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Determinants of farmers' choice of adaptation strategies against climate variability and change: Lessons from central Tanzania in Manyoni district

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ABSTRACT

Farmers' adaptation strategies against climate variability and change impact are fundamental in abating the effects in this epoch. Previous studies have confirmed the presence of context-specific farmers' adaptation strategies in Tanzania. However, it is not clear what factors influence farmers to select specific adaptation strategies. This study contributes to filling this knowledge gap. We used the cross-sectional research design in a survey of a random sample of 330 small-scale farmers. The multivariate probit was used to model the factors determining the choice of adaptation strategies. Farmers adapted a number of strategies, nonetheless, there were four key adaptation strategies: drought-resistant varieties, use of early maturing varieties, resistant livestock breeds, and conservation agriculture. Farmers used more than one strategy, and the choice was determined by multiple factors that showed a statistically significant impact at 5 %. We categorize the factors into four groups: (i) individual farmer and or household characteristics covering age, farming experience of the household head; household size; and household wealth, especially livestock ownership (ii) farm characteristics like location of the farm and farm size (iii) institutional factors that include access to extension services, technology, and provision of title deeds for land ownership to the farmers; and (iv) knowledge of manifestation of CV & C like shifting of rain seasons, and awareness of using meteorological information in decision making. These factors should be considered in policy development to heighten the effectiveness of the adaptation strategies in cushioning climate variability and change impact in the study area and central Tanzania at large.

Practical implications

Empirical studies show sufficient evidence of climate variability and change manifestation at global, regional, national, and local levels. To that effect, farmers' adaptation against climate variability and change impact is increasingly becoming important for human survival. Some adaptation strategies like use of drought resistant varieties and planting early maturing varieties are becoming widespread. Others like movements of agro-pastoralists are more common in Sub-Saharan Africa than other regions in the world.

The decision to select a specific and appropriate adaptation strategy in a particular context is determined by multiple factors. However, the factors are not well unpacked in countries like Tanzania. In order to fill this knowledge gap, the results of this study uncovered four major farmers' adaptation strategies whose choice was determined by different factors. The common ones were access to extension services and livestock ownership. These factors determined the choice of all key adaptation strategies in the study area. While extension services were necessary to enhance the adoption of the adaptation strategies, livestock ownership is an indicator of wealth in rural Tanzania and so improved adaptive capacity against CV & C impact. The choice to use drought-resistant varieties was determined by many factors compared to other adaptation strategies, including the use of extension services and individual farmer, household, and farm characteristics that need not be generalized across the board. These, in particular, include the age and farming experience of the household head, household size, farm size, and location of the farm. Other factors were using title deeds for land ownership, knowledge of climate variables, rainfall variability and temperature trends, and awareness of meteorological information in decision-making. These factors have implications for enhancing interventions that improve the use of drought-resistant varieties.

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The decision to select early maturing varieties was determined by the individual farmer and household characteristics, predominantly age, household size, household wealth, mainly livestock ownership. Others were institutional factors and knowledge of climate variables. Similarly, the choice of keeping resistant livestock breeds was determined by the household wealth and use of extension services, whereas the selection of conservation agriculture was determined by awareness of rainfall trends and the use of extension services. Therefore, interventions that focus on improving institutional factors like extension services and awareness of the variability of climate variables are especially fundamental. The practical implications of the results are that the common determinant factors should be upheld and supported by the government. Similarly, all factors that enhanced the choice of adaptation strategies should be up-scaled in a similar agro-ecological zone.

1. Introduction

The debate about whether climate variability and change (CV & C) have happened or not and whether they are global phenomena has ended by concluding the manifestation of the phenomena at local, national, regional, and global levels. These phenomena encompass two broad concepts: climate change and climate variability (Kabote et al., 2017). Climate change entails changes in a long-term mean, usually a minimum of 30 years, of weather variables like rainfall and temperature, whereas climate variability refers to short-term changes in the same variables. The phenomena affect different economic sectors differently depending on the capacity of farmers' adaptation and government interventions. The impact attributed to CV & C is threatening. In developing countries like Tanzania, climate variability is more challenging than climate change because of low farmers' adaptive capacity attributed to rampant poverty among small-scale farmers (Kabote et al., 2017; Nyoni et al., 2024).

Scholars have currently concluded that CV & C impact is affecting vulnerable farming communities, more so in Sub-Saharan Africa (SSA) than the rest of the world (URT, 2007; Belay et al., 2017; Magesa et al., 2023). Although the body of literature on CV & C and farmers' adaptation strategies against CV & C impact is skyrocketing in SSA, including Tanzania (URT, 2007; Mary & Majule, 2009; Swai et al., 2012; Kabote et al., 2014; Kahimba et al., 2015; Sawe et al., 2018; Lema & Majule, 2021; and Mligo et al., 2022; Magesa et al., 2023), farmers' adaptation against CV & C impact is gradually happening in most countries in the region (Atube et al., 2021). This is principally because of poverty, which explains miniature farmers' adaptive capacity. In addition, the literature on the factors that determine farmers' choice of adaptation strategies against CV & C is tinny (Kahimba et al., 2015), particularly in Tanzania. This challenges research-based decisions to promote farmers' adaptation strategies applicable in the agricultural sector to which the livelihood of the majority is anchored in the country.

Tanzania like other countries in SSA is struggling to strengthen CV & C adaptation strategies to cushion CV & C impact. The national-level efforts to understand the impact and adaptation strategies of the phenomena commenced in 2007 with the development of the National Adaptation Programme of Action (NAPA) (URT, 2007). The overall purpose of the NAPA is to identify effective adaptation strategies for CV & C that support sustainable development in the country, notwithstanding the presence of the phenomena. In this context, an effective adaptation strategy robustly cushions CV & C impact, specifically reinforcing agricultural sector growth and the national economy.

The NAPA concludes the manifestation of CV & C in Tanzania. Overall, the mean annual temperature is increasing and is predicted to increase by 2.2 ^{0}C by 2100 (Kahimba et al., 2015). Scholars, including Kabote et al. (2013), confirmed an increasing trend in temperature while rainfall shows a decreasing trend in the central parts of Tanzania, particularly in the Iramba district and the Lake Victoria zone in Meatu district. According to the NAPA, rainfall in the eastern parts of Tanzania and some parts of the Lake Victoria zone is expected to increase by 50 % by 2100 (URT, 2007). Generally, the ecological zones that receive bimodal rainfall patterns are predicted to experience an increased rainfall between 5 and 45 %, whereas those that receive unimodal rainfall are likely to experience decreased rainfall between 5 and 15 % (Kahimba et al., 2015). Semi-arid environments covering central Tanzania in the Singida and Dodoma regions are likely more affected by CV & C than other agro-ecological zones. Based on the aforementioned scientific evidence, there is currently no more debate on the fact that CV & C has happened in Tanzania, implying that they are factual phenomena and will continue affecting the economy if they continue unabated in the country.

Farming in Tanzania is vulnerable to CV & C impact because it is rainfall-dependent, which is increasingly becoming unpredictable. Overall, the National Climate Change Strategy developed in 2012 succinctly states that Tanzania is one of the most highly vulnerable countries to CV & C impact in the world (URT, 2012). To that effect, farmers have no option except to adapt to the phenomena to curtail the impact on agricultural-based livelihood. This study contributes to the literature on what and how factors influence farmers' choice of specific adaptation strategies. The study is guided by a research question: "What and why do farmers choose specific adaptation strategies and leave others in the study area?" The results from this study will help decision-makers and policymakers put in place appropriate actions to strengthen farmers' choice of pertinent adaptation strategies against CV & C impact.

1.1. Farmers' adaptation strategies against CV & C impact in Tanzania

The fact that CV & C has negatively impacted fundamental sectors of the economy, including agriculture, the Government of Tanzania, through NAPA, identifies a number of sector-specific adaptation strategies that should be integrated into the policy-making and implementation process to minimize the impact. The recommended adaptation strategies include changing farming systems, changing planting dates, drip irrigation, growing drought-resistant varieties like sorghum and millet, growing short-season crop varieties, using climate information, creating awareness of the negative impact of CV & C, and strengthening the early warning system (URT, 2012). Based on the previous empirical studies, Table 1 summarizes several farmers' adaptation strategies practiced by small-scale farmers in Tanzania.

