# 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

## 1. Introduction

Rice is a staple food for the majority population and a source of income and employment for more than 200 million households from developing countries (Kulyakwave et al., 2019). According to the International Rice Research Institute, the demand for rice is increasing, with Africa being one of the regions where the demand is increasing at a high rate. In Africa, climate and technological influences have been forecasted to reduce rice prices. However, the financial crisis across the world was expected to turn the trend upside down from 3% to 15% accelerating the focus shift from consumers to producers (Katunze et al., 2017).
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.

FAO (2015) argues that in most areas of Tanzania lack of accurate and relevant agricultural information by small-scale farmers is a major factor constraining efforts to improve the agriculture sector. 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. The major cash crops grown in Kyela district are rice and cocoa, and farming activities are being conducted by using poor implements such as hand hoes, and it is family labour based which results in low yields per area thus a need to invite investors to come and invest in agriculture so that the sector will be improved (Gwelo et al., 2016).

The size of farms ranges from 0.5 to 3 hectares located at Kyela's Wards One of the policies issued by the government in the agricultural sector is to increase rice production by ambitious rural investments in irrigation and by tariff protection of its rice industry from cheap imported rice subsidies. Uniquely, in this storage facilities system, farmers do not need to rush to sell their crops because farmers can first store their crops at storage facilities and sell them when the market price starts to stabilize.

Rice plays a significant role in enhancing household incomes and supporting the national economy by contributing to both the agricultural sector and the overall Gross Domestic Product (GDP) reflected in the national budget. Approximately 20 percent of farmers are engaged in rice cultivation. However, the rice sector faces significant losses resulting from adverse weather conditions, moisture, rodents, birds, insects, and microbial activity. Traditional polypropylene bag storage systems can help mitigate these losses. Such systems enable the absorption of surplus production, thereby increasing output and minimizing post-harvest losses by providing farmers with access to storage facilities and credit. This access allows producers to optimize their profits by granting them flexibility in determining the timing and buyers of their sales. Various storage systems present distinct advantages and opportunities for smallholder rice farmers. Regrettably, farmers have limited strategies to manage storage-related losses, which compels many to sell their produce immediately after harvest to minimize these losses. Inadequate storage capabilities prevent most farmers from benefiting from post-harvest price increases. Consequently, they often transition from being sellers to buyers of grain during the storage period, thereby compromising their food security. Access to efficient storage technology remains a significant challenge throughout the post-harvest value chain. Additionally, there is an increasing demand for improved storage solutions, as it is economically more viable to transport milled rice rather than paddy. One way of addressing this problem is to focus on developing farmers' storage capacity. Without adequate storage, farmers forfeit potential profits that could be realized by holding their stocks after harvest and selling them later in the marketing year, when prices are generally higher.

## 2. Literature Review

Rice (*Oryza sativa*) ranks as the second most significant food crop 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.

Postharvest loss constitutes a significant challenge for numerous farmers in Tanzania, jeopardizing their livelihoods and food security, while resulting in an annual loss of approximately 30 to 40 percent of the country's harvested crops (Bisheko & Rejikumar, 2024). Different grain storage practices are adopted by smallholder farmers in developing countries globally, are conventional storage practices such as gunny bags, woven granaries and cribs, and wooden boxes. Storage losses, mainly occurring due to insects and mycotoxins, are considered to be the highest among the post-harvest steps of grain produced by smallholder farmers and could occur in the farm as well as market storage (Manandhar et al., 2018). Also, a study by Adikaram and 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., 2024).

According to a study by Baributsa et al. (2017), increasing attention is being directed toward the adoption of improved storage technologies, including hermetic storage solutions such as Purdue Improved Crop Storage (PICS) bags and metal silos, as effective measures to minimize postharvest losses and enhance grain quality. A study by Gitonga et al. (2013) shows that, in Kenya, farmers are more commonly store the shelled grain in polypropylene bags, and many smallholder farmers sell off their grain immediately after harvest to avoid damage by storage pests and consequently receive a low price. Maina et al. (2016) observed that most farmers in the Eastern and Rift Valley regions of Kenya first packed their grain in polypropylene bags, after which they stored it in the granaries. PICS bag is a simple, low cost triple bagging technology originally introduced for postharvest storage of cowpea, but has been evaluated for applicability to maize storage mainly in West Africa (Ndegwa et al., 2016). However, the uptake of these enhanced storage technologies remains limited, primarily due to financial barriers, insufficient awareness, and restricted access among smallholder farmers (Bisheko and Rejikumar, 2023)

The storage of grain in Tanzania is done at both traditional and modern storage techniques. According to, Chidege et al. (2024), there are various traditional storage methods in Tanzania including woven polypropylene bags, traditional granaries, and other non-hermetic containers and improved storage technologies such as 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). As regards "modern" methods are stored in jute sacks and polypropylene bags at home, which is very common.

