table 3.1: Sample size distribution

Ward	Target population	Proportion	Estimated sample size	Actual sample size
Katumba songwe	6948	0.36	142	97

Makwale	6327	0.33	129	88
Mwaya	5835	0.31	122	82
Total	19110	1	393	267

3.3 Data collection methods

In this study primary data from the smallholder farmers was used to understand the usage of storage systems in Kyela district. The primary data was collected through a structured survey questionnaire, and quantitative data on different socioeconomic and economic characteristics such as age, education, farm size, storage system type, etc, were collected.

3.4 Analytical framework

3.4.1 To determine the nature and characteristics of smallholder rice farmers in Kyela district based on the storage systems they use

To characterise smallholder rice farmers by conducting descriptive statistics using STATA software (StataCorp, 2023). Descriptive statistics such as mean, frequencies, percentages, and standard deviation were used to analyse quantitative variables that are important in explaining farmers' use and extent of use of storage systems.

3.4.2 To determine factors that influence the use of storage systems and their extent among the smallholder rice farmers in Kyela district

This objective used double hurdle model to determine factors that influence the smallholder rice farmer’s use of storage systems and the extent of use. The Tobit model could also be used, but is limited because it restricts that both decisions are simultaneously influenced by the same independent variables, and also only explores the factors influencing decisions to use storage systems, but does not explore the impacts of such factors on profitability (Wooldridge, 2012). The Heckman model could also be used, where it is suitable for non-random samples, but in this study, we assume that the samples are randomly selected. So, the double hurdle is a less restrictive variant of the Heckman and is best suitable for samples drawn through random probabilistic sampling procedures (Dlamini & Huang, 2019).

The double hurdle model introduced by Cragg (1971) was used to analyse farmers’ decisions on the extent of using storage systems as a result of two processes: the first stage is to determine the decision of the farmer to use the storage system (first hurdle), and the second stage is to determine the level of intensity on the use of storage system (second hurdle). Kamau et al., 2024; Nkuya et al., 2019 and Okoffo et al., 2016 are examples of studies used double hurdle model in their studies. The probit model was used in the first hurdle to determine the probability that a farmer's decision to use the storage systems, and the Tobit model was used in the second hurdle to determine the intensity to use the storage system. Engel & Moffatt (2014) Specify the model as;

$d_i^* = z_i'\alpha + \varepsilon_{1i}$ use (2)

$y_i^* = x_i'\beta + \varepsilon_{2i}$ Extent to use (3)

Where d_i^* and y_i^* are latent variables describing the farmer's decision to use (dummy variable, 1=yes, and 0=no) and the extent to use, z_i' and x_i' are vectors of observed covariates explaining farmers' decisions, and the extent to use, $\alpha\ and\ \beta$ are vectors of unobserved parameters to be estimated, and $\varepsilon_{1i}\ and\ \varepsilon_{2i}$ are the respective error terms capturing all other factors affecting d and y apart from z_i' and x_i'. The error terms are assumed to be independent and normally distributed asε_{1i}; N ~ (0, 1), and ε_{2i} ; N ~ (0,δ^2).

The following estimation models is due to the integration of the two decisions;

$$\begin{cases} d_i = z_i'\Upsilon + \varepsilon_{1i}\ if\ d_i^* > 0, and = 0\ if\ otherwise \\ y_i = x_i^*\beta + \varepsilon_{2i} if\ y_i^* > 0, and = 0\ if\ otherwise \end{cases} \quad (4)$$

Aristei & Pieroni (2008) specified the maximum likelihood to allow the heteroscedasticity and non-normal error term as follows;

$$L(\Upsilon, \beta, \delta^2 = \prod\nolimits_0 \left[1 - \varphi(z_i'\Upsilon)\varphi\left(\frac{x_i'\beta}{\sigma}\right)\right] \times \prod\nolimits_1 \left[\varphi(z_i'\Upsilon)\sigma^{-1}\emptyset\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right]$$
(5)

To determine the effects of regressors on the extent of use, the marginal effects will be evaluated. According to Yen and Jones (1997), the marginal effect is specified as;

$$E(y_i \mid y_i > 0) = \emptyset\left(\frac{x_i''\beta}{\sigma_i}\right)^{-1} \int_0^\infty \left[\frac{y_i}{\sigma_i\sqrt{1+\theta^2 y_i^2}} \emptyset \frac{T(\emptyset y_i - x_i'\beta)}{\sigma_i}\right] dy_i$$
(6)

The empirical model for farmers' decision to use the storage system was estimated by the probit model as follows;

$$Use\ (yes/no) = \Upsilon_0 + \Upsilon_1 age + \Upsilon_2 sex + \Upsilon_3 edu + \Upsilon_4 hhsiz + \Upsilon_5 marst + \Upsilon_6 farmsiz + \Upsilon_7 atraining + \Upsilon_8 acredit + \Upsilon_9 aextension + \Upsilon_{10} grpmemb + \Upsilon_{11} on\_farm + \Upsilon_{12} off\_farm + \varepsilon_{1i} \quad (7)$$

The second equation for the extent to use was estimated by the Tobit model; the dependent variable was the quantity of rice stored in particular storage systems, which are traditional granaries and polypropylene bags.

$$astored = \Upsilon_0 + \Upsilon_1 age + \Upsilon_2 sex + \Upsilon_3 edu + \Upsilon_4 hhsiz + \Upsilon_5 marst + \Upsilon_6 farmsiz + \Upsilon_7 atraining + \Upsilon_8 acredit + \Upsilon_9 aextension + \Upsilon_{10} grpmemb + \Upsilon_{11} on\_farminc + \Upsilon_{12} off\_farminc + \varepsilon_{2i} \quad (8)$$

Table 3.2: Variables used in the Double Hurdle Model

Variables	Description and Measurements	Expected Sign
Dependent variables		
use	Decision to use the storage system Dummy (1=Yes, 0=No)	
Astored	Amount of rice stored Continuous (Continuous (Kg of rice stored)	
Independent variables		
age	Household age (Continuous, Years)	+/-
sex	Household gender, Dummy (1=Male, 0=Female)	+/-
edu	Level of education, Dummy (0= No formal education, 1=Primary, 2=Secondary, 3=College/ University degree	+
hhsiz	Size of the household, Continuous (Number of individuals in the household)	+
marst	Marital status Dummy (0=Single, 1=Married, 2=Divorced, 3=Widowed)	+
farmsiz	The size of the land practices farming (Continuous, land size in acres)	+
atraining	Training access, Dummy (1=Yes, 0=No)	+
acredit	Credit access, Dummy (1=Yes, 0=No)	+
aextension	Extension services access, Dummy (1=Yes, 0=No)	+

grpmemb	Group membership, Dummy (1=Yes, 0=No)	+
on_farminc	On-farming income (Continuous, amount in TZS)	+
off_farminc	Non-farming income (Continuous, amount in TZS)	+

3.4.3 Factors that influence the choice of storage system among the smallholder rice farmers

Multivariate logistic regression model evaluates the association between more than one explanatory variables and a categorical dependent variable (Park, 2013). The binary logistic regression model was used since the dependent variable is dichotomous and the explanatory variables are either continuous or categorical (Orme & Combs-Orme, 2009). Also, the multivariate logistic regression model gives each predictor a coefficient that measures its independent contribution to variation in the dependent variable (Park, 2013) . The dependent variable gives the value 1 if the smallholder farmers used the polypropylene bags as a storage system, and takes the value 0 if the smallholder farmers used traditional granaries as a storage system. Thus, the model results were easily interpreted based on statistical significance. Also, the use of the storage system was a binomial distribution because the dependent variable was coded as use and not use. The statistical model that was used can be presented mathematically as follows;

The algebraic expression of the multivariate logistic regression model was specified as follows: the model form for predicted probabilities is expressed as a natural logarithm (ln) of the odds ratio:

$$Logit(P_i) = \left(\frac{P_i}{1-P_i}\right) = \Upsilon_1 + \Upsilon_2 age + \Upsilon_3 sex + \Upsilon_4 edu + \Upsilon_5 hhsiz + \Upsilon_6 effstorage + \Upsilon_7 farmsiz + \Upsilon_8 rqharvested + \Upsilon_9 totalstorage + \Upsilon_{10} atraining + \Upsilon_{11} aextension + \Upsilon_{12} grpmemb + \varepsilon_i \quad (9)$$

Where by P_i = probability of using polypropylene bags as a storage system and $1 - P_i$ = Probability of using traditional granaries as a storage system.

Table 3.3: Variables of the logistic regression model

Variables	Description and measurements	Expected sign
Dependent variable		
storagetype	Type of storage system (Dummy, 1= Polypropylene bags, 0=traditional)	
Independent variables		
age	Household age (Continuous (Years)	+/-
sex	Household gender (Dummy, 1=Male, 0=Female)	+
edu	Level of education (Dummy, 0=No formal education, 1=Primary, 2=Secondary,3=College/University degree)	+
hhsiz	Household size (Continuous, number of individuals in hh)	+
atraining	Training access (Dummy, 1=Yes, 0=No)	+
aextension	Extension services access (Dummy, 1=Yes, 0=No)	+
grpmemb	Group membership (Dummy, 1=Yes, 0=No)	+
effstorage	Effectiveness of the storage system (Dummy, 1=Polypropylene bags, 2= Jutes sacks 3= Traditional granaries 4= PICs)	+
farmsiz	The size of the land practices farming (Continuous, land size in acres)	+
totalstorage	Total storage cost (Continuous, TZS)	+
qrharvested	Quantity of rice harvested (Continuous, rice quantity in kg)	+

CHAPTER FOUR
RESULTS AND DISCUSSIONS

The study at hand focused on evaluating the use of storage systems among smallholder rice farmers in the Kyela District in Tanzania. Particularly, the study intended at characterising smallholder farmers, estimating both the factors that influence the use and extent of use of storage systems, and estimating the determinants of the choice of a particular type of storage system. In the next section, the characteristics of smallholder rice farmers are presented, followed by factors that influence the use of storage systems and their extent among smallholder farmers are presented. Finally, a section on factors influencing the choice of type of storage systems is presented.

4.1 Nature and smallholder rice farmers' characteristics

4.1.1 Socio-economic characteristics

Table 4.1 presents the results as follows. Concerning age, the average number of years for users of the storage system was found to be about 46 years, and the average for those who were not willing to use the storage system was 44 years old. The smallest user was found to be 20 years old, and the most aged was 79 years old, but those who were not willing to use were 22 years old for the smallest farmer and 91 years old for the most aged. generally, the average age was almost 46 years, the youngest farmer was 20 years old, and the most aged was 91 years old. The average age of the interviewee gives the notion that most of the smallholder farmers were in the productive age group; this can have an influence on the uptake of storage systems. This study is aligned with a study by Oparinde et al. (2016), which stated that the average age of the rice farmers was 46 years.