Based on the NAPA, the Government of Tanzania considers drought-resistant and early-maturing varieties different adaptation strategies. While drought-resistant varieties tolerate prolonged dry spells and do not necessarily mature earlier, early maturing varieties are characterized by a shorter life cycle to attain the harvesting stage. So, addressing the impact of a shortened growing season is attributed to a late onset of rainfall concurrently with early cessation of rainfall. For this reason, the two are considered different adaptation strategies against CV & C impact in this study. A few studies, including Swai et al. (2012), Kahimba et al. (2015), and Hella et al. (2016) examined factors influencing farmers' choice of adaptation strategies in Tanzania. Swai et al. (2012), for example, reported institutional factors like the use of improved technologies, individual farmer characteristics, and non-farm activities. Nonetheless, this study failed to determine the effectiveness of the factors that could be promoted and possibly scaled up to minimize CV & C impact. Hella et al. (2016), in their study conducted in Pangani, Tanzania, and Pemba island in Zanzibar, added factors like the location of a farmer (upper, middle, or low land) and agro-ecological zone: dry or wet.

What influences farmers to adapt against CV & C impact? An empirical literature.

Empirical evidence shows several farmers' adaptation strategies to minimize CV & C impact in SSA and elsewhere. Nevertheless, the literature is not conclusive in illuminating factors that influence farmers'

Table 1
Summary of farmers' adaptation strategies against CV & C in Tanzania.

Location of study	Type of crops or sector-specific	Method used	Key farmers' adaptation strategies	Source
Semi-arid central Tanzania in Manyoni, Bahi, Kongwa, Iramba, Kondoa and Dodoma districts	Maize, bulrush millet and sorghum, sweet potatoes, finger millet, paddy, sunflower and groundnuts	Mixed methods, including survey	Use of soil fertility improvement management practices, soil tillage practices, planting before the rain, use of mixed cropping, feeding livestock tree leaves, mobility with livestock, use of manure, asking rain from God, use of ridge farming, use of contour farming.	Mary and Majule (2009), Swai et al. (2012), Mayaya et al. (2014)
Lake Victoria Zone in Meatu district	Maize, bulrush millet and sorghum, sweet potatoes, finger millet, sunflower	Mixed methods, including survey	Use of ridge farming, changing planting dates, mixed cropping, and moving with livestock	Kabote et al. (2014)
Tabora, Shinyanga, and Southern Highlands	Agriculture	Mixed methods, including survey	Expanding the area under cultivation, switching to more drought-resistant varieties, changing planting dates, growing alternative crops, increasing cultivation in wetlands, and diversification into non-farm activities	Mongi et al. (2009), Lyimo and Kangalawe (2010)
No specific location in Tanzania	Agriculture	Document review	Use of improved crop varieties, crop and livestock breeding for drought tolerance and pest resistance, pest risk analysis, and improvement of pest management techniques, awareness creation of climate change, strengthening early warning systems, better use of climate and weather data, improving irrigation potential, and development of sound land management practices	Kahimba et al. (2015)

choice of adaptation strategies. For example, Atube et al. (2021) are of the view that small-scale farmers in Northern Uganda adapted against CV & C impact principally through the use of different crop varieties, drought-resistant varieties, fallowing, and use of improved seeds. These were fundamental for the farmers to survive the negative impact: some planted trees and a few used chemical fertilizers. The empirical results, using the binary logit regression model in that study, showed a number of factors that determined the choice of adaptation strategies. Such factors were the marital status and gender of the household head, access to credit, access to extension services, household income, time taken to the market, farming experience, household size, and farm size (Atube et al., 2021).

Antwi-Agyei et al. (2021) categorized adaptation strategies into on-farm and off-farm in West Africa, particularly Ghana. While On-farm adaptation strategies include irrigation, adjusting planting dates, land fragmentation, soil conservation measures, and planting improved crop varieties, off-farm adaptation strategies include the use of agro-ecological knowledge, relying on family and friends, and seasonal migration. The same study reported institutional and individual farmer characteristics. Using multinomial logistic regression, Antwi-Agyei et al. (2021) conclude that institutional factors, particularly the quality of climate information, quality of extension services, access to credit, and training, had a stronger impact on climate change awareness and the choice of adaptation strategies among small-scale pineapple farmers than individual farmer characteristics like gender, marital status and farmers' age in Ghana.

Another study conducted in Ghana by Baffour-Ata et al. (2023) posts that yam small-scale farmers are aware of the existing CV & C impact. As such, they are adapting to the impact. Using the binary logistic regression model, the choice of adaptation strategies is predominantly determined by socio-economic and demographic factors like age, years of stay in the community, household size, marital status, education, farming experience, and household income. Other institutional factors include access to extension services, climate information, and farm factors, principally farm size.

A study conducted by Gemeda et al. (2023) acknowledges that farmers' adaptation is fundamental for sustainable livelihood in developing countries. Such a study used a multivariate probit model to analyze factors that influence households to adapt to CV & C impact in the Southwestern parts of Ethiopia. Using a cross-sectional research design and a sample of 442 farmers, Gemeda et al. (2023) identified a number of adaptation strategies whose choice is chiefly determined by access to extension services and climate information. The two strategies enabled farmers to choose other different adaptations. In addition, using a similar model with a sample size of 404, Negera et al. (2022) are of the view that farmers' choice to adopt climate-smart agriculture, which is an adaptation strategy against CV & C impact, is influenced by socio-economic and demographic factors like age of the household head, education, household wealth measured by total asset value, awareness to climate change; institutional factors like access to extension services, and farm factors mainly farm size. Gebru et al. (2020) used a multinomial logistic regression model and found that farmers' adaptation to CV & C impact was determined by education of the household head, livestock holding, cooperative membership, extension services, farmers' income, and farmers' perception of climate change in Ethiopia.

In South Asia, Paudel et al. (2022) succinctly show that farmers, particularly in Nepal, have adapted to the CV & C impact primarily by diversifying crop production, immigration, changing occupation, and shifting farming practices. The majority of the farmers considered agroforestry the second option. Using the logit model, their study shows that the determinants of choosing adaptation strategies are the household head's age, education, and habit of growing commercial species. Similarly, the choice of agroforestry is determined by factors such as gender and household income. Jha and Gupta (2021) used a binary logistic regression model to understand factors determining farmers' choice of adaptation strategies in India. With a sample of 700 farmers, 80 % adapted against CV &C impact, and their choice of adaptation strategies was determined by variables mainly farmer's age, gender, household size, education level, off-farm income, and farm size.

Based on the preceding literature review, it is absolute that for a farmer to choose an appropriate adaptation strategy, first, the farmer should perceive the presence of CV & C impact, and second, should be aware of the available adaptation strategies. This is followed by a choice of an adaptation strategy whose net benefit should be greater than the benefit of not using it. Thus, the choice of an adaptation strategy is guided by the utility maximization theory. Another general conclusion emanating from the literature review is that CV & C impact is more pronounced in SSA. Therefore, a struggle to cushion the impact needs the integration of many factors into policy making and implementation, including individual farmer factors, also known as socioeconomic and demographic factors, which seem to be common irrespective of the context. Others include institutional factors, farm factors, and off-farm variables. It is also worth noting that the factors that determine the choice of farmers' adaptation strategies vary depending on the social and cultural context. This implies that determinants of the choice of adaptation strategies are context-specific, and generalization is difficult. The current study determined factors influencing farmers' choice of adaptation strategies against CV & C impact in a semi-arid agro-ecological environment of Manyoni District to contribute new knowledge to the literature.

