Technological Advancement in Food Production and Management and its Implications on Food Security:

A Case Study of Rice and Maize Products in Tanzania

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Technological Advancement, Food Production and Management, Food Security, Rice, Maize, Tanzania.

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LIST OF ACRONYMS

CAPI	:	Computer Personal Assisted Interviews
FAO	:	Food and Agriculture Organization
FGT	:	Foster, Geer and Thor Becker
ICT	:	Information and Communications Technology
LSMS	:	Living Standard Measurement Integrated Survey
NBS	:	National Bureau of Statistics
PC	:	Personal Computer
PPS	:	Probability Proportion to Size
SSR	:	Self Sufficient Ratio
TAM	:	Technology Acceptance Model

TNBC	:	Tanzania National Business Council
URT	:	United Republic of Tanzania
UTAUT	:	Unified Theory of Acceptance and Use of Technology
WFP	:	World Food Pogramme

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ABSTRACT

The study intended to analyse the impact of technology adoption in the production and management of staple foods, particularly maize, and rice, and its corresponding implications on food security, as well as post-harvest losses. The study was motivated by the premise that, although most literature explores the importance of adopting technology on post-harvest losses, few studies have examined how technology adoption through the entire production and storage chain (a range of technologies in each stage), and its impacts on food security and post-harvest loss. Food security was computed using FAO's Food Security Index, with slight modifications to improve contextual relevancy. The technology adoption index was computed by considering the proportion of technologies adopted by a farmer, compared to the theoretically plausible number of technologies required. Post-harvest loss was measured using a binary response variable, whether a farmer had experienced post-harvest losses or not. The study employed an inverse probability weighting regression approach to estimate the impact of the technological adoption of food security.

Among others, the findings showed that adoption of technology is low for rice producers and relatively higher for maize farmers. Further, the findings confirm that technological adoption in production increases farm productivity and it has a desirable impact on food security. However, the adoption of technology during storage is not significant in impacting food security and post-harvest losses. This may be justifiable given that, in the study areas, nearly all farmers who store their products use the central collection points, which seem not to have modern facilities for food storage. Equally, food insecurity status is slightly higher in rice farming households as compared to maize farming households. Furthermore, through key informants and success stories, the study was able to reveal that most farmers sell their produce soon after harvest, hence it does not matter how storage is carried out.

Based on the findings of this study, the following recommendations are found to be plausible. First, continued efforts advocating for modern methods of agricultural production increases not only food productivity but also the chances of being food secure. Secondly, the study recommends intervention in the centralized storage points owned by both individuals and the government, to ensure that the warehouses are in good enough condition to guarantee the security and quality of stored crops. This will subsequently reduce crop losses due to rotting, insects and mosses, and theft.

1. BACKGROUND TO THE RESEARCH PROBLEM

Ending hunger and poverty, as well as achieving food security, have been long acknowledged as global concerns towards the realization of people's well-being, improved living standards, and healthier life. This is well documented in the first, and second goals of the 2030 Agenda for Sustainable Development, (United Nations, 2015), as well as in the 2063 Agenda, "The Africa We Want", (African Union Commission, 2015). It is, for instance, envisioned that by the year 2063, Africa should have adopted modern farming systems in order to increase production and improve productivity, accordingly, addressing issues related to hunger and food security, (African Union Commission, 2015).

In The United Republic of Tanzania, such global agendas are reflected in the Tanzania Development Vision (URT, 1999), and in the National Five-Year Development Plans, (URT, 2016b, 2021). Food supply and availability according to the United Nations, (2019) reflects the "supply side of food security" and is determined by, among others, available food stocks, production capacity, and net trade.

In complying with both national and international agendas, the United Republic of Tanzania has been setting out programs and priorities to improve farm produce and productivity. Among others, the KILIMO KWANZA[1] initiative was introduced, primarily to address ten key areas, including the integration of science and technology in supporting agricultural transformation and improving productivity, (TNBC, 2009). Evidence shows that such initiatives have, to some extent, been crucial in improving food self-sufficiency.

For instance, the Comprehensive Food Security and Nutrition Assessment Report documents the national average food Self Sufficient Ratio (SSR) of over 100 for the time periods 2012/2013 to 2015/2016, (URT, 2017b). However, despite the national food SSR being consistently over 100, disaggregate level data show variations in food production, hence food deficit at regional, district and household levels. Among others, Cotula *et al.*, (2006) & URT, (2017a, 2019b, 2019a), identify the reasons for such low productivity, including but not limited to, inadequate agricultural inputs, low technology and lack of relevant skills in using modern farming technologies, particularly for the rural poor.

Citing specific documentation on maize and rice production in Tanzania, evidence shows that the government has identified the rice and maize subsectors as strategic and priority crops for agricultural development in the country. The crops are being spotted as essential in dictating the incomes and welfare of farming communities, particularly rural households. Furthermore, they are regarded as potential crops for improving households' food security. Owing to the utility and importance of maize and rice farming in the country, the government realizes the intimate need for the transformation of maize and rice from subsistence farming to commercial and modern farming, through the

[1] A Tanzania's Green Revolution to transform its agriculture into a modern and commercial sector.

advancement of crop production technologies, food management technologies, and developing agricultural infrastructure that supports crop production and farming.

On the other hand, like other developing countries, studies show that farmers in Tanzania have been prone not only to low agricultural yields but also to pre- and post-harvest losses. Evidence, as documented among others in the Postharvest Management Strategy of The United Republic of Tanzania, shows that a significant proportion of the harvest does not reach the final consumers, and is lost at different stages of the agricultural value chain, (URT, 2019a). Else, (URT, 2019b), reports that these losses have been leading to depleting food stocks, economic loss and food insecurity. Impliedly, low yields and food loss are not only linked to nutritional deficiencies, but also impact producers through low economic gains.

However, despite the relevance of using modern farming technologies in managing and improving the quality and quantity of agricultural produce being immensely documented in the empirical literature, the discussion over the extent to which it impacts food security has been inconclusive. It is against this background the authors find the relevance of this study.

2. STATEMENT OF THE PROBLEM AND INITIAL RESEARCH QUESTIONS

The Comprehensive Food Security and Nutrition Assessment Report documents that maize and rice are among the major food crops in Tanzania and the main source of such crops (over 95 percent) is from own production, (URT, 2017b). Crops are among the major source of calories, income, and well-being, (Amaza & Abass, 2016; Ndunguru et al., 1998; Sewando, 2012). The government identifies rice and maize as priority crops, particularly in ending hunger and achieving food security, (URT, 2014, 2016a, 2017a). For that reason, it has been promoting technological adoption and best practices in agro-processing and postharvest management, in order to reduce food losses and increase productivity and food self-sufficiency, (URT, 2019b).

However, notwithstanding such initiatives, the disaggregate estimates show that the country still faces substantial low harvests, (NBS, 2012, 2016b, 2016a; URT, 2017b). Even with such low harvests, there still exist unmanageable postharvest losses (URT, 2019a), such that a substantial amount of farm produce is lost at different stages of the agricultural value chain, (Mutungi & Affognon, 2013). The losses have been a root cause of food poverty in most households, consequently leading to nutritional deficiencies, (URT, 2019a).

For instance, despite advocating the adoption of technologies in food production and management of the harvests, URT, (2019c) and WFP, (2021) report that one in ten Tanzanians live below the food poverty line (they are food insecure), and at least one third of children are chronically malnourished. As a way of containing the problem, the Government of Tanzania, among other key players and stakeholders, recognized the importance of improving agricultural productivity, particularly maize, and rice, which are the country's strategic and priority crops.

The government is committed to addressing technological challenges in the production and management of maize and rice. These include, but are not limited to, the availability of machinery for farming, irrigation, harvesting and winnowing, improved seeds and fertilizers, (URT, 2017, 2019). However, despite the intimate need of the government to address these challenges, the impacts of technological advancement in food production and management and its implications on food security in Tanzania, are less documented in the empirical literature. This calls for the need and confirms the relevance of the current study, among others, to help the concerned parties make informed decisions.

3. OBJECTIVE OF THE STUDY

The general objective of this study was to examine the influence of technological adoption in food production and management and its corresponding impact on household food security. Specifically, the study aimed to:

i. Determine the extent to which the adoption of technology improves the production and management of rice and maize.
ii. Estimate the effect of technological adoption in maize and rice production on food security.
iii. Estimate the effect of technological adoption in the management of maize and rice on food security.
iv. Ascertain the impact of technology adoption in the agricultural value chain of maize and rice on household productivity, food security, and post-harvest losses.

4. **LITERATURE REVIEW**

4.1 Theoretical Literature

4.1.1 Diffusion Innovation Theory

Diffusion innovation theory fits in addressing the current study. Advocated by Rodgers (1995), the theory postulates that the decision of a person to adopt new technology is essentially determined by four major elements: innovation, communication, the time at which the message/idea is shared, and existing social systems, (Bilali *et al.,* 2021; Taherdoost, 2018). In the perspective of the current study, the theory offers grounds for maize and rice farmers, at either household or community level, to accept innovations and new ideas in farming, notably new technologies such as the use of improved agricultural inputs and equipment. The decision of adopting may categorically be guided by the time at which it is introduced and existing social systems. Further, the channels from which information is shared with farmers may also impact farmers' technological adoption decisions.

4.1.2 Technology Acceptance Model (TAM)

Advocated by Davis (1989), TAM rests its assumption on the usefulness and easiness of using a particular technology as the main determinant for one to either adopt or reject technological adoption (Lai, 2017; Sahin, 2006). Reflecting the theory in the context of the current study, farmers' decisions to adopt modern farming technologies may be influenced by the efficacy of such technology, for instance in increasing farm products, hence productivity. On the other hand, ease of use may impact their decisions in situations such as having technical know-how (relevant skills) in using such technology. The model has been extensively applied in the literature to model technological adoption decisions. For instance, (Silva et al., 2017), found that perceived usefulness has a positive influence on farmers' attitudes and behavioural intentions regarding the intention of bean farming households in Brazil, to adopt and use Integrated Production.

4.1.3 Unified Theory of Acceptance and Use of Technology (UTAUT)

The theory was postulated by Venkatesh back in 2003, by combining eight theories that were previously postulated to explain adoption behaviours. The advocate of UTAUT proposes four main constructs that are critical in dictating technological adoption. Further, the theory suggests other predictors and observable variables that may have an influence on one's adoption decision. They include age, sex, the voluntariness of use and experience, (Lai, 2017; Taherdoost, 2018).

Theoretical underpinnings, as UTAUT pustulates, are in line with the current study, in that it may impact farmers' decisions to adopt a certain technology. For instance, with reference to facilitating conditions as one of the components, it is evident that existing infrastructure, organizational policies, and regulations, may impact farmers' technological adoption decisions. If such conditions are not supportive, farmers may choose not to adopt. Equally, some other exogenous variables determined in the model, such as the age of a farmer, gender, and years of experience in farming, may also impact technological adoption options, (Sahin, 2006).

4.2 Empirical Literature

Several studies have examined the linkage between technology adoption and household welfare indicators, and findings have shown that technological adoption increases food security. For instance, (Sinyolo, 2020), using the Tobit Regression Model, evidence that technological adoption, particularly the adoption of improved seeds in farming, improves maize productivity. Further, this positively impacts household food expenditure, and consequently, food security. Further, the author shows that females are more likely to adopt improved agricultural technologies, as compared to their male counterparts. Similarly, (Sinyolo, 2020), uses the multivariate probit to model technology adoption choices and an ordered probit model to examine the impact of modern agricultural inputs and labour-intensive technologies, on implication to household food security. Among others, study findings showed that the probability of being food and nutrition secure increases with an increase in the number of adopted technologies. Further, the study confirms that households (farmers) who had a choice of using improved seeds in production, were not only less likely to experience scarcity of food during the summer, but also the number of months they had to stay without food in a year was significantly reduced.

Furthermore, Muhaimin et al., (2020), examine the nexus between technological adoption in agriculture, income, and food security. Using the probit model and the propensity score matching technique, the author finds that age impacts technological adoption decisions positively when the farmer is young, and negatively when the farmer is older. On the other hand, household size and the number of dependents in the household did not have any significant impact on farmers' decisions to adopt new technologies. Further, evidence shows that technological adoption positively impacts the income of cassava farming households. Nevertheless, the study did not find a significant difference in household food security among adopters and non-adopters. This is in line with a study by Obisesan, (2015), on the effects of off-farm activity and technology adoption on food security in Nigeria. Among others, the author found participation in off-farm activities positively impacting the level of technological adoption. Equally, adopters with off-farm activities had a lower food insecurity index than adopters without off-farm activities.

Moreover, Pan *et al*., (2018), analyse agricultural extension and technology adoption for food security in Uganda using a regression discontinuity approach. The findings showed that households residing in eligible villages are likely to use improved agricultural inputs that are relatively less costly than their counterparts. Correspondingly, the use of improved agricultural technology results is observed to improve food security. Else, Ejemeyovwi et al., (2021), use a logit model in examining the influence of ICT utilization in agriculture on food security. Among others, the study reveals a positive and significant relationship between ICT and food security in male-headed households, and an inverse and statistically insignificant relationship between ICT and food security in female-headed households, which is, nevertheless, insignificant. Further, the study revealed that agricultural productivity, labour wage, labour hours, educational qualification and age were also significant in explaining household food security.

Ngongi & Urassa, (2014), investigate farm households' food production and household food security status in Kahama District, Tanzania. Using primary data collected from 150 farm households, the study depicts the determinants of food production and supply in Kahama District, along with food insecurity coping strategies. The author used food consumption tables and recommended dietary energy intake to determine the dietary energy consumption per adult equivalent. The study used multiple linear regression to quantify the magnitude to which the predictor variables impact food production and supply, and a binary logistic regression model to unveil the predictors of food security. Among others, the study found annual income, amount of maize, number of plots owned, amount of paddy, number of cattle owned and the gender of the head of the household to be significant predictors of food production and supply in Kahama. Correspondingly, the use of fertilizers, the amount spent on food items, relying on less preferred foods, borrowing food from relatives, and purchasing food on credit, were significant predictors of household food security status.

Emiliano & Vigani, (2015), studies technological adoption and multiple dimensions of food security in Tanzania. Specifically, the study presents the causal effects of agricultural technologies, notably the use of improved seeds and inorganic fertilizer in maize production, on the four dimensions of food security: food availability, food access, food utilization and food stability. The study uses wave two datasets of the 2011/2012 National Panel Survey, sourced from the National Bureau of Statistics and matching techniques in establishing causality among the variables under study. The study found justifiable evidence of the probability of a household adopting new technologies in production. It was evident that a household’s technological adoption increases with an increase in the education level of the head of the household, the size of the planted area and the involvement in participation in extension services. On the contrary, an increase in the distance from the farm to the main road was observed to impact technological adoption negatively.

Further, the study findings as documented by Emiliano & Vigani, (2015), show that technological adoption impacts household food security. The author shows that the use of improved seeds in production positively impacts food availability and access. Amidst all, the study measured food utilization in terms of dietary intake and found the use of both improved seeds and inorganic fertilizer in maize production has a positive influence on household food utilization. Additionally, the study findings revealed that technological adopters, particularly those using improved seeds in production, had low dependence on staple foods. Impliedly, the use of improved seeds lessens the likelihood of a household depending on staple foods. Furthermore, a household's food stability was determined in terms of vulnerability and resilience to food security. Evidence from the literature shows that the application of inorganic fertilizers in maize production improves a household's resilience to food security, while on the opposing end, the use of inorganic fertilizer lowers vulnerability to food insecurity.

4.3 Research Gap

Empirical evidence, as documented in vast social-economic research, depicts the importance of adopting technology in the production and management of food crops and how it impacts food security. Nevertheless, a significant number of studies primarily focuses on technology applied a particular stage on agricultural value chain, for instance, adaptation of improved maize, new machinery, or irrigation techniques in farming. Essentially, this neglects the fact that the agricultural value chain is an integrated wholly process. That being noted, it is evident that studies documenting the impact of technology adoption (at each stage of the agricultural value chain) on the production, management, and productivity of food crops (particularly maize and rice) in Tanzania, and its implications on post-harvest losses and households' food security, remain limited. As such, empirical evidence regarding the extent to which technology adoption is relevant in improving maize and rice production and its corresponding influence on improving food security and reduction of postharvest losses, is less documented in the literature and equably, inconclusive. Therefore, it's against knowledge gap this study finds quite important to investigate how technological adoption in agricultural value chain using a case of maize and rice as vital staple food products in Tanzania influence food security as well as crop-loss.

5. METHODOLOGY

5.1 Study Area, Sampling Methodology and Sample Size

The thematic treatment of this study covers maize and rice farming households as they are widely used food crops in the country. In reaching out to the intended study participants, the study employed a multi-stage sampling methodology. In the first sampling stage, the study selected two regions, which are the main producers of the maize and rice crops. In the second stage, one district from each of the selected regions was selected to constitute the study sample. Selection of a district from each region was done on merit basis. For maize, the study selected a district which is the main producer of maize, and so for rice. In the third round, villages were selected based on probability proportional to size. Lastly, systematic sampling was used to select a required number of households to be used as study units.

Based on the data from the National Sample Census of Agriculture 2019/2020 (NBS,2020), the regions which are the main producers of maize and rice are Ruvuma and Morogoro, respectively. Therefore, for maize, the study visited Ruvuma Region and for rice, Morogoro Region. In Morogoro, the study covered Kilombero District and used probability proportional to size (PPS) of rice farming households in the villages, to select villages for the survey and systematic sampling approach to obtain the ultimate sampling units, households within selected villages. In Ruvuma, the study covered Mbinga District and selected villages and households, using the same approach. For some of the villages, the list of farmers (sampling frame) of a particular crop was not available. In such situations, the study used the zigzag sample selection approach to ensure biasedness is not introduced in the sample selection.

Furthermore, since the sample selected at the district level was meant to be representative of the farmers of each crop, the optimum sample size was calculated using the Cochran approach[2]. In addition, since the population size was unknown, we used a formula that allows for the estimation of sample size with an unknown population. Specifically, sample calculation was done using the formula in (1).

$$n = \frac{\left(Z_{\frac{\alpha}{2}}\right)^2 \times p(1-p)}{e^2} \tag{1}$$

Where:

- n=sample size
- $z\alpha/_2$ is a critical value of the level of significance. For this study, it is taken as 1.96 (at 5% level of significance/confidence).

[2] For the review on sample size determination see for instance (Nanjundeswaraswamy & Divakar, 2021)

- p is the proportion of the population with the characteristic of interest, here we assumed 0.85 since the selected districts/councils have, considerably, the higher number of farmers of the said crop
- e is the level of precision. This is advisable to be as small as possible, however considering the nature of the study and the cost, 0.05 was used.

