Journal of Agriculture and Environmental Sciences

Research Article

Adoption of climate-smart agricultural practices by grape-producing smallholder farmers in Dodoma, Tanzania

Dickson Utonga*, Sekela A. Mundilege, Tracey E. Masigazwa, Veronica M. Kihungwe

Department of Project Planning and Management, Tengeru Institute of Community Development, Arusha, Tanzania
***Corresponding author:** dickiedannie@gmail.com

Received: November 2, 2024; Received in revised form: December 15, 2024; Accepted: December 19, 2024

Abstract: *Sustainable agricultural practices are vital for enhancing productivity, resilience, and sustainability among smallholder farmers in developing countries like Tanzania. Various factors frequently constrain the adoption of such practices despite their importance. This study examined the factors influencing the adoption of climate-smart agricultural practices (CSAPs) among smallholder grape farmers in Dodoma, Tanzania. We analyzed data collected from 120 farmers, selected through a multistage sampling procedure, using descriptive statistics and a multivariate probit model. The analysis assessed the effect of various factors on the adoption of crop rotation, crop diversification, intercropping, pest and disease management, and water and nutrient management. The findings reveal that access to finance, while negatively associated with crop diversification, significantly promoted the adoption of crop rotation. Male-headed households were less likely to adopt crop rotation, whereas married households were more inclined to adopt intercropping, water and nutrient management, and pest and disease management practices. Interestingly, increased grape yield and access to training slightly discouraged the adoption of intercropping and water management practices. Additionally, access to extension services positively influenced the adoption of pest and disease management, contributing to more sustainable farming practices. This study recommends that policymakers work with financial institutions to enhance financial access by providing affordable input loans. To effectively engage both male and female farmers, development practitioners should design gender-sensitive outreach programs and strengthen extension services. Furthermore, local governments and NGOs should implement targeted interventions to encourage widespread adoption of CSAPs, fostering sustainability and resilience in grape farming.*

Keywords: Climate-Smart Agriculture, Intercropping, Grape Farming, Multivariate Probit Model
Citation: Utonga, D., Mundilege, S.A., Masigazwa, T.E. and Kihungwe, V.M. (2024). Adoption of climate-smart agricultural practices by grape-producing smallholder farmers in Dodoma, Tanzania. *J. Agric. Environ. Sci.* 9(2): 93-110. https://doi.org/10.20372/jaes.v9i2.10644

1. Introduction

Climate change is a global threat to human livelihoods, ecosystems, and economic systems. The agricultural sector, which is sensitive to climate change, exhibits substantial vulnerability (Hossain et al., 2023). Agricultural productivity, livelihoods, and environmental sustainability face growing threats of climate change, especially in developing countries where the economy relies heavily on agriculture. The sector primarily comprises smallholder farmers who produce for subsistence (Utonga, 2022b). Despite contributing significantly to food security and supporting farmers' livelihoods, farmers' reliance on climate-sensitive crops renders them vulnerable to the consequences of climate change.

Smallholder farmers in developing economies face climate-related challenges, including unpredictable rainfall, frequent extreme weather events, and rising temperatures (the Intergovernmental Panel on Climate Change [IPCC], 2014). These changes result in lower crop yields, food insecurity, and economic instability, seriously threatening long-term agricultural sustainability. Limited access to adaptation measures exacerbates these risks, as farmers lack the resources to mitigate climate-related threats (Mutengwa et al., 2023). This situation exposes them to environmental and economic shocks.

In response to these challenges, CSAPs have emerged as viable strategies for enhancing resilience and sustainability in smallholder farming systems. As the IPCC highlights, CSAPs reduce the adverse impacts of climate change (FAO, 2010) and equip farmers with strategies to adapt effectively (FAO, 2013). Agroforestry, conservation agriculture, crop diversification, effective water management, soil conservation measures, and climate-resilient crop varieties are some practices that fall under these strategies (Abegaz et al., 2024; Kizito et al., 2022).