4.27 of the household size members were not willing to use storage system and 4.77 household size members were willing to use storage system. In general, the average of household size members was 4.63 members, which is above Tanzania's national average of 4.3 household size (NBS, 2022). The minimum household size had 1 member, and the maximum had 13 members. More, the results show that those who were willing to use had a larger household size relative to non-users. Deressa et al. (2009) argue that large family sizes are typically linked to larger labour endowments, allowing a household to carry out a variety of agricultural duties. A past study by Manandhar et al. (2018) revealed that, farmers being able to use appropriate storage methods due to the large number of household and higher consumption level of grains. Mmasa & Msuya (2023) found that, holding another factors constant, household income increases by approximately 8.5% with each additional household member. This indicates that larger households particularly those with a higher proportion of working age individuals relative to dependents possess greater labour capacity, enabling them to participate more actively in productive activities and, consequently, generate higher income levels.

According to Table 4.1, the average size of a farm was 3.09 acres, with the smallest farmer owning just 1 acre and the largest owning 9 acres. In comparison, potential non-users had a mean of 2.46 acres, and potential users had substantially larger parcels of land, as shown by an average of 3.36 acres. This result supports a study by Manandhar et al. (2018), smallholder farmers with a greater land holding were better able to use modern storage technology than those with smaller farms. Benimana et al. (2023) shows that smallholder farmers in Gatsibo District with larger land holdings (as indicated by more plots cultivated) are significantly more likely to adopt modern hermetic storage technologies such as silos and hermetic bags than farmers with less land.

The potential users were found to have an average of about 2979 kg of rice quantities harvested, with a minimum of 200 kg of rice quantities harvested and a maximum of 9000 kg of rice quantities harvested, as indicated in Table 4.1 The potential non-users had an average of 2035 kg of rice quantity harvested, with a minimum of 400 kg of rice quantity harvested and a maximum of 5400 kg of rice quantity harvested. Overall, the average was about 2710 kg with a minimum of 200 kg of rice quantities harvested and a maximum of 9000 kg of rice quantities harvested.

Table 4.1: Socio-economic characteristics for continuous variables

		Variables	N	Mean	Std dev	Min	Max
Willingness to use	No-users	age	78	43.88	13.24	22	91
		hhsiz	78	4.27	1.59	1	9
		farmsiz	78	2.46	1.19	1	6
		rqharvested	78	2035	1187.49	400	5400
	Users	age	189	45.99	11.48	20	79
		hhsiz	189	4.77	1.552	2	13
		farmsiz	189	3.36	1.62	1	9
		rqharvested	189	2978.6	1626.82	200	9000
	Overall	age	267	44.45	12.23	20	91
		hhsiz	267	4.63	1.578	1	9

	farmsiz	267	3.1	1.565	1	9
	rqharvested	267	2709.9	1569.55	200	9000

Table 4.2 shows the results of the household heads in education level in the Kyela district. Only 13 of the participants did not attend to school, means that 254 of the participants accessed formal education. Even so, most of participants accessed primary and secondary education, while few participants accessed college or university-level education. Among the users, those who accessed no formal education (no general education), primary, and secondary were 5, 90, and 72, respectively, while those who accessed college or university education were 22. On the contrary, 5 of the potential non-users attained no formal education, 36 had primary education, 32 had secondary education, and 2 had college or university education. The small number of farmers had a college or university education, and this can be due to the fact that those smallholders accessed higher level of education tend to be involved in using storage systems as their level of education increases. A study by Fadeyi (2022) reported that since education makes it easier for farmers to adopt new technology, smallholder farmers without education may find it difficult to use better storage methods. Also, Mbesa et al. (2024) found that smallholder farmers with higher education level is more significant in choosing modern hermetic storage (PICS bags, etc.) over other storage methods.

Table 4.2: Education level of the household head

			No Formal Education	Primary	Secondary	College/University	Total
Willingness to use	Non-users	Frequency	8	36	32	2	78
		Percent	10	46	41	3	100
	Users	Frequency	5	90	72	22	189
		Percent	3	47	38	12	100
Total		Frequency	13	125	104	24	267
		Percent	5	47	39	9	100

Regarding gender, results show that 64.4% were males and 35.6 were females. For the use of storage systems, male users were 70% while female users were 30%. This implies that males use more storage systems than females. This finding is consistent with Oparinde et al. (2016), about 68% and 32% of smallholder farmers were male and female respectively. Also, a study by Tufa et al. (2022) indicating a consistent pattern in which male farmers exhibit higher and more rapid adoption rates of various agricultural technologies compared to their female counterparts. This indicates that men are predominantly involved in rice farming in the study area, perhaps as a result of the intense nature of farming activities.

Concerning marital status, results indicate that 82% of the potential users were married, 7% were single, 6% were widowed, and 5% were divorced, as shown in Table 4.3. A large proportion of potential users was married in relation to the potential non-users. Zvinavashe et al. (2015) suggest that married household heads are more likely to use certain storage technologies, possibly due to greater household responsibilities, increased decision-making stability, or access to more labor and pooled resources, which collectively facilitate the use of appropriate post-harvest practices. Majority of smallholder farmers marry at an early age and bring up children who later provide needed farm labour as potential in farming activities (Conteh et al., 2015).

Table 4.3: Gender and marital status

Variable	Description	Users (N=70.8%)	Non-users (N=29.2%)	$\chi2$	p value
Gender	Male	70	51	8.3	0.004**
	Female	30	49		
Marital status	Married	82	55	22.45	0.000**
	Not married	18	45		

Note: *, **, and ***significant at 1%, 5% and 10% respectively

Makwale ward had more users of the storage system (64%) than Katumba Songwe and Mwaya. A plausible explanation for this is that, in Makwale, there is availability of infrastructure support such as large godowns and irrigation schemes, which influence them to store more of their grains. Figure 4.1 indicates that 70%, 64% and 55% of Makwale, Katumba Songwe, and Mwaya, respectively, are potential users of the storage systems, while their counterparts are 18%, 33%, and 27% of Makwale, Katumba Songwe, and Mwaya were non-users.

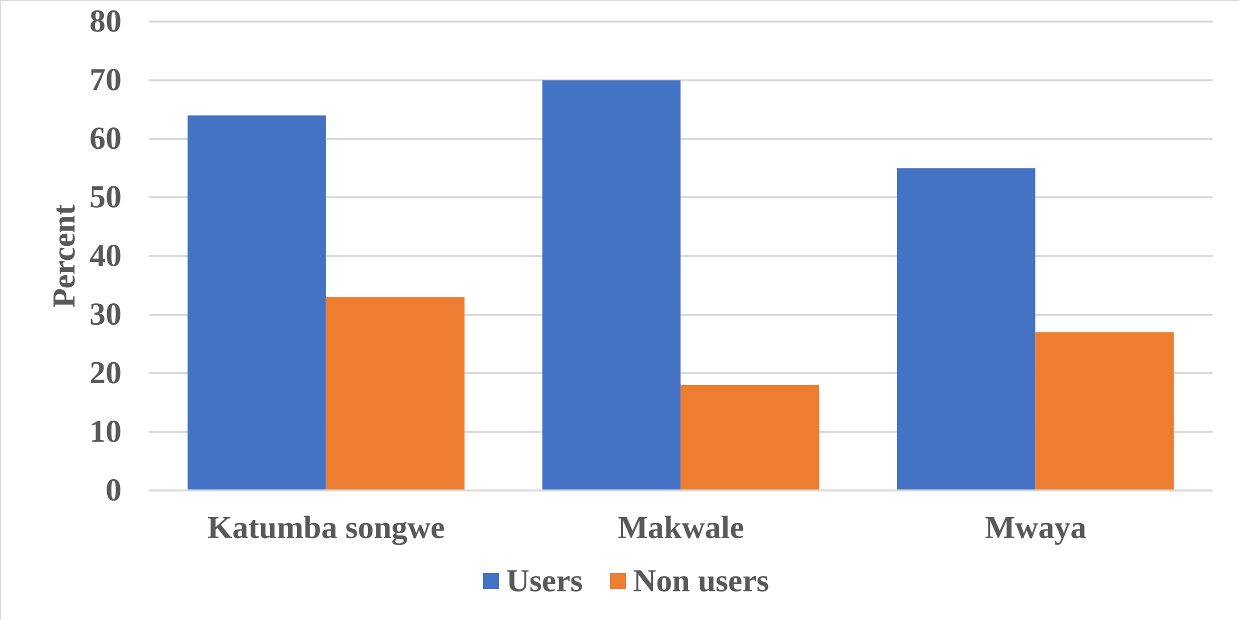

Figure 4.1: Decision to use the storage system by ward

4.1.2 Institutional characteristics

Group membership play a role in influencing smallholder farmers to make decision on the use of the storage system. Among the non-users, 8% of the farmers did not engage themselves in group membership, while 21% were engaged, as shown in Table 4.4. Additionally, Table 4.4 shows that among the potential users, 9% did not involve themselves in group membership in relation to 62% who did. These findings aligned with Sanga et al. (2025), who found that, farmer groups are positively influences the adoption of storage technologies like hermetic bags, as group membership increases exposure, information sharing, and support (extension) that help with adoption.

Table 4.4: Group membership by willingness to use the storage system

		Group membership	Frequency	Percentage
Willingness to use	Non-users	No	21	8
		Yes	57	21
	Users	No	23	9
		Yes	166	62

Furthermore, the study also explored the reasons for involvement in various groups. The respondents mentioned that subsidized inputs (69%), market information (49%), production information (40%), easy credit access (26%), joint input purchase at lower price (17%), better price through joint marketing (11%), easy access to technology (8%) and easy access to storage facilities (3%) were the main reasons behind their membership, as presented in Figure 4.2 below. Tolno et al. (2015) found that smallholder farmers who engaged in group were able to access extension services and credit for 94.6% and 75% respectively than their counterparts. Also, findings revealed that respondents benefited from groups such as Amcos, Community development group, Farmers group, Vicoba, Youth group, and Women's groups. Twilumba et al. (2020) found that farmer groups are key role in facilitating the distribution of agricultural information and extension services. So that, they can reduce barriers to adoption by lowering transaction costs and enhancing access to improved storage technologies through collective activities, group savings schemes, or shared procurement mechanisms. Farmers who are engaged in group are more easily to be supported by the government (Ramdwar et al., 2014).