Plugging these values in the formula, a sample of 196 respondents for each crop was considered. Further, considering the non-response rate, the current study recruited 200 respondents from each district/council. As a result, the expected total sample size was 400 respondents. However, the sample size obtained during field visits was 399, with 1 non-response. For the case studies, success stories and key informants, a purposive sampling approach was used to recruit and obtain study participants.

5.2 Study Approach and Data Collection Instruments

The study used a cross-sectional design. To answer research objectives, the study employed a mixed-method research approach by combining both quantitative and qualitative research methods.

For the quantitative approach, a survey questionnaire was designed, covering all aspects of the study. The questionnaire was coded in Survey Solutions and programed into tablets for data collection. Computer Personal Assisted Interviews (CAPI) were used to administer household surveys. The quantitative research design was used to gather the information that aimed to answer the question of how technology adoption in different stages of food production improves food security and reduces post-harvest losses.

For qualitative data, success stories and key informant interviews were gathered. Data collected from key informant interviews was organized to produce further insights into how technological adoption improves food security and reduces postharvest losses in the community. Specifically, case study descriptions and success stories were used to support quantitative findings through triangulation.

5.3 Measurement of Variables

5.3.1 Technology Adoption

The study was interested in investigating how technology adoption at different stages of food production and management, impacts food security. As a result, a discussion of how technology adoption is measured at this stage is warranted.

Foremost, it is of paramount importance to note that the study examined the food production and management process in a stepwise approach, identifying every kind of technology that is usually adopted at a particular stage based on the literature and experience, (Hodges & Stathers, 2016). It is also important to note that technological adoption refers to the uptake/adoption of new, known modern agricultural tools and/or techniques in either production, management or both, typically referring to the level of usage, (Abu Bakar et al., 2020). Therefore, the adoption index was computed based on the application of technology during production, management, and the entire agricultural value chain, before entry into the market.

Henceforth, for the production process, fifteen stages were identified, of which every aspect is critical in the production process. Specifically, the production process was divided into levels, starting from farm and seed preparation to harvest techniques. Depending on the level of production, questions were designed to reflect the application of the technology at that stage, hence, the study classified a farmer at that stage as an adopter or non-adopter. The stages identified were; testing the fertility of the seeds, following scientific arrangement when planting the seeds, using modern/scientific techniques to clean the seeds before planting, use of machines or animals in farm preparation, use of modern seed types, use of fertilizers (both organic and inorganic), use of herbicides, use of pesticides, whether irrigation was applied to the crop, whether a farmer has ever left the farm fallow in the near past, whether a farmer has ever changed the crop in the farm in the near past, techniques used to thresh product during harvest and method used to clean products after threshing.

For the case of storage of food or rather food management, techniques considered as the best approach in preserving the products were identified and a farmer was classified as adopter or non-adopter if he/she had applied that technique. Specifically, management was considered from the point of harvesting afterward. Firstly, a farmer was asked if he/she considered the timing for harvest, whether he/she dried the products before harvesting, storage type, and whether he/she has done anything to prevent the crop from invading the store.

To obtain the adoption index for a particular stage, the proportion of technology adopters was computed (2).

$$AI_i = \frac{\sum \text{Adopted technologies}}{\sum \text{Potential technologies}} \tag{2}$$

Where AI is the Adoption Index and i represents the stage of technology adoption (production and storage). This approach uses equal weighting in the computing technology adoption index, on the basis that each stage of production/storage is important and ignoring one might have repercussions, even if others were well considered. For instance, if farm/seed preparation was not done properly, modern types of seeds will have little impact on the total production level.

Furthermore, the entire chain was considered by combining these two stages. As a result, three measures of technology adoption were used: adoption at the production stage, adoption at the storage stage and adoption of the entire chain. For each adoption index, farmers were classified as non-adopters (AI=0), lower adopters (0<AI<=0.33), medium adopters (0.33<AI<=0.66) and higher adopters (AI>0.66).

5.3.2 Food Security

Food security was measured using FAO's approach for computing the Food Security Index. The FAO Food Security Index is computed from a list of questions that captures the degree of household ability to access food, meal intake, subjective assessment of being insecure or secure, and others. For this study, eight (8) questions were asked (following the customization of FAO series of questions[3]), which helped to gauge the food security status of the household.

In addition, two more questions were asked to reflect the long-term food status in the household, and they were incorporated when computing food security index[4]. Food secure households were those with rare occurrences of conditions for food insecurity, including worry about not having enough food. Further, the current study categorized households that were food insecure into four groups, namely, mildly insecure, moderately insecure, insecure, and severely insecure. However, during the analysis, these categories were found to be invariant (very few observations for some of the categories), which limited the ability of analysis techniques, especially analytical models. Therefore, for analytical models, the food index was collapsed to have only two categories, which are insecure and secure. Further, it is worth noting that in the context of the current survey, severe food insecurity constituted those who used to borrow food or rely on help from a friend or relative, have no food of any kind in the household, and/or go a whole day and night without eating anything.

5.3.3 Analytical Methods

A propensity score matching approach was used to achieve the intended objectives. The propensity score matching approach is used in observational studies to control for pretreatment imbalances, in order to estimate the causal impact of the treatments or intervention (Cefalu & Buenaventura, 2017; Garrido et al., 2014; Jann, 1923; McCaffrey et al., 2013). The propensity score is the conditional probability of being in either the control or treated group. The propensity score is estimated using either logit or probit models and then used to match between treated and non-treated subjects in the study. Following proper matching, the outcome of interest is compared between the matched subjects. There are several approaches used in matching treated and non-treated subjects (Garrido et al., 2014).

[3] The customization done was, instead of asking a response to rank his/her household of insecure status for a particular question, the household was asked, for the past seven days, how many days did the household experience a particular condition. Then, we used the response to state the insecurity status of the respondent's household. The major reasoning for following this approach was to reduce bias due pessimism nature respondents tends to portray.

[4] The questionnaire is included as the appendix for further references.

However, one of the critical issues that always arises in the literature on the propensity score is a specification of the model for observable covariates. In case the model is incorrectly specified for either treatment or outcome, the estimation of treatment effect becomes biased. To counterattack this weakness, the study used inverse probability weighting regression adjustment to estimate the impact of treatment. The approaches allow for control of estimation bias in both treatment and outcome models, since it only requires that one model is specified correctly (Manda et al., 2018; McCaffrey et al., 2013).

In the estimation of the probability of being treated based on observable covariates, the study employed a probit model. Although there is a very small distinction between the results of estimation between the probit and logit model for dichotomous variables, we find the probit model appropriate as no causal interpretation is associated with the estimation of the propensity score, which might be affected by the violation of normality assumption. Therefore, we estimate the probability of being treated (adopting technology) using a set of covariates. The estimation model is given in (3).

$$p(T) = P(T = 1|X) = F(h|X) = E(T = 1|X) \tag{3}$$

Where:

X is a vector of pretreatment observable characteristics and $F(.)$ is a cumulative distribution function of the probability of being treated. For all the treatment models, we used a set of covariates that predicts a likelihood of a household adopting technology, regardless of the revealed status quo.

A propensity score of technological adoption was calculated based on observable characteristics of the households. A propensity score was used to classify likely groups into treated and control groups. The food security outcomes of these two groups were compared to examine any significant differences due to technological adoption. To further curtail the possibility of having self-selection to technological adoption by households, in the estimation of the propensity score, variables that are likely to affect the uptake of technology, but not food security were included.

Furthermore, the estimated probabilities of being treated p_i were used to calculate the inverse probability of treatment and weights, which were then used to estimate the causal effects of being treated. To estimate the impact of technology adoption on food security, the study employed the Inverse probability weighting regression adjustment model. As argued earlier in this section, this model is technically referred to as doubly robust, as it controls for specification bias in both treatment and outcome models, if at least one model is specified correctly. Based on the IPWA model, the causal effect of the treatment (ATT) was estimated in two stages, (Manda *et al*., 2018). The first stage was regression adjustment, and the second stage was the weighting regression equation. Hence, the IPWA estimator was given by equation (4).

$$ATT_{IPWA} = (n_a)^{-1}\left(\sum_{i=1}^{n} T^i[r^A(X, \delta_A) - r^N(X, \delta_N)]\right) \quad (4)$$

Where n_A is the number of treated and matched samples, T represents treatment, A and N represent treated and non-treated individuals, respectively. Both δ_A and δ_N are obtained from a weighting regression procedure. Diagnostic tests were carried out to ensure that both conditional independence and overlapping assumptions of the IPWA model were not violated.

5.3.4 Triangulation

To support the findings of the impact evaluation model, we triangulated qualitative information from case studies and success stories, with quantitative results. The themes that support or refute quantitative findings, as well as observations, were examined from recordings of success stories and digital information, like pictures to support the findings.

6. RESULTS AND DISCUSSIONS

6.1 Demographic and Housing Characteristics

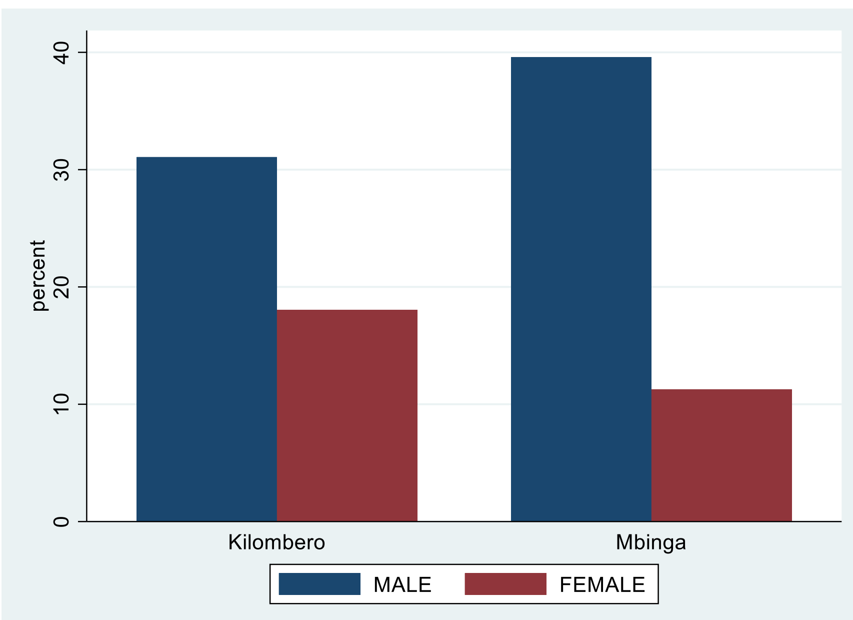
Table 1 presents the demographic and housing characteristics of the study respondents. As depicted, respondents were aged between 21 and 80 years of age, with their age averaging at 44 years implying that a significant number of farmers are middle-aged. Household size averaged 5 persons, with a minimum and a maximum number of household members found to be 1 and 15, respectively.

Table 1:General characteristics of Respondents

Description	N	Mean	Median	SD	Min	Max
Age of the respondent	398	43.85	42.50	12.61	21	80
Household size	398	5	5.00	2.05	1	15

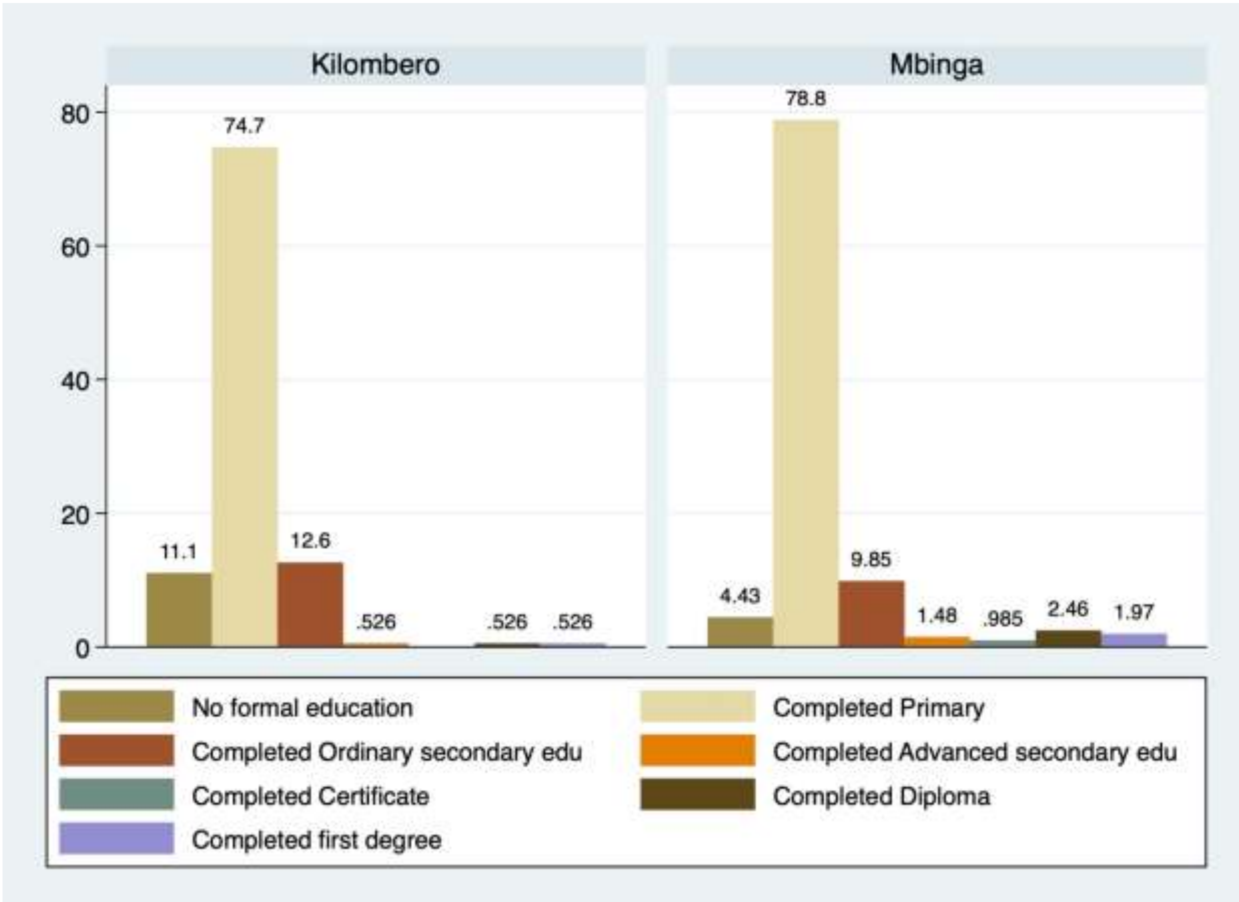
The study findings further revealed that most of the survey respondents were males (Figure 1). It is depicted that the percentage of male respondents outweighed their female counterparts in each district.

Figure 1: Distribution of Respondents by District and Sex



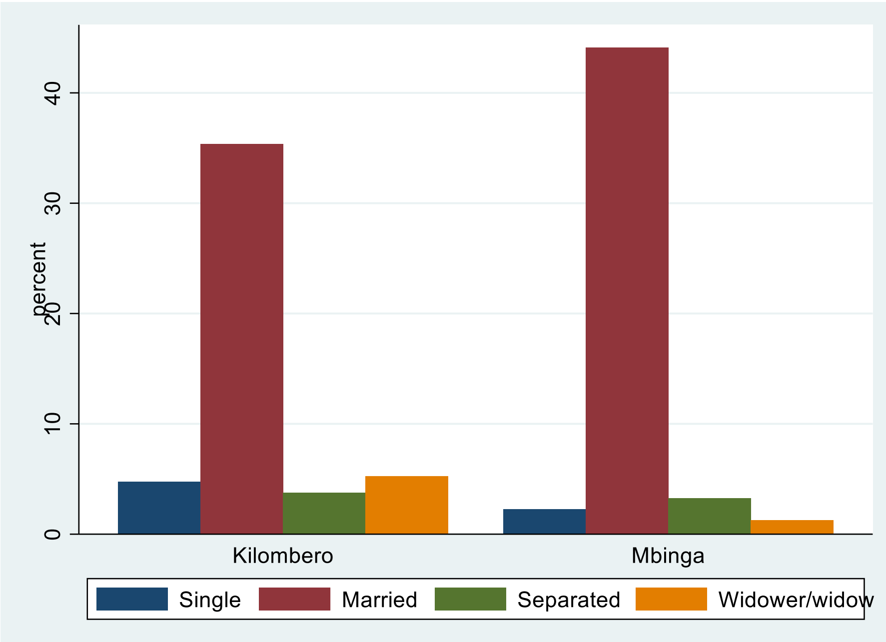
Analysis of the study respondents by education level showed that most of the farmers had completed primary education (**Error! Reference source not found.**). This was followed by individuals who had either completed secondary education or had no formal education. As evidenced, representation of the rest of the categories was minimal.

Figure 2: Respondent distribution by Education level and District.



Error! Reference source not found. presents the marital status of the study respondents. As depicted, a large proportion of the study respondents were married. The proportion of married couples was higher in both districts. The rest of the categories had fewer representations.

Figure 3: Marital Status of respondents by District



6.2 Production and Farm Characteristics

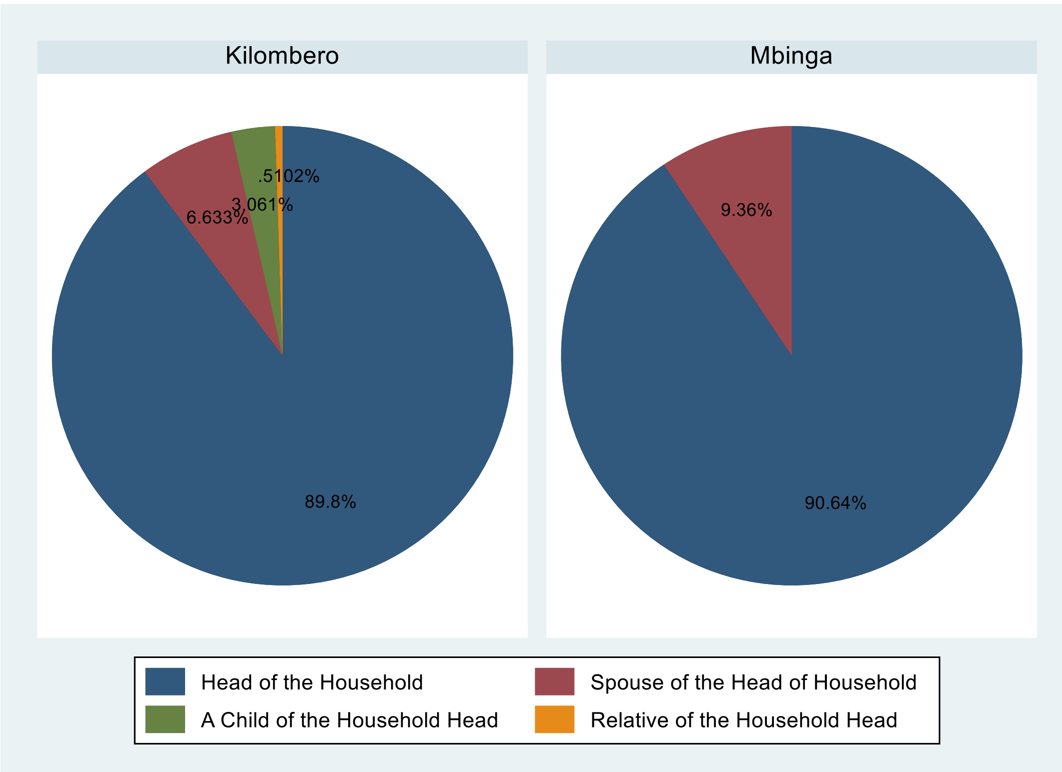
Statistics on production and farm characteristics of the areas surveyed are presented in *Table 2*. For rice producers, the overall size of the plots averaged 3.6 ha. The size of the farm cultivated was, however, close to the available farm size. On average, farmers harvested around 7049.99 kg. However, the median value (2,400 kg) implies that half of the surveyed population harvested up to 2400 kg. The maximum harvest for maize crops sums up to 260,000 kilograms. In terms of the monetary value of the harvests, evidence shows that some farmers earned up to TZS91,000,000. However, we find further evidence that at least half of the surveyed population earned as little as TSH. 750,000.