Various factors influence the adoption of CSAPs in the agricultural sector. These include access to extension services, financial resources, reliable information, and broad socioeconomic conditions, environmental factors, institutional frameworks, social dynamics, and market conditions all play essential roles in shaping farmers' decisions to adopt CSAPs (Agyekum et al., 2024; Aryal et al., 2018; Gemtou et al., 2024; Gudina and Alemu, 2024; Kassa and Abdi, 2022; Makate et al., 2019; Ndung'u et al., 2023; Negera et al., 2022; Nyang'au et al., 2020; Sanogo et al., 2023; Silva et al., 2024). It is important to understand these factors when designing policies and support systems that promote the adoption of CSAPs to increase farmers' resilience and agricultural system sustainability in climate change.

Although governments, international organizations, and stakeholders have made considerable efforts to promote the adoption of CSAPs, their uptake remains uneven. While adoption rates are higher in developed countries because of better access to technology, resources, and supportive policies, developing regions, particularly sub-Saharan Africa, experience lower adoption levels (Ogisi and Begho, 2023). Constraints, such as resource limitations, inadequate access to technology, poor infrastructure, and weak institutional support, hinder progress (Gumbi et al., 2023; Ouédraogo et al., 2019). Smallholder farmers in these regions, including those in the grape farming subsector, remain vulnerable to climate risks and agricultural shocks. Despite experiencing the effects of climate change, farmers are slowly transitioning to CSPAs (Gemtou et al., 2024; Ogisi and Begho, 2023; Wakweya, 2023).

This controversy in adoption patterns reveals farmers' difficulties in implementing the practices in different agricultural subsectors, including the grape farming subsector. In this sub-sector, the adoption of CSAPs has varied between developed and developing countries. In developed countries, farmers increasingly adopt advanced technologies to mitigate climate risks, such as automated irrigation systems and climate-controlled greenhouse gas production (Costa et al., 2020). In developing nations like Tanzania, farmers depend on methods such as rainwater harvesting, irrigation, and organic soil management in grape farming to mitigate climate change (Agus et al., 2015; Kiggundu et al., 2018; Ndlovu et al., 2020). In addition, implementing a combination of adaptation strategies at different scales has been proven to enhance the effectiveness of agricultural climate change adaptation (Naulleau et al., 2021).

Grape farming in Tanzania is important in supporting smallholder farmers' livelihoods and economic well-being, particularly in Dodoma, a region renowned for its grape production (Nalyoto and Ngaruko, 2023). While CSAPs have shown recognition for their potential to enhance sustainability and resilience in agriculture, their adoption by smallholder grape farmers in Dodoma remains poorly understood. Existing research has primarily focused on other aspects of grape farming, such as profit efficiency (Nalyoto and Ngaruko, 2023), contributions to household income and welfare (Lwelamira, 2015), value addition (Chacky and Pande, 2022), value chain (Kulwijila et al., 2018; Mlay, 2021), and consumer preferences (Kimaro et al., 2024). These studies provide valuable knowledge into various aspects of the grape farming subsector but leave an opportunity to explore the landscape of CSAP adoption in the subsector. This study addresses this research gap by examining the factors influencing the adoption of CSAPs among smallholder grape farmers in Dodoma.

This study is driven by the rationale that understanding the adoption factors is essential for developing interventions that improve resilience, sustainability, and economic stability in grape farming communities. It contributes to efforts to promote agricultural sustainability, support smallholder farmers' adaptation to climate change, and improve rural livelihoods. The findings offer practical knowledge to guide agricultural practices and policy development.