In 2019, the Government of Tanzania introduced the National Postharvest Management Strategy (NPHMS) 2019–2029 as a comprehensive framework to combat food loss and waste across agricultural value chains. The strategy is designed to reduce postharvest losses, enhance stakeholder awareness, build institutional and data management capacity, and improve farmer access to adequate storage facilities and related infrastructure. The government has additionally implemented the Agriculture Sector Development Strategy II (ASDS, 2015–2025), which prioritizes the enhancement of competitive value chains, including the development of postharvest management infrastructure such as silos and rural market facilities (Rutta, 2024).

In relation to above, have empirically tested factors influencing the decision to use storage system among the smallholder farmers. The adoption and effective use of storage systems by smallholder farmers are influenced by a complex interplay of socioeconomic, institutional, and cultural factors. Understanding these influences is essential for designing interventions aimed at reducing post-harvest losses and improving food security at the household level. Socioeconomic status plays a critical role in influencing the adoption of storage technologies among smallholder farmers. Those with higher income levels are generally more likely to invest in improved or modern storage systems, as their enhanced financial capacity enables them to afford the initial investment and ongoing maintenance costs associated with such technologies (Twilumba et al., 2020). In contrast, farmers with limited financial resources frequently depend on traditional or basic storage methods, which are often less efficient in maintaining the quality and longevity of agricultural produce over extended periods.

Access to reliable information is a key factor influencing farmers' decisions regarding storage practices. Farmers who receive support from agricultural extension services or have exposure to other sources of technical knowledge are more likely to be aware about improved storage technologies and the advantages they offer (Chirwa et al., 2019). This awareness often translates into a higher likelihood of adoption, as informed farmers tend to better understand the economic and quality losses linked to inadequate storage practices. In many cases, the availability and accessibility of storage technologies are additional factors that significantly affect adoption rates. In many rural regions, especially within sub Saharan Africa, inadequate infrastructure and restricted access to markets for storage related inputs present substantial obstacles to adoption. Even when farmers demonstrate a willingness to adopt modern storage systems, their efforts are often hindered by logistical challenges or the unavailability of local suppliers. (Adetunji et al., 2020).

There are also different literature discussing the factors influencing the extent (quantity stored) of use of storage system among smallholder farmers. The quantity of produce stored by smallholder farmers is influenced by factors such as farm size, access to credit, market conditions, knowledge of post-harvest management, and availability of storage facilities. Farm size is a critical factor influencing the volume of agricultural produce stored by smallholder farmers. Larger landholdings generally yield higher production levels, often exceeding the immediate consumption needs of the household. This surplus enables farmers to allocate a greater portion of their harvest to storage. According to Munyua et al. (2017), smallholder farmers with relatively expansive farms in Western Kenya demonstrated a higher propensity to store greater quantities of maize than those with smaller plots. The ability to store surplus produce not only mitigates the risk of seasonal food shortages but also facilitates strategic market participation when prices are favorable.

Also, access to credit and financial resources plays a critical role in shaping smallholder farmers' capacity to invest in advanced storage technologies, thereby influencing the quantity of agricultural produce stored. Mungai and Masese (2019) highlight that smallholder farmers in Tanzania with access to affordable credit were more inclined to adopt modern storage solutions such as hermetic bags and metal silos. These technologies allow for the safe preservation of larger quantities of produce over extended periods. In contrast, farmers with limited financial means are often constrained to using traditional storage methods, which are frequently inadequate for handling large volumes and are susceptible to significant post-harvest losses due to pests and spoilage.
Additionally, market related factors, such as fluctuations in commodity prices and accessibility to reliable markets, significantly influence farmers' storage decisions. In many cases, farmers utilize storage as a strategic mechanism to optimize income, particularly when higher prices are anticipated in future market cycles. Ndiritu et al. (2018) found that smallholder farmers in Central Kenya responded to seasonal price variability by increasing the volume of produce stored, thereby engaging in a form of market driven arbitrage. Nonetheless, inadequate access to timely market information and underdeveloped infrastructure often hampers such strategic storage practices. As a result, many farmers are compelled to store only minimal quantities, primarily for immediate household use, rather than for commercial purposes. Notably, the extent of storage among smallholder farmers is significantly influenced by their level of awareness and technical proficiency in post-harvest management. As demonstrated by Minde et al. (2020), farmers who possess knowledge of appropriate practices such as effective drying, cleaning, and pest prevention are more likely to exhibit confidence in post-harvest handling and are consequently more inclined to store larger volumes of produce.