Table 2: Farm characteristics and harvests

Description	N	Mean	Median	SD	Min	Max
Farm size	399	3.63	2.0	5.5	.5	80
Cultivated portion of the farm	399	3.34	2.0	5.4	0	80
Total harvest in Kg	399	7049.99	2400.0	22219.9	0	260000
Total value of the harvest (TZS)	398	1794377.90	750000.0	5377921.4	0	91000000

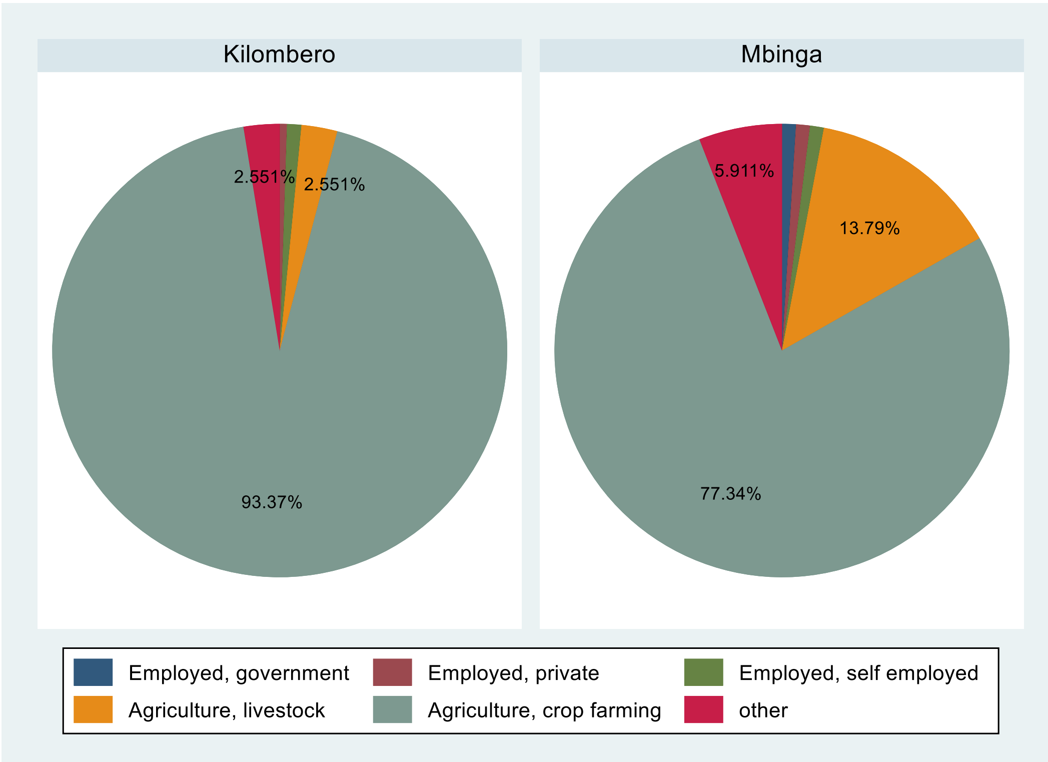
Further, the survey collected information on the person responsible for managing/making the final decision regarding farming activities at the household level (**Error! Reference source not found.**). Except for Mbinga District where such activities were distributed between the head of household (90.64 percent) and spouse (9.36 percent), the scenario was different in Kilombero (rice producers). 0.5 percent of the study respondents reported that relatives of the head of household do make decisions over farming activities, and 3.06 percent reposted that children are the ones responsible for making such decisions. Nevertheless, the findings showed that heads of households still dominate decision-making on farming activities, as 89.8 percent of the respondents agreed to the same.

Figure 4: Farming activities responsibilities in the household.



On the other hand, the survey collected information on the employment status of the study respondents. For rice growers (Kilombero), a large proportion of the study respondents (93.37 percent) were employed in agriculture, predominantly being involved in crop farming. Likewise, 77.34 percent of maize growers (Mbiga) were employed in agriculture, specifically doing crop farming. About 13.79 percent were also in agriculture, but they were mainly involved in the rearing of domestic animals. Further details are depicted (**Error! Reference source not found.**).

Figure 5:Respondent main occupation over the last 12 months.



6.3 Households Food Consumption and Food Security

6.3.1 Food Consumption

The survey collected information regarding food consumption at different reference periods for adults and children (Table 3). Overall, the findings showed that half of the study respondents reported consuming at least three meals per day. However, some households reported having no access to food during the reference period, and some others had up to five meals.

Regarding food consumption expenditure, the reported median food consumption was TZS 35,000.00, implying that in the past week, half of the study population spent up to TZS 35,000.00 on food. However, it was on the other hand evidenced that, some households did not make expenditure on food, while others spent up to TZS 440,000 in the same reference period. Considering non-food consumption, the reported average and median consumption were TZS 18,080.23 and TZS 10,000.00, respectively. Owing to the fact some households did not spend on non-food items, the median becomes the best statistic considered over average consumption. The value of median consumption on non-food items implies that half of the surveyed population spent up to TZS 10,000.00 on non-food items per week.

Table 3: Food and Non-Food Consumption and Expenditure

Description	N	Mean	Median	SD	Min	Max
Average meals of adult per day for the past 7 days	399	2.57	3.00	.56	1	4
Average meals of children per day for the past 7 days	391	2.38	3.00	1.10	0	5
Average meals of adults per day for the past 12 months	398	2.55	3.00	.58	0	4
Average meals of children per day for the past 12 months	392	2.39	3.00	1.09	0	5
Total food consumption for the past week	397	39414.11	35000.00	32637.36	0	440000
Total non-food consumption for the past 12 months	397	18080.23	10000.00	23404.68	0	300000

6.3.2 Food Security.

This subsection presents descriptive statistics regarding food security indicators. Respondents were asked some questions primarily meant to capture their food security status. Using reference periods of either "past week" or "last seven days", respondents were asked to report the number of days that they have gone without having access to some indicators. Study findings depict that some household members had to rely on less preferred food, limit the variety of foods eaten, reduce the number of meals eaten in a day, restrict consumption by adults for small children to eat, and go a whole day and night without eating anything at least once in a week. As depicted, the maximum number of days reported in different scenarios was seven (7), implying that some households were not able to meet food requirements throughout the week.

Correspondingly, it is also worth noting that, none of the households had to limit portion sizes at mealtimes, borrow food, rely on help from a friend or relative, or have no food of any kind in their household. Considering the averages, the findings revealed some households to have gone for at least two days in a week relying on less preferred foods, limiting portion size at mealtimes, reducing the number of meals eaten in a day, and restricting consumption by adults for small children to eat.

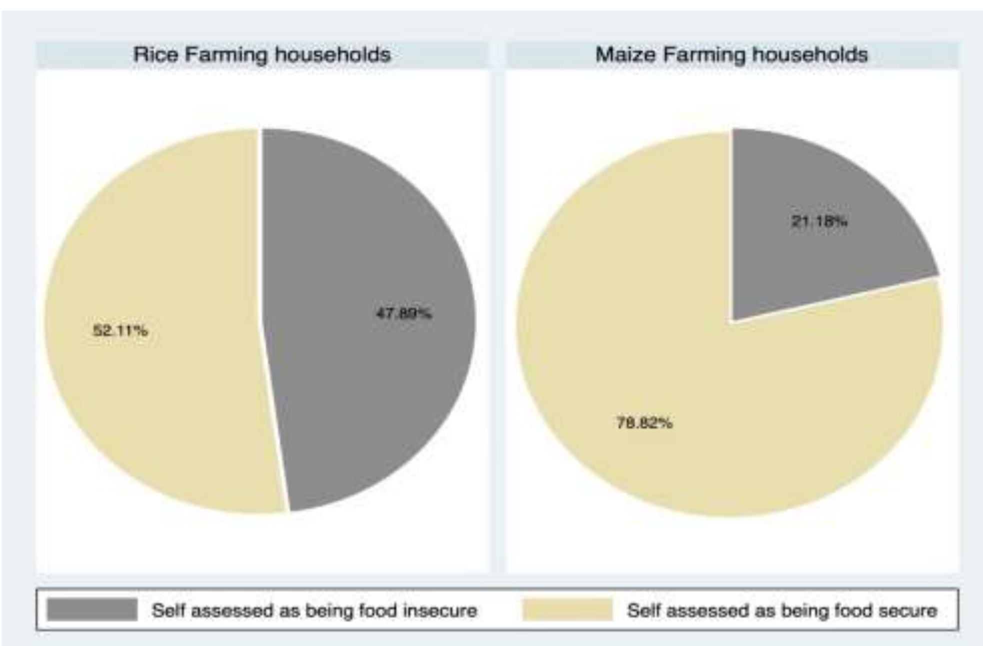
Table 4: Summary statistics of food security Indicators

Variable	Obs	Mean	Std. Dev.	Min	Max
Rely on less preferred foods	399	2.088	1.490	1	7
Limit the variety of foods eaten	399	1.822	1.319	1	7
Limit portion size at mealtimes	398	2.015	1.405	0	7
Reduce number of meals eaten in a day	399	1.872	1.226	1	7
Restrict consumption by adults for small children to eat	397	1.589	1.193	1	7
Borrow food, or rely on help from a friend or relative	397	1.244	0.646	0	5
Have no food of any kind in your household	398	1.239	0.772	0	7
Go a whole day and night without eating anything	398	1.158	0.538	1	6

6.3.3 Household's Food Insecurity Self-Assessment

During fieldwork, study respondents were asked to rate how they perceive their food security status. The study indented to know how the study respondents perceive food security from their own experience. As shown in (**Error! Reference source not found.**), 47.48 percent of rice growers (Kilombero district) and 21.18 percent of maize producers (Mbinga district), perceived themselves as being food insecure. Among others, their perception of being food insecure rests on the grounds of not being able to meet minimum dietary requirements that qualify them to be food secure.

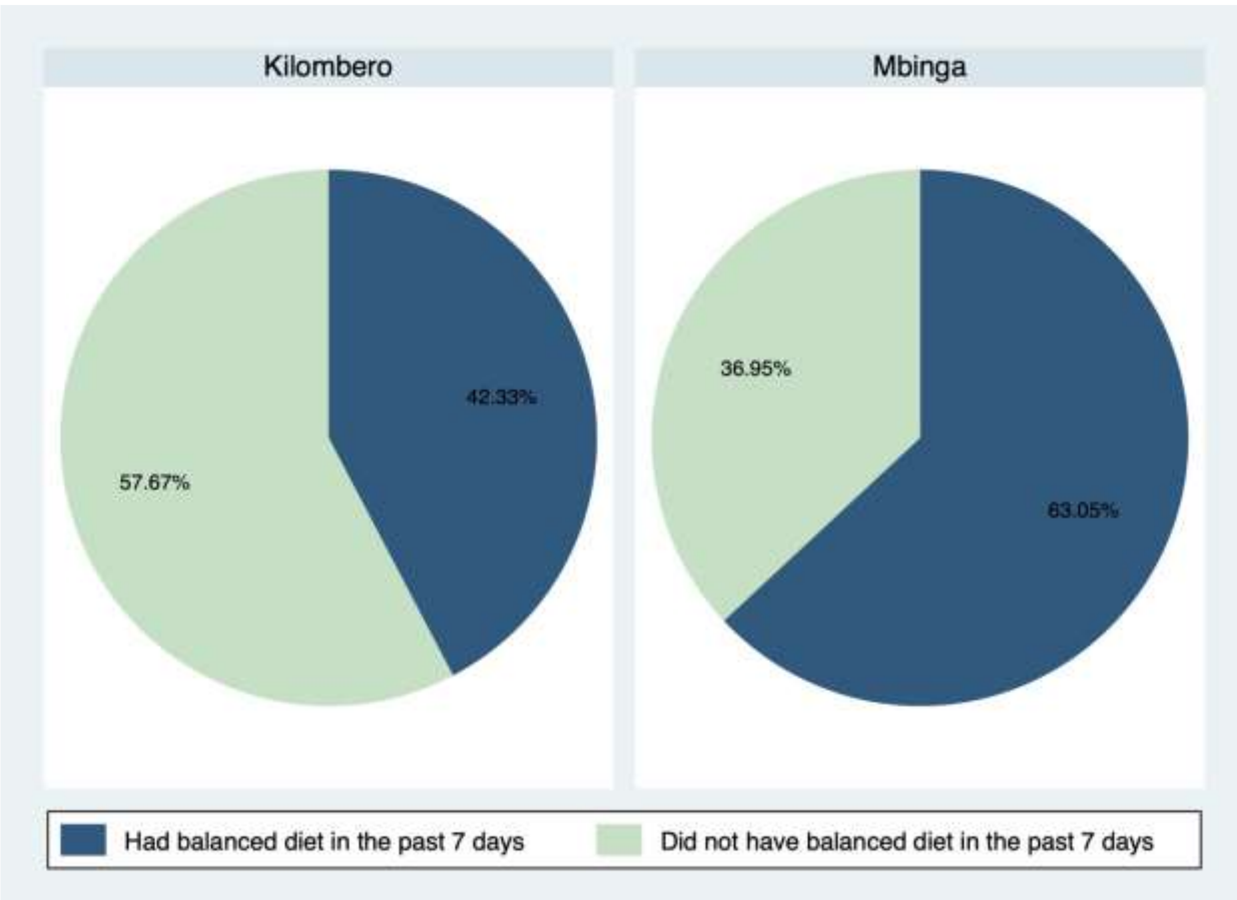
Figure 6: Respondents opinion on food insecurity in the household.



6.3.4 Households' Access to a Balanced Diet

Respondents were asked to report on whether they were able to meet minimum dietary requirements, that is, have a balanced diet during the specified reference period (last seven days). Study findings as depicted in Figure 7 show that 42.56 percent of the respondents from Kilombero reported having access to a balanced diet, while 57.44 percent did not have the ability to eat a balanced diet during the specified reference period. On the contrary, the proportion of study respondents who reported having had access to a balanced diet in Mbinga (maize producers) aggregated to 63.3 percent. The rest (36.95 percent) had no access to a balanced diet.

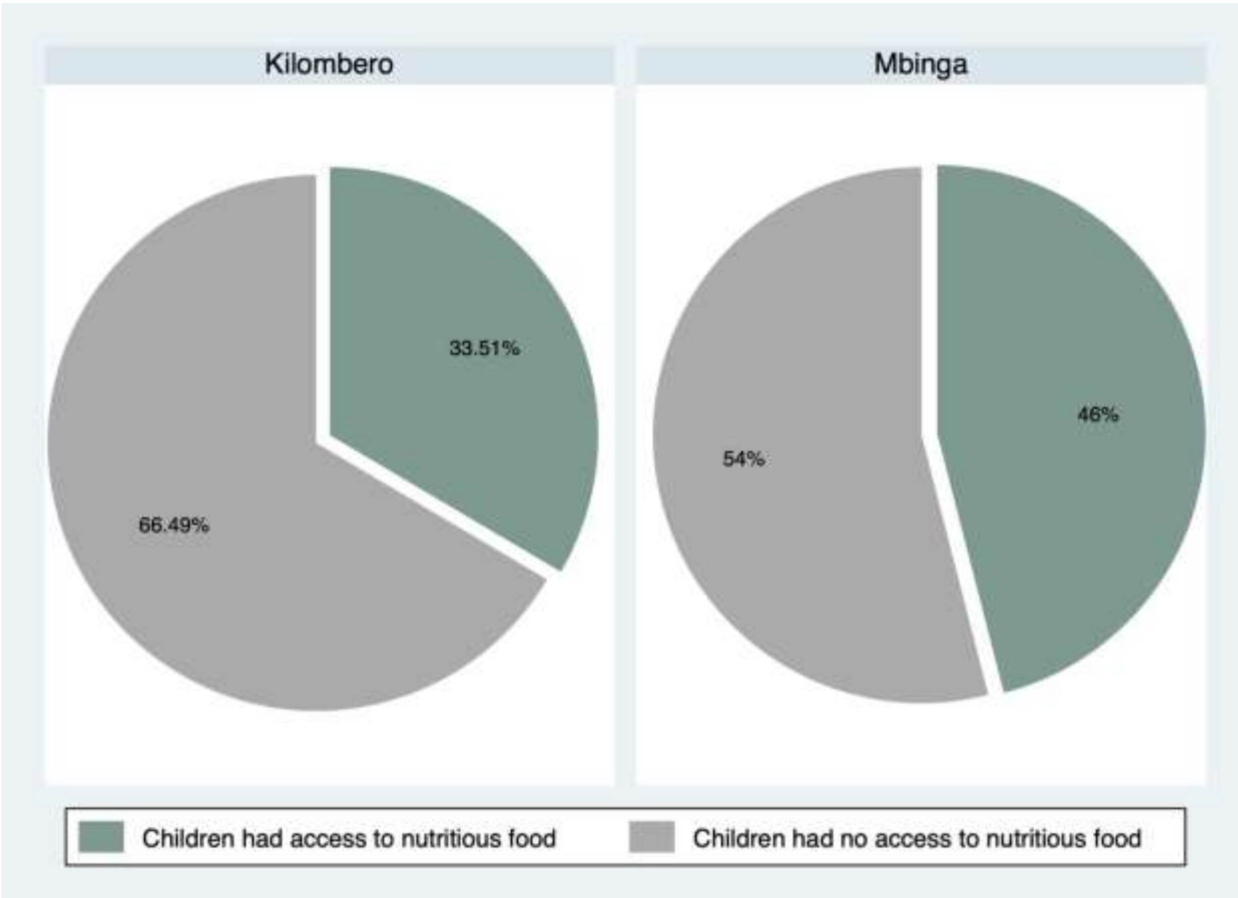
Figure 7: Respondents' opinions on the availability of a balanced diet in the household



6.3.5 Children's Access to Nutritious Food

Error! Reference source not found. depicts the survey's findings regarding access to nutritious food by children in the surveyed households. The survey asked whether children in the visited households were able to access food as per recommended nutrition guidelines for children. As evidenced, a large proportion of respondents from the surveyed districts (64.96 percent from Kilombero and 54.00 percent from Mbinga), reported that their children had no access to nutritious food during the reference period. Consistently, 35.05 percent of the study respondents from Mbiga District reported that their children had access to nutritious food, and so, 46.00 percent from Mbinga.