2. Research Methodology

2.1. Description of the study area

This study was conducted in Dodoma District, an administrative area in the Dodoma Region, central Tanzania. Dodoma City, the capital of Tanzania, is the district's administrative center. Geographically, the district lies at approximately 6°10′S latitude and 35°45′E longitude, with an altitude of about 1,200 meters above sea level. It covers an area of 2,769 square kilometers and has a population of approximately 410,956, based on the 2022 Tanzania National Census. This population translates into a population density of about 148 persons per square kilometer. Figure 1 illustrates a locational map of the district, showing its position within the Dodoma Region and its administrative boundaries.

Dodoma District has semi-arid climatic conditions, with annual rainfall between 500 and 800 millimeters. The climate features distinct wet and dry seasons, with the dry season prevailing most of the year. These climatic conditions, water scarcity, and soil degradation challenge agricultural activities. Despite these constraints, agriculture remains the primary economic activity, particularly in rural areas, where small-scale farming predominates. Smallholder farmers notably generate significant income from agriculture, especially grape farming.

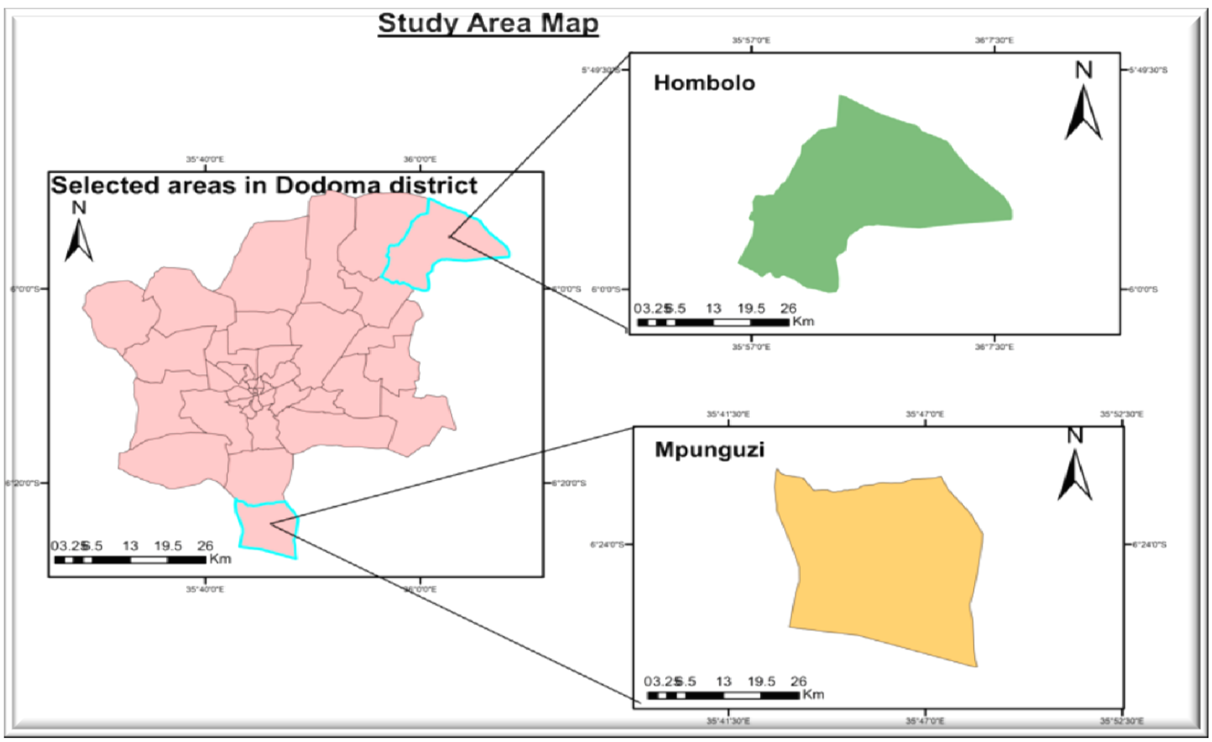

Figure 1: Map of the study areas

2.2. Study design

This study employed a cross-sectional design to examine the factors influencing the adoption of CSAPs by grape farmers in Dodoma District, Tanzania. The design was used in the study because it allowed for data collection at a single point, giving a picture of the levels of adoption, practices, and factors that affect grape farmers' decisions to use

CSAPs in response to climate change. This approach was suitable for understanding the current state of CSAP adoption and identifying the factors influencing farmers' adoption decisions. Additionally, this design allowed the study to capture a comprehensive view of current practices and trends, providing valuable information on CSAP adoption patterns.