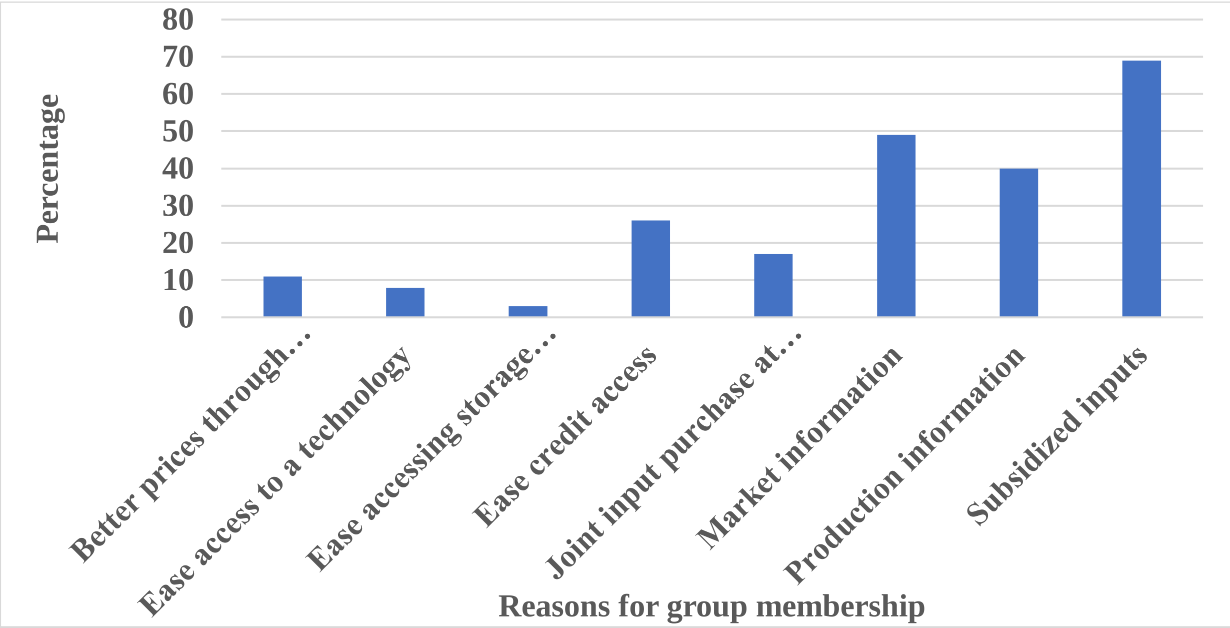

Figure 4.2: Reasons for group membership

The study also determined access to training among the users and non-users of the storage system. There is a significant relationship between the use of the storage system and access to training in the study area. This is as shown by the chi-squared value of 6.254 and the probability value of 0.012, which is less than 0.05 at 5% significance level. This indicates that potential users received more training than their counterparts. Donye et al. (2013) found that 90% of organizations and stakeholders (farmers inclusive) indicated the need for training on storage and postharvest technology.

Results on credit indicate that 81% of the potential users had access to credit, while non-users had 19%. Also, 42% of the potential users had no access to credit, while their counterparts had 58%. Access to credit is significantly at 5% level because the probability value is 0.000, which is less than 0.05. This implies that the smallholder farmers who had access to credit were more influenced to use the storage system. This study found that the main sources of their credits are banks, Vicoba, agricultural input dealers, and relative/friends, and smallholder farmers had no access to credit due to various reasons, such as no enough collateral, the business is risky (they do not lend for rice farming), and the amount of loan was too big. This is related to a study by Hancock (2015), who investigates the influence of both formal and informal credit access on the storage practices of maize farmers in northern Ghana, focusing on their use of on-farm and off-farm storage systems. Also, William & Kaserwa (2015), found that the warehouse receipt system enables farmers to store their produce and utilize the issued receipt as collateral to access credit. This study demonstrates that participation in such systems enhances farmers' access to credit and contributes to the use of improved agricultural technologies As most rural farmers are poor and lack collateral security, they are hardly considered creditworthy by loan institutions (Conteh et al., 2015).

Extension services also had the potential to influence the use of the storage system. The results in Table 4.5 indicate that the smallholder farmers who accessed extension services were 68% users, and 32% for non-users. Extension services are significant at 5% because the probability value is 0.001, which is less than 5%. The possible explanation for this is that extension services provide information, knowledge, and skills that enhance smallholder farmers to use the storage system. Maponya & Mpandeli (2013) argues that extension services enhance the efficiency of making decisions to use new technology. Also, Manda et al. (2024), evaluates the extent to which agricultural extension services, in conjunction with community learning, accelerate the adoption of PICS bags as type of modern post-harvest storage technology among smallholder farmers.

Table 4.5: Institutional characteristics for discrete variables

Variables	Response	Users (N=70.8%)	Non-users (N=29.2%)	$\chi 2$	p value
Access to training	Yes	60	56	6.254	0.012**
	No	40	44		
Access to credit	Yes	81	58	40.376	0.000***
	No	19	42		
Access to extension services	Yes	68	53	10.175	0.001***
	No	32	47		

Note: *, ** and *** significant at 1%, 5% and 10% levels respectively

4.1.3 Storage system characteristics

Polypropylene bags observed as more storage system used in the study area, with greater than half (89%) of the farmers using it, as indicated in Figure 4.3. Traditional granaries (Kihenge) were the least used storage system, with only 11% of farmers storing rice grain in the study area. This may be due to the presence, accessibility, and affordability of polypropylene bags in the study area. This result agrees with Omodara et al. (2021) that polypropylene bags are commonly used in developing countries.

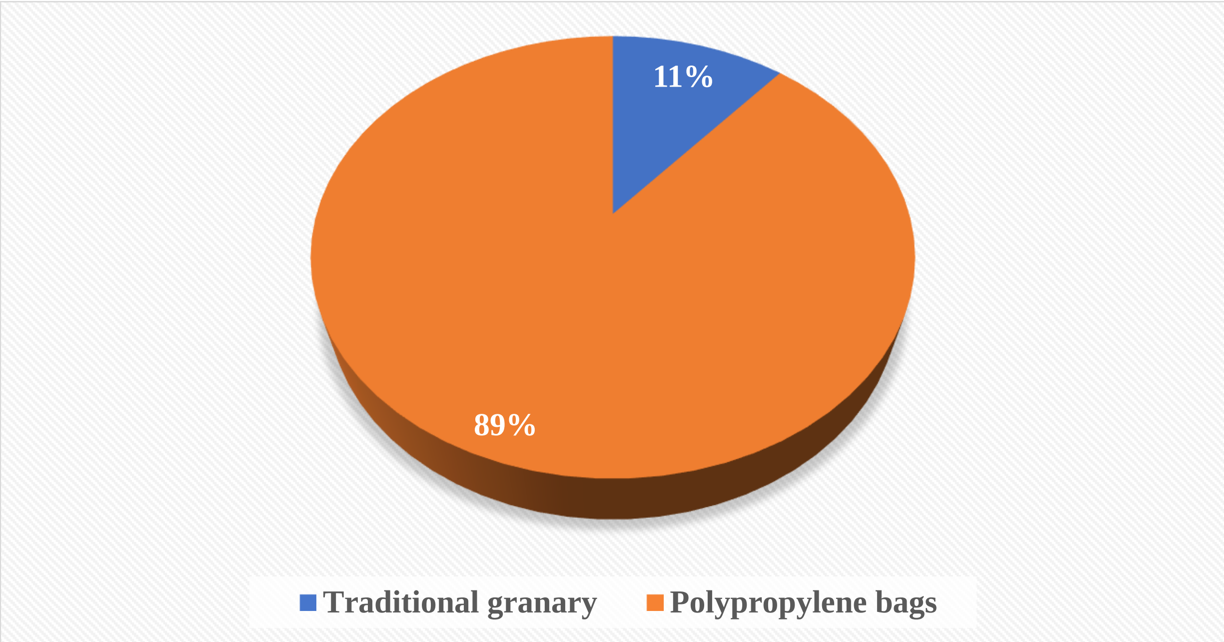

Figure 4.3: Storage systems used

The study also determined the effectiveness of the storage system for grain loss in the study area. Results in Table 4.6 show that 45% of the respondents rated jute bags to be effective for the prevention of grain loss; however, their initial high cost was a key challenge to their use by smallholders. 34.8% of the respondents reported traditional granaries to be effective, although they were not used too much because of theft, so farmers decided to take care of their rice in their houses, and 19.9% of the respondents perceived that polypropylene bags were effective, although they were the most common storage system used in the study area. This finding is concurrent with Abd El Salam et al. (2022), jute bags performed more favorably in certain quality parameters during short-term storage. In contrast, other types of storage bags, such as polypropylene bags, exhibited varying impacts on factors such as grain breakage and protein content.

Table 4.6: Effective storage system for grain loss

An effective storage system for grain loss	Frequency	Percent
Jute bags	121	45.3
Polypropylene bags	53	19.9
Traditional granaries	93	34.8
Total	267	100

The study also determined the place for storage, and the results in Figure 4.4 show that the smallholder farmers stored their grains at home (51%), grinding machine (37%), and godown (12%). A plausible justification for this is that a most of smallholder farmers stored their grains at home because of the small quantity of rice and to escape the costs charged by the machine and godown. This finding is matching with Sharon et al. (2014), that most of the grains produced are stored at the home level. Also, a study by Msongore & Mauki (2020), emphasizes various storage methods employed by smallholder farmers, including the use of bags, traditional cribs, chemically treated cribs, in house storage facilities (home), and advanced imported technologies such as Super Grain bags.