Figure 8:Respondent opinions on access of nutritious food by children in the household.



6.3.6 Households' Food Security Status

Although analysis of questions or indicators is important in revealing the food security situation in the household, a scientific measure of the status of a household in the food security metric is important. The current study adopted a contextually modified FAO Food Security Index. The index classifies households into five categories, depending on the combination of questions related to food security conditions in the households. The questions used in this study are presented in Table 4.

Borrowing the FAO Food Security Index classification, the current study, therefore, defined food-secure households as those with no indication of any food insecurity, such that they do not experience a reduction of meals, lack preferred foods or reduce adult meals, while severe food insecure households were those experiencing critical food insecurity conditions, such as worrying about not having enough food, having no food of any kind in the household in the past seven days and/or going the entire day and night without eating. Other categories were intermediate, depending on how often they experience food insecurity conditions, however with no severe food insecurity conditions.

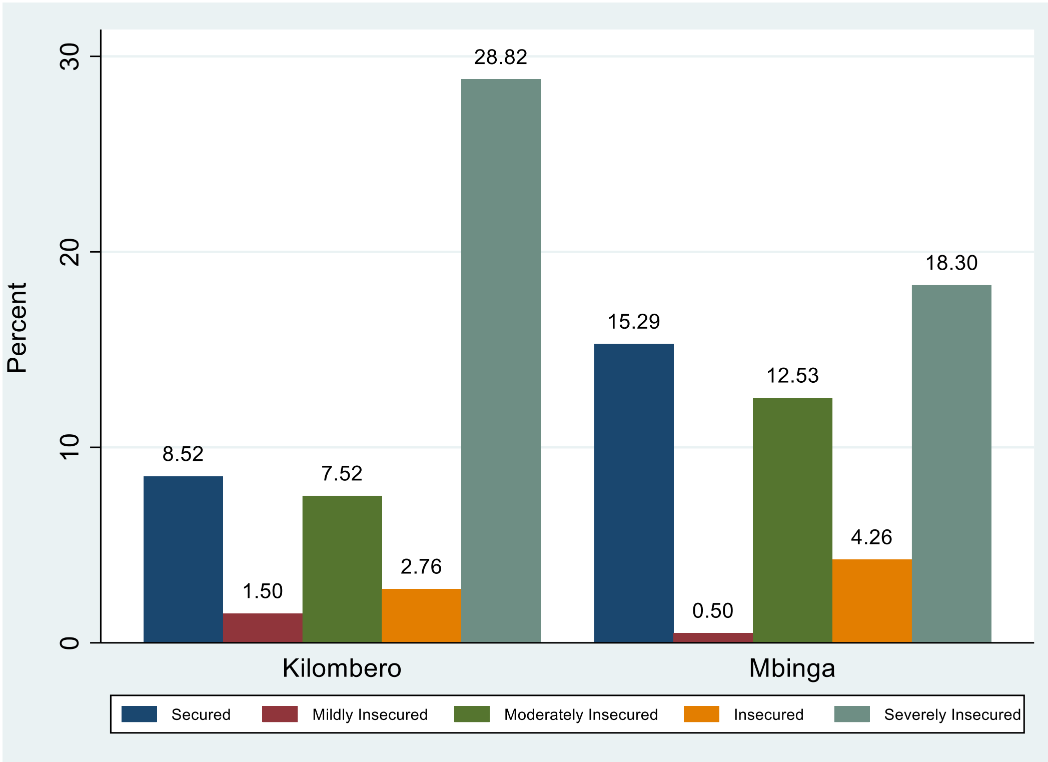
Study findings on households' food security status are presented in Table 5. The findings depict that, of the visited households, 47.12 percent were severely food insecure, while 23.81 percent were food secure. Moderately food-insecure households accounted for 20.05 percent of the households, while the percentage of mildly insecure and insecure households was relatively small. This is suggestive that although the two-extreme status of food insecurity prevails, low variability is observed among other categories.

Table 5: Household food security status

Food Security	Frequency	Percent
Secured	95	23.81
Mildly Insecure	08	02.01
Moderately Insecure	80	20.05
Insecure	28	07.02
Severely Insecure	188	47.12
Total	**399**	**100.00**

Else, comparative analysis across districts (crops for that matter), shows that food insecurity seems to be more prevalent among rice farmers (Kilombero District), compared to maize farmers (Mbinga District). While 28.82 percent of the respondents who are food insecure were from Kilombero District, the proportion which comes from Mbinga District sums up to 18.30 percent. Similarly, a large proportion of food-secured households comes from Mbinga (15.29 percent), as compared to 8.52 percent from Kilombero District.

Figure 9:Household food security status by district.



6.4 Technology Adoption

6.4.1 Production Stage

Table 6 presents farmers' responses on various technology adoption indicators. The proportion of farmers using a particular indicator varies across districts. It is, for instance, depicted that among those who used improved seeds, 78 percent were maize farmers, while 21 were rice farmers. Correspondingly, 79.75 percent of those who reported using traditional seeds were rice producers and 20.25 percent were maize farmers. Impliedly, a slightly large proportion of maize producers have graduated from using traditional seeds, and they have adopted either improved or improved and recycled seeds. Further details are tabulated (Table 6).

Table 6: Technology adoption indicators in production

Variable	District	
	Kilombero	**Mbinga**
Type of Seed used		
Improved	21.12	78.88
Traditional	79.75	20.25
Improved, recycled	42.67	57.33
Use scientific or professional measures when planting		
Yes: used recommended measures	39.33	60.67
No: did not use recommended measures	52.12	47.88

Variable	District	
	Kilombero	Mbinga
Cleaning seeds using special techniques before planting		
Yes: cleaned seeds	84.62	15.38
No: did not clean seeds	45.28	54.72
Use of organic fertilizers		
Yes: used organic fertilizer	88.89	11.11
No: did not use organic fertilizer	48.33	51.67
Use herbicide		
Yes: used herbicides	77.14	22.86
No: did not use herbicides	26.91	73.09
Use pesticide		
Yes: used pesticides	94.29	5.71
No: did not use pesticides	39.51	60.49
Use of machines (tractor, power tiller etc.)		
Yes: used machines	91.19	8.81
No: did not use machines	21.34	78.66
Applying irrigation		
Yes: applied irrigation	95.83	4.17
No: did not apply irrigation	45.84	54.16
Whether changed the type of crop (Crop rotation)		
Yes: did crop rotation	10.97	89.03
No: did not rotate crops	73.36	26.64
Harvesting time (Whether observed)		
Yes: harvested on time	47.86	52.14
No: did not harvest on time	58.33	41.67

During field work, it was observed that some farming households have their own modern farming equipment, like tractors and harvesters, (Photo 1and Photo 2).

Photo 1*: Tractor and hallower for maize farming as observed in one of the farming households, Mbinga Ruvuma*
Source*: Courtesy by researchers 2022.*

Photo 2: *Maize Planter*
Source: *Courtesy by researchers 2022.*

Further, during field work, some of the common modern and scientifically recommendable planting techniques were observed in some of the visited maize and rice farms (Photo 3 and Photo 4).

Photo 3: *Well-arranged (rice) seed plants at Mkula village, Kilombero – Morogoro*
Source*: Courtesy by researchers 2022.*

Photo 4*: Well-planted maize at Lihutu, Mbiga-Ruvuma.*
Source*: Courtesy by researchers 2022.*

6.4.2 Technology Adoption Index

The technology adoption index was computed from indicators of technological adoption (*Table 6*). The index was computed as a proportion of technology adopters over the total number of technologies that could be adopted in production. This was done with the concept of equal weighting to measure the extent to which a farmer has intensified technology adoption. This was the case because the index does not necessarily depend on whether a particular technology was adopted, but also on the number of technologies adopted and the modality of adoption (how it is adopted).

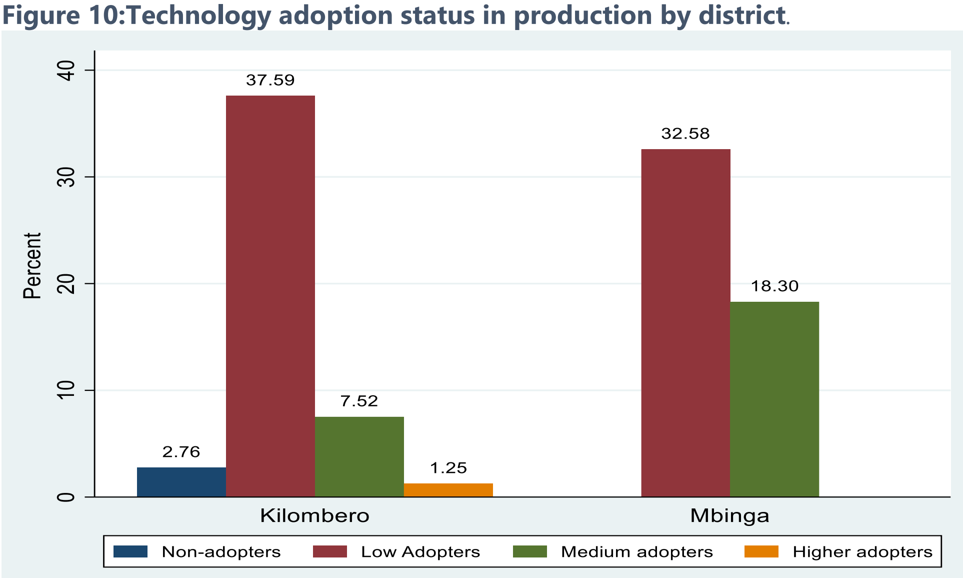
Therefore, following the computation of the technology adoption index, the households were categorized as non-adopters (with a technology adoption index of zero), low adopters (with a technology adoption index of greater than zero but less than 33 percent), medium adopters, with a technology adoption index of greater than 33 but less than 66 percent) and higher adopters (with technology adoption index of greater than 66). The results are presented in Table 7.

Table 7:Technology adoption status in production

Description	Frequency	Percent
Non-adopters	11	2.76
Low Adopters	280	70.18
Medium adopters	103	25.81
Higher adopters	5	1.25
Total	**399**	**100.00**

Further, the study analysed technological adoption by crop type. The findings, as depicted in **Error! Reference source not found.**, show that all the non-adopters engaged in rice farming. Impliedly, all maize farming households adopted at least one kind of technology. Out of the 70.18 percent who were low adopters, 37.59 percent were rice producers and 32.58 were maize producers. Similarly, in the case of medium producers (25.81 percent), the proportion of maize producers was relatively higher (18.3 percent) than that of rice producers (7.52 percent). Besides, higher adopters were rice farming households only.

Figure 10:Technology adoption status in production by district.



6.4.3 Food Management and Storage

The study further explored technological adoption in food management, particularly during the entire process of harvesting and storage. Field observation showed that some farmers use modern technologies in food management and storage. Some households have their own harvesters, threshing and winnowing machines, and they do store farm products in modern stores.

Photo 5: *Some of the modern stores used to store food crops.*
Source: *Courtesy by researchers 2022.*

Study findings, as reported in Table 8 showed that most rice producers use machines like tractors and other simple machines to harvest. Out of those who use machines, 71.43 percent were rice producers and 28.57 percent were maize producers. Correspondingly, the proportion of maize farmers who reported using hands and local tools in harvesting, was relatively higher (51.67 percent), as compared to 48.33 percent of rice producers. Regarding threshing methods, 99.41 percent of those who reported using hands and local tools in an open space were from rice farming households. On the contrary, 91.98 percent of those who reported using machines, like tractors, were from maize farming households. Further details are depicted (Table 8).

Table 8: Technology adoption indicators in food management

Variable/Technology	District	
	Kilombero	Mbinga
Main harvest method in the last farming season		
Hands and local tools	48.33	51.67
Harvest machines like tractors and others	71.43	28.57
Main method used for threshing this crop in the last farming season		
Using hands and local tools in an open space	99.41	0.59
Using hands and plastic/nylon bags	40.00	60.00
Using machines like tractor	8.02	91.98

Variable/Technology	District	
	Kilombero	Mbinga
Main method used to clean the crop after threshing (winnowing)		
Using hands and local tools	95.11	4.89
Using machines (advanced tools)	7.96	92.04
Did not winnow	12.50	87.50
Whether crops/harvest were dried before storing		
Yes: dried crops before storing	71.86	28.14
No: did not dry crops before storing	26.50	73.50
Methods used for drying		
Sunning	71.86	28.14
Main method used to store the crop		
Locally made traditional structure	93.33	6.67
Locally made improved structure	49.23	50.77
Modern store	88.89	11.11
Sacks / open drum	50.00	50.00
Airtight drum	5.56	94.44
Whether a farmer did anything to protect the harvest in store		
Yes: took protective measures	16.41	83.59
No: did not take protective measures	79.27	20.73
Methods used to protect the harvests in store		
Spraying	6.82	93.18
Smoking	83.33	16.67

6.4.4 Technological Adaptation in Food Management

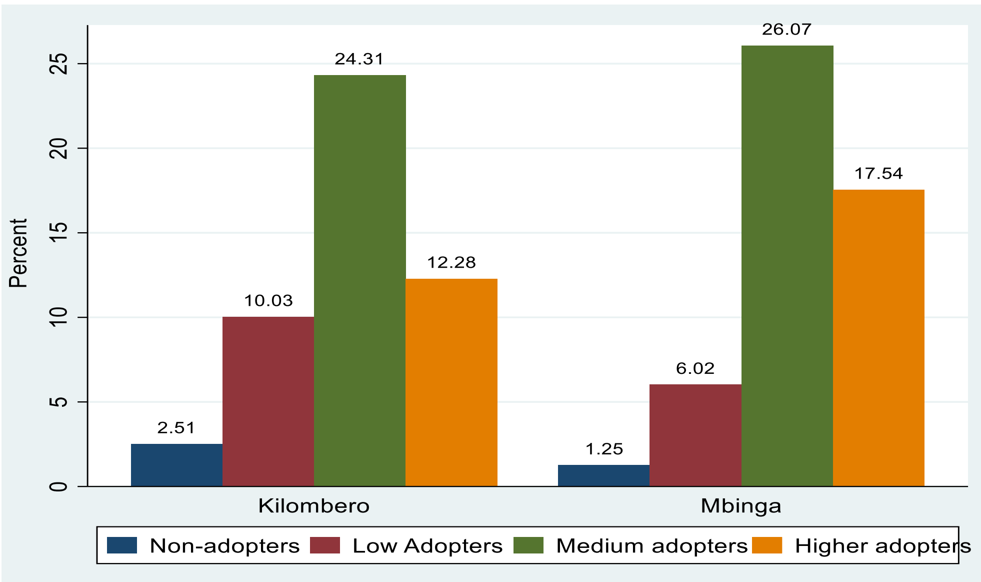
The study computed the index of technology adoption and then grouped the respondents into four categories: non-adopters, low-adopters, medium adopters, and higher adopters. As depicted, non-adopters constituted about 15 percent, low adopters were 16.04 percent, medium adopters accounted for almost half of the study population and higher adopters were 29.82 percent. Table 9 presents further details.

Table 9: Technology adoption status in food management

Description	Frequency	Percent
Non-Adopters	15	03.76
Low Adopters	64	16.04
Medium Adopters	201	50.38
Higher Adopters	119	29.82
Total	399	100.00

Further, disaggregating the percentage distribution of technology adoption in each category by district, the study depicts evidence that most of the higher and medium adopters were from Mbinga Region (maize farming households). On the contrary, a relatively higher percentage of the non-adopters or low adopters were from Kilombero District (rice farming households). Thus, technological adoption prevails in maize farming more than it is in the case of rice farming households. Details are presented (**Error! Reference source not found.**).

Figure 11: Technology adoption status in food management by district.



6.4.5 Technological Adoption in the Entire Agricultural Value Chain

The study examined technological adoption options in the entire agricultural value chain. In computing the adoption index and subsequent adoption choices, the current study combined the indicators used at the production stage (details in *Table 6*) and indicators used at the food management stage (details in Table 8). Study findings as depicted in Table 10, showed that only a single person, equivalent to 0.25 percent, reported having never used any technology in the entire agricultural value chain, that is from food production to food management. Else, 205 respondents (51.38 percent) were low adopters, 186 (46.62 percent) were medium adopters and 7 (1.75 percent) were higher adopters.

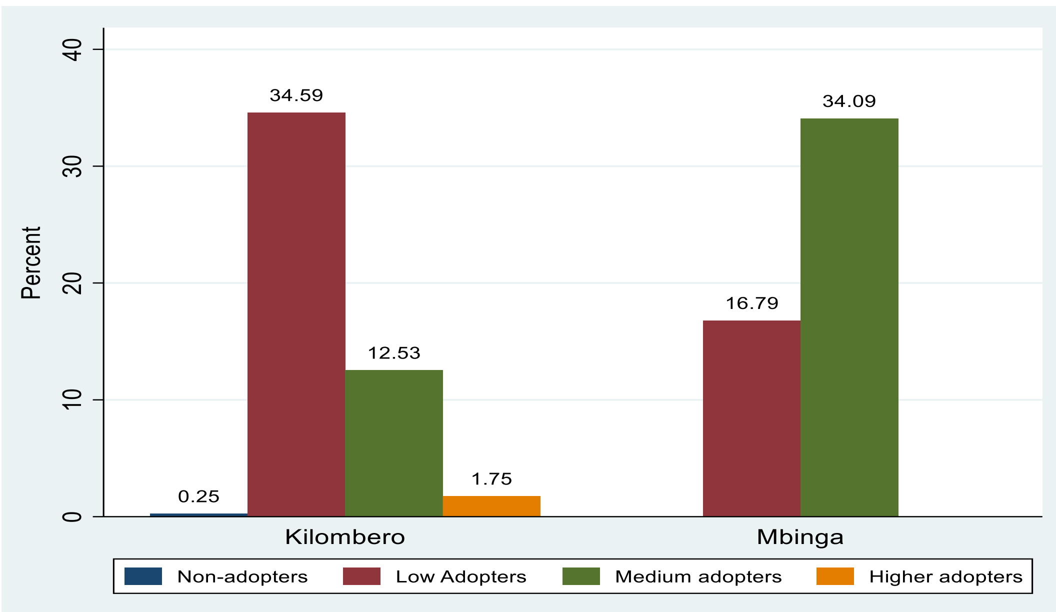
Table 10: Technology adoption status in agricultural chain

Description	Frequency	Percent
Non-adopters	1	0.25
Low Adopters	205	51.38
Medium Adopters	186	46.62
Higher Adopters	7	1.75

Total	399	100.00

Additionally, the study explored the technological adoption possibilities district-wise. As shown (Figure 12), a non-adopter was from Kilombero District, that is, it was a rice farming household. Else, it is shown that a large proportion of low adopters (34.59 percent) were rice producers, and the medium adopters (34.09 percent) were maize farming households. It is worth noting that despite having a relatively high proportion of low adopters and less of medium adopters, seven respondents who in the context of this study were higher adopters came from Kilombero District, that is, they were rice producers.