2.3. Population and sampling

The target population for this study comprised smallholder grape farmers in the Dodoma Urban District, a central grape-producing region in Tanzania. A sample size of 120 farmers was determined using the approach by Singh and Masuku (2014), ensuring sufficient representation for an in-depth analysis. The sample size calculation incorporated a margin of error of 8.95%, a population proportion of 50%, a 95% confidence level, and an assumed unknown population of grape farmers. The formula used for sample size determination is presented as follows:

$$n = \frac{Z^2 \times pq}{d^{\,2}} = \frac{1.96^2 \times 0.5 \times 0.5}{0.0895^2} = 120 \qquad [1]$$

Where:
n is a sample size (120)
Z-score at 95% confidence level (1.96)
P represents the population proportion of 50%,
q = complement of p, (1-p)
The symbol d represents the margin of error, which is 8.95 percent.

The farmers were randomly selected from two wards, Mpunguzi and Hombolo, chosen for their substantial involvement in grape farming. Of the 120 farmers, 15 were from Mpunguzi and 85 from Hombolo. This uneven distribution resulted from farmers' availability during the survey, as many were occupied with other commitments.

A multistage sampling technique was employed to ensure a representative selection of respondents. In the first stage, Dodoma District was selected purposively for its significant role in grape production within the Dodoma region (Nalyoto and Ngaruko, 2023). Two wards were purposively chosen in the second stage because they are key grape-producing wards (Chacky and Pande, 2022). This reflects their prominence in grape farming activities within the district. Finally, farmers were randomly selected from these wards. This approach ensured a representation of grape farmers, enhancing the reliability and applicability of the findings to similar agricultural contexts.

2.4. Data collection

This study collected primary data to examine the factors influencing the adoption of CSAPs by smallholder grape farmers in the Dodoma District, Tanzania. The data collection aimed to capture information on farmers' characteristics, farming practices, and the factors affecting their decisions to adopt CSAPs. The study utilized a combination of survey and key informant interviews.

The questionnaire served as the primary data collection tool for the survey. The tool gathered quantitative data on various aspects, including the demographic characteristics of the farmers, their farm sizes, farming practices, perceptions of climate change, access to extension services, financial resources, and the use of CSAPs. The instrument was pre-tested to ensure the questions' clarity, reliability, and validity before being administered to the farmers. Its format allowed for systematic comparisons between variables and ensured that the data could be analyzed statistically. It was suitable for gathering data on adopting CSAPs and other quantifiable characteristics.

Besides the survey, key informant interviews were conducted with local agricultural officers, extension officers, and community leaders to gather information about the contemporary agrarian context, the role of policies in promoting CSAPs, and the challenges grape farmers face. The method, which utilized interview guides, provided a qualitative dimension to the study, allowing for the exploration of issues such as local perceptions of climate change and barriers to adopting CSAPs, which the surveys alone could not capture. Using key informant interviews added depth and context to the findings.

2.5. Methods of data analysis

2.5.1. Descriptive analysis

The descriptive analysis in this study describes the characteristics of grape farmers, focusing on demographics and CSAP adoption patterns. This analysis provides baseline information that helps interpret the primary trends and relationships in CSAP adoption. Demographic data, including age, gender, education level, household size, and years of farming experience, outlines the typical farmer's profile. Frequencies and percentages were used to summarize these variables. These descriptive statistics provide a foundational understanding of grape farmers' conditions, informing the interpretation of the study findings and potential policy recommendations for enhancing CSA adoption in similar agricultural contexts.