## 3. Methodology

### 3.1 Study Area

The study was conducted in three wards of Kyela District: Makwale, Mwaya, and Katumba Songwe, located in the Mbeya region. Kyela is one of six districts, including 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. Kyela district lies between Latitude 70 and 90 31' and between Longitude 320 and 350 East of Greenwich. It is bordered to the north by Rungwe district, to the northeast by Njombe Region, to the southeast by Lake Nyasa, to the south by Malawi, and to the west by Ileje District (URT, 2019). According to the 2012 Tanzania National Census, the population of the Kyela District was 221,490 NBS (2013). The main rainy season in Kyela District is between November and June, with a mean annual rainfall between 2000mm and 3000mm. Normally in April and May, the District experiences heavy rainfall accompanied by the floods of the rivers Songwe, Kiwira, Mbaka, and Lufilyo. The District has a warm and humid climate with a mean daily temperature of 23 ˚C. Most people depend on agriculture, and the most cultivated food crops are paddy, maize, sweet potatoes, and groundnuts.

### 3.2 Sampling and Sampling Procedure

A multistage sampling procedure was used to select respondents. The first stage involves a purposive selection of the Kyela district because 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 based on the fact that they have a large number of farmers. Then, a random sample technique was used to identify respondents from each of the three wards who were farmers. All farmers had equal chances of being included in this study.

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). 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.

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

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

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

### 3.3 Data Collection and Analysis

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.

To characterise smallholder rice farmers, descriptive statistics, STATA, and Ms Excel were used to analyse data. 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 Empirical Model Specification

The double-hurdle model was used in this case 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 explanatory 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.

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 hurdle, determining whether the farmer is a zero type, and the second hurdle, determining the extent to use given that the farmer is not a zero type. The double hurdle model has been applied in many studies, including (Aristei and Pieroni, 2008; Dlamini and Huang, 2019; Okoffo et al., 2016). It is reasonable to assume that the choice of using was not only an economic decision but was also influenced by social and demographic factors. In the first hurdle, the probit model was used 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 level of use. (Engel and Moffatt, 2014) specify the model as;

$$d_i^* = z_i'\alpha + \varepsilon_{1i} \text{ use } \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$y_i^* = x_i'\beta + \varepsilon_{2i} \text{ Extent to use } \ldots\ldots\ldots\ldots \quad (4)$$

Where $d_i^*$ and $y_i^*$ are latent variables describing the farmer's decision to use (dummy variable, 1=yes, and 0=no) and extent to use, $z_i'$ and $x_i'$ are vectors of observed covariant explaining farmer's decision and 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 as$\varepsilon_{1i}$; N ~ (0, 1), and $\varepsilon_{2i}$ ; N ~ $(0,\delta^2)$.

The integration of the two decisions results to the following estimation models;

$$\begin{cases} d_i = z_i'\alpha + \varepsilon_{1i}\, if\ d_i^* > 0, and = 0\ if\ otherwise \\ y_i = x_i^*\beta + \varepsilon_{2i} if\ y_i^* > 0, and = 0\ if\ otherwise \end{cases} \ldots.(5)$$

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

$$L(\alpha, \beta, \delta^2 = \prod\nolimits_0 \left[1 - \varphi(z_i'\alpha)\varphi\left(\frac{x_i'\beta}{\sigma}\right)\right] \times \prod\nolimits_1 \left[\varphi(z_i'\alpha)\sigma^{-1}\emptyset\left(\frac{y_i - x_i'\beta}{\sigma}\right)\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

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

$$E(y_i \mid y_i > 0) = \emptyset\left(\frac{x_i''\beta}{\sigma_i}\right)^{-1} \int_0^\infty \left[\frac{y_i}{\sigma_i\sqrt{1+\theta^2 y_i^2}}\emptyset\frac{T(\emptyset y_i - x_i'\beta)}{\sigma_i}\right] dy_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