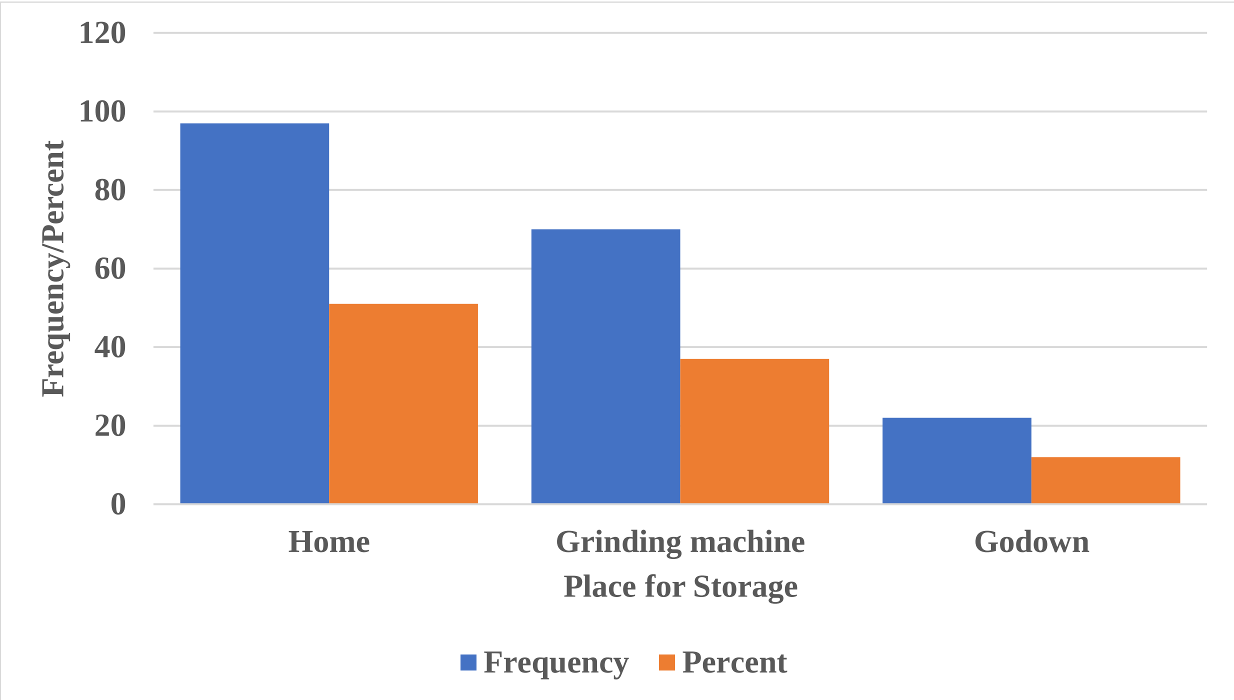

Figure 4.4: Place for storage

This study was also interested in understanding the factors that influenced 189 (70.8%) respondents to use storage systems. In this case, 54% mentioned that selling for a higher price was the major reason to use the storage system; other reasons indicated were: food security

(37%), seed for planting (6%), and to prevent post-harvest loss (3%), as indicated in Figure 4.5. Similarly, Kumar & Kalita (2017) discovered that most of the smallholder farmers produce their crop seasonally and they make decision to store their grains for the food security and as agricultural inputs for the next planting season. A study by Dowell & Dowell (2012) reported that food security and revenue growth can be risen by reducing postharvest losses. Also, Chuma et al. (2020) demonstrates that, using traditional granaries significantly increases the probability of farmers becoming net sellers of grains, consequently improving household income levels and food security.

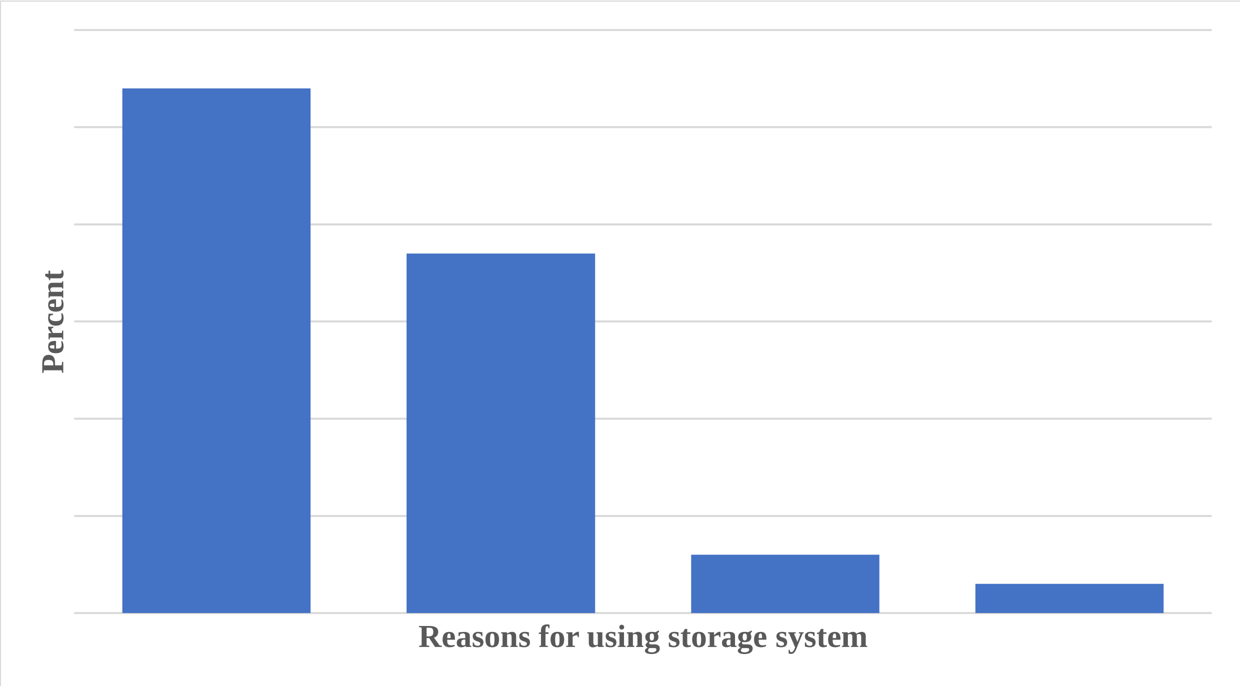

Figure 4.5: Reason for using a storage system

The study also determined the challenges that smallholder farmers face during the storage period, as shown in Figure 4.6. In this case, 28.1% of the smallholder farmers mentioned that pressing family needs were the main challenge facing them in the storage period. This is because, during storage, there were family matters that arose, such as paying school fees and family basic needs, so some of the rice was sold. Other challenges facing the smallholder farmers during the storage were a lack of enough capital (24.3%), poor storage facilities (15%), price volatility (14.2%), rodents such as rats (12.4%), and little knowledge (6%). In many situations, insect pests are the major cause of the weight and quality losses that occur during storage (Shepherd, 2012). Channa et al. (2022) highlight that limited access to capital is a significant constraint preventing smallholder farmers from investing in storage technologies, thereby reinforcing their vulnerability to post-harvest losses. This finding is consistent with Swai et al. (2019), about 38% and 54% of smallholder farmers trade their grains immediately after harvest for pressing family needs and educational expenses respectively.

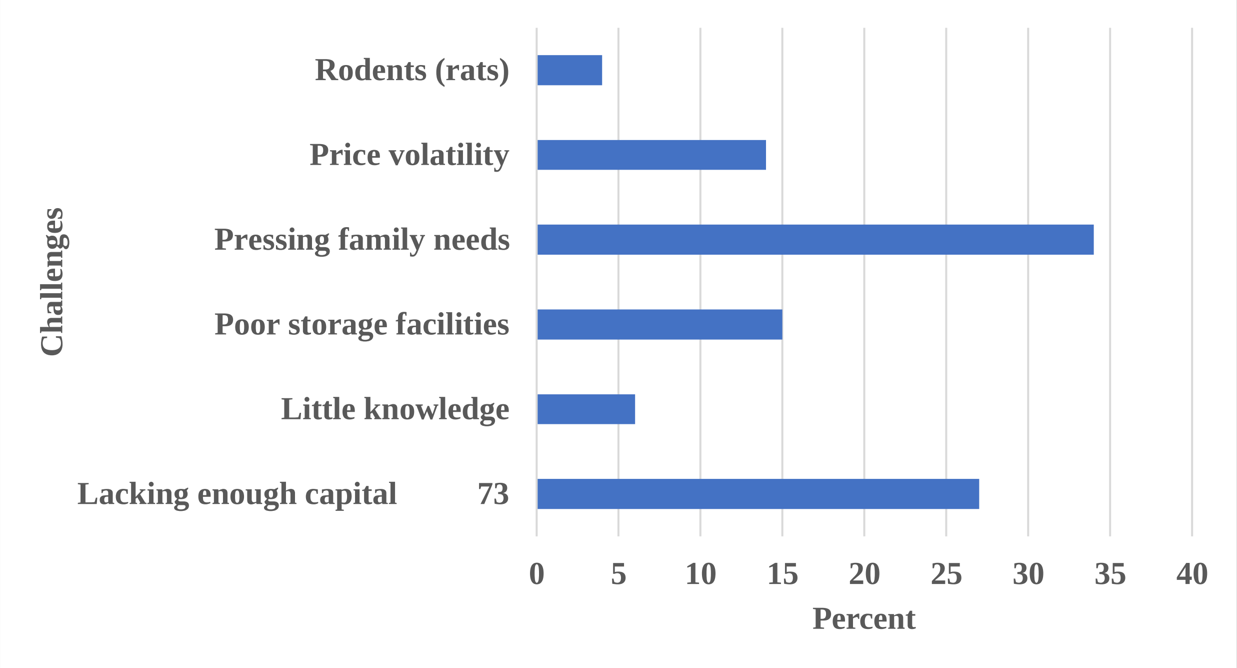

Figure 4.6: Challenges facing smallholder farmers in using storage systems

4.2 Factors that influence the use of storage systems and their extent among the smallholder rice farmers in Kyela district

4.2.1 Factors influencing the use of the storage system

The analysis of factors influencing the decision to use the storage system and its intensity in quantity of rice stored was estimated by applying a double hurdle model. Even so, before running the final regression analysis, all preliminary tests were made. Findings for the determinants of use of the storage system that is binary in nature and are estimated using the Probit model (the first hurdle) as shown in Table 4.7. The likelihood ratio test implies that the general goodness of fit of the double hurdle model is statistically significant at 1% significance level. This reveals that those independent variables jointly described the probability of using the storage system. The double hurdle model was fitted with 12 explanatory variables as shown in Table 4.7. The first hurdle model results indicate that 5 variables sex, household size, access to training, access to extension services, and on-farm income significantly affect the decision of the smallholder farmers. Also, the second hurdle result revealed that 3 variables farm size, group membership, and on-farm income significantly affect the quantity of maize stored by smallholder farmers. The significant variables are described as follows.