2.5.2. Econometric analysis

Model specification

The study utilized a multivariate probit model to analyze binary adoption decisions for various CSAPs, addressing the simultaneity issues associated with separate univariate probit estimations. As highlighted by Greene (2008), treating adoption decisions as independent processes neglects the interdependence and correlation between unobserved factors influencing these decisions. The multivariate probit approach captured these interdependencies, reflecting farmers' tendency to adopt multiple practices while accounting for the factors influencing each decision and their correlations. While alternative models like univariate logit or seemingly unrelated regression (SUR) could be considered, their inability to simultaneously capture interdependencies and correlations among multiple binary adoption decisions made them less appropriate for this study. Similarly, the significant correlation among the adoption of CSAPs validated the superiority of the multivariate probit model over bivariate models like probit and logit, an issue these alternatives could not adequately address.

Model formulation

Let Y_{ij} denote the binary adoption decision for the farmer i on CSA practice j,where j = 1, 2, 3, …, J, with J representing the number of CSA practices considered. For each adoption decision, $Y_{ij} = 1$ if the farmer adopts the practice j, and $Y_{ij} = 0$ otherwise. The underlying latent variable Y_{ij}^* is specified as:

$$Y_{ij}^* = X_i\beta_j + \varepsilon_{ij} \quad [2]$$

Where:

Y_{ij}^* = unobserved propensity for farmer i to adopt CSA practice j,

X_i = a vector of explanatory variables for farmer i,

β_j = a vector of parameters specific to practise j,

ε_{ij} = an error term capturing unobserved factors influencing adoption. It is assumed to be jointly normally distributed with a mean zero and a variance-covariance matrix Σ.

The observed adoption decision Y_{ij} is linked to the latent variable as:

$$Y_{ij} = \begin{cases} 1, & if\ Y_{ij}^* > 0 \\ 0, & if\ Y_{ij}^* \leq 0 \end{cases} \quad [3]$$

The multivariate probit model enables correlation among the error terms. ε_{ij}, addressing unobserved variations in adoption decisions. This correlation structure captures the influence of shared unobserved factors on a farmer's decision to adopt multiple CSAPs.

Estimation procedure

The multivariate probit model was estimated through maximum likelihood estimation (MLE), yielding parameter estimates for each adoption equation while accounting for the correlation among error terms across the equations. It was estimated jointly for all adoption decisions, facilitating efficient and unbiased estimates. The estimation produced marginal effects showing the influence of each explanatory variable on the likelihood of adopting each CSAP.

Data and description of variables

Survey data were obtained from 120 smallholder grape farmers within the Hombolo and Mpunguzi wards. The data utilized in this study are described in Table 1.