The empirical for farmer's decision to use the storage system was estimated by the probit model as follow;

$$Use\ (yes/no) = \alpha_0 + \alpha_1 age + \alpha_2 sex + \alpha_3 edu + \alpha_4 hhsiz + \alpha_5 marst + \alpha_6 farmsiz + \alpha_7 atraining + \alpha_8 acredit + \alpha_9 aextension + \alpha_{10} grpmemb + \alpha_{11} on\_farm + \alpha_{12} off\_farm + \varepsilon_{1i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

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

$$astored = \alpha_0 + \alpha_1 age + \alpha_2 sex + \alpha_3 edu + \alpha_4 hhsiz + \alpha_5 marst + \alpha_6 farmsiz + \alpha_7 atraining + \alpha_8 acredit + \alpha_9 aextension + \alpha_{10} grpmemb + \alpha_{11} on\_farminc + \alpha_{12} off\_farminc + \varepsilon_{2i} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

## 4. Result and Discussion

### 4.1 Descriptive Statistics

In terms of age, the mean number of years for potential users of the storage system was found to be 45.99 years, and the mean for those who were not willing to use the storage system was 43.88 years. The youngest potential user was found to be 20 years old, and the oldest was 79 years old, but those who were not willing to adopt were 22 years old for the youngest farmer and 91 years old for the oldest. Overall, the mean age was 45.38 years, the youngest farmer was 20 years old, and the oldest was 91 years old. The mean age of the respondents gives the impression that the majority of the smallholder farmers were in the active age group; this can have an impact on the uptake of storage systems.

The mean of the household size was found to be 4.27 members for those who were not willing to adopt and 4.77 members for those who were willing to use. Overall, the mean was 4.63 members which is slightly above the Tanzania's national mean of 4.3 members per household (NBS, 2022). The smallest household size had 1 member and the highest had 13 members. Further, the results indicate that those who were willing to use had a larger household size compared to potential non-users. Deressa et al. (2008) argue that large family sizes are typically linked to larger labour endowments, allowing a household to carry out a variety of agricultural duties.

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 indicated by a mean of 3.36 acres. This finding supports Manandhar et al. (2018), who found that smallholder farmers with a greater land holding were better able to use modern storage technology than those with smaller farms.

The potential users were found to have a mean of 2978.57 rice quantities harvested with a minimum of 200 rice quantity harvested and a maximum of 9000 rice quantity harvested as shown in Table 1. The potential non-users had a mean of 2035 rice quantity harvested with a minimum of 400 rice quantity harvested and a maximum of 5400 rice quantity harvested. Overall, the mean was 1.48 with a minimum of 200 rice quantities harvested and maximum of 9000 rice quantity harvested.

**Table 1:** Summary statistics of socio-economic characteristics for continuous

| | | 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 |
| | | reharvested | 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 |
| | | reharvested | 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 |
| | | reharvested | 267 | 2709.9 | 1569.55 | 200 | 9000 |

Regarding to gender, results indicate that 64.4% were males and 35.6 were females. In term of the use of storage systems, male users were 70% while females were 30%. This implies that males use more storage systems than females. This indicates that men are predominately 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 indicated in Table 2. The large size of the potential users was married compared to that of the potential non-users. The majority of smallholder farmers marry at early ages and bring up children who later provide needed farm labour that is expected to strengthen the decision-making process in agricultural activities (Conteh et al., 2015).

**Table 2:** Gender and marital status

| Variable | Description | Users (N=70.8%) | Non-users (N=29.2) | χ2 | p value |
|---|---|---|---|---|---|
| Gender | Male | 70 | 51 | 8.297 | 0.004** |
| | Female | 30 | 49 | | |
| Marital status | Married | 82 | 55 | 22.446 | 0.000** |
| | Divorced | 5 | 10 | | |
| | Single | 7 | 26 | | |
| | Widowed | 6 | 9 | | |

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

### 4.2 Empirical Results

**Smallholder rice farmers decision to use storage systems**

The analysis of factors influencing the decision to use the storage system and its intensity in quantity of rice stored was estimated by using a double-hurdle model regression. However, before running the final regression analysis, all preliminary tests were made. Results 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 presented in Table 3. The likelihood ratio test indicates that the overall goodness of fit of the double hurdle model is statistically significant at 1% significance level. This indicates that those explanatory variables jointly explained the probability of using the storage system. The double-hurdle model was fitted with 12 explanatory variables as presented in Table 3. The first stage model results show 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. The second hurdle result confirmed 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.