Table 4.7: Estimates of the double-hurdle model for determinants of the decision to use the storage system and quantity stored

	First hurdle		Second hurdle	
Variables	Coef.	Marginal effect	Coef.	Prob. [yi > 0|x]
Age (years)	0.00183	0.000483	-0.00319	-0.00017
	-0.00907	-0.0024	-0.0262	-0.00143
Sex (1=male)	0.369*	0.0976*	1.457**	0.0794 **
	-0.192	-0.0499	-0.58	-0.0316
Household size	0.151**	0.0398**	0.305	0.0166
	-0.0684	-0.0176	-0.189	-0.0103
Education level (Ref: no formal education)				
Primary School education	-0.0468	-0.013	0.363	0.0212
	-0.424	-0.116	-1.359	-0.0809
Secondary School education	-0.00375	-0.00103	0.88	0.0494
	-0.441	-0.121	-1.416	-0.0835
College/University degree	1.036	0.206	1.642	0.0869
	-0.649	-0.129	-1.698	-0.0936
Marital status (married=1)	0.0732	0.0193	0.758	0.041
	-0.289	-0.0763	-0.86	-0.047
Access to training (1=yes)	0.922***	0.244***	3.268***	0.178***
	-0.262	-0.0646	-0.893	-0.0474
Farm size	-0.132	-0.035	-0.565*	-0.0308*
	-0.119	-0.0312	-0.31	-0.0167
Access to credit (1=yes)	-0.0549	-0.0145	0.996	0.054
	-0.27	-0.0713	-0.779	-0.042
Access to extension services (1=yes)	0.593**	0.157**	2.421***	0.132 ***
	-0.277	-0.0716	-0.93	-0.049
Group membership (1=yes)	0.279	0.0737	-0.0432	-0.0024

	-0.266	-0.0698	-0.803	-0.044
Off-farm income (log)	0.00114	0.0003	-0.0602	-0.0033
	-0.0238	-0.00628	-0.0718	-0.0039
On-farm income (log)	0.806***	0.213***	4.404***	0.240 ***
	-0.261	-0.0658	-0.782	-0.041
var(e.lrice_stored)			16.25***	
			-1.915	
Constant	-13.33***		-67.27***	
	-3.535		-10.7	
Observations	267	267	267	267

Note: Standard errors in parentheses, ***, **, * significant at 1%, 5% and 10%

Households headed by males were associated with a positive and significant influence on farmers' decision to use a storage system at a 10% significance level. Marginal effect indicates that male-headed households were associated with a 9.76% increase in farmers' decision to use a storage system, holding all other factors constant. This implies household's male headed are more likely to decide to use storage facilities in relation to their female counterparts. This is findings are concurrent with the study by Benimana et al. (2021), who observed that gender of the farmers has a significant impact on the use of the storage system. Zacharia et al. (2024) reports that male headed households are 12.4% more likely to use hermetic storage systems than female headed households.

Household size had a positive and significant influence on farmers' decision to use a storage system at 5% significance level. The marginal effect indicates that for each additional household member, the farmers' decision in using the storage system increases by 3.98%, holding all other factors constant. This means that the greater the family member, the greater the farm ownership, hence labour is presence to use the storage system. Extended families have ability to put their resources together and conduct different activities as unit (Nwanmuoh et al., 2024). This is also similar to other studies Madu et al. (2018); Mignouna et al. (2011), which found that family size had a significant and positive effect on the decision to use the storage system. As noted by Benimana et al. (2023), larger households are more likely to adopt hermetic storage technology than smaller ones.

Access to training had a positive and significant influence on farmers' decision to use the storage system at 1% significance level. Marginal effect indicates that farmers' participation decision in using the storage system increases by 24.4%, holding all other factors constant. To ensure the good storage of grains produced, smallholder farmers should access training for the purpose of reducing post-harvest losses and high crop value. An example of such training is to get the knowledge on using appropriate storage system. Kassie et al. (2015) also argue that, smallholder farmers should be offered the skills and knowledge on postharvest management and storage training. The farmers who receive training significantly adopt hermetic storage system compared to their counterpart because through training they were able to improve knowledge, awareness and storage practices Mbesa et al. (2024).

The results to access to agricultural extension services, shows that the household head with access to this service were attributed to a 15.7% increase in farmers' involvement decision in adopting the storage system. Through the provision of agricultural extension services, farmers are able to choose good storage systems for their grains, hence enhancing to the postharvest management, food security and income generation. This finding is related to the studies by Akello et al. (2022) and Maonga et al. (2013), in their studies found the provision of agricultural services are very important in enhancing the choice of storage, increasing awareness and knowledge. Additionally, postharvest management through agricultural extension services helps to temperature management, humidity and pest control. Also, Sanga et al. (2025) pointed that, access to extension services positively influences use of hermetic bags.

As expected, on-farm income has a positive and significant influence on the smallholder's decision to use the storage system. For every additional 1 TZS in the log of on-farm income, the probability of using storage facilities increases by 21.3% holding other factors constant. This means that the smallholders who earn more income from farming activities are more likely to decide to use the storage system than those who earn less income from farming activities. On-farm income motivates smallholder farmers to store crops because they believe prices will increase after storage, so income will increase more. In the same manner, Benimana et al. (2023) revealed that farmers using hermetic storage technologies attained higher income levels than those who did not use these methods. This indicates that greater on-farm income may serve as a motivating factor for the adoption of such storage technologies. This finding disagrees with Manda et al. (2024), who discovered that off-farm income plays an essential role in facilitating farmers' ability to purchase hermetic storage technologies, as these technologies are commonly received through cash payments rather than credit arrangements.

4.2.2 Factors influencing the extent of use of the storage system

The second stage of the double-hurdle model evaluates the extent of the storage system usage among potential users. The random effect censored regression model (Tobit model) was applied to be consistent with the Random effect probit model. The number of observations that were censored was 92, and the uncensored observations were 175. The second hurdle result confirmed that three variables farm size, group membership, and on-farm income significantly affect the quantity of maize stored by smallholder farmers.

Household head sex (male) had a positive and significant effect at 5% level on the extent of use of the storage system. A male-headed household has a 7.94% influence on the extent to use the storage system 5% significance level. Households headed by men are more likely to make significant use of crop storage systems because men frequently have easier access to resources, financing, and extension services. In order to safeguard harvests and revenue, they can invest more in storage because they have more decision-making authority in agricultural operations at the household level. These findings are inconsistent with those of Ndaghu et al. (2023, who revealed that female-headed households were approximately 55% more likely to adopt Purdue Improved Cowpea Storage (PICS) bags compared to their male-headed counterparts. Additionally, the quantity of output had a significant positive effect on the intensity of storage among female farmers. Zacharia et al. (2024) found that, both male and female headed households benefit from using hermetic storage, and there was no significant difference between genders in storage quantity increase. This implies that once they use, female headed households store roughly as much extra as male headed ones.

Access to training had a positive and significant influence on the extent to use the storage system was used at 1% significance level. Holding everything constant, a household with access to training has a 17.8% increase in the probability of the extent of using the storage system. Nepali & Maharjan (2025) found that, smallholder farmers who were encouraged with information (training) about PICS bags stored significantly more maize: for example, those adopting two to three bags stored ~80-130 kg depending on subsidy level.

An increase in 1 acre of farm size is associated with a 3.08% decrease in the extent of smallholder farmers' use of the storage system. Large farm sizes are likely to produce more and are likely to sell most of their harvest quickly after production in order to make money, leaving less for storage. But smaller farmers with small farm size store more since they save more for their own consumption and food security. However, it contradicts the studies by Taku-Forchu et al., 2023), who found that larger farm size was significantly associated with a greater number of hermetic bags used per season for maize storage.

The result also shows that access to extension services influence on the extent of using the storage system at 1% significance level. Holding everything else constant, access to extension services increases the probability of the extent of smallholder farmers using storage systems by 13.2%. The smallholder farmers who had access to extension services are more likely to store their grains than those who did not have access to extension services. Due to this result, the extent of using storage system by smallholder farmers can be influenced by extension services. This observation is consistent with a study by Debebe (2022) argue that, the smallholder farmers increase the amount of harvested grains to keep in storage for the purpose of enhancing postharvest management after accessing extension services supports.

On-farm income had a positive and significant influence on the extent to use the storage system was used at 1% significance level. For every additional 1 TZS in the log of on-farm income increases the probability of the extent of smallholder farmers using the storage system increases by 24%. This result implies that smallholder farmers who generated higher income from agriculture activities are more influenced to use storage systems and store the high quantity of crops, hence are being able to reduce postharvest losses from their grains. Through the increasement of income generated, smallholder farmers are being able to keep their crops at storage for a long period of time and waiting to trade at the time of favourable price at the market.

This finding is related to a study by Zacharia et al. (2024), found that smallholder farmers with higher farm income are more likely to use hermetic storage system and store their maize at larger quantities. This result is inconsistent with Wekesa et al. (2003) that smallholder farmers who generated larger income from agricultural activities do not influenced to use and store the larger amount of grains, this means that farm income is not significantly to the use and intensity to use the storage systems.

4.3 Factors that influence the choice of storage system among the smallholder rice farmers

The logistic regression model was used to analyse the factors influencing smallholder farmers’ choices of grain storage systems. This model shows the likelihood of the smallholder farmers in choosing a given storage system from the different alternative grain storage systems available in the study area (polypropylene bags and traditional granary storage systems are dominantly in use). The dependent variable was labelled 1 if the household used polypropylene bags and 0 if traditional granary storage systems were used. Table 4.8 show that six variables are significant at 1%, and one variable is significant at 10%. From the results, observed binary logit model fits well the data as measured by Pseudo R2 of 0.5615, which implies that the variables included in the model can explain about 56% of the probability of smallholder farmers' decision to choose a particular storage system.

The log-likelihood ratio tests are used to show how well the model fits the data. The probability of the model (Chi square =105.36) was 0.000, smaller than the level of significance of 0.01 (P<0.01). This also implies that the model can be used to explain the differences in choices among the smallholder farmers in the sample for the chosen storage system.