Figure 12: Technology adoption status in agricultural chain by district



6.5 Technology Adoption and Food Security

6.5.1 Technology Adoption in Production and Food Security

The current study employed a chi-square test for independence to examine if there is any significant relationship between technological adoption at the production stage and food security status. As indicated (Table 11), the findings gave justifiable evidence to infer that there exists a relationship between technology adoption and food security. The relationship is, however, significant at 10 percent level of significance (see Pearson Chi-square and its probability of type I error). Impliedly, the adoption of technology at various levels is correlated with different statuses of food security. Nevertheless, a close examination of the table reveals that there is low variability of both technological adoption and the status of food security.

Table 11: Relationship between technology adoption in production and food security

Technology adoption status	food security					
	Secured	Mildly Insecure	Moderately Insecure	Insecure	Severely Insecure	Total
Non-adopters	1	0	0	0	10	11
	(1.05)	(0.00)	(0.00)	(0.00)	(5.32)	(2.76)
Low Adopters	65	7	49	24	135	280
	(68.42)	(87.50)	(61.25)	(85.71)	(71.81)	(70.18)
Medium adopters	28	1	29	4	41	103
	(29.47)	(12.50)	(36.25)	(14.29)	(21.81)	(25.81)
Higher adopters	1	0	2	0	2	5
	(1.05)	(0.00)	(2.50)	(0.00)	(1.06)	(1.25)
Total	**95**	**8**	**80**	**28**	**188**	**399**
	100.00	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Pearson Chi2 = 19.56 Prob = 0.0759

**percentage in parenthesis

At this stage (production stage), invariability was observed in more than two categories. Therefore, the adoption index was categorized into two groups, which are adopters and non-adopters. For the same reasons, household food security status was also recategorized into only two categories. As a result, a binary response variable model was relevant for estimation.

For the treatment model, we estimate the probability of adopting technology at the production stage using a set of household observable covariates, as presented in Table 12. The sex of the household head, education level and the person responsible for agricultural activities, are likely to predict the adoption of technology at the production stage. Female-headed households are less likely to adopt technology in agriculture than males (moving from 1 to 2), while education level is positively influencing technology uptake. The results are similar to those found by Manda *et al.* (2018), in assessing the conditional adoption of improved maize varieties in Tanzania.

Regarding education levels, educated heads of households have awareness of the gains/benefits of using modern farming techniques and how to apply those techniques, as well as seek professional consultation. Hence, they are more likely to adopt technology in production. On the other hand, females face bigger constraints compared to their male counterparts. Coupled with lower academic achievements (women are less educated compared to men), women also face other constraints, including capital and assets, as patriarchal societies still prevail in major parts of Tanzania, including areas visited for this study. These findings further conform to the Unified Theory of Acceptance and Use of Technology (UTAUT), (Lai, PC. 2017; Taherdoost, H, 2018).

Table 12: Impact of technological adoption in production on food security

Food Security Status	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
ATE[5]	-0.134	0.058	-2.32	0.021	-0.248	-0.021	**
Mean[6]	0.569	0.036	16.01	0.000	0.50	0.639	***
Outcome Model for Non-Adopters							
Age	0.014	0.012	1.21	0.225	-0.009	0.038	
Sex	0.113	0.328	0.34	0.730	-0.530	0.756	
Education level	0.271	0.161	1.68	0.092	-0.044	0.587	*
Occupation	1.095	0.297	3.68	0.000	0.513	1.678	***
Marital status	-0.036	0.229	-0.16	0.874	-0.485	0.412	
A person responsible for agricultural activities	0.44	0.347	1.27	0.204	-0.239	1.12	
Household Size	0.054	0.074	0.72	0.472	-0.092	0.199	
A most educated member of the household	-0.174	0.164	-1.06	0.288	-0.495	0.147	
Constant	-6.787	2.036	-3.33	0.001	-10.778	-2.796	***
Outcome Model for Adopters							
Age	0.048	0.021	2.23	0.026	0.006	0.089	**
Sex	0.753	0.617	1.22	0.222	-0.456	1.963	
Education level	0.339	0.176	1.93	0.054	-0.006	0.684	*
Occupation	-0.023	0.257	-0.09	0.929	-0.528	0.482	
Marital status	-0.092	0.593	-0.16	0.876	-1.254	1.070	
A person responsible for agricultural activities	-0.791	0.711	-1.11	0.266	-2.186	0.603	
household	-0.080	0.125	-0.64	0.524	-0.325	0.165	
A most educated member of the household	-0.051	0.244	-0.21	0.835	-0.529	0.428	
Constant	-2.366	1.996	-1.19	0.236	-6.278	1.546	
Treatment Model							
Age	0.000	0.006	-0.02	0.980	-0.011	0.011	
Sex	-0.453	0.180	-2.52	0.012	-0.806	-0.101	**
Education level	0.315	0.089	3.53	0.000	0.140	0.489	***
Occupation	-0.140	0.147	-0.95	0.340	-0.429	0.148	

[5] Average treatment effect
[6] Population means of Control group (non-adopters)

Food Security Status	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Marital status	-0.016	0.123	-0.13	0.895	-0.257	0.225	
A person responsible for agricultural activities	0.162	0.076	2.14	0.032	0.014	0.311	**
Constant	-0.297	0.796	-0.37	0.709	-1.857	1.263	
Mean dependent var	0.540		SD dependent var	0.499			

*** p<.01, ** p<.05, * p<.1

For outcome model, significant factors differ between adopters and non-adopters. For adopters, education level and age seem to be important variables in predicting the food security status while for non-adopters it is education level and occupations.

The results seem to be supported by qualitative results, as one of the respondents mentioned that age is important in making production decisions and food security in the household, as he had this to say:

> "We succeed because we have been doing this for a long time, hence we have better experience. We do not even depend on instructions from the Government because we know how maize farming works, since we have over 30 years of experience".
>
> **Source:** *Male respondent, middle-aged, March 2022 as translated by the researcher.*

Although the age of the household head does not necessarily imply one's higher experience in farming, it can however, be used as a proxy for exposure to farming. This is justifiable and contextually relevant for this study, since most farmers were local-residents and farmers who claimed to have made agricultural decisions were, more often not young.

When it comes to the impact of technology adoption at the production stage and food security status, the study estimated the probability of being food insecure. As evidenced by the survey findings (Table 12), the average treatment effect, which in the context of the current study is the coefficient of technology adoption is negative (- 0.134) and significant (p = 0.012) at five percent level. Impliedly, technology adoption at production stage impacts food insecurity negatively. As such, adopting technology during production of food crops reduces the chances of a household being food insecure by 13.4 percent.

6.5.2 Technology Adoption in Food Management and Food Security

The relationship between technology adoption in food storage, that is using advanced scientific techniques in storing crops after farming and food security, seems to be peculiar, that is non-existing as the p-value of the chi-square test of association is insignificant at all conventional levels (Table 13). The plausible explanation is that, first, in the visited area, most farmers do not store produce at their homes but in the central collection area known as a warehouse, or in Swahili, "*ghala*". Secondly, for most farmers, farm products are sold immediately after harvest to meet cash demands, and there is consequently little variation observed in storage techniques.

Moreover, like technological adoption in production, small variability is observed in technological adoption in food storage. As a result, the categories of technology adoption were further regrouped to only adopters and non-adopters, and hence impact evaluation model was estimated using the binary outcome variable.

Table 13:Relationship between technology adoption in food management and food security

Technology adoption in food management	Food security*					
	Secured	Mildly Insecure	Moderately Insecure	Insecure	Severely Insecure	Total
Non-adopters	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.53)	1 (0.25)
Low Adopters	44 (46.32)	6 (75.00)	29 (36.25)	17 (60.71	109 (57.98)	205 (51.38)
Medium adopters	48 (50.53)	2 (25.00)	49 (61.25)	11 (39.29	76 (40.43)	186 (46.62)
Higher adopters	3 (3.16)	0 (0.00)	2 (2.50)	0 (0.00	2 (1.06)	7 (1.75)
Total	95 100.00	8 100.00	80 100.00	28 100.00	188 100.00	399 100.00

Pearson Chi2 = 17.22 Prob = 0.1416

* Percentages in brackets

The impact evaluation model was estimated to further confirm the impact of technology adoption in food storage on food security. Consistent with the estimation outputs for chi-square test the for independence, the average treatment effect which presents the coefficient of technological adoption in food storage was negative (-0.101), and insignificant at all convention levels (p-value = 0.128). Impliedly, the current study failed to find reasonable evidence for rejecting the null and therefore it was rational to infer that technological adoption in food storage is not significantly impacting household food security (Table 14).

Table 14: Impact of technology adoption in food management on food security

Food Security Status	Coef.	St. Err.	t-value	p-value	[95% CI		Sig
ATE	-0.101	0.066	-1.52	0.128	-0.230	0.029	

Food Security Status	Coef.	St. Err.	t-value	p-value	[95% CI		Sig
Population means	0.616	0.060	10.29	0.000	0.499	0.734	***
Outcome Model for Non-adopters							
Age	-0.003	0.024	-0.15	0.883	-0.050	0.043	
Sex	0.053	0.574	0.09	0.927	-1.073	1.179	
Education level	0.551	0.480	1.15	0.252	-0.391	1.492	
Occupation	0.484	0.479	1.01	0.312	-0.454	1.422	
Marital status	0.239	0.421	0.57	0.57	-0.586	1.064	
A person responsible for agricultural activities	0.673	0.579	1.16	0.246	-0.463	1.808	
Household size	0.104	0.129	0.81	0.418	-0.148	0.357	
A most educated member of the household	0.093	0.293	0.32	0.750	-0.481	0.667	
Constant	-4.88	3.821	-1.28	0.2010	-12.37	2.608	
Outcome Model for Adopters							
Age	0.018	0.010	1.76	0.079	-0.002	0.038	*
Sex	0.665	0.298	2.24	0.025	0.082	1.249	**
Education	0.116	0.132	0.88	0.38	-0.143	0.374	
Occupation	0.297	0.217	1.37	0.172	-0.129	0.722	
Marital status	-0.292	0.220	-1.33	0.184	-0.723	0.139	
A person responsible for agricultural activities	-0.201	0.360	-0.56	0.576	-0.907	0.505	
Household size	-0.023	0.059	-0.39	0.696	-0.140	0.093	
A most educated member of the household	-0.168	0.131	-1.28	0.201	-0.425	0.089	
Constant	-2.039	1.378	-1.48	0.139	-4.739	0.661	
Treatment Model							
Age	-0.002	0.006	-0.24	0.807	-0.014	0.011	
Sex	-0.308	0.170	-1.81	0.071	-0.642	0.026	*
Education level	-0.089	0.082	-1.09	0.274	-0.250	0.071	
Occupation	-0.082	0.134	-0.62	0.538	-0.345	0.180	
Marital status	0.025	0.134	0.19	0.849	-0.237	0.288	
A person responsible for agricultural activities	-0.151	0.076	-1.99	0.047	-0.301	-0.002	**
Constant	2.140	0.796	2.69	0.007	0.578	3.701	***
Mean dependent var		0.540	SD dependent var		0.499		

**** p<.01, ** p<.05, * p<.1*

6.5.3 Technology Adoption in the Agricultural Chain and Food Security

The study was further interested to understand the linkage between food security and technological adoption in the agricultural chain. As a result, we examined the relationship between food security status and the use of modern technology in the entire agricultural chain. The adoption index for the entire agriculture chain (from production to storage) was computed and grouped into four categories, like other indices in production and storage. The relationship between food security and technology adoption in the agricultural value chain was then examined. As shown (Table 15), the relationship between food security and technological adoption in the agricultural value chain is none-existent. The Chi-square test for the association is not significant.

Table 15: Relationship between technology adoption in agricultural value chain and food security

Technology adoption status	food security*					
	Secured	Mildly Insecure	Moderately Insecure	Insecure	Severely Insecure	Total
Non-adopters	0	0	0	0	1	1
	0.00	0.00	0.00	0.00	0.53	0.25
Low Adopters	44	6	29	17	109	205
	46.32	75.00	36.25	60.71	57.98	51.38
Medium Adopters	48	2	49	11	76	186
	50.53	25.00	61.25	39.29	40.43	46.62
Higher Adopters	3	0	2	0	2	7
	3.16	0.00	2.50	0.00	1.06	1.75
Total	95	8	80	28	188	399
	100.00	100.00	100.00	100.00	100.00	100.00

Pearson Chi2 = 17.22 Prob = 0.1416

*First row has *frequencies,* and the second row has *column percentages*

To confirm the impact of technology adoption in the agricultural chain on food security, the impact model was estimated. Contrary to chi-square results, the impact estimation model shows that the influence of technological adoption in the agricultural chain on the probability of being food insecure is negative (-0.137) and significant at a 5 percent level (p-value = 0.049). Impliedly, compared to non-adopters, adopters are less likely to be food insecure by 13.7 percent. Nevertheless, the impact is cautionary as the confidence interval of the coefficient includes 0, which implies that the impact might not be entirely far from zero.

Table 16 : Impact of technology adoption in the agriculture value chain on food security

Food Security Status	Coef.	St. Err.	t-value	p-value	[95% Conf.	Interval]	Sig
ATE	-0.137	0.069	-1.970	0.049	-0.273	0.000	**
Population means	0.595	0.059	10.00	0.000	0.478	0.711	***
Outcome Model for Non-adopters							
Age	0.023	0.015	1.60	0.110	-0.005	0.052	
Sex	0.524	0.354	1.48	0.138	-0.169	1.217	
Education level	0.100	0.472	0.21	0.833	-0.826	1.025	
Occupation	0.198	0.590	0.34	0.738	-0.958	1.353	
Marital status	-0.201	0.268	-0.75	0.454	-0.725	0.324	
A person responsible for agricultural activities	0.809	0.433	1.87	0.062	-0.039	1.657	*
Household size	-0.007	0.096	-0.07	0.943	-0.194	0.181	
A most educated member of the household	0.045	0.176	0.26	0.798	-0.300	0.390	

Food Security Status	Coef.	St. Err.	t-value	p-value	[95% Conf.	Interval]	Sig
Constant	-2.917	3.215	-0.91	0.364	-9.218	3.385	
Outcome Model for Adopters							
Age	0.024	0.015	1.62	0.105	-0.005	0.053	
Sex	0.637	0.417	1.52	0.127	-0.182	1.455	
Education level	0.181	0.129	1.40	0.162	-0.073	0.435	
Occupation	0.202	0.224	0.90	0.369	-0.238	0.641	
Marital status	-0.308	0.37	-0.83	0.406	-1.033	0.418	
A person responsible for agricultural activities	-0.982	0.601	-1.63	0.102	-2.16	0.196	
Household size	-0.088	0.085	-1.04	0.301	-0.255	0.079	
A most educated member of the household	-0.319	0.181	-1.76	0.078	-0.673	0.036	*
Constant	-0.682	1.517	-0.45	0.653	-3.654	2.291	
Treatment Model							
Age	-0.005	0.006	-0.95	0.341	-0.016	0.006	
Sex	-0.434	0.156	-2.77	0.006	-0.74	-0.127	***
Education level	0.481	0.112	4.28	0.000	0.26	0.701	***
Occupation	-0.237	0.136	-1.74	0.082	-0.505	0.03	*
Marital status	-0.015	0.116	-0.13	0.898	-0.243	0.213	
A person responsible for agricultural activities	0.032	0.07	0.46	0.645	-0.104	0.169	
Constant	0.863	0.782	1.10	0.270	-0.669	2.395	
Mean dependent var		0.540	SD dependent var		0.499		

**** p<.01, ** p<.05, * p<.1*

The findings of the current study are in line with the studies by Sinyolo, (2019), Sissoko *et al.*, (2022), and Vigani & Magrini, (2014), who found similar effects. However, Muhaimin *et al.*, (2020), did not find any significant effects of technological adoption on food security. This implies that the results are still contradictory but rather area specific.

6.6 Technology Adoption, Post-Harvest Loss, and Productivity

Although the major interest of the study is to infer the causal effect of technology adoption on food security using FAO's Food Security Index, the study examined its impacts on two implied measures of food security, which are post-harvest loss and productivity. Lower post-harvest loss implies availability of enough (quantity) and quality food, but also the higher the productivity, the better the food status in the household. We first estimate the impact of technology adoption on productivity and finalize the discussion with the estimation of its effects on post-harvest loss.

6.6.1 Technology Adoption and Productivity

As the findings indicate (Table 17), the coefficient of technological adoption of agricultural productivity is positive (838.898) and significant (p-value < 0.001). Thus, the current study gives justifiable evidence to infer that, technological adoption in crop production positively impacts crop productivity. That is, compared to non-adopters, food productivity for adopters of technology in production is 838.9 kilograms higher per acre. Survey findings suggest that using modern farming techniques, following scientific methods in the preparation and planting of seeds, using modern/improved seeds and other technologically advanced techniques, have a positive impact on farm productivity. The findings are in line with other studies. For instance Ngongi & Urassa, (2014), show that the use of improved fertilizers is likely to increase food production.