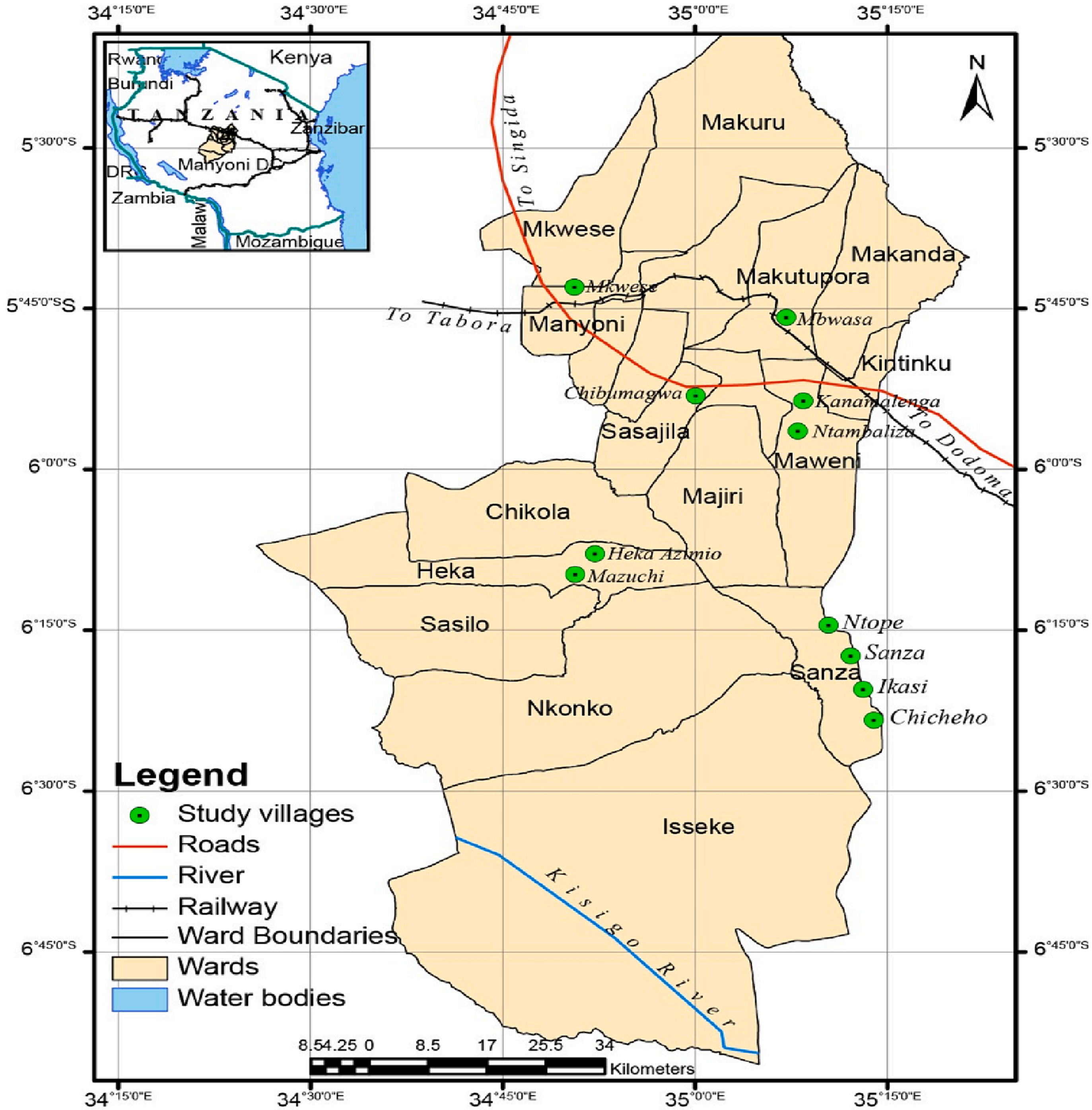

Fig. 1. Map of the Manyoni district showing the study sites (Authors' Construction).

2. Methodology

2.1. The study area and context

The study was conducted in the Manyoni district in Singida region (Fig. 1). Data collection for this study took place between May 2019 and December 2019. Agriculture is the major occupation and source of livelihood for the majority of the population in the district. Most small-scale farmers cultivate crops, predominantly maize, sorghum, millet, groundnuts, cassava, beans, and sweet potatoes. We selected the Manyoni district because it lies in the semi-arid environment of Tanzania, and the CV & C impact has disrupted farming and food systems in the western and eastern parts of the district (Benedict & Majule, 2015). In terms of mean annual rainfall, the western Manyoni experiences between 500 and 700 mm of rainfall per annum (Sawe et al., 2018; URT, 2017), whereas rainfall ranges from 500 to 650 mm per annum in the eastern parts. This amount of rainfall is a pure characteristic of semi-arid agro-ecological environments. The eastern zone has a high proportion of livestock, mainly cattle (URT, 2017), which have been affected by the CV & C impact. Therefore, small-scale farmers have, over the years, adapted against CV & C impact, but the determinants of the key adaptation strategies remain unclear. Fig. 1 shows the sites involved in the study.

2.1.1. Sampling techniques and sample size

The study used purposive sampling techniques to select six wards in the survey based on the drought frequency. Subsequently, a simple random sampling was adopted to select eleven villages. In each village, a sub-sample of 30 households was randomly selected, making a total sample size of 330 for the survey. A minimum sub-sample of 30 in each village was considered because the study population was homogeneously composed of small-scale farmers principally producing sorghum, one of the drought-resistant crops. For a homogenous population, a minimum sub-sample of 30 cases randomly selected is a true representative of the population and is adequate for statistical data analysis (Martinez-Abrain, 2014). Combining the homogeneousness and the use of a random sampling technique, the sub-sample of 30 cases, irrespective of the village population size, was fundamental to evade the wastage of resources that could be used if proportionate sampling techniques were adopted (Mgoba & Kabote, 2020).

2.2. Research design, methods and tools for data collection

We used a cross-sectional research design that allows data collection at a single point in time (Creswell, 2003). The design has a greater degree of accuracy and precision in social science studies as compared to other research designs (Casley & Kumar, 1998). As reported by Kesmodel (2018), cross-sectional studies allow the examination of multiple factors and multiple outcomes in a single study. The data collection method was a household survey using a structured questionnaire with closed and open-ended questions.

2.2.1. Descriptive and econometric analysis

Data analysis was done using descriptive and econometric techniques. Descriptive analysis was used to acquire the percentage distribution of adaptation strategies. Guided by the utility maximization theory, we used a multivariate probit econometric model with STATA software version 16, which concurrently models the influence of the set of explanatory variables on each of the outcome variables while permitting the unobserved factors (error terms) to be freely correlated (Belderbos et al., 2004; Lin et al., 2005). We followed Lin et al. (2005) in estimating the multivariate probit model. Unlike structural equation modeling, which is also a multivariate statistical analysis that works well with interval data, the multivariate probit model estimates several correlated binary outcomes jointly with continuous, discrete, and dummy independent variables (Anderson & Gerbing, 1988; Wuensch, 2014). Previous studies including Sosa-Rubi et al. (2009), Freedman & Sekhon (2010) and Candelon et al. (2013) have confirmed robustness of the multivariate probit model. The multivariate probit model results are therefore robust to the choice of explanatory variables and even to the choice of lags as emphasized by Candelon et al. (2013). Furthermore, according to Sosa-Rubi et al. (2009), the multivariate probit model deals with endogeneity, and in this study, dealt with endogeneity of the determinants of the households' binary decision to choose climate change adaptation strategies. Nevertheless, when different studies are analyzed, heterogeneity occurs on the constants, coefficients and residue correlations. However, this does not affect validity of the statistical inference (Liu et al., 2015). It is, for this reason that the multivariate probit model was preferred to structural equation modeling.