The first hurdle (Probit Model) indicates that male-headed households significantly influence the 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 male-headed households are more likely to decide to use storage facilities compared to their female counterparts. This is findings are concurrent with the study by Benimana et al. (2021), who found that the sex of the household head 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 adopt hermetic storage technologies hermetic storage technologies than female headed households. However, it contradicts the study by Gitonga et al. (2015), who found that the sex of the household head had no significant effect on the use of the storage system.

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 is implied by the idea that the larger the family size, the more "own farm" labour is available to use the storage system. A rice storage system requires substantial labour, and so the farmer's decision to use the storage system may be influenced by the availability of family labour, proxied by household size. Construction of improved storage structures often requires intensive labour, and family labour is a major source of on-farm labour in developing countries. In most developing countries in the past, the people residing in a village were more or less an extended family and therefore could assist each other with most of the activities. However, with the recent increase in rural-urban migration in many developing countries by those in search of better employment opportunities and an improved standard of living, many rural families have lost massive family members and village labour resources. This is also similar to other studies Madu et al. (2018); Mignouna et al. (2011), which found that household size had a significant and positive effect on the decision to use the storage system. According to 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. Access to training on proper storage of produce is crucial for smallholder farmers in minimizing post-harvest losses and maximizing the value of the crop. These findings are supported by results from Kassie et al. (2015), who highlighted the necessity of certain knowledge and skills offered during the training of post-harvest handling and storage training. Similarly, households with access to agricultural extension services were associated with a 15.7% increase in farmers' participation decision in using the storage system, holding all other factors constant. This could be attributed to the fact that agricultural extension services are important in guiding smallholder farmers on choosing and using appropriate storage systems for their produce, ultimately contributing to food security and improved household livelihoods. A study by Mbesa et al. (2024), shows that, training significantly improved farmers' Knowledge, attitude and practice scores, and resulted in higher adoption of hermetic storage technologies among those who received training versus those who did not.

Additionally, these agricultural extension services provide smallholder farmers with vital information on pest control, humidity, and temperature management, which are crucial in reducing post-harvest losses. This is similar to other studies that highlighted the importance of agricultural extension services in increasing knowledge and choice of storage (Akello et al., 2022; Maonga et al., 2013). 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 a crucial role in facilitating farmers' ability to purchase hermetic storage technologies, as these technologies are typically procured through cash payments rather than credit arrangements.

**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 rice 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 and 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 training are more likely to store their grains than those who did not have access to credit. This indicates that access to extension services increases the probability and extent of use of the storage system. This is also similar to other study by Debebe (2022), who found that extension support services were significantly reduce post-harvest losses among farmers, which in effect increases the quantity of harvested crops that can be stored successfully.

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 could be attributed to the fact that smallholder farmers with higher on-farm income are more able to invest in storage facilities and give an incentive to protect their produce from post-harvest losses. Thus, the increased income enables smallholder farmers to store their crops longer and sell when market prices are favourable, leading to greater use of storage systems. This finding is line with a study by Zacharia et al. (2024), who investigate that, households with higher farm income are more likely to adopt hermetic storage technologies and store greater quantities of maize. These results contradict with Wekesa et al. (2003) that a higher level of on-farm income has a negative influence on the adoption of technology and differences in farm income among farmers do not significantly influence the quantity of additional maize stored through the use of improved storage methods (Negede et al., 2023).

**Table 3:** 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 |

## 5. Conclusion and Recommendations

### 5.1 Conclusion

This study assessed the factors that influence the use of storage systems and their extent among the smallholder rice farmers in Kyela district, Tanzania. Findings from this study revealed that users of the storage system had higher on-farm income than non-users. They are also more educated, more participate in group membership, have more access to extension services, more access to credit, and more access to training than non-users. These results reveal the importance of storage systems among the smallholder farmers in reducing and or avoiding postharvest loss of their produce, including rice.

### 5.2 Recommendations

Based on the obtained findings, this study recommends that extension services and training should emphasise the importance of post-harvest management, showing the economic benefits of the storage system. Outreach programs through partnerships between government agencies, NGOs, and the private sector can ensure training and extension services are accessible even in remote areas. To promote widespread use of storage systems, more information about the operational effectiveness of applied storage systems and the financial benefits of those storage systems is required. Smallholder farmers needed training on how to use storage systems effectively because rice farming predominates in the research area.

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