Table 17: Impact of technological adoption on productivity

Productivity	Coef.	St. Err.	t-value	p-value	[95% Conf Interval]		Sig
ATE	838.897	116.35	7.210	0.000	610.854	1066.940	***
Population means	933.769	90.670	10.30	0.000	756.059	1111.478	***
Outcome Model for Non-adopters							
Age	-20.4150	5.8600	-3.48	0.000	-31.9010	-8.9290	***
Sex	-332.964	140.41	-2.37	0.018	-608.174	-57.753	**
Education level	11.6690	156.37	0.07	0.941	-294.816	318.154	
Occupation	179.697	148.23	1.21	0.225	-110.839	470.232	
Marital status	-1.84600	100.73	-0.02	0.985	-199.274	195.583	
A person responsible for agricultural activities	-163.444	95.997	-1.70	0.089	-351.594	24.7060	*
Household size	-38.441	33.873	-1.13	0.256	-104.831	27.949	
A most educated member of the household	-41.620	71.040	-0.59	0.558	-180.855	97.615	
Outcome Model for Adopters							
Constant	1749.78	804.30	2.18	0.030	173.371	3326.196	**
Age	-19.054	6.2700	-3.04	0.002	-31.343	-6.76500	***
Sex	-346.712	178.72	-1.94	0.052	-697.002	3.57800	*
Education level	25.602	58.776	0.44	0.663	-89.5970	140.802	
Occupation	-183.356	109.21	-1.68	0.093	-397.421	30.7090	*
Marital status	-86.129	155.97	-0.55	0.581	-391.839	219.581	
A person responsible for agricultural activities	526.672	253.29	2.08	0.038	30.2200	1023.123	**
Household size	13.127	41.575	0.32	.752	-68.358	94.612	
A most educated member of the household	-65.62	87.001	-0.75	.451	-236.139	104.899	
Constant	3458.89	741.39	4.67	0.000	2005.78	4912.01	***
Treatment Model							
Age	-0.005	0.006	-0.95	0.341	-0.016	0.006	
Sex	-0.434	0.156	-2.77	0.006	-0.740	-0.127	***

Productivity	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Education level	0.481	0.112	4.28	0.000	0.260	0.701	***
Occupation	-0.237	0.136	-1.74	0.082	-0.505	0.030	*
Marital status	-0.015	0.116	-0.13	0.898	-0.243	0.213	
A person responsible for agricultural activities	0.032	0.07	0.46	0.645	-0.104	0.169	
Constant	.863	.782	1.10	.27	-.669	2.395	
Mean dependent var		1302.483	SD dependent var		1070.966		

**** p<.01, ** p<.05, * p<.1*

Quantitative results are supported by the qualitative explanation given by key informants through success stories, as one of the respondents was keen to say:

> "Technology is important in production. It helps someone to cultivate a larger farming area compared to those using local means, who only cultivate where human power is capable".
>
> **Source**: Female respondent Mbinga district, March 2022 as translated by the researcher.

Another key informant was also keen to add:

> "Using local means of cultivation consumes a lot of time, but using tractors saves time and cultivates much bigger areas".
>
> **Source**: Female respondent Mbinga district, March 2022 (translated by the researcher).

6.6.2 Technology Adoption and Post-Harvest Losses

To examine the impact of technology on post-harvest loss, technological adoption at the food storage stage was used to estimate the causal effect of adopting technology on the probability of experiencing post-harvest losses. As presented in Table 18, the study did not find enough evidence to support the hypothesis that using modern methods in food storage decreases the chances of experiencing post-harvest losses. The coefficient was positive (0.012), nevertheless insignificant at all conventional levels (p-value = 0.838).

The explanation could be repeated for the case of the impact of adopting technology on storage on food security. Most farmers do not store food crops at their homes, but in the central collection areas, known as warehouses, or in Swahili, 'ghala.' Also, some sell their farm produce immediately after harvest to meet cash demands. As such, variation in storage techniques may remain negligible. Furthermore, even in the warehouses where most farmers store their crops/produce, no modern preservation methods are adopted, and hence farmers still experience post-harvest losses. However, the results are contrary to some of the findings of the previous studies. For instance, (Chegere *et al.*, 2022), found that treated groups for both training and the use of improved technologies, significantly reduce post-harvest losses in Tanzania. Yet, the findings might be incomparable since the findings for this study are non-experimental and more importantly, associated with self-adopted technology, rather than induced technology adoption.

Table 18:Impact of Technology adoption on post-harvest loses.

Postharvest	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
ATE	0.012	0.061	0.200	0.838	-.0107	0.132	
Population means	0.571	0.05	11.39	0.000	0.473	0.669	***
Outcome Model for Non-Adopters							
Age	0.038	0.014	2.62	0.009	0.009	0.066	***
Sex	0.201	0.370	0.54	0.588	-0.525	0.927	
Education level	-0.112	0.413	-0.27	0.786	-0.921	0.697	
Occupation	0.662	0.584	1.13	0.257	-0.483	1.808	
Marital status	-0.047	0.284	-0.17	0.868	-0.604	0.509	
A person responsible for agricultural decisions	0.283	0.421	0.67	0.501	-0.542	1.108	
Household size	-0.021	0.092	-0.23	0.82	-0.201	0.159	
A most educated member of the household	-0.207	0.185	-1.12	.263	-0.57	0.156	
Constant	-4.213	3.075	-1.37	0.171	-10.24	1.815	
Outcome Model for Adopters							
Age	0.007	0.014	0.52	0.605	-0.020	0.034	
Sex	-0.417	0.402	-1.04	0.300	-1.205	0.371	
Education level	-0.158	0.132	-1.20	0.230	-0.417	0.100	
Occupation	0.031	0.222	0.14	0.888	-0.403	0.466	
Marital status	0.310	0.419	0.74	0.460	-0.512	1.131	
A person responsible for agricultural activities	0.760	0.479	1.59	0.112	-0.178	1.699	
Household size	0.054	0.079	0.69	0.493	-0.101	0.210	
A most educated member of the household	-0.225	0.175	-1.28	0.199	-0.568	0.119	
Constant	-0.586	1.711	-0.34	0.732	-3.94	2.767	
Treatment Model							
Age	-0.005	0.006	-0.95	0.341	-0.016	0.006	
Sex	-0.434	0.156	-2.77	0.006	-0.740	-0.127	***
Education level	0.481	0.112	4.28	0.000	0.260	0.701	***
Occupation	-0.237	0.136	-1.74	0.082	-0.505	0.030	*
Marital status	-0.015	0.116	-0.13	0.898	-0.243	0.213	
A person responsible for agro. activities	0.032	0.07	0.46	0.645	-0.104	0.169	
Constant	0.863	0.782	1.10	0.27	-0.669	2.395	

Postharvest	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Mean dependent var	0.604		SD dependent		0.490		

*** p<.01, ** p<.05, * p<.1*

6.7 Success Stories in the Use of Technology

Although most of the qualitative information was used to support quantitative findings, success stories explored during field visits warrant a lone treatment. In the visited areas, volatility in the adoption of various techniques in the production and management of maize and rice food crops, was observed. Most farmers appeared to be incapable of adopting some technologies which require an extensive amount of breakthrough cost, including the use of tractors, irrigation schemes and construction of modern storage facilities.

In conformity to the Technology Acceptance Model (TAM), which advocates the usefulness and easiness of using a particular technology as the main determinants for one to either adopt or reject a technology (Sahin, I, 2006; Lai, PC. 2017), farmers were observed to mostly adopt quick result techniques, like the use of fertilizer, herbicides, and pesticides. However, some farmers and key informants reported the use of such technologies as causing the destruction of natural food composition.

With these observations, some success stories were observed. One that stands out is the farming scheme at Mukula Village in Kilombero District. This village has a well-established farming scheme, with irrigation throughout the year (Photo 6), controlled farming techniques, including planting and seed treatment techniques (Photo 7), and a government-constructed storage facility. According to key informants, the farmers in this village outperform others. For instance, the village leader was asked what is different in their village compared to others, and he was keen to say:

> "In my village, a person can get up to 30 sacks per acre, while in other areas, a person barely gets three sacks (on average). Also, in my village, a person can cultivate up to three times per year, due to irrigation and use more quality seeds because he/she is sure of water availability. We also use modern storage facilities, hence our rice is considered to be of superior quality".
>
> **Source**: *Male respondent Kilombero, March 2022 (translated by the researcher)*

Photo 6*: Modern Irrigation scheme at Mkula village*

Photo 7*: Well-arranged rice plants at Mkula village*

Source*: Courtesy by researchers, 2022*.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

The study was carried out with the interest of estimating the impact of adopting technology in the production and management of maize and rice crops on production, food security, as well as post-harvest losses. The study was motivated by the understanding that, although most literature explores the importance of adopting technology on post-harvest losses, few studies have examined how technology adoption through the entire production and storage chain (a range of technologies in each stage), impacts food security and post-harvest loss. Furthermore, the study estimated the impact of technology adoption in the production stage on farm productivity, and presented how the adoption of better food management techniques reduces post-harvest losses.

Food security was computed using the FAO Food Security Index, with slight modifications to improve contextual relevancy. The technology adoption index was computed by considering the proportion of technologies adopted by a farmer, compared to the theoretically plausible number of technologies required. Post-harvest loss was measured using a binary response variable, whether a farmer had experienced post-harvest losses or not.

The study employed an inverse probability weighting regression approach to estimate the impact of the technological adoption of food security. This approach uses propensity scores estimated from limited dependent variable models, for this case dummy variable probit models compared the outcome variable between treated and controlled groups. The model controls for selection bias in both treatment and outcome models and is hence referred to as a doubly robust model. The model is an advanced propensity score matching approach to counterattack the weakness of the ordinary PSM model.

The results show that technology adoption among visited farmers (both rice and maize) farmers is low, and maize farmers are more likely to adopt modern farming techniques compared to rice farmers, although some techniques, like the application of irrigation, are more adopted by rice farmers.

Furthermore, although there is low variability among farmers on the status of food security, a slightly large proportion are food insecure. Comparatively, food insecurity is higher in rice-farming households (28 percent) than in maize-farming households (18 percent).

On the impact of technology adoption on food security, the findings reveal that technological adoption in food production is important at the production stage. Also, technology adoption in the agricultural chain (both production and storage) has a desirable impact on food security. Thus, the current study concludes that adopting technology in production and the entire agricultural value chain decreases the probability of the household being food insecure.

Moreover, technological adoption in production significantly increases the productivity of the farm. Compared to non-adopters, adopters have higher average productivity. Regarding specific technologies on food storage, the study did not find a significant effect of adopting technology on food security, as well as postharvest losses. It is important to note that although the study does not find a significant effect of adopting technology in food storage on food security and postharvest losses, the findings might be limited by the fact that, for the visited areas, nearly all farmers who store their farm products use the central collection points, referred to as warehouse, owned by individuals. The warehouses do not seem to have modern facilities for food storage. Furthermore, through key informants and success stories, the study was able to reveal that most farmers sell their produce soon after harvest, and hence it does not matter how storage is carried out.

7.2 Recommendations

Based on the survey findings, the following recommendations are plausible:

(i) Advocating for modern methods of agricultural production increases not only the chances of being food secure, but also productivity. Therefore, policymakers and practitioners are advised to emphasize the use of modern techniques in production, but also design policy incentives that increase the uptake of modern farming techniques. Technology adoption should be considered a complete phenomenon, as every stage of production is important and has an influence on the outcome which is either productivity or food security in the household.

(ii) Although the study did not find enough evidence that technology in the storage of food has an impact on food security, the findings might be limited due to identified reasons. Thus, based on this information, further investigation to supplement the current findings is recommended. Nevertheless, based on the actual field observations (KII), the study recommends that intervention should be made in the centralized storage points owned by both individuals and the government in preserving farmers' produce, to ensure that the desired quality of food crops is maintained.

(iii) The farmers face the insecurity of losing their produce in the warehouses due to rotting, insects, and rodents, as well as theft. The study further finds that farmers store their produce in warehouses because of the little credit security offered by the warehouse owners, with conditions to process their products in the respective warehouse. Therefore, even though all farmers may store their products in the warehouse, intervention is needed to increase the security of the crops.

8. REFERENCES

Abu Bakar, T. H. S. T., Man, N., Nawi, N. M., Shah, J. A., Muhamad, N., & Nor, M. M. (2020). Factors Explaining Post Harvest Practices Adoption among Fruit Farmers in Johor. *IOP Conference Series: Earth and Environmental Science*, *549*(1), 012095.

African Union Commission. (2015). *Agenda 2063: The Africa We Want* (Issue April).

Amaza, P. S., & Abass, A. B. (2016). Adoption of Mechanized Postharvest Cassava rocessing Technologies, and the Determinants of High-Quality Flour (HQCF) Processing in Tanzania. *Tropicultura*, *34*(4), 411–423.

Bilali, H., Hassen, T., Bottalico, F., Berjan, S., & Capone, R. (2021). Acceptance Adoption of Technologies in Agriculture. *AGROFOR International Journal*, *6*(1), 135–150.

Cefalu, M., & Buenaventura, M. (2017). *Propensity Scores for Multiple Treatments: A Tutorial on the MNPS Command for Stata Users*. RAND Corporation.

Chegere, M. J., Eggert, H., & Söderbom, M. (2022). The Effects of Storage Technology and Training on Postharvest Losses, Practices, and Sales: Evidence from Small-Scale Farms in Tanzania. *Economic Development and Cultural Change*, *70*(2), 729–761.

Cotula, L., Toulmin, C., & Quan, J. (2006). *Better land access for the rural poor and challenges ahead Better land access for the rural poor and challenges ahead*.

Ejemeyovwi, J. O., Osabohien, R., Adeleye, B. N., & de Alwis, T. (2021). Household ICT Utilization and Food Security Nexus in Nigeria. *International Journal of Food Science*, *2021*.

Emiliano, M., & Vigani, M. (2015). Technology adoption and the multiple dimensions of food security: the case of maize in Tanzania. *Agriculture in an Interconnected World*.

Garrido, M. M., Kelley, A. S., Paris, J., Roza, K., Meier, D. E., Morrison, R. S., & Aldridge, M. D. (2014). Methods for Constructing and Assessing Propensity Scores. *Health Services Research*, *49*(5), 1701–1720.

Hodges, R., & Stathers, D. T. (2016). *Training Manual for Improving Grain Postharvest Handling and Storage*. 248.

Jann, B. (1923). *Why Propensity Scores Should Be Used for Matching*. 84.

Lai, P. (2017). The Literature Review of Technology Adoption Models and Theories for the Novelty Technology. *Journal of Information Systems and Technology Management*, *14*(1).

Manda, J., Gardebroek, C., Kuntashula, E., & Alene, A. D. (2018). Impact of improved maize varieties on food security in Eastern Zambia: A doubly robust analysis. *Review of Development Economics*, *22*(4), 1709–1728.

McCaffrey, D. F., Griffin, B. A., Almirall, D., Slaughter, M. E., Ramchand, R., & Burgette, L. F. (2013). A tutorial on propensity score estimation for multiple treatments using generalized boosted models. *Statistics in Medicine*, *32*(19), 3388–3414.

Ministry of Agriculture Development, Government of Nepal. (2016). *Maizing farming Techniques Manual*. Sindhupalchok, Chautara.

Muhaimin, A. W., Toiba, H., Retnoningsih, D., & Yapanto, L. M. (2020). The Impact of Technology Adoption on Income and Food Security Of Smallholder Cassava Farmers: Empirical Evidence From Indonesia. *International Journal of Advanced Science and Technology*, *29*(9), 9.

Mutungi, C., & Affognon, H. (2013). *Fighting Food Lossess in Tanzania: The Way Forward for Postharvest Research and Innovations*. *3*.

Nanjundeswaraswamy, T. S., & Divakar, S. (2021). Determination of Sample Size and Sampling Methods In Applied Research. *Proceedings on Engineering Sciences*, *3*(1), 25–32.

NBS. (2012). *National Sample Census of Agriculture 2007/2008. Volume II: Crop Sector—National Report*. *II*, i–507.

NBS. (2016a). *Annual Agricultural Sample Survey (2016/2017)*.

NBS. (2016b). Large Scale Farms Survey Report 2012/2013. *NBS*.

Ndunguru, G. T., Graffham, A. J., Modaha, F., Rwiza, E., Bancroft, R. D., & Westby, A. (1998). The use of needs assessment methodologies to focus technical interventions in root and tuber crop post-harvest systems: A case study to improve incomes and reducse losses associated with marketing of fresh cassava from rural areas to Dar es Salaam. In *NRI Report; R2364(R)* (Issue 2).

Ngongi, A. M., & Urassa, J. K. (2014). *Farm Households Food Production and Households' Food Security Status: A Case of Kahama District, Tanzania*. *13*(2), 19.

Obisesan, A. A. (2015). *Agris on-line Papers in Economics and Informatics Causal Effect of Off-Farm Activity and Technology Adoption on Food Security in Nigeria: Vol. VII*.

Sahin, I. (2006). Detailed Review of Rogers' Diffusion of Innovations Theory and Educational Technology. *The Turkish Online Journal of Educational Technology*, *5*, 1303–6521.

Sewando, P. T. (2012). Urban Markets -Linked Cassava Chain in Morogoro Rural District, Tanzania. *Journal of Sustainable Development in Africa*, *14*(3), 1–12.

Silva, A. G., Canavari, M., & Sidali, K. L. (2017). A technology acceptance model of common bean growers' intention to adopt integrated production in the Brazilian Central Region. *Journal of Land Management, Food and Environment*, *68*(3), 131–143.

Sinyolo, S. (2019). Technology adoption and household food security among rural households in South Africa: The role of improved maize varieties. *Technology in Society*, *60*, 101214.

Sissoko, P., Synnevag, G., & Aune, J. B. (2022). Effects of low-cost agricultural technology package on income, cereal surplus production, household expenditure, and food security in the drylands of Mali. *AIMS Agriculture and Food*, *7*(1), 22–36.

Tanzania bureau of Standards. (774). *Production and handling of maize grains—Good Agriculture Practice (GAP)*. Tanzania Bureau of Standards.

Taherdoost, H. (2018). A review of technology acceptance and adoption models and theories. *Procedia Manufacturing*, *22*, 960–967.

TNBC. (2009). The Kilimo Kwanza Resolution. In *Tanzania National Business Council*.

United Nations. (2015). Transforming our World: The 2030 Agenda for Sustainable Development. *United Nations, New York*, *August*, 1–31.

United Nations. (2019). World Food and Agriculture—Statistical Pocketbook 2018. In *World Food and Agriculture—Statistical Pocketbook 2018*.

URT. (1999). The Tanzania Development Vision 2025. In *Ministry of Finance and Planning*.

URT. (2014). *Agriculture Climate Resilience Plan, 2014–2019* (Issue September 2014).

URT. (2016a). *Agricultural Sector Development Strategy—II (2015/2016—2024/2025)*.

URT. (2016b). National Five-Year Development Plan 2016/17—2020/21. In *Ministry of Finance and Planning*.

URT. (2017a). *Agricultural Sector Development Program Phase II*.

URT. (2017b). *Comprehensive Food Security and Nutrition Assessment Report* (Issue February).

URT. (2019a). *National Postharvest Management Strategy*.

URT. (2019b). *Post Harvest Management Strategy Implementation Plan (2019–2024)*.

URT. (2019c). Tanzania National Nutrition Survey 2018. In *Dar es Salaam, Tanzania: MoHCDGEC, MoH, TFNC, NBS, OCGS, and UNICEF* (Issue June).

URT. (2021). *National Five-Year Development Plan 2021/22-2025/26*.