Based on the descriptive statistical analysis, the study identified four dummy dependent variables: drought-resistant varieties, early maturing varieties, resistant livestock breeds, and conservation agriculture. Since the four dependent variables are mutually inclusive, a farmer could choose multiple adaptation strategies, and so, using the multivariate probit model was unavoidable (Rahut & Ali, 2018). The model was run once (Appendix 2 for the command) and correlated with the dependent variables to determine the factors influencing choices of adaptation strategies. According to the utility maximization theory, farmers are rational and, when faced with a decision to select several alternatives, would prefer an option that provides the maximum level of satisfaction. As such, the choice of a given adaptation strategy can be considered a function of the expected utility derived from using that strategy (Fishburn, 1969). Previous studies, including Gemeda et al. (2023), Negera et al. (2022), and Paudel et al. (2022) that investigated determinants of farmers' choice of adaptation strategies against CV & C impact employed similar multivariate probit model. In addition, economic studies like Hailu (2017), Abate et al. (2019), and Mauki et al. (2023) have successfully used the multivariate probit model to determine factors influencing market outlet choices.

We tested the null hypothesis: independent variables have no impact on the choice of dependent variables (drought-resistant varieties, early maturing varieties, resistant livestock breeds, conservation agriculture). Hence, farmers chose an adaptation strategy if the expected utility from it exceeded that of other adaptation strategies such that:

$$\begin{aligned} Y^{*} &= Y_i \quad If \quad V_i > V_j \\ &= Y_j \quad if \quad V_j \leqslant V_j \end{aligned} \tag{1}$$

Where, Y_i represents the strategy type i, Y_j an alternative strategy type j, V_i and V_j the corresponding expected indirect utility values of strategy type i and its alternative j, while Y* represents the strategy type chosen. Therefore, we can view farmers' decisions on the adaptation strategy within a random utility discrete choice model. This is particularly appropriate for modeling discrete choice decisions, such as between adaptation strategies, because it is an indirect utility function where an individual with specific characteristics associates an average utility level with each alternative adaptation strategy in a choice set. In this framework, the utility function is assumed to be known for each farmer,but some of its components are unobserved by the researcher. This unobserved part of the utility is treated as a random variable. For the *i* strategy decision, the expected indirect utility was then modeled as the sum of the observed variables and non-observed random component:

$$V_i = \beta^1 i X_i + \varepsilon_i \tag{2}$$

As in Equation (1), we can write the choice utility of implementing any alternatives as follows:

$$V_j = \beta^1 j X_j + \varepsilon_j \tag{3}$$

Where, $\beta^1 i$ and $\beta^1 j$ are vectors of parameters. Hence, farmers can decide simultaneously whether to choose one or more adaptation strategies conditional upon the vectors of explanatory variables X_J and X_J. In this approach; we can use a multivariate probit model to study the farmers' joint decisions to adaptation strategy. Following equations (2) and (3), the empirical specification of the model takes the form:

$$Y^{*}ij = V_i = \beta^{1} iX_i + \varepsilon_1 \tag{4}$$

With j = 1, 2, 3, 4, 5

$$Y_i = 1 \text{if} Yi^{*} > 0 \text{ and } 0 \text{ otherwise} \tag{5}$$

Where, Yi* is an unobservable latent variable denoting the probability of choosing j type of adaptation strategy, for i = 1 (drought resistant crops), i = 2 (early maturing crops), i = 3 (resistant livestock breeds) i = 4 (conservation agriculture). Thus, empirically the model can be specified as follows:

$$Y_I1 = \beta_1 X_{ij1} + \varepsilon_{i1} \tag{6}$$

$$Y_I2 = \beta_2 X_{ij2} + \varepsilon_{i2} \tag{7}$$

$$Y_I3 = \beta_3 X_{ij3} + \varepsilon_{i3} \tag{8}$$

$$Y_I4 = \beta_4 X_{ij4} + \varepsilon_{i4} \tag{9}$$

Where, Y_I1= 1, if a farmer chooses drought-resistant crops (0 otherwise), Y_I2 = 1, if the farmer chooses early maturing crops (0 otherwise), Y_I3=1, if the farmer chooses resistant livestock breeds (0 otherwise), Y_I4=1 if the farmer chooses conservation agriculture (0 otherwise), Xi = vector of factors influencing the choice of coping strategy (annual income, sex, age, farm size, farming experience, household size, technology uses, ownership of livestock, shift in rain season, extension services), βj = vector of unknown parameters (j = 1,2,3,4,), and ε = is the error term. To estimate the four equations (6)–(9) it assumes that the error term (ε1, ε2, ε3, and ε4) may be correlated. Then, instead of being independently estimated, they are considered to be a multivariate limited dependent-variable model in which the four error terms follow a multivariate normal distribution with zero mean and variance and a covariance matrix. Table 2 shows variables entered in the model.

Table 2
Variables entered in the multivariate probit model.

Variable	Unit	Description and measurement of the variable	The expected sign of the independent variable on the dependent variable
Dependent Variable			
Drought resistant varieties	Decision %	Dummy = 1 if HH chooses drought-resistant varieties, 0 otherwise	
Early maturing varieties	Decision %	Dummy = 1 if HH chooses early maturing varieties, 0 otherwise	
Resistant livestock breeds	Decision %	Dummy = 1 if HH chooses resistant livestock breeds, 0 otherwise	
Conservation agriculture	Decision %	Dummy = 1 if HH chooses conservation agriculture, 0 otherwise	
Independent Variables			
Age of household head	Years	Continuous	+ or -
Household size	Number	Continuous	+
Farm size	Hectare	Continuous	–
Farming experience	Years	Continuous	+
Use of Technology	Percent	Dummy, 1 = yes, 0 = otherwise	+
Household annual income	TZS	Continuous	+
Extension services	Percent	Dummy, 1 = yes, 0 = otherwise	+
Ownership of livestock	Percent	Dummy, 1 = yes, 0 = otherwise	+
Shift in rain season	Percent	Dummy, 1 = yes, 0 = otherwise	+ or -
Meteorological information uses	Percent	Dummy, 1 = yes, 0 = otherwise	+
Farm location	Percent	Dummy, 1 = wetland, 0 = dryland	+
Engagement petty business	Percent	Dummy, 1 = yes, 0 = otherwise	+
Access to loan	Percent	Dummy, 1 = yes, 0 = otherwise	+
Training on adaptations	Percent	Dummy, 1 = yes, 0 = otherwise	+
Land tenure system	Percent	Dummy, 1 = Title deeds, 0 = otherwise	+
Trend in rainfall	Percent	Dummy, 1 = Increasing, 0 = otherwise	+
Trend in temperature	Percent	Dummy, 1 = Increasing, 0 = otherwise	+

In the multivariate model, where the choice of several adaptation strategies is possible, the error terms jointly follow a multivariate normal distribution (MVN) with zero conditional mean and variance normalized to unity (for identification of the parameters) where (µx1, µx2, µx3, µx4) MVN~ (0, Ω) and the symmetric covariance matrix Ω is given by:

$$\Omega = \begin{bmatrix} 1 & \rho \times 1 \times 2 & \rho \times 1 \times 3 & \rho \times 1 \times 4 \\ \rho \times 2 \times 3 & 1 & \rho \times 2 \times 3 & \rho \times 2 \times 4 \\ \rho \times 3 \times 1 & \rho \times 3 \times 2 & 1 & \rho \times 3 \times 4 \\ \rho \times 4 \times 1 & \rho \times 4 \times 2 & \rho \times 4 \times 3 & 1 \end{bmatrix} \tag{10}$$

The off-diagonal elements in the covariance matrix are of particular interest, as they represent the unobserved correlation between the stochastic components of the different types of strategies. This assumption means that equation (10) generates the model that jointly represents the decision to choose a particular adaptation strategy. This specification with non-zero off-diagonal elements allows for correlation across error terms of several latent equations, which represent unobserved characteristics that influence the choice of alternative strategies. Following the formula used by Cappellari and Jenkins (2003), the log-likelihood function associated with a sample outcome is then given by:

$$\ln = \sum_{n}^{N} \omega_i \ln \varnothing (\mu_{1,} \Omega \tag{11}$$

Where, ω is an optional weight for observation I and Φi is the multivariate standard normal distribution with arguments μ_i and Ω, where μ_i can be denoted as:

$$\mu_i = (k_{i1}\beta_1 x_{i1,} k_{i2}\beta_2 x_{i2,} k_{i3}\beta_3 x_{i3}) \tag{12}$$

$$\Omega_{jk} = \Omega_{jk} = k_{ij}\ k_{ik}\ \ \rho_{jk}\ for\ j \neq k\ k = 1, 2, 3 \ldots With\ K_{ik} = 2y_{ik} - 1 \tag{13}$$

The multivariate probit model showed that the Wald chi-square was $X^2 = 29.192$, $df = 11$, at p-value = 0.000. This implies that the model was significantly associated with the observed individual variables related to making the decision to choose adaptation strategies. The p-value implies that the model well fitted and was significant at a 5 % level of significance. We also tested for multicollinearity, whereby the Variance Inflation Factor (VIF) for all variables ranged between 1.05 and 2.62. Generally, the VIF falling in the range ≤1 and <10 indicates no multicollinearity problem in the model (Zach, 2020).