Table 4.8: Results on logistic regression model

Variables	Odds ratio	Std. err.	P>z
Age (years)	1.11799	0.04445	0.005***
Sex (1=male)	0.58223	0.40458	0.436
Household size	0.44703	0.11589	0.002***
Education level (Ref: no formal education)			
Primary School	2.16666	3.52523	0.635
Secondary School	3.66317	6.27903	0.449
College/University degree	6.52526	12.83153	0.34
Marital status (married=1)	12.42311	11.73396	0.008***
Access to training (1=yes)	11.26936	11.68923	0.020**
Effectiveness of the storage system	1.68972	1.38638	0.523
Log total storage cost	0.00882	0.00981	0.000***
Farm size	1.3604	0.44777	0.35
Log rice quantity harvested	4.6333	6.5462	0.001***
Access to credit (1=yes)	0.42584	0.37107	0.327
Access to extension services	1.12049	1.2004	0.915
Group membership (1=yes)	1.22823	1.1475	0.826
Log off farm income	0.84329	0.12499	0.25
Log on farm income	0.0258	0.033752	0.005***
Constant	3.839864	1.918119	0.000***
Observations			267
LR chi2(17)			105.36
Prob > chi2			0
Pseudo R2			0.5615

Log likelihood	-41.1477

Note: ***, **, * significant at 1%, 5% and 10% respectively

Age of the household head had a positive and significant influence on the choice of the storage system at 1% significance level. These results show that as age increases, the smallholder farmers are 1.12 times more likely to use polypropylene bags. This is due to the reason that farmers practices in agriculture activities for a long period and become conscious on the post-harvest handling procedures, hence increasing their possibility of choosing the appropriate storage system. In Uganda, Akello et al. (2022) found age as a factor in their model of storage technology choice among potato farmers, finding that it helps explain which storage facility farmers choose. This finding is inconsistent with Ngowi & Selejio (2019), as age of smallholder farmers increases the greater the risk for them to use modern storage system.

The result in household size indicate that the coefficient was significant at 1% significance level and negatively associated to the choice of storage systems. The negative sign of the coefficient aligns with a priori explanation, indicate that if household size increases, the smallholder farmers are 55% less likely to use polypropylene bags and more likely to use traditional granaries. This large household size means that the smallholder farmers will prefer fewer polypropylene bags due to high expenditure. A smallholder farmers with large family size is challenging to store and invest because of the high consumption level (Okeke et al., 2015).

Marital status is significantly related to the choice of storage system where by married household farmers are 12.41 times more likely to adopt polypropylene bags than those who have no marriage. Smallholder farmers choice and use a certain storage system due to their marital status. Household headed with marriage needs labour availability, different sources of finance and larger requirement for food security thus they are responsible to use and maintain appropriate storage systems. Married households play a crucial role to enhance the knowledge, and choices for storage systems that improve postharvest management and ensure the food security to the family member because they are able to share agricultural skills. This finding is in line with Chuma et al. (2020), where by the smallholder farmers influenced to choose and use a metal silo storage system due to their marital status. Married household heads are more possible to be ready to use a metal silo.

Those smallholder farmers who were able to access training were 11.3 times more likely to adopt polypropylene bags than their counterpart. This is due to the fact that the access of training enabled the smallholder farmers to acquire knowledge and skills that can help them in using storage system. Also, a study conducted in Osun State (Nigeria) investigates that the choice of an appropriate storage system is determined by training (Oladejo, 2016). Also, Zacharia et al. (2024) found that, access to training is among the major factors influencing the decision to use alternative maize storage systems (hermetic bags, silos etc.) instead of traditional sacks or chemical treatments. Thus, training influences which storage technology households choose.

Moreover, the cost of the storage system has a negative and significant effect to influence on the choice of the storage system. As the cost of the storage system increases, the smallholder farmers are less likely to use polypropylene bags by 99%. A study by Negede et al. (2023) also found that smallholder farmers adopt to use hermetic storage system in storing their maize although are cost full due to their lifespan in storage. These results are inconsistent with expectations since the farmer can use propylene bags because they can store their grains at home or in a godown to reduce the cost of granary construction. Oparinde et al. (2016) also found that people are reluctant to any capital-intensive storage system and Luoga (2019) shows that storage systems with high investment costs are less likely to be used by smallholders unless expected returns are sufficiently large. The high acquisition and maintenance costs of storage facilities significantly limit smallholder farmers' ability to choose "good" storage options (Tibaingana et al., 2024).

Analysis of the rice quantity harvested indicates that the coefficient was significant at the 1% significance level and positively related to the choice of storage systems. The positive sign of the coefficient implies that as rice quantity harvested increases, the smallholder farmers are more likely to use polypropylene bags. Similar results were found by Ruhinduka et al. (2020) who stated that farmers who produce larger harvests are more inclined to process and store rice for future sale. Smallholder farmers who are capable to harvest a larger quantity of their grains and connected to milling facilities are more likely to involve in postharvest processing and storage compared to their counterparts who trade immediately after harvest. (Okeke et al., 2017) found that the farmers use traditional method in storing their produces because of the high production of outputs after harvest.

Additionally, an increase in on-farm income is related with a decrease in the use of polypropylene bags. The decrease in the adoption of polypropylene bags implies that farmers with higher income are more likely to change from less costly, ineffective storage to more reliable, more reliable options. Smallholder farmers who earn higher incomes are able to access storage system that enhance postharvest management, such as metal silos, and hermetic bags. This indicates that the farmers with limited resources and smaller income are influenced to use polypropylene bags because it is cheap storage system. Kotu et al. (2019) argue that smallholder farmers with higher income are notably less likely to use polypropylene bags than other effective storage systems.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter gives a summary of the study based on its reported objectives and the methodologies applied. It also examines the main conclusions, presents relevant policy implications, and recommends areas for future research.

5.1 Summary

This study intended to assess the use of storage systems among smallholder rice farmers in the Kyela District in Tanzania. To achieve the objectives of this study, descriptive statistics were used to characterize smallholder rice farmers based on the storage systems they use. Also, the Double Hurdle model was used to determine factors influencing the use of storage systems and the intensity of use among smallholder rice farmers. As well, the multivariate logit model was used to determine factors influencing the choice of a type of storage system among smallholder rice farmers in Kyela District. This study was carried out using data from 267 respondents.

5.2 Conclusions

The study identified that male-headed households, larger household sizes, access to training, extension services, and higher on-farm income positively affect both adoption and intensity of use. Interestingly, larger farm size negatively correlates with storage use, suggesting alternative post-harvest strategies among larger producers. These findings highlight the importance of targeted training and infrastructure support to reduce post-harvest losses and enhance food security.

Also, the choice of polypropylene bag over traditional storage is significantly and positively determined by household head age, married household head, training accessibility, and amount of grains harvested, while household size, total storage cost, and on-farm income had a negative effect.

5.3 Policy implications and recommendations

Strengthening the capacity of extension officers and increasing access to post-harvest handling and storage training can help farmers make informed decisions about appropriate storage technologies. Tailored training programs should focus on the economic benefits and proper use of improved storage systems.

Since the cost of storage systems is a major limiting factor, governments and development partners should support the subsidization or local production of affordable storage options such as hermetic bags and small-scale silos. Financial incentives, such as credit schemes or input bundles, may also encourage adoption.

Gender specific constraints should be addressed by designing inclusive interventions that recognize the differing roles and capacities of male- and female-headed households. Ensuring women have equal access to training, inputs, and finance can enhance overall adoption levels.

The potential for higher prices during the off season encourages farmers to store more. Interventions that improve market access, promote warehouse receipt systems, and provide timely market information can incentivize farmers to increase the quantity stored. Policies that facilitate collective marketing, farmer cooperatives, and price information systems should be prioritized.

Farmers often base their choices on experience and cultural practices. Efforts should be made to integrate proven traditional storage methods with modern improvements to enhance using while maintaining local relevance.

In summary, policymakers and development actors need to give priority to integrated interventions that incorporate market-oriented storage solutions, training, financial assistance, and group action. In addition to lowering post-harvest losses, these actions will support the national agricultural reform program, increase food security, and improve household welfare.

5.4 Suggestions for further research

This study evaluates the use and extent of use of the storage system on smallholder rice farmers' income in Kyela district. Also, the study determined factors influencing the choice of storage systems in the region of Mbeya. Therefore, it is suggested that further research be done on the impacts of storage systems on smallholder rice farmers' income in other regions: Morogoro, Tabora, and Shinyanga. Likewise, to determine the contribution of various marketing channels to smallholder farmers' decisions to use storage systems. Additionally, factors considered socioeconomic factors that influence the choice of storage systems, such as education, on-farm and off-farm income. Other factors, such as cultural and societal factors like norms, beliefs, and values, shows a significant role in influencing not only the choice of storage systems but also the use of the storage system. Therefore, future studies should consider these factors. Moreover, these results could be expanded upon in future studies by looking at how storage adoption affects food security, market integration, and household welfare over the long run.

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APPENDICES

SECTION A: SOCIAL ECONOMIC CHARACTERISTICS OF THE HOUSEHOLD

1. Name of the household head…………………………….
2. Age of the household head……………………………..
3. Sex of the household head (a) Male [ ] (b) Female [ ]
4. Education level of the household head (a) No General Education [ ] (b) Primary School [ ] (c) Secondary School [ ] (d) College [ ] (e) University degree [ ]
5. Marital status (a) Single [ ] (b) Married [ ] (c) Divorced [ ] (d) Widowed [ ]
6. Work or job of the household head (a) Crop Production [ ] (b) Livestock Production [ ] (c) Formal Employment [ ] (d) Casual Employment [ ] (e) Food Processing [ ] (f) Brokerage [ ] (g) Hawk [ ] (h) Small Business [ ] (i) Student, not working [ ] (j) House wife, domestic chore [ ] (k) House husband, not working [ ] (l) Kid, not working [ ]
7. What is the main reason for engaging in the above activity? (a) Income [ ] (b) Food source [ ] (c) Other [ ], Specify……………………….
8. What is the main source of income for this household? (a) Sale of farm produce [ ] (b) Formal Employment [ ] (c) Income from other business [ ] (d) Casual Employment [ ] (e) Sale of livestock and its products [ ] (f) Brokerage commission [ ] (g) Hawking [ ] (h) Other [ ], Specify…………………………
9. Please indicate the number of people who have been staying together at least for six months……………………………….

SECTION B: HOUSEHOLD STORAGE STATUS

10. Have you ever heard/ have knowledge of storage practices? (a) Yes [ ] (b) No [ ]
11. Have you ever participated in any training about storage systems? (a) Yes [ ] (b) No [ ]
12. Where did you get the information or training? (a) Mass Media (Radio, TV, Newspaper) [ ] (b) Social Media (YouTube, etc.) [ ] (c) Seminar/ Training [ ] (d) NGO/ CBO [ ] (e) Friends/ Relatives [ ] (f) Government Extension [ ] (g) Farmers Cooperative/ Union [ ] (h) Farmers Group [ ] (i) Research Centres (university, colleges, and research organizations) [ ] (j) other [ ], Specify…………..,…….
13. Do you use any storage system in marketing your rice products? (a) Yes [ ] (b) No [ ]
14. If not, why don't you use storage? (a) Pressing family needs [ ] (b) Repaying loan [ ] (c) Poor storage facilities (d) Price volatility [ ] (e) Little knowledge [ ] (f) Lacking enough capital [ ](g) Other [ ], Specify………………………..