Vigani, M., & Magrini, E. (2014). *Technology adoption and the multiple dimensions of food security: The case of maize in Tanzania*.

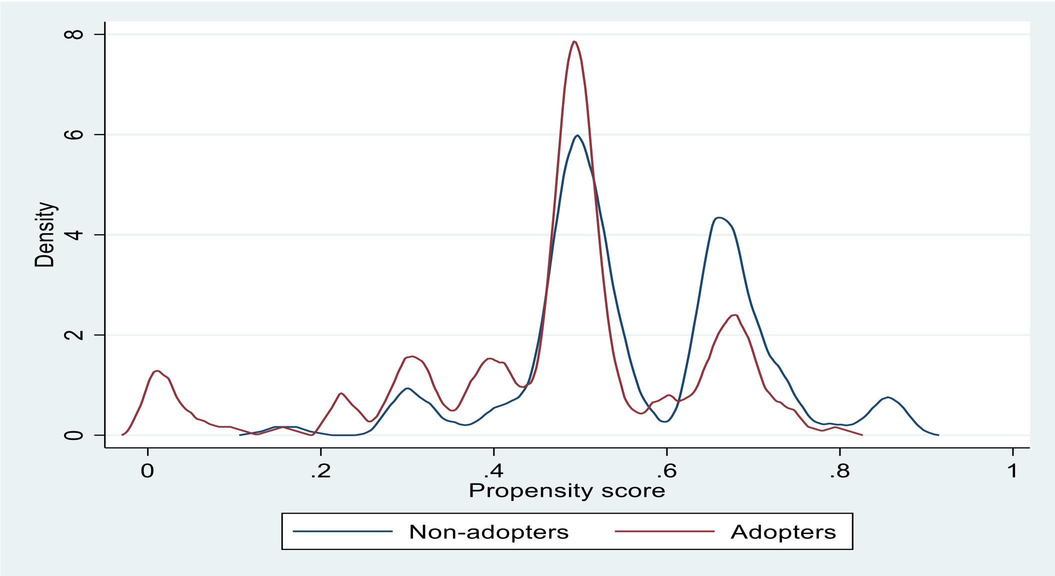
WFP. (2021). *WFP Tanzania Country Brief May 2021*. *July 2011*, 2020–2021.

9. ANNEXES

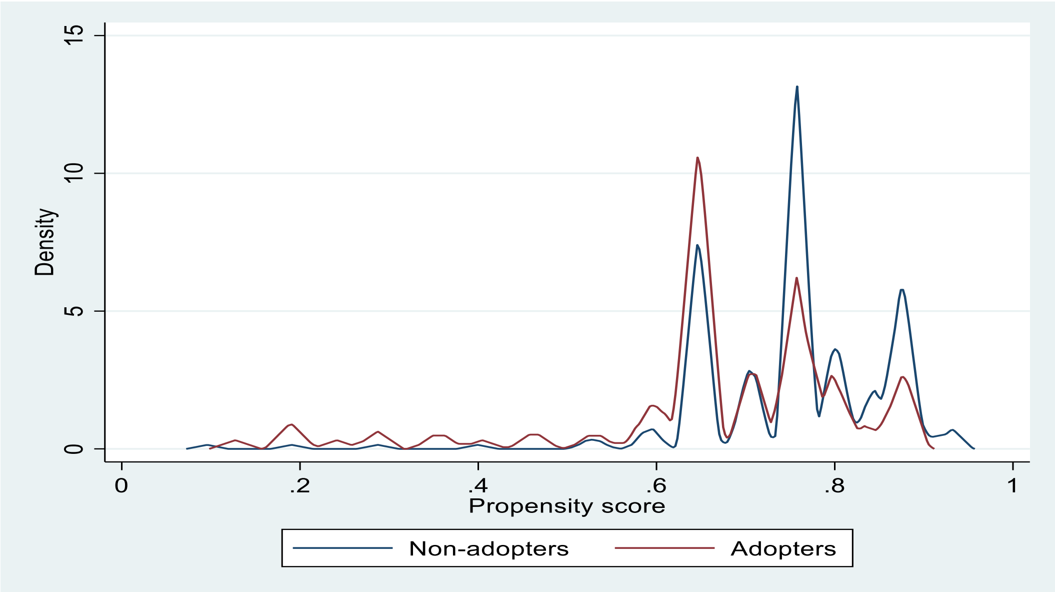
9.1 Annex 1: Diagnostic Tests

To ensure, the study findings are plausible, some diagnostic tests were carried out. First, the balance property was examined using overlapping assumptions. For all the models, evidence of a violation of overlapping assumption was not found. See the graphs below.

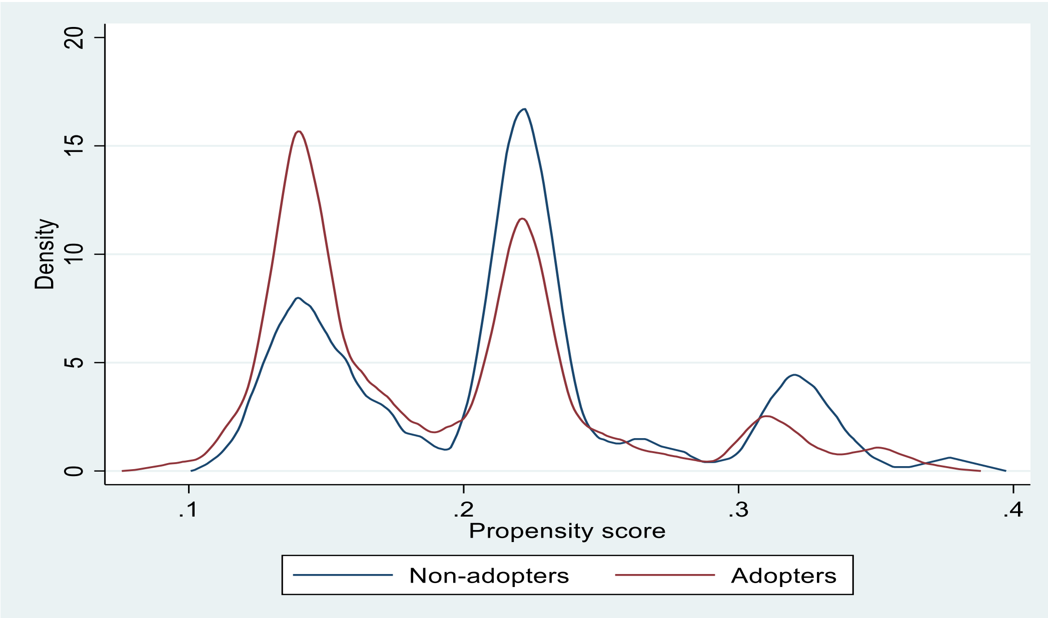
Adoption of technology (agricultural chain)



Adoption of technology(production)



Technology adoption (storage stage)



We also used an over-identification test to check the covariates balance. The test shows that the covariates are balanced and hence no evidence of a violation of the conditional independence assumption. See Table 19 and Table 20 for details.

Table 19:Covariate Balance Summary

	Raw	Weighted
Number of obs =	396	396.0
Treated obs =	318	198.7
Control obs =	78	197.3

	Standardized Differences		Variance Ratio	
	Raw	Weighted	Raw	Weighted
A5_1_age	-0.071	0.049	0.799	0.875
A5_2_sex	-0.251	-0.028	0.819	0.972
A5_3_educatio~l	-0.046	-0.031	0.814	1.022
A5_4_occupation	-0.096	-0.033	1.753	1.299
A5_5_marital_~s	-0.076	-0.034	0.647	0.718
A9_aged_member	-0.254	-0.012	0.764	0.917

Table 20: Overidentification Test for Covariate Balance

H0: Covariates are balanced

Chi-Square	5.62414
Probability	0.5843

9.2 Annex 2: Questionnaire

TECHNOLOGICAL ADVANCEMENT IN FOOD PRODUCTION AND MANAGEMENT AND ITS IMPLICATIONS ON FOOD SECURITY

A Case Study of Staple Food Products in Tanzania

HOUSEHOLD QUESTIONNAIRE

INTORUDUCTORY INFORMATION

I am Edwin Magoti from the Eastern Africa Statistical Training Centre (EASTC). We are conducting a study to investigate the role of technological advancement in food production and management and its implications on food security in Tanzania. This research is funded by the REPOA, a non-profit institution with a core function of conducting research on various social-economic aspects. The findings of this research will be useful in informing the Government and other development stakeholders/partners on the role of technological advancement in food production, management and the impact it poses on food security, consequently, building as base for informed decision making. Your responses will be treated with highest degree of confidentially and be used for research purposes only.

I dearly request you to take part in this study and respond to the questions to the best of your knowledge.

May you please allow me to proceed with the interview, feel free to ask any question before we start.

SECTION A: IDENTIFICATION AND HOUSEHOLD CHARACTERISTICS

1. Region ……………
2. District ……………
3. Village/Street ……………
4. Household identification Number
   ……………
5. Household head information
   a) Age in complete years ____________
   b) Sex
      1 = Male
      2 = Female
   c) Highest level of education
      1=No formal education
      2=Completed Primary
      3=Completed Ordinary secondary education
      4=Completed Advanced secondary education
      5=Completed first degree
      6=Completed more than first degree

   d) What was your main occupation for the past 12 months?
      1=Employed, government
      2=Employed, private
      3=Employed, self employed
      4=Agriculture, livestock
      5=Agriculture, crop farming
      6=other, specify

   e) What is your marital status?
      1=Single
      2=Married
      3=Divorced
      4=separated
      5=Widower/widow
      6=Living together

6. Who is responsible for agricultural/farming activities in this household?

    1=Head of the household
    2=Spouse of the head of household
    3=A child of the household head
    4=Any other relative of the household head
    5=Any other person in the household

7. If 6≠1, Ask information for a person responsible
    a) Age in complete years. ________
    b) Sex. ________

    c) Highest level of education
        1=No formal education
        2=Completed Primary
        3=Completed Ordinary secondary education
        4=Completed Advanced secondary education
        5=Completed first degree
        6=Completed more than first degree

    d) What was main occupation of the household head for the past 12 months?
        1=Employed, government
        2=Employed, private
        3=Employed, self employed
        4=Agriculture, livestock
        5=agriculture, crop farming
        6=other, specify

    e) What is marital status of the household head?
        1=Married, one spouse
        2=Married, multiple spouse
        3=Divorced
        4=separated
        5=Widower/widow
        6=other

8. Number of household members ________

9. Who has the highest level of education in the household?

    1=Head of the household

2=Spouse of the head of household
3=A child of the household head
4=Any other relative of the household head
5=Any other person in the household

10. What is the highest education level of a person who is more educated in the household?

    1=No formal education
    2=Completed Primary
    3=Completed Ordinary secondary education
    4=Completed Advanced secondary education
    5=Completed first degree
    6=Completed more than first degree

11. Does a person who has the highest level of education participate in decision making about agricultural activities?

    1=Yes
    2=No

SECTION B: CONSUMPTION AND FOOD SECURITY

(This section should be responded by a household member familiar more with food consumption in the household)

1. In the last week, on average how many meals per day does adult household members (14 years and above) consume? ....

2. In the last week, on average how many meals per day does young household members (below 14 years and) consume? ....

3. In the 12 months, on average how many meals per day does adult household members (14 years and above) consume? ....

4. In the 12 months, on average how many meals per day does young household members (below 14 years and) consume? ....

5. In the past 7 days, how many days have you or someone in your household had to (*if no days, record zero*)
    a. Rely on less preferred foods? ....
    b. Limit the variety of foods eaten? ....

c. Limit portion size at meal-times? ....
d. Reduce number of meals eaten in a day? ....
e. Restrict consumption by adults for small children to eat? ....
f. Borrow food, or rely on help from a friend or relative? ....
g. Have no food of any kind in your household? ....
h. Go a whole day and night without eating anything? ....

6. In the last month, did your household get a balanced diet (with different types of food) at least for one meal per day?
   1=Yes
   2=No

7. Do children in your household access important food nutrients for their health as recommended by health professionals?
   1=Yes
   2=No

8. In the last 12 months, have you been faced with a situation when you did not have enough food to feed the household?
   1=Yes
   2=No

9. If 8==1, What was the cause of this situation? (Mention three causes)
   1=Inadequate household stocks due to drought/poor rains
   2=Inadequate household food stocks due to crop pest damage
   3=Inadequate household food stocks due to small land size
   4=Inadequate household food stocks due to lack of farm inputs
   5=Food in the market was very expensive
   6=Not able to reach the market due to high transportation costs
   7=No food in the market
   8=Floods/water logging/hailstorm
   9=No money
   10=Other, specify

10. For the last week, what was the monetary value of food consumed in your household (TZS)? ....

11. What was the value of consumption produced within the household (TZS)? ....

12. What was the value of consumption obtained as a gift or grants from outside the household (TZS)? ....

13. Consider all non-food consumption like public transport, cigarette/tobacco, electricity, water, lighting matches, airtime, petrol/diesel, charcoal, soap, etc. incurred in your household for the past week, what was the total monetary value (TZS)? ....

SECTION C: FARMING PRACTICES AND TECHNOLOGY APPLICATION

(This section should be administered to a household member familiar more agriculture/farming activities of the household during the past farming season)

1. What was the last farming season in this household for the maize/paddy crop?
   1=2020
   2=2021
   3=2022

2. What was the size of the farm cultivated by you or your household in the last farming for this crop? (acres) ....

3. What was the portion of the land harvested? (acres) ....

4. Was this crop planted alone in the plot?
   1=Yes
   2=No

5. If 6=1, what was the reason of mixing the crop?
   1= Improve soil fertility
   2= Mitigating the risk of lacking crops/harvest
   3= Other (Specify)

6. What was the name of the main seed variety for this [CROP] on this plot)? ....

7. Was the seed used?
   1=Improved
   2=Traditional
   3=Improved, recycled
   4=Other, specify

8. Did you use organic fertilizer for the last farming season?
    1=Yes
    2=No

9. If 9=1, How much organic fertilizer did use? (Kg) ....

10. Did you use inorganic fertilizer for the last farming season?
    1=Yes
    2=No

11. If 11=1, How much organic fertilizer did use? (Kg) ....

12. The main inorganic fertilizer used for this crop was of what type?
    1= Di-ammonium Phosphate (DAP)
    2=UREA
    3=Triple Super Phosphate (TSP)
    4=Calcium Ammonium Nitrate (CAN)
    5=Sulphate of Ammonium (SA)
    6=Nitrogen Phosphate Potassium (NPK)
    7=Minjikingu Rock Phosphate (MRP)
    8=Other (Mention)

13. Did you use any herbicide on this plot in the last farming season?
    1=Yes
    2=No

14. If 14=1, How much herbicide did you use?
    a. Unit ....
    b. Amount ....

15. Did you use any pesticide on in the last farming season?
    1=Yes
    2=No

16. If 16=1, How much pesticide did you use?
    a. Unit ....
    b. Amount ....

17. Did you use any machines (tractor, power tiller etc.) in this plot for the last farming season?
    1=Yes
    2=No

18. Did you use any animal traction on this plot in the last farming season?
    1=Yes
    2=No

19. Was irrigation applied for this crop in the last farming season?
    1=Yes
    2=No

20. If 20=1, what kind of irrigation did you use?
    1=Flooding
    2=Sprinkler
    3=Drip irrigation
    4=Bucket / watering can
    5=Water hose
    6=Other(specify)

21. Was this plot left fallow ever?
    1=Yes
    2=No
22. If 22=1, When was this plot left fallow for the last time? ....

23. Have you ever changed the type of crop planted in this farm/plot?
    1=Yes
    2=No

24. If 24=1, when was last time when the crop was changed? ....

25. How often do you change the type of crop to be planted in this plot? ....

26. Do you use scientific or professional measures when planting crops in this plot (for instance distance between crop and crop)?
    1=Yes
    2=No

27. Before planting your crops/seed, are there special scientific techniques used to clean the crop/seeds?
    1=Yes
    2=No

28. If 28=1, Mention those techniques?
    a...
    b...
    c...
    d...

29. Do you usually test seed fertility before planting?
    1=Yes
    2=No
30. Why? (Any response in 29)
31. In the last 12 months, has anyone in this household received any training about agricultural activities? (Mention the kind of training received).
    1=Yes, training about using technology in production
    2=Yes, training about using technology in food management
    3=Any other(specify)
    4=No

32. If 13≠4, Did a person who received training participate in decision making about agricultural activities in the household for the last farming season?
    1=Yes
    2=No

Section D: Harvest and Storage of crops

1. In the last farming season, what was the amount of harvest? (Kgs) ________
2. What was the value of harvest at the time of harvest? (TZS) ________
3. What was the main harvest method in the last farming season?
    1=hands and local tools
    2=Harvest machines like tractors and others
    3=Others (Specify)
4. What was the main method used for threshing this crop in the last farming season?

1=Using hands and local tools in an open space
2=Using hands and plastic/nylon bags
3=Using machines like tractor
4=Did not thresh
5=Other (Specify)

5. What was the main method used to clean the crop after threshing (winnowing)
    1= Using hands and local tools
    2= Using machines (advanced tools)
    3=Did not winnow
    4=Other(specify)

6. Was the crops/harvest dried before storing?
    1=Yes
    2=No

7. If 4=1, What methods was used for drying?
    1=Sunning
    2=Heat
    3=Advanced tools/machines
    4=Industrial chemicals
    5=Other (Specify)

8. Was there any crop loss at the farm?
    1=Yes
    2=No

9. If 8=1, What was the reason for the loss?
    1=Birds
    2=Animals
    3=Insects
    4=Diseases
    5=Theft
    6=Flood/rain
    7=Drought
    8=Other, specify

10. What is the estimate of the quantity of crop lost while at the farm (Kg)?............

11. What is the estimate of the cost of crop lost at the farm (TZS)?...........

12. Did you use any method to stop/reduce crop losses at the farm?
    1=Yes
    2=No

13. If 10=1, Which method did you use? (specify)
    a............... b.......................... c.................

14. Do you know any modern/technological method that you could have used to reduce pre-harvest loss?
    1=Yes
    2=No

15. If 12=1, did you use that method?
    1=Yes
    2=No

16. If 13=2, why didn't you use such method?
    1=restriction from society/government
    2=costs associated with the method
    3=Others (Specify)

17. Did you store any portion of crops for food or future income?
    1=Yes
    2=No (*skip to 20)*

18. What was the main method used to store the crop?
    1=locally made traditional structure
    2=locally made improved structure
    3=modern store
    4=sacks / open drum
    5=airtight drum
    6=unprotected pile
    7=ceiling
    8=other, specify

19. Take a photo/picture of the storage mechanism (Photo)

20. Did you do anything to protect the harvest in store?

1=Yes
2=No

21. If 18=1, What did you do?

    1=Spraying
    2=Smoking
    3=Other, specify

22. Before harvesting, do you consider timing appropriate for harvesting?
    1=Yes
    2=No

23. Was any portion of this production lost post-harvest to rotting, insects, rodents, theft, etc.?
    1=Yes
    2=No

24. If 21=1, What was the main reason for the loss?
    1=Rotting
    2=Insects
    3=Rodents
    4=Theft
    5=Other, Specify

25. What is the approximate quantity of the harvest lost (Kg)..................?

26. What is the approximate value of the harvest lost (TZS)..................?

INTERVIEW GUIDE FOR KEY INFORMANTS

1. Type of respondent
    a. Farmer
    b. Extension officer
    c. Community leader (VC or VEO)
    d. Other

2. Can you elaborate on how technology is important for maize/rice production in your area?

3. Can you elaborate on how technology is important for maize/rice storage/management in your area?

4. Let's speak of your best scenario case on technological advancement on maize/rice production
   a. What was it
   b. What was so important about it
   c. What impact did it have?
   d. Do you recommend the case for other farmers?
   e. Why or why not?
   f. Can anything be done to improve the scenario?
   g. What can be done?