3. Results and discussion

3.1. Individual farmer, farm, and household characteristics

The results in Table 3 show that 89.7 % of the respondents had different levels of formal education. The mean age of the respondents was 46 years, with nearly 59 % falling under the age group between 35 and 60 years. In addition, 54.8 % of households had 5 to 8 members; 55.2 % of the respondents owned 0.51 to 1.0 ha of land, more than 77 % of the household heads were men, and the majority of them were married (79.1 %) (Table 3). The level of formal education shows that small-scale farmers were categorically trainable and had reading skills. This is in line with Damnyag et al. (2021). Concerning respondents' age, it is logical to argue that the majority of the respondents were physically active and capable of providing a labor force for farming. According to NBS (2017), the age group that ranges from 15 to 60 years is considered an active and energetic working age group in Tanzania. These results conform to the findings Arragaw and Woldeamlak (2017) reported in Ethiopia. That study is of the view that the age of a household head increases the probability of taking up choices of adaptation measures because older farmers have farming experience and are able to realize climatic changes in the local environment followed by timely adaptation strategies to survive with the phenomena. At the same time, old age reduces the likelihood of choosing some adaptation strategies because adaptive capacity decreases with increasing age.

The current study also deduces that the population in the study area provides an adequate labor force for farming and adaptation strategies. According to NBS (2019), a household with 5 to 8 members is considered a medium household size and can make use of the labor force available for farming and other socio-economic tasks. This also implies that the available labor force can be diverted to off-farm activities to improve household livelihood. Oloo (2013) concurs with these results. The land size reported in Table 3 is considered a small farm size in Tanzania (URT, 2015). This is a typical characteristic of small-scale farmers in rural Tanzania, who usually own small pieces of land for subsistence farming (FAO, 2015). In addition, FAO (2015) also argues that the small pieces of land are attributed to poor tillage tools, particularly a hand hoe, and insufficient capital to manage larger farms. Pauline (2015) in Mbarali and Kilolo districts and Balama et al. (2013) in Kilombero district had similar observations. Since the majority of household heads were male, it is interpreted in this study that males dominated the decision to adapt against CV & C impact. This has also been reported by Nti (2012) in Northern Ghana, implying that decisions at a household level in rural Africa are male-dominated. In Africa, males, who are mostly household heads, have more access to information and other resources than their female counterparts, which helps them adapt against CV & C impact (Pauline, 2015).

Table 3
Socio-economic and demographic characteristics of respondents (n = 330).

Parameters		Frequency	Percent
Education Level of Household Head	No formal	34	10.3
	Formal	296	89.7
Age of Household head	15–24	10	3
	25–34	74	22.4
	35–60	194	58.8
	≥61	52	15.8
Household Size	1–4	92	27.9
	5–8	181	54.8
	≥9	57	17.3
Farm Size (hectare)	0.20–0.50	29	8.8
	0.51–1	182	55.2
	1.01–3	68	20.6
	≥3.01	51	15.5
Sex of Household Head	Female	73	22.1
	Male	257	77.9
Marital Status of Household Head	Single	6	1.8
	Married	261	79.1
	Divorced	38	11.5
	Widow	25	7.6

3.2. Climate variability and change adaptation strategies

The results confirmed that small-scale farmers in the study area perceived the presence of and used different adaptation strategies to minimize CV & C impact (Fig. 2). These strategies have been in practice in different parts of the study area, which is a semi-arid agro-ecological zone, for many years in response to CV & C impact (Fig. 2). Famers' adaptation against CV & C impact is increasingly becoming fundamental at different levels, including in countries like Tanzania (Shirima & Lubawa, 2017). Although adaptation strategies are context-specific, some strategies, like planting drought-resistant varieties, are increasingly becoming widespread in SSA, west Africa, and other developing countries, implying that they are effective in cushioning the impact of drought and rainfall variability.

In most cases, extreme weather events as consequences of CV & C result in an outbreak of pests and diseases that negatively impact crop and livestock production. Therefore, small-scale farmers domesticate livestock breeds (local breeds) that are pest- and disease-resistant. In addition, a substantial number of the respondents adopted conservation agriculture to counteract CV & C impact (Fig. 2). This includes mulching to maintain moisture, contouring and terracing farming to control soil erosion, and planting trees in farm plots. Conservation agriculture is becoming effectively adopted by small-scale farmers in SSA to minimize CV & C impact, as observed by FAO (2015) and Jug et al. (2018) in Tanzania and Ghana, respectively, and also by Umar (2021) in Zambia.

4. Econometric results on the determinants of farmers' choice of adaptation strategies

4.1. Overall fitness of the multivariate probit model

The decisions made by farmers to choose adaptation strategies, including drought-resistant varieties, early maturing varieties, resistant livestock breeds, and conservation agriculture, are interrelated. Such decisions are binary in nature, and to that effect, using a multivariate probit model was appropriate in predicting the four adaptation strategies collectively on an individual-specific basis, with parameter estimates obtained through simulated maximum likelihood estimation. Thus, the model determined the impact of independent variables on choosing a specific adaptation strategy. The statistical significance of the Wald Chi2 test, $\chi2$ (68) = 298.11, at the 1 % level of significance (Table 4), suggests that the subset of coefficients in the model were collectively significant, and the independent variables included in the model demonstrate acceptable explanatory power.

The results of the likelihood ratio test in the model show that the likelihood ratio test of χ^2 (6) = 17.96, Prob > χ^2 = 0.0063 was statistically significant at a 5 % level of significance, justifying the null hypothesis that choices of the four adaptation strategies against CV & C impact are independent is rejected. This shows that the likelihood ratio test for the null hypothesis of independence among choices of the adaptation strategies ($\rho21 = \rho31 = \rho41 = \rho32 = \rho42 = \rho43 = 0$) is statistically significant at a 1 % level of significance. This underscores the suitability and effectiveness of the multivariate probit model in explaining the relationship between the variables. Therefore, the likelihood ratio test of independence showed that there were different climate change adaptation choice behaviors among small-scale farmers.

The ρ values (ρij) denote the correlation between each dependent variable representing adaptation choices. Specifically, $\rho41$ signifies the correlation between the choice of conservation agriculture and drought-resistant varieties, $\rho32$ represents the correlation between choosing early maturing varieties and resistant livestock breeds, $\rho42$ indicates the correlation between choosing conservation agriculture and early maturing varieties, and $\rho43$ denotes the correlation between selecting

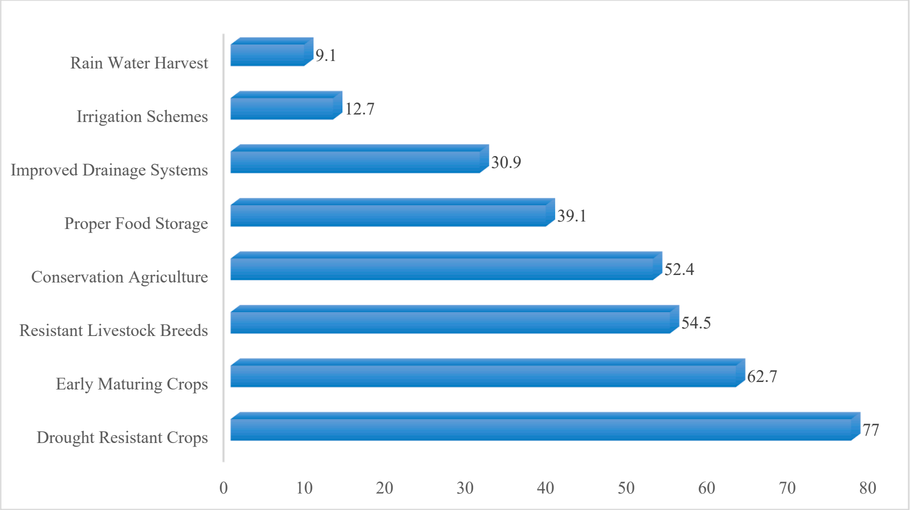

Fig. 2. Adaptation strategies in Manyoni district.