15. How do you store the rice paddy? (a) Polypropylene bags [ ] (b) Jute bags [ ] (c) Traditional granary [ ] (d) PICs (e) Other [ ], Specify
16. Which of the storage systems are effective for grain loss reduction? (a) Polypropylene bags [ ] (b) Jute sacks [ ] (c) Traditional granary [ ] (d) PICs [ ] (e) Other [ ], Specify
17. Where do you store the harvested rice paddy? (a) Home [ ] (b) Godown [ ] (c) Grinding machine [ ] (d) Other [ ], Specify
18. Where do you source the materials for storage? (a) Own [ ] (b) Private company [ ] (c) Government [ ] (d) Research Centres (university, colleges, research organisations) [ ] (e) Farmers' Cooperative/ Union [ ] (f) Other [ ], Specify………………………
19. For what reasons do you use the storage system? (a) Food security [ ] (b) To sell for a higher price [ ] (c) To prevent post-harvest loss [ ] (d) Seed for planting [ ] (e) Other [ ], Specify………………………
20. What are the current challenges facing farmers in using the storage systems? (a) Pressing family needs [ ] (b) Repaying loan (c) Poor storage facilities [ ] (d) Price volatility [ ] (e) Little knowledge [ ] (f) Lacking enough capital [ ] (g) Other [ ], Specify………………..
21. What was your total storage cost in the 2021 main production season? ....

SECTION C: RICE PRODUCTION QUANTITY, MARKETING, AND MARKET INFORMATION *(This section requires information on the quantity of rice produced by the farmer in the 2021 MAIN SEASON, marketing of the produce, and market information accessed)*

22. Land size used by the farmer for rice farming in the 2021 main season (Kindly indicate the land size in acres)……………..
23. Land size harvested (in acres)……………..
24. Rice quantity harvested (in kilograms)…………….
25. Rice quantity GIVEN OUT (e.g., as a donation or tithe, etc.) in kilograms………..
26. Rice quantity left for family consumption (in kilograms)………………
27. Rice quantity sold before storage (in kilograms)……………..
28. Price per kilogram for the rice quantity sold before storage…………….
29. Rice quantity sold after storage (in kilograms)………………
30. Price per kilogram for the rice quantity sold after storage……………
31. In what form did you sell your rice? (a) Shelled rice [ ] (b) Deshelled rice [ ] (c) Both [ ]
32. Which market did you use? (a) Farm gate [ ] (b) Village/ Ward market [ ] (c) District market [ ] (d) Provisional market [ ] (e) City markets outside Mbeya [ ]

SECTION D: CREDIT, EXTENSION SERVICES, AND SOCIAL GROUP

33. Did you need credit for rice farming? (a) Yes [ ] (b) No [ ]
34. If not, why did you not need credit for rice farming? (a) Borrowing risky [ ] (b) Interest rate is high [ ] (c) Too much paper work/ procedures [ ] (d) Expected to be rejected (did not try) [ ] (e) I have no asset for collateral [ ] (f) No money lender in this area for this purpose [ ] (g) Lenders do not provide the amount needed [ ] (h) No credit association [ ] (i) Not available in time (j) Not cash constrained (k) Rice farming is not profitable [ ]
35. If yes, did you apply credit for rice farming? (a) Yes [ ] (b) No [ ]
36. Did you receive the applied credit for rice farming? (a) Yes [ ] (b) No [ ]
37. If no, why did you not receive the applied credit? (a) I did not have enough collateral (b) The business is risky (they do not lend for rice farming) [ ] (c) Applied loan was too big [ ] (d) Other [ ], Specify……..
38. If yes, what was the source of the credit? (a) Fellow farmer [ ] (b) Private money lender [ ] (c) Farmers group or cooperative (d) Vicoba/ COCOBA [ ] (e) SACCOS (f) Bank [ ] (g) Microfinance (h) Merry go round [ ] (i) Relative or friend [ ] (j) Trader [ ] (k) Agricultural input dealers [ ] (l) Other [ ], Specify………..
39. Did you need an extension service for rice farming? (a) Yes [ ] (b) No [ ]
40. If not, why did you not need an extension service? (a) Had enough information/ knowledge [ ] (b) Had no time [ ] (c) Not aware of the service [ ] (d) Poor service (not helpful) [ ] (e) Other [ ], Specify……….
41. If yes, did you receive extension service for rice farming? (a) Yes [ ] (b) No [ ]
42. Where did you get the extension service? a) Mass Media (Radio, TV, Newspaper) [ ] (b) Social Media (YouTube, etc.) [ ] (c) Seminar/ Training [ ] (d) NGO/ CBO [ ] (e) Friends/ Relatives [ ] (f) Government Extension [ ] (g) Farmers' Cooperative/ Union [ ] (h) Farmers Group [ ] (i) Research Centres (university, colleges, research organisations) [ ] (j) Fellow farmer (k) Trader (l) other [ ], Specify…….
43. Was the extension service received helpful? (a) Yes [ ] (b) Not at all [ ] (c) Partially helpful [ ]
44. Are you a member of a social group? (a) Yes [ ] (b) No [ ]
45. If yes, which group(s) do you belong to? (a) Farmers group (b) Amcos (Farmers' cooperative) (c) Saving and credit association (SACCOS) [ ] (d) Vikoba/ COCOBA (e) Merry go round (f) Marketing group [ ] (g) Youth group [ ] (h) Women group [ ] (i) Livestock group [ ] (j) Community development group [ ] (k) Spiritual faith group (church, mosque or traditional) [ ] (Other [ ], Specify…………………

46. What service or benefits do you get from such a group? (a) Joint input purchase at lower price [ ] (b) Subsidized inputs [ ] (c) Ease credit access (d) Serving [ ] (e) Production information [ ] (f) Market information [ ] (g) Better prices through joint marketing [ ] (h) Ease accessing storage facilities [ ] (i) Ease access to a technology [ ] (j) Spiritual service [ ] (k) Other [ ], Specify………

SECTION E: COMPONENTS OF COSTS AND RETURNS

47. Please complete the table below, indicating the quantities of storage systems used and their costs for calculation of fixed costs (Q= Quantity of stored rice in kg, C= Cost of each)

Type of Costs			Storage Systems			
			Polypropylene bags	Jute Sacks	Traditional granaries	PICs
FIXED COST	Storage capacity	Q				
		C				
	Capital Costs	Q				
		C				
	Useful Life	Q				
		C				

48. Please complete the operational costs for storage systems used below (FL=Family labour, HL=Household labour in an 8-hour working day; P=Number of people; D=Number of days, H=Number of hours spent)

Type of Costs	Categories	Polypropylene bags			Jute Sacks			Traditional granaries			PICs		
Labour costs		FL	HL	Cost	FL	HL	Cost	FL	HL	Cost	FL	HL	Cost
		FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8			FL,HL=(P*D*H)/8		
	1. Contruction												
	2. Packing												
	3. Staking												
	4. Inspecting												
	5. Dusting												
	6. Repair												
Insectide													
Percentage loss													

49. How much did you generate from farming activities in 2021? ....

50. How much did you generate from off-farm activities in 2021? ....

Thank you all!

Appendix B: Key data analysis output

(a) Estimated results of coefficient of the first stage (Hurdle 1)

```
. probit DV_Objective1 Q3_AgeHH Sex Q10_StayHH ib2.Educ_level married ///
>         access_train Q27_LandSize Access_credit access_enstension ///
>         member_group off_farm_income on_farm_income

Iteration 0:  Log likelihood = -161.28192
Iteration 1:  Log likelihood = -126.66591
Iteration 2:  Log likelihood = -125.97556
Iteration 3:  Log likelihood = -125.97305
Iteration 4:  Log likelihood = -125.97305

Probit regression                                       Number of obs =    267
                                                        LR chi2(14)   =  70.62
                                                        Prob > chi2   = 0.0000
Log likelihood = -125.97305                             Pseudo R2     = 0.2189

-------------------------------------------------------------------------------------------
           DV_Objective1 | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------------------------------------------------------------------------------------
                Q3_AgeHH |    .001827   .0090743     0.20   0.840    -.0159583    .0196124
                     Sex |   .3693989   .1923048     1.92   0.055    -.0075115    .7463093
              Q10_StayHH |   .1507212   .0684255     2.20   0.028     .0166096    .2848327
                         |
              Educ_level |
College/University degree |   1.035644   .6491618     1.60   0.111    -.2366895    2.307978
          Primary School |  -.0468076   .4238379    -0.11   0.912    -.8775146    .7838995
        Secondary School |  -.0037519   .4407953    -0.01   0.993    -.8676948    .8601911
                         |
                 married |    .073203   .2889928     0.25   0.800    -.4932124    .6396184
            access_train |   .9218518   .2620501     3.52   0.000      .408243    1.435461
            Q27_LandSize |  -.1323655   .1186729    -1.12   0.265    -.3649602    .1002292
           Access_credit |  -.0549343    .270108    -0.20   0.839    -.5843362    .4744675
       access_enstension |   .5928916   .2774446     2.14   0.033     .0491102    1.136673
            member_group |   .2788217   .2657282     1.05   0.294    -.2419959    .7996394
         off_farm_income |   .0011355   .0237917     0.05   0.962    -.0454954    .0477665
          on_farm_income |   .8057605   .2613678     3.08   0.002      .293489    1.318032
                   _cons |   -13.3322   3.534682    -3.77   0.000    -20.26005   -6.404349
-------------------------------------------------------------------------------------------
```