5. Let's speak of your best scenario case on technological advancement on maize/rice management
   a. What was it
   b. What was so important about it
   c. What impact did it have?
   d. Do you recommend the case for other farmers?
   e. Why or why not?
   f. Can anything be done to improve the scenario?
   g. What can be done?

Record the images and scenario narrated by respondents

6. How do you rate the uptake of technology in food production at your area?
   a. Very high
   b. High
   c. Moderate
   d. Low
   e. Very low

7. Why do say so?
   a. ....
   b. ....
   c. ....
   d. ....
   e. ....

8. How do you rate the uptake of technology in food management at your area?
    a. Very high
    b. High
    c. Moderate
    d. Low
    e. Very low

9. Why do say so?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

10. Do you think the government and other stakeholders should encourage uptake of technology food production and management in your area?
    1=Yes
    2=No

11. Why?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

12. Do you think the government and other stakeholders are doing what is necessary to improve uptake of technology in your area?
    1=Yes
    2=No

13. What do you think the government should do?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

14. Is there any technology in either food production or management that you think are more suitable in this community?
    1=Yes
    2=No

15. Mention those technology
    a. Food production
        i. ....
        ii. ....
        iii. ....
        iv. ....
    b. Food management
        i. ....
        ii. ....
        iii. ....
        iv. ....

16. Why do you think that technology is more suitable in your community?
    a. ....
    b. ....
    c. ....
    d. ....
    e. ....

9.3 Annex 3: Research Permits

Ofisi ya Taifa ya Takwimu

Simu: +255 26 - 2963822
Nukushi: +255 26 - 2963828
Barua pepe: sg@nbs.go.tz
Tovuti : www.nbs.go.tz

Barabara ya Jakaya Kikwete
S.L.P. 2683
Dodoma
TANZANIA

Unapojibu tafadhali taja:
Kumb. Na: CB.317/377/01

27/1/2022

Katibu Mkuu,
Ofisi ya Rais,
Tawala za Mikoa na Serikali za Mitaa (TAMISEMI),
Barabara ya Nane,
S. L. P. 1923,
41181 DODOMA.

Yah: KIBALI CHA KUFANYA UTAFITI KUHUSU MAENDELEO YA TEKNOLOJIA NA UMUHIMU WAKE KATIKA UDHIBITI NA USALAMA WA CHAKULA.

Tafadhali husika na somo tajwa hapo juu.

2. Ofisi ya Taifa ya Takwimu (NBS) ilipokea barua ya tarehe 20 Januari 2022 kutoka Chuo cha Takwimu Mashariki mwa Afrika (EASTC) ikiomba kibali cha kufanya utafiti tajwa hapo juu katika halmashauri mbili (2) ambazo ni Mbinga na Kilombero.

3. Napenda kukutaarifu kuwa, NBS imepitia nyaraka zote zilizowasilishwa kwa ajili ya utafiti huo. Kwa mujibu wa Sheria ya Takwimu Sura Na. 351, NBS inatoa kibali ili utafiti huu ufanyike kwa kuwa utafiti huu ni sehemu ya shughuli za kielimu.

4. Kwa barua hii, naomba Ofisi yako iweze kuitambulisha taasisi tajwa hapo juu katika mikoa iliyotajwa hapo juu, ili iweze kutekeleza zoezi la utafiti uliokusudiwa. Utafiti huu unatarajiwa kufanyika kuanzia mwezi Februari, 2022 hadi Mei, 2022 na mwisho wa kibali cha Utafiti huu ni tarehe 30 Julai, 2022.

5. Pamoja na barua hii naambatanisha dodoso litakalotumika katika Utafiti huo.

Wako Katika Ujenzi wa Taifa
OFISI YA TAIFA YA TAKWIMU

Benedict Mugambi
Kny MTAKWIMU MKUU WA SERIKALI

Nakala: Chuo cha Takwimu Mashariki mwa Afrika,
S.L.P 35103,
Dar es Salaam.

Email: info@eastc.ac.tz (*Tafadhali wasilisha rasimu ya ripoti ya utafiti huu TAMISEMI na Ofisi ya NBS kabla ya kusambaza*)

Majibu yote yatumwe kwa Mtakwimu Mkuu wa Serikali

JAMHURI YA MUUNGANO WA TANZANIA

OFISI YA RAIS
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

Anuani ya Simu "TAMISEMI" DODOMA
***Simu Na:* +255 26 2321607**
***Nukushi:* +255 26 2322116**
***Barua pepe:*ps@tamisemi.go.tz**

Mji wa Serikali – Mtumba,
Mtaa wa TAMISEMI,
S.L.P. 1923,
41185 DODOMA.

Unapojibu tafadhali taja:-

Kumb. Na. AB.307/323/01/ 54

04 Februari, 2022

Makatibu Tawala wa Mikoa,
Ruvuma na Morogoro,

Yah: **KIBALI CHA KUFANYA UTAFITI KUHUSU MAENDELEO YA TEKNOLOJIA NA UMUHIMU WAKE KATIKA UDHIBITI NA USALAMA WA CHAKULA**

Tafadhali rejeeni somo tajwa hapo juu.

2. Ofisi ya Rais –TAMISEMI ikishirikiana na Ofisi ya Taifa ya Takwimu (NBS) imetoa kibali kwa **Chuo cha Takwimu Mashariki mwa Afrika (EASTC)** kwa ajili ya kufanya utafiti tajwa katika Mikoa ya Ruvuma na Morogoro.

3. Muda wa kufanya utafiti huu ni kati ya mwezi Februari, 2022 na tarehe 30 Julai, 2022. Ofisi ya Rais -TAMISEMI kwa kushirikiana na Taasisi nyingine za Serikali itafanya ukaguzi wakati wowote kujiridhisha na utekelezaji sahihi wa kibali hiki. Takwimu zitakazokusanywa kutokana na utafiti huu ni kwa ajili ya matumizi ya ndani tu na iwapo zitatakiwa kuchapishwa na kusambazwa kibali kutoka Mamlaka husika kitapaswa kuombwa.

4. Kwa barua hii, tafadhali waelekezeni Wakurugenzi wa Halmashauri za Mikoa yenu ili kutoa ushirikiano utakaohitajika na kukamilisha utafiti huu kama ulivyokusudiwa. Kazi hii isimamiwe na Watakwimu wa Mikoa na Halmashauri husika na kutoa taarifa ya utekelezaji.

Ninawashukuru kwa ushirikiano wenu.

Gerald G. Mweli, *ndc*
KAIMU KATIBU MKUU

Nakala: Katibu Mkuu Kiongozi,
Ofisi ya Rais,
IKULU,
1 Barabara ya Julius Nyerere,
Chamwino,
S. L. P. 1102,
40400 DODOMA. *(Waione RSO wa Mikoa ya Ruvuma na Morogoro).*

Mtakwimu Mkuu wa Serikali,
Ofisi ta Taifa ya Takwimu (NBS),
S.L.P 2683,
DODOMA. *(Rejea barua yenye Kumb Na.CB.317/377/01)*

Chuo cha Takwimu Mashariki mwa Afrika (EASTC),
S. L. P 35103,
DAR ES SALAAM. *(Nakala ya taarifa ya utafiti iwasilishwe NBS, Ofisi ya Rais -TAMISEMI na Ofisi husika za Wakuu wa Mikoa na Halmashauri: Kibali kinaweza kufutwa muda wowote endapo kutakuwa na ukiukwaji wowote au sababu nyingine yoyote)*

JAMHURI YA MUUNGANO WA TANZANIA
OFISI YA RAIS
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

Anuani ya Simu: "MKUUMKOA"
Simu Nambari: (023)2934305/2934306
Fax Nambari: (023)260 4988
Email: ras.morogoro@tamisemi.go.tz
Tovuti www.morogoro.go.tz
Unapojibu tafadhali taja:

Ofisi ya Mkuu wa Mkoa
Boma Road,
S.L.P. 650,
67117 MOROGORO.

Kumb. Na. AB.175/245/01J/59

21 Februari, 2022

Katibu Tawala Wilaya,
KILOMBERO.

YAH: KUFANYA UTAFITI KUHUSU MAENDELEO YA TEKNOLOJIA NA UMUHIMU WAKE KATIKA UDHIBITI NA USALAMA WA CHAKULA

Tafadhali rejea kichwa cha habari hapo juu.

2. Ofisi ya Mkuu wa Mkoa imepokea barua kutoka OR – TAMISEMI yenye Kumb. Na AB.307/323/01/54 ya tarehe 4 Februari, 2022 kuhusu mada tajwa.

3. Barua hiyo imeeleza kwamba OR – TAMISEMI imetoa kibali kwa **Chuo cha Takwimu Mashariki mwa Afrika (EASTC)** kwa ajili ya kufanya utafiti tajwa katika Halmashauri. Muda wa kufanya utafiti huu ni kati ya mwezi Februari, 2022 hadi Julai, 2022. Takwimu zitakazokusanywa kutokana na utafiti huo ni kwa ajili ya matumizi ya ndani tu na iwapo zitatakiwa kuchapishwa na kusambazwa kibali kutoka Mamlaka husika kitapaswa kuombwa.

4. Kwa barua hii, naomba utoe ushirikiano kwa watafiti hao ili kufanikisha kazi hiyo. Aidha, OR – TAMISEMI kwa kushirikiana na Taasisi nyingine za Serikali itafanya ukaguzi wakati wowote kujiridhisha na utekelezaji wa utafiti huu. Watakaoshiriki utafiti huu ni **Sikujua N. Samweli, Halima M. Fadhili, Oliva E. Sanga, Abdulkadir Othuman na Frank F. Msele.**

5. Katika ushirikiano.

Rwegasira
Dr. Rozalia Rwegasira
Kny: KATIBU TAWALA WA MKOA

Nakala: Mkurugenzi wa Mji,
IFAKARA.

Chuo cha Takwimu Mashariki mwa Afrika (EASTC)
S.L.P 35103,
DAR ES SALAAM.

JAMHURI YA MUNGANO WA TANZANIA
OFISI YA RAIS
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

Anuani ya simu: MKUU WA WILAYA
Simu Nambari: 023-2931511/2931525
Fax Nambari 2931511/2931525
Barua pepe: das.kilombero@morogoro.go.tz
Unapojibu tafadhali taja:

Ofisi ya Mkuu wa Wilaya Kilombero
S.L.P. 34,
IFAKARA

21 Februari, 2022

Kumb. Na.AB. 23/367/01B/249

Mkurugenzi,
Halmashauri ya Mji
IFAKARA

Yah: **KIBALI CHA KUFANYA UTAFITI**

Tafadhali husika na somo tajwa hapo juu

2. Ofisi ya Mkuu wa Wilaya Kilombero imepokea barua kutoka Ofisi ya Mkuu wa Mkoa wa Morogoro yenye Kumb. Na. AB.175/245/01'J'/50 ya tarehe 21 Februari, 2022 inayowatambulisha ***Ndugu Lemiani Makori Alais na Edwin Tito Magoti*** kutoka **Chuo cha Takwimu Mashariki mwa Afrika (EASTC)** ambao ni Watafiti na watafanya utafiti katika Tarafa ya Ifakara na Mang'ula katika Vijiji vya ***Kanyenja, Mhelule, Ichonde, Mpanga, Bwawani, Mkasu, Signal, Mkula, Katurukila, Lumemo, Mtaa wa Ifakara, Uhuru, Viwandani, Uwanja wa Taifa 'A', Katindiuka 'C' na Kiyongwile 'B' Wilaya ya Kilombero.*** Watasaidiwa na Ndugu ***Sikujua N. Samweli, Halima M. Fadhili, Oliva E. Sanga, Abdulkadir Othuman na Frank F. Msele.***

3. Kiini cha utafiti wao ni "***Matumizi ya Teknolojia katika Uzalishaji, Udhibiti wa Chakula na Umuhimu wake katika Usalama wa Chakula".***

4. Kibali cha Utafiti ni kuanzia Februari, 2022 hadi Julai, 2022.

5. Tafadhali wape ushirikiano na watake Wataalam wa Kilimo kushirikiana nao katika utafiti wao.

Magesa V.M
Kny: **KATIBU TAWALA WILAYA**
KILOMBERO

KATIBU TAWALA WILAYA
S. L. P. 34
IFAKARA - KILOMBERO

Nakala:
Katibu Tawala Mkoa
MOROGORO
Mkuu wa Wilaya
KILOMBERO - Aione ndani ya jalada
Afisa Tarafa
Mang'ula na Ifakara
WILAYA YA KILOMBERO
Chuo cha Takwimu Mashariki mwa Afrika (EASTC)
S.L.P. 35103,
DAR ES SALAAM
Ndugu Edwin Tito Magoti - Kwa niaba ya wenzake
MTAFITI

JAMHURI YA MUUNGANO WA TANZANIA

OFISI YA RAIS
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

HALMASHAURI YA MJI IFAKARA

Unapojibu tafadhali taja:

Kumb. Na. IFTC/E.10/80/VOL IV/20 22/02/2022

Watendaji wa Kata Husika
Halmashauri ya Mji Ifakara,
S.L.P 433,
IFAKARA.

KUH: KUWATAMBULISHA NDG. LEMIAN MAKORI ALAIS NA EDWIN TITO MAGOTI

Husika na mada tajwa hapo juu.

2. Watajwa hapo juu ni wanachuo kutoka Chuo cha Takwimu Mashariki mwa Afrika (EASTC) ambao ni watafiti watafanya utafiti katika Tarafa ya Ifakara na Mang'ula katika vijiji vya Kanyenja, Mhelule, Ichonde, Mpanga, Bwawani, Mkasu, Signal, Mkula, Katurukila, Lumemo, Mtaa wa Ifakara, Uhuru, Viwandani, uwanja wa Taifa A, Katindiuka c na Kiyongwile B Wilaya ya Kilombero. Watafanya utafiti wao kwa mada inayohusu **"Matumizi ya Teknolojia katika uzalishaji, Udhibiti wa Chakula na Umuhimu wake katika Usalama wa Chakula.** Utafiti huu ni kuanzia Februari, 2022 hadi Julai, 2022.

3. Kwa barua hii nawatambulisha watajwa hapo juu na kuwapa ushirikiano katika utafiti wao.

4. Nakutakia kazi njema.

MKURUGENZI WA MJI
S.L.P 433
IFAKARA

Edina B. Oscar
Kny: **MKURUGENZI MJI**

Nakala: Katibu Tawala Wilaya
Kilombero - Kwa taarifa

" Lemian Makori Alais Na, – Mtafiti
" Edwin Tito Magoti – Mtafiti

OfisiyaMkurugenziwaMji, S.L.P. 433 IFAKARA, Simu 023-2934212, Nukushi 023-2934212, Baruapepe: info@ifakaratc.go.tz, Tovuti: http://ifakaratc.go.tz

JAMHURI YA MUUNGANO WA TANZANIA
OFISI YA RAIS
TAWALA ZA MIKOA NA SERIKALI ZA MITAA

MKOA WA RUVUMA
Simu Nambari 025-2602256/2602238
Fax No. 2602144
Email: ras.ruvuma@tamisemi.go.tz
Tovuti: www.ruvuma.go.tz

Ofisi ya Mkuu wa Mkoa,
S. L. P. 74,
SONGEA.

Kumb. Na. AB 228/276/01/H/88

15 Februari, 2022

Mkurugenzi wa Manispaa,
SONGEA.

Mkurugenzi wa Mji,
Halmashauri ya Mji,
MBINGA.

Wakurugenzi Watendaji,
Halmashauri za Wilaya,
SONGEA, NYASA, MBINGA,
NAMTUMBO,TUNDURU, MADABA.

YAH: KIBALI CHA KUFANYA UTAFITI KUHUSU MAENDELEO YA TEKNOLOJIA NA UMUHIMU WAKE KATIKA UDHIBITI NA USALAMA WA CHAKULA

Ofisi ya Mkuu wa Mkoa imepokea barua kutoka Ofisi ya Rais TAMISEMI yenye Kumb. Na. **AB.307/323/01/54** ya tarehe **04 Januari, 2022** kuhusu somo tajwa hapo juu.

2. Ofisi ya Rais – TAMISEMI ikishirikiana na Ofisi ya Taifa ya Takwimu (NBS) imetoa kibali kwa Chuo cha Takwimu Mashariki mwa Afrika (EASTC) kwa ajili ya kufanya utafiti tajwa katika Mikoa ya Ruvuma na Morogoro.

3. Muda wa kufanya utafiti huu ni kati ya mwezi Februari 2022 na tarehe 30 Julai, 2022. Ofisi ya Rais - TAMISEMI kwa kushirikiana na Taasisi nyingine za Serikali itafanya ukaguzi wakati wowote kujiridhisha na utekelezaji sahihi wa kibali hiki. Takwimu zitakazokusanywa kutokana na utafiti huu, ni kwa ajili ya matumizi ya ndani tu na iwapo zitatakiwa kuchapishwa na kusambazwa kibali kutoka Mamlaka husika kitapaswa kuombwa.

4. Kwa barua hii, unatakiwa kutoa ushirikiano utakaohitajika na kukamilisha utafiti huu kama ulivyokusudiwa. Kazi hii isimamiwe na Watakwimu wa Mikoa na Halmashauri husika na kutoa taarifa ya utekelezaji..

5. Ninawashukuru kwa ushirikiano wenu.

Onesmo Z. Mpuya
Kny: KATIBU TAWALA MKOA
RUVUMA

Kny: KATIBU TAWALA MKOA
RUVUMA

REPOA HQs

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Dar es Salaam, Tanzania.
Tel: +255 (22) 270 0083 Cell: +255 (0)784 555 655
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Email: repoa@repoa.or.tz

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Dodoma, Tanzania