Table 4
Overall fitness, probabilities, and correlation matrix of choice of adaptation strategies from the model.

Variables	Drought resistant varieties	Early maturing varieties	Resistant livestock breeds	Conservation agriculture
Predicted probability	0.887	0.435	0.452	0.104
Joint probability (success)				0.060
Joint probability (failure)				0.452
Number of draws				5
Observation				330
Log-likelihood				−621.469
Wald $\chi^2(68)$				298.11
Prob > χ^2				0.000***
	ρ_1	ρ_2	ρ_3	ρ_4
ρ_1	1.00			
ρ_2	0.130***	1.00		
ρ_3	0.093	−0.022**	1.00	
ρ_4	0.165**	0.150***	0.373**	1.00
Likelihood ratio test of $\rho21 = \rho31 = \rho41 = \rho32 = \rho42 = \rho43 = 0$		$\chi^2(6) =$ 17.956 Prob > $\chi^2 =$ 0.0063		

Key: *** = Significant at 1 % and ** = Significant at 5 %.

conservation agriculture and resistant livestock breeds. These correlations were positive and statistically significant at 1 % and 5 % levels of significance, implying that farmers who chose conservation agriculture also chose drought-resistant varieties, early-maturing varieties, and resistant livestock breeds (Table 4). Based on the predicted probabilities, the simulated maximum likelihood estimation shows that the likelihood of choosing drought-resistant varieties was relatively high (88.7 %) compared to the probabilities associated with choosing early maturing varieties (43.5 %), resistant livestock breeds (45.2 %), and conservation agriculture (10.4 %) (Table 4).

4.2. Drought resistant varieties

The results in Fig. 2 show that 77 % of the respondents adopted drought-resistant varieties. Eight factors at the 5 % level of significance determined the decision to select drought-resistant varieties out of seventeen factors entered in the model (Table 5).

The determinant factors of drought-resistant varieties include farming experience, use of meteorological information, location of the farm, engagement in petty business, ownership of livestock, land ownership rights, and rainfall trends. This implies that multiple factors determined the farmers' choice of drought-resistant varieties. Farming experience positively and significantly impacted the choice of drought-resistant crops at ß = 0.030 and P = 0.000, implying that farming experience was fundamental in choosing drought-resistant varieties. The argument that farming experience increases with years spent in farming and also through training is undebatable. Access and use of meteorological information also significantly positively impacted the adaptation strategy choice at ß = 1.517 and P = 0.000. Principally, the use of meteorological information improved experience in dealing with CV & C, including drought. In addition, the location of the farm in either wetland or dry land showed a significant positive impact at ß = 0.538 and P = 0.002. This implies that farmers cultivating in wetlands also used drought resistant varieties. This is further attributed to an increasing CV & C impact that is widespread up to the wetlands. It can also be interpreted that CV & C's impact has intensified to the extent of affecting agriculture in both dry and wetlands.

In addition to farming experience, use of meteorological information, and farm location, trends in rainfall also showed a significant positive impact on the choice of drought-resistant varieties at ß = 0.354 and P = 0.045 (Table 5). Categorically, trends in rainfall show decreasing patterns in most parts of central Tanzania, more so in semi-arid environments. This happens concurrently with the unpredictability of rainfall and the increasing frequency and length of dry spells (Kabote et al., 2013). Therefore, it is undeniable that for the farmers to survive with the decreasing rainfall trends, increasing frequency of drought, and length of dry spells, they had to use drought resistant varieties. Furthermore, the land tenure security, particularly the procession of a title deed, significantly impacted the choice of drought-resistant varieties at ß = 0.409 and P = 0.019 (Table 5). Farmers with title deeds were likely to access loans from financial institutions to improve purchasing power for drought-resistant varieties, unlike farmers without title deeds. Furthermore, our results show that farmers who owned livestock showed a significant positive impact at ß = 1.324 and P = 0.000. In farming communities, livestock is an indicator of wealth that could, in this case, be used to purchase drought-resistant varieties. To that effect, agro-pastoralists were likely to use drought-resistant varieties compared to non-livestock keepers. Similarly,

Table 5
Multivariate probit model results for factors influencing farmers’ choices of adaptation strategies.

Variables	Drought resistant crops		Early maturing crops		Resistant livestock breeds		Conservation agriculture	
	Coef.	**P > z**	Coef.	P > z	Coef.	P > z	Coef.	P > z
Age of Household	−0.044	**0.000**	0.022	**0.006**	−0.014	0.092	0.010	0.158
Household size	0.013	0.774	−0.119	**0.002**	0.047	0.221	−0.046	0.148
Farm size	0.014	0.551	0.015	0.477	−0.030	0.116	0.017	0.297
Farming experience	0.030	**0.013**	−0.011	0.263	−0.001	0.949	−0.005	0.525
Use of technology	−1.072	**0.000**	−0.228	0.264	0.178	0.366	−0.164	0.332
Household annual income	−0.000	0.264	0.000	0.567	0.000	0.091	0.000	0.383
Use of meteorological information	1.517	**0.000**	−0.179	0.556	−0.277	0.307	−0.411	0.085
Farm location	0.538	**0.002**	−0.378	**0.012**	0.083	0.590	−0.036	0.781
Engagement to small business	0.436	**0.050**	0.218	0.259	−0.334	0.086	0.144	0.381
Loan access	−0.443	0.137	−0.365	0.173	−0.648	**0.040**	−0.356	0.161
Extension services	−0.457	**0.028**	0.770	**0.000**	0.431	**0.024**	0.555	**0.001**
Ownership of livestock	1.324	**0.000**	0.417	**0.028**	1.593	**0.000**	−0.316	0.056
Training on adaption and coping	−0.152	0.534	0.148	0.574	−0.431	**0.047**	0.285	0.139
Land Tenure System	0.409	**0.019**	−0.089	0.561	−0.953	**0.000**	−0.127	0.404
Trend of rainfall	0.354	**0.045**	0.860	**0.000**	−0.106	0.355	0.213	**0.034**
Shift in Rain seasons	0.216	0.384	1.190	**0.000**	0.036	0.859	−0.087	0.621
Trend of Temperature	−0.661	**0.000**	−0.977	**0.000**	−0.208	0.108	−0.074	0.528
_cons	0.862	0.205	0.196	0.758	2.649	0.000	0.241	0.672

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0.
chi^2 (6) = 18.5542 Prob > chi^2 = 0.0050.

farmers engaged in petty business showed a significant positive impact at ß = 0.436 and P = 0.050 for the same reason: improved purchasing power for drought-resistant varieties.

Other factors like age (ß = −0.044 and P = 0.000), use of technology (ß = −0.661 and P = 0.000), extension services (ß = −1.457 and P = 0.028), and trends in temperature (ß = −1.072 and P = 0.000) showed a significant negative impact on the choice of drought-resistant varieties (Table 5). Unlike farming experience, the use of meteorological information, location of the farm, engagement in petty business, livestock ownership, title deed ownership, and trends in rainfall showed positive impact and so increased the likelihood of choosing drought-resistant varieties; the factors that showed negative impact reduced likelihood of using drought-resistant varieties.