(b) Estimated results for the marginal effect of the first stage (Hurdle 1)

```
. margins, dydx(*) post

Average marginal effects                                    Number of obs = 267
Model VCE: OIM

Expression: Pr(DV_Objective1), predict()
dy/dx wrt:  Q3_AgeHH Sex Q10_StayHH 1.Educ_level 3.Educ_level 4.Educ_level married access_train Q27_LandSize Access_credit access_enstension
            member_group off_farm_income on_farm_income

--------------------------------------------------------------------------------------------
                          |            Delta-method
                          |      dy/dx   std. err.      z    P>|z|     [95% conf. interval]
--------------------------------------------------------------------------------------------
                 Q3_AgeHH |   .0004826   .0023968     0.20   0.840     -.004215    .0051802
                      Sex |   .0975764   .0498947     1.96   0.051    -.0002155    .1953682
               Q10_StayHH |   .0398128   .0176465     2.26   0.024     .0052264    .0743993
                          |
               Educ_level |
College/University degree |   .2060227   .1294612     1.59   0.112    -.0477165    .4597619
           Primary School |  -.0129566   .1162337    -0.11   0.911    -.2407704    .2148573
         Secondary School |  -.0010283   .1207322    -0.01   0.993     -.237659    .2356024
                          |
                  married |   .0193365   .0763095     0.25   0.800    -.1302274    .1689004
             access_train |   .2435063   .0645622     3.77   0.000     .1169667    .3700458
             Q27_LandSize |  -.0349642   .0311754    -1.12   0.262    -.0960668    .0261384
            Access_credit |  -.0145109   .0713159    -0.20   0.839    -.1542874    .1252657
        access_enstension |   .1566117   .0715826     2.19   0.029     .0163124    .2969111
             member_group |   .0736505   .0698116     1.05   0.291    -.0631777    .2104787
          off_farm_income |   .0002999   .0062847     0.05   0.962    -.0120178    .0126177
           on_farm_income |   .2128408   .0657718     3.24   0.001     .0839304    .3417513
--------------------------------------------------------------------------------------------
Note: dy/dx for factor levels is the discrete change from the base level.
```

(c) Estimated results for coefficients of the second stage (Hurdle 2)

```
. tobit lrice_stored Q3_AgeHH Sex Q10_StayHH ib2.Educ_level married ///
>         access_train Q27_LandSize Access_credit access_enstension ///
>         member_group off_farm_income on_farm_income, ll(0)

Refining starting values:

Grid node 0:  Log likelihood =  -602.3786

Fitting full model:

Iteration 0:  Log likelihood =  -602.3786
Iteration 1:  Log likelihood = -570.36645
Iteration 2:  Log likelihood = -567.25834
Iteration 3:  Log likelihood =  -567.2001
Iteration 4:  Log likelihood = -567.19999
Iteration 5:  Log likelihood = -567.19999

Tobit regression                                    Number of obs     =    267
                                                           Uncensored =    175
Limits: Lower =    0                                    Left-censored =     92
        Upper = +inf                                   Right-censored =      0

                                                    LR chi2(14)       = 120.21
                                                    Prob > chi2       = 0.0000
Log likelihood = -567.19999                         Pseudo R2         = 0.0958
```

lrice_stored	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
Q3_AgeHH	-.0031878	.0261962	-0.12	0.903	-.0547782	.0484026
Sex	1.457401	.5799392	2.51	0.013	.3152774	2.599524
Q10_StayHH	.3053243	.1890472	1.62	0.108	-.0669824	.677631
Educ_level						
College/University degree	1.641522	1.697736	0.97	0.335	-1.701974	4.985017
Primary School	.3633595	1.358724	0.27	0.789	-2.312491	3.03921
Secondary School	.88033	1.416329	0.62	0.535	-1.908967	3.669627
married	.7581023	.8596024	0.88	0.379	-.9347855	2.45099
access_train	3.268266	.8925587	3.66	0.000	1.510475	5.026058
Q27_LandSize	-.5649793	.3099832	-1.82	0.070	-1.175455	.0454968
Access_credit	.9963368	.7791402	1.28	0.202	-.5380901	2.530764
access_enstension	2.420962	.9302857	2.60	0.010	.588871	4.253052
member_group	-.043155	.8026313	-0.05	0.957	-1.623845	1.537535
off_farm_income	-.0601686	.0718073	-0.84	0.403	-.2015848	.0812476
on_farm_income	4.40445	.7817453	5.63	0.000	2.864892	5.944007
_cons	-67.2693	10.69869	-6.29	0.000	-88.33914	-46.19945
var(e.lrice_stored)	16.25333	1.915208			12.88722	20.49867

(d) **Estimated results for the marginal effect of the first stage (Hurdle 2)**

```
. margins, dydx(*) predict(pr(0,.))

Average marginal effects                                 Number of obs = 267
Model VCE: OIM

Expression: Pr(lrice_stored>0), predict(pr(0,.))
dy/dx wrt:  Q3_AgeHH Sex Q10_StayHH 1.Educ_level 3.Educ_level 4.Educ_level married access_train Q27_LandSize Access_credit access_enstension
            member_group off_farm_income on_farm_income
```

	dy/dx	Delta-method std. err.	z	P>|z|	[95% conf. interval]	
Q3_AgeHH	-.0001737	.0014276	-0.12	0.903	-.0029717	.0026243
Sex	.0794226	.031574	2.52	0.012	.0175386	.1413065
Q10_StayHH	.016639	.0102801	1.62	0.106	-.0035097	.0367876
Educ_level						
College/University degree	.0869206	.0935769	0.93	0.353	-.0964868	.270328
Primary School	.0211517	.0808596	0.26	0.794	-.1373302	.1796335
Secondary School	.0493904	.0834666	0.59	0.554	-.1142013	.212982
married	.0413136	.0467909	0.88	0.377	-.0503949	.1330221
access_train	.1781076	.0474195	3.76	0.000	.085167	.2710481
Q27_LandSize	-.0307891	.0166832	-1.85	0.065	-.0634877	.0019094
Access_credit	.0542964	.0424914	1.28	0.201	-.0289851	.1375779
access_enstension	.1319328	.0494419	2.67	0.008	.0350284	.2288373
member_group	-.0023518	.0437455	-0.05	0.957	-.0880913	.0833878
off_farm_income	-.003279	.0039037	-0.84	0.401	-.0109301	.0043722
on_farm_income	.2400251	.0410621	5.85	0.000	.1595448	.3205054

Note: dy/dx for factor levels is the discrete change from the base level.

(e) Estimated results for odds ratio of the Logit model

```
. logistic storage_type Q3_AgeHH Sex Q10_StayHH ib2.Educ_level married ///
>         access_train effective_storage total_storage_cost Q27_LandSize ///
>         rice_quantity_harvested Access_credit access_enstension ///
>         member_group off_farm_income on_farm_income

Logistic regression                                    Number of obs =    267
                                                       LR chi2(17)   = 105.36
                                                       Prob > chi2   = 0.0000
Log likelihood = -41.147739                            Pseudo R2     = 0.5615
```

storage_type	Odds ratio	Std. err.	z	P>|z|	[95% conf. interval]	
Q3_AgeHH	1.117987	.0444506	2.81	0.005	1.034173	1.208593
Sex	.5822278	.4045757	-0.78	0.436	.1491468	2.272856
Q10_StayHH	.4470266	.1158912	-3.11	0.002	.268943	.7430302
Educ_level						
College/University degree	6.525261	12.83153	0.95	0.340	.1382807	307.9174
Primary School	2.166664	3.525234	0.48	0.635	.0893015	52.56837
Secondary School	3.663171	6.279032	0.76	0.449	.127296	105.4143
married	12.42311	11.73396	2.67	0.008	1.950954	79.1067
access_train	11.26936	11.68923	2.34	0.020	1.475654	86.06255
effective_storage	1.689715	1.386379	0.64	0.523	.3383908	8.437392
total_storage_cost	.0088202	.0098119	-4.25	0.000	.0009967	.0780512
Q27_LandSize	1.360399	.4477748	0.94	0.350	.7136634	2.593217
rice_quantity_harvested	504.6333	906.5462	3.46	0.001	14.9224	17065.27
Access_credit	.4258362	.3710701	-0.98	0.327	.0771814	2.349484
access_enstension	1.120491	1.2004	0.11	0.915	.1372467	9.147758
member_group	1.22823	1.147503	0.22	0.826	.1967998	7.665402
off_farm_income	.8432907	.1249919	-1.15	0.250	.6306855	1.127565
on_farm_income	.0257957	.0337516	-2.80	0.005	.0019853	.3351783
_cons	9.37e+24	1.27e+26	4.24	0.000	2.65e+13	3.32e+36

Note: **_cons** estimates baseline odds.
Note: 0 failures and 78 successes completely determined.

Appendix C: Research permit

UNITED REPUBLIC OF TANZANIA

MINISTRY OF EDUCATION, SCIENCE AND TECHNOLOGY

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY

RESEARCH PERMIT

Permit No.	2023-041-NA-2023-1615
Date Issued	March 14, 2023
Researcher's Name	IKUPA PATSON MWANJABALA
Nationality	Citizen of Tanzania
Research Title	EVALUATING THE EFFECT OF STORAGE SYSTEMS ON SMALLHOLDER RICE FARMER'S INCOME IN KYELA DISTRICT-TANZANIA
Research Area(s)	Kyela
Validity	From March 14, 2023 To March 13, 2024
Contacts of local Collaborator (With Affiliated Institution)	Egerton University

....
Director Of Research Cordination And Promotion

....
Director General

IMPORTANT REQUIREMENTS

- A PI who wishes to continue with a research beyond the expiry date of the research permit should write to COSTECH two months before the operational permit's expiry date, to request for an extension or renewal of the permit.
- Research permit that involves collecting human, plant or animal materials / data that will be exported outside Tanzania must submit a signed Material Transfer Agreement (MTA), Data Transfer Agreement (DTA) between Tanzania host institution and the foreign counterpart. The MTA/DTA will indicate terms for collecting, storing/managing, transporting, disposal or returning of the materials/DATA to Tanzania after the closure of the research project.
- Any patent or intellectual property and royalty emanating from any research approved by the National Research Clearance Committee shall be owned as stipulated in the research proposals and in accordance with the IP policy of the respective research institutions.
- All researchers are required to report to a Regional Administrative Secretary (RAS) of the study area and present the introduction letter and activity schedule(plan) prior starting any research activity.
- All researchers are required to submit semi-annual, annual and final reports and all relevant publications made after completion of the research.
- All communications should be addressed to COSTECH Director General through rclearance@costech.or.tz; dg@costech.or.tz or +255 (022) 2700749; +255 (022) 2771358. Terms and conditions of the permit are found at www.costech.or.tz

Appendix D: Publication abstract

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Determinants of Storage System Adoption and Usage Intensity Among Smallholder Rice Farmers in Kyela District, Tanzania

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Abstract: ***This study investigates the factors that influence both the decision to adopt and the extent of use of storage systems among smallholder farmers I Kyela district, Tanzania. Using data from 267 respondents and applying the Double Hurdle Model, the study identified that male-headed households, larger household sizes, access to training, extension services, and higher on-farm income positively affect both adoption and intensity of use. Interestingly, larger farm size negatively correlates with storage use, suggesting alternative post-harvest strategies among larger producers. These findings highlight the importance of targeted training and infrastructure support to reduce post-harvest losses and enhance food security.***

Keywords: Double hurdle model, Post-harvest loss, Smallholder farmers, Storage system