For instance, the age of the household head increased with decreasing choice of drought-resistant varieties because such an adaptation strategy has cost implications that old farmers hardly meet because of poverty that increases with old age among small-scale farmers, particularly in countries like Tanzania (Kadigi et al., 2007). The use of technology and extension services also decreased the likelihood of choosing drought resistant varieties. With regard to technologies, it is interpreted that the government and the private sector have not done enough in terms of developing new agricultural technologies that could be at the disposal of the farmers to counteract drought. Regarding extension services, the negative impact implies a limited number of extension workers in the study area, which is further attributed to inadequate extension services available to the farmers.

4.3. Use of early maturing varieties

Our results showed that 62.7 % of the respondents chose early maturing varieties (Fig. 2), with their choice determined by many factors, including institutional factors, particularly access to extension services and awareness of CV & C, mainly shift in rain season. Other factors were individual farmer characteristics, specifically the age of the household head and household size. Location of the farm, livestock ownership, and trends in rainfall and temperature also showed similar impacts. Our econometric results show that extension services had a significant positive impact on choosing early maturing varieties (β = 0.770 and P = 0.000) (Table 5). This is interpreted as early maturing varieties were available and accessible to the farmers. These results have implications on institutional factors in which the government is principally responsible for providing extension services. Atinkut and Mebrat (2016) and Ojo et al. (2021) found similar results in Ethiopia and South Africa, respectively. A shift in rain season in response to CV & C also significantly impacted the choice of early maturing varieties at β = 1.190 and P = 0.000 (Table 5). In the context of this study, the shift in the rainy season is explained by a shorter duration of a growing season that is further explained by late-onset and early cessation of the rainy season. This reduces the growing season’s length, so effectively producing it requires early maturing varieties. Rodenburg et al. (2020) and Umar (2021) found similar results in SSA.

The age of the household head also showed a statistically significant positive impact on the choice of early maturing crops at ß = 0.022 and P = 0.006 (Table 5). This is interpreted that as the age of the household head increases by one year, the probability of the household head planting early maturing varieties increases by 0.022 (Table 5). This is further interpreted as any additional year of a household head in farming increasing the capability to make a rational decision on the choice of early maturing varieties. Comparable results were reported in Ethiopia by Atinkut and Mebrat (2016) and Arragaw and Woldeamlak (2017). Livestock ownership and trends in rainfall also showed a significant positive impact. In agro-pastoralist communities, wealth is kept in livestock, which increases farmers’ adaptive capacity. The general picture shows that the rainfall trend is decreasing, particularly in semi-arid and arid environments. This, among other factors, necessitates farmers’ adaptation to early maturing varieties.

Other factors showed a significant negative impact on the choice of early maturing varieties. These include household size, farm location, and temperature trends. The negative sign implies that such factors reduced farmers’ likelihood to choose early maturing varieties. For example, larger households were likely to reduce the choice of early maturing varieties, possibly because of increased household needs and expenditures attributed to the household size, which in turn negatively affected adaptive capacity. In addition, farmers who cultivated in wetlands did not need to use early maturing varieties, possibly because an increasing temperature affected even early maturing varieties and so negatively determined their choice. The results of this study demonstrated the use of drought-resistant varieties in the wetlands to survive an increasing length of dry spells in central Tanzania (Kabote et al., 2013).

4.4. Resistant livestock local breeds

The results of this study demonstrated that 54.5 % of the respondents chose resistant livestock breeds as an adaptation strategy against CV & C impact (Fig. 2). These were households that owned livestock and cultivated crops. The choice of resistant livestock breeds was significantly and positively determined by livestock ownership and access to extension services. For example, livestock ownership showed a significant positive impact on the choice of domesticating livestock breeds resistant to diseases and drought at β = 1.593 and P = 0.000) (Table 5). Farmers who kept resistant livestock breeds improved adaptive capacity. Chanamuto and Hall (2015) and Diallo et al. (2020) demonstrated similar results in Mali and Tanzania, respectively, implying that the strategy is fundamental and widespread in Africa. The situation of owning livestock is a wealth by itself, particularly in rural African countries, including Tanzania. In addition, resistant livestock breeds require financial capability to purchase breeds that can effectively survive in the context of CV & C impact. To that effect, agro-pastoralist households were more likely to adapt to resistant livestock breeds than non-livestock keepers. This was also reported by Marie et al. (2020) and Bahta (2020) in Northwestern Ethiopia and South Africa, respectively.

Access to extension services also showed a significant positive impact on the choice of resistant livestock breeds at β = 0.431 and P = 0.024 (Table 5). Nevertheless, extension services in Tanzania are in shambles because inadequate extension workers constrain the use of the farm visit approach despite efforts to adopt ICT technologies. Extension workers are also demotivated by the poor working environment (Philip, 2015; Lukuyu et al., 2021), necessitating improvement of the situation, especially in the period when CV & C are the reality. Apart from livestock ownership and access to extension services, which impacted the choice of resistant livestock breeds significantly and positively, access to loans, training on adaptation, and land tenure explained by the existence of a title deed showed a negative significant impact. This implies that such factors reduced the likelihood of selecting the adaptation strategy. For example, access to loans showed a significant negative impact at β = -0.648 at P = 0.040. It is interpreted that farmers had challenges accessing loans, possibly because of a lack of collateral. Access to loans would definitely improve household capacity to use resistant livestock breeds. Similarly, the land tenure system particularly lacks a title deed to own land that could be used for farming and grazing livestock, which significantly and negatively impacted the adaptation strategy at β = 0.953 and P = 0.000. This implies that farmers who did not own a title deed hardly adapted resistant livestock breeds. In the era of CV & C, the right to own a piece of land for grazing is increasingly becoming important because of shrinking pasture areas. Access to training on adaptation strategy also showed a negative significant impact at β = -0.431 and P = 0.047, implying limited training to create awareness of adaptation strategies that, in turn, reduced farmers' likelihood to use resistant livestock breeds.

4.5. *Conservation agriculture*

The results of this study showed that 52.4 % of the respondents chose conservation agriculture to cushion CV & C impact (Fig. 2). The choice of conservation agriculture was determined by institutional factors, essentially access to extension services and changing trends in rainfall. The access to extension services showed a significant positive impact on the choice of conservation agriculture at β = 0.555 and P = 0.001) (Table 5). The tasks involved in conservation agriculture include mulching to conserve soil moisture, reduce soil tillage, and diversify crop rotation (Keba & Milkias, 2020; Getahun et al., 2021). Our results imply that access to extension services, despite its challenges in Tanzania, determined the choice of conservation agriculture. This adaptation strategy is particularly fundamental in a situation of inadequate soil moisture attributed to CV & C impact.

The trends in rainfall also showed a significant positive impact on the choice of conservation agriculture in the study area at β = 0.213 and P = 0.034 (Table 5). Studies, including the one conducted by Kabote et al. (2017) in some parts of central Tanzania using farmers' perceptions of rainfall trends combined with meteorological data, show that rainfall is increasingly becoming unpredictable with a decreasing trend. To that effect, although decreasing rainfall trends are one of the manifestations of CV & C, they are also factors that determine farmers' choice of conservation agriculture to minimize CV & C impact. The interpretation is that decreasing trends in rainfall, while surface temperature is increasing, translates into decreasing soil moisture. This, in turn, necessitates farmers to adapt to conservation agriculture that encompasses moisture conservation.

5. Conclusions and policy recommendations

This study dealt with determinants of farmers' choice of adaptation strategies against CV & C impact in Manyoni District of Tanzania. Based on the discussions, the study concludes the following: First, farmers had adopted a number of strategies against CV & C impact, but the key ones were the use of drought-resistant varieties, planting early maturing varieties, domestication of resistant livestock breeds, and practicing conservation agriculture. Importantly, farmers chose more than one adaptation strategy to enhance the effectiveness of cushioning CV & C impact. Second, the choice of farmers' adaptation strategies was determined by multiple factors, which, when promoted, have the potential to strengthen farmers' adaptive capacity. Some determinant factors, particularly extension services, and livestock ownership were widespread, while others influenced some adaptation strategies only. Third, we categorize the determinant factors into four major groups, including (i) individual farmer and or household characteristics covering age and farming experience of the household head; household size; and household wealth, especially livestock ownership (ii) farm characteristics like location of the farm and farm size (iii) institutional factors that include access to extension services, technology, and provision of title deeds for land rights ownership to the agro-pastoralists; and (iv) knowledge of manifestation of CV & C like shifting of rain seasons, and awareness of using meteorological information in decision making.

Some factors reduced the likelihood of using any or all of the four key adaptation strategies identified in the study area. This includes the use of technologies, access to credit or loans, training, and the use of title deeds to augment rights for land ownership. The question of using agricultural technologies is, for example, very critical not only to cushioning CV & C impact but also to improving agricultural productivity in general. Furthermore, access to agricultural credits, training, and use of title deeds for land rights ownership is equally fundamental. Therefore, the study recommends the following: First, policy interventions should focus on reversing the trends for factors that reduced the likelihood of choosing the adaptation strategies while enforcing all factors that showed a significant positive impact. For example, although extension services and technologies are imperative to cushioning CV & C impact, they reduced farmers' capacity to adapt to some of the strategies, including the use of drought resistant varieties. This is explained by a little effort to generate new agricultural technologies and also by minimal extension services at the farmers' disposal. Second, breeders should strive to generate crop varieties and livestock breeds that are drought tolerant, while the government should strive to reinforce the use of ICT for extension services to counteract an inadequate number of extension workers. The environment for the extension workers should also be improved in terms of transport facilities and housing conditions. This can be done through credit provision for the extension workers. Similarly, agricultural credits should be extended to the farmers to improve their adaptive capacity.

The third recommendation emanates from the view that improved land rights to own a piece of land among crop growers and agro-pastoralists is equally fundamental. Free grazing is increasingly becoming a challenge in Tanzania, such that the government's provision of title deeds for agricultural and grazing pieces of land remains crucial. Since customary rights exist concurrently with statutory land laws in Tanzania, the Certificate of Customary Rights of Occupancy and statutory title deeds should be enhanced. Fourth, the government should consider increasing the provision of training among crop growers and agro-pastoralists to create awareness of CV & C impact and how to reduce it. Awareness creation about the use of meteorological information is equally pertinent.

5.1. Limitations of the study

Although the study used robust statistical analysis techniques that generated robust results, the results may not be generalized across all agro-ecological environments in Tanzania. The country has classified seven agro-ecological zones that support different adaptation strategies against CV & C impact depending on the characteristics of each agro-ecological zone. On the one hand, semi-arid environments where this study was conducted are dry, with mean annual rainfall ranging from 500 to 700 mm. The driest, however, are arid areas that receive mean annual rainfall from 200 to 500 mm. On the other hand, the northern highlands, coastal, and alluvial zones receive the highest mean annual rainfall between 1500 and 2000 mm. The rest of the agro-ecological zones, including the plateau and southern and western highlands, receive higher mean annual rainfall next to the northern highlands. With that, different agro-ecological environments are affected by CV & C impact differently, so farmers adapt against CV & C differently, making the results of this study only generalizable in semi-arid and arid agro-ecological environments and not in others.

CRediT authorship contribution statement

Samwel J. Kabote: Writing – review & editing, Methodology, Formal analysis, Conceptualization. **Edward P. Mbwambo:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Benedicto B. Kazuzuru:** Writing – review & editing, Methodology, Formal analysis.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix

Appendix 1:. Multivariate probit model results for factors influencing the choices of adaptation strategies

Variables	Drought resistant crops			Early maturing crops			Resistant livestock breeds			Conservation agriculture		
	Coef.	Std. Err.	P > z	Coef.	Std.Err.	P > z	Coef.	Std.Err.	P > z	Coef.	Std.Err.	P > z
Age of Household	−0.044	0.009	**0.000**	0.022	0.008	**0.006**	−0.014	0.008	**0.092**	0.010	0.007	0.158
Household size	0.013	0.046	0.774	−0.119	0.038	**0.002**	0.047	0.039	0.221	−0.046	0.032	0.148
Farm size	0.014	0.023	0.551	0.015	0.021	0.477	−0.030	0.019	0.116	0.017	0.017	0.297
Farming experience	0.030	0.012	**0.013**	−0.011	0.010	0.263	−0.001	0.010	0.949	−0.005	0.009	0.525
Use of technology	−1.072	0.246	**0.000**	−0.228	0.205	0.264	0.178	0.197	0.366	−0.164	0.169	0.332
Household annual income	−0.000	0.000	0.264	0.000	0.000	0.567	0.000	0.000	0.091	0.000	0.000	0.383
Meteorological information uses	1.517	0.381	**0.000**	−0.179	0.303	0.556	−0.277	0.271	0.307	−0.411	0.239	0.085
Farm location	0.538	0.175	**0.002**	−0.378	0.150	**0.012**	0.083	0.154	0.590	−0.036	0.128	0.781
Engagement to small business	0.436	0.223	**0.050**	0.218	0.193	0.259	−0.334	0.194	**0.086**	0.144	0.165	0.381
Loan access	−0.443	0.298	0.137	−0.365	0.268	0.173	−0.648	0.316	**0.040**	−0.356	0.254	0.161
Extension services	−0.457	0.207	**0.028**	0.770	0.196	**0.000**	0.431	0.191	**0.024**	0.555	0.165	0.001
Ownership of livestock	1.324	0.249	**0.000**	0.417	0.190	**0.028**	1.593	0.207	**0.000**	−0.316	0.166	0.056
Training on adaption and coping	−0.152	0.244	0.534	0.148	0.263	0.574	−0.431	0.217	**0.047**	0.285	0.193	0.139
Land Tenure System	0.409	0.174	**0.019**	−0.089	0.152	0.561	−0.953	0.206	**0.000**	−0.127	0.152	0.404
Trend of rainfall	0.354	0.176	**0.045**	0.860	0.178	**0.000**	−0.106	0.115	0.355	0.213	0.100	0.034
Shift in Rain seasons	0.216	0.248	0.384	1.190	0.237	**0.000**	0.036	0.202	0.859	−0.087	0.176	0.621
Trend of Temperature	−0.661	0.187	**0.000**	−0.977	0.240	**0.000**	−0.208	0.129	0.108	−0.074	0.117	0.528
_cons	0.862	0.680	0.205	0.196	0.635	0.758	2.649	0.719	0.000	0.241	0.569	0.672

Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0:
chi2 (6) = 18.5542 Prob > chi2 = 0.0050.

Appendix 2:. MVP command

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asdoc mvprobit(Domesticasting_resist = AGOHHH Household_size Farm_size Farming_experienc Use_of_technology HH_anual_income Meteorolgical_info_uses Parcel_location Engagement_to_small_bussness Loan_access Extension_services Ownership_livestock Training_on_adaption_and_coping Land_Tenure_Sytem Trend_of_raifall Shift_in_Rain_seasons Trend_of_Temperature)(Early_planting = AGOHHH Household_size Farm_size Farming_experienc Use_of_technology HH_anual_income Meteorolgical_info_uses Parcel_location Engagement_to_small_bussness Loan_access Extension_services Ownership_livestock Training_on_adaption_and_coping Land_Tenure_Sytem Trend_of_raifall Shift_in_Rain_seasons Trend_of_Temperature)(Conc_agricultal_prctc = AGOHHH Household_size Farm_size Farming_experienc Use_of_technology HH_anual_income Meteorolgical_info_uses Parcel_location Engagement_to_small_bussness Loan_access Extension_services Ownership_livestock Training_on_adaption_and_coping Land_Tenure_Sytem Trend_of_raifall Shift_in_Rain_seasons Trend_of_Temperature)(Planting_drought_resist = AGOHHH Household_size Farm_size Farming_experienc Use_of_technology HH_anual_income Meteorolgical_info_uses Parcel_location Engagement_to_small_bussness Loan_access Extension_services Ownership_livestock Training_on_adaption_and_coping Land_Tenure_Sytem Trend_of_raifall
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Shift_in_Rain_seasons Trend_of_Temperature).

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