Table 1: Variables and descriptions

Variable	Description	Variable Type	Measurement	Expected Sign
Crop diversification	The cultivation of multiple types of crops within a farming system.	Dependent	Binary (1 = adopted, 0 = not adopted)	N/A
Crop rotation	This involves planting different crops on the same land to manage soil health sequentially.	Dependent	Binary (1 = adopted, 0 = not adopted)	N/A
Intercropping	Simultaneously cultivating two or more crops in proximity to optimize land use.	Dependent	Binary (1 = adopted, 0 = not adopted)	N/A
Water and nutrient management practices.	Techniques to optimize water resources and nutrients essential for crop growth.	Dependent	Binary (1 = adopted, 0 = not adopted)	N/A
Pest and Disease Management Practice.	Strategies to control pests and diseases affecting crops.	Dependent	Binary (1 = adopted, 0 = not adopted)	N/A
Marital Status	The farmer is married or not.	Independent	Binary (1 = married, 0 = not married)	Positive
Quantity of harvested grapes	The total quantity of grapes harvested	Independent	Continuous (measured in kilograms)	Positive
Access to financial resources	The availability of financial resources for farming activities.	Independent	Binary (1 = has access, 0 = has no access)	Positive
Awareness of CSAPs	Knowledge of CSAPs	Independent	Binary (1 = aware, 0 = unaware)	Positive
Farm size	The total area of land used for grape cultivation.	Independent	Continuous (measured in acres)	Positive
Access to training	Availability of educational programs or workshops for farmers to improve their skills.	Independent	Binary (1 = has access, 0 = has no access)	Positive
Input availability	The accessibility of agricultural input.	Independent	Binary (1 = available, 0 = not available)	Positive
Gender of the farmer	The farmer is male or female.	Independent	Binary (1 = male, 0 = female)	Positive
Access to extension services	Availability of agricultural extension services providing support and advice to farmers.	Independent	Binary (1 = has access, 0 = has no access)	Positive
Number of household members	The total number of people living in the farmer’s household.	Independent	Continuous (count of household members)	Positive
Farming experience	Years of experience in grape farming	Independent	Continuous measured in years	Positive
Education	Levels of education	Independent	Ordinal measured in levels	Positive
Age	Age of the farmer	Independent	Continuous measured in years	Negative

2.5.3. Ethical considerations

The district council approved the study prior to data collection. All participants provided informed consent, and confidentiality and anonymity were maintained throughout the research.

3. Results and Discussion

3.1. Demographics of farmers

Table 2 presents the demographic profile of the surveyed farmers, covering variables such as age, marital status, education level, and household size. These characteristics were essential for understanding the context of the grape farming sample. The table illustrates the distribution of these variables, providing valuable information for analyzing practice utilization in the study area.

3.1.1. Age distribution

The age distribution in Table 2 reveals a significant concentration of middle-aged farmers, particularly those aged 29 to 49, who comprise 78% of respondents. This demographic dominance shows that the workforce likely possesses the experience and skills essential for practical grape farming. The engagement of young adults (ages 29-39) demonstrates a readiness to adopt innovative practices, driving the subsector forward. However, the limited representation of younger farmers (ages 18-28) raises concerns about the future sustainability of grape farming, as this age group represents only 9% of respondents. Their low participation may stem from barriers such as resource access and preference for alternative livelihoods. Conversely, older farmers (ages 50 and above) represent a smaller segment, highlighting challenges related to succession and the need for knowledge transfer to younger generations. This age dynamic is relevant for adopting CSAPs, as younger farmers are more open to new technologies. In contrast, older farmers offer a valuable mentoring experience.

3.1.2. Gender distribution

The gender distribution in Table 2 reveals a significant disparity, with 62.5% of farmers being male and only 37.5% female. Men have traditionally been in charge of farming, which is reflected because most farmers are men. This is also true in other areas, like carrot farming (Sewando et al., 2022) and maize production (Utonga and Kamwela, 2024). This gender imbalance can influence decision-making and resource allocation within farming households, potentially limiting the effectiveness of agricultural practices and policies aimed at inclusivity. The underrepresentation of female farmers may hinder efforts to promote sustainable agricultural practices. The limited participation of CSAPs in grape farming could negatively impact the agricultural productivity, sustainability, and uptake of CSAPs.

3.1.3. Marital status

The data presented in Table 2 reveals the marital status of a sample population of 11 individuals who are not married and 109 individuals who are married. This reveals that most respondents were married, which may have various implications for social, economic, and demographic analyses. The percentage of married individuals highlights the importance of family structures, economic stability, and social support systems within the community. This trend may reflect cultural or societal norms favoring marriage among the population studied. This finding aligns with Utonga (2022a), who reported that 86% of maize farmers were also married, illustrating a consistent marriage trend within agricultural communities.

Such similarities emphasize the significance of family structures in agricultural settings, where collaborative efforts and shared responsibilities often play a crucial role in decision-making. This interconnectedness can enhance the adoption of CSAPs because families that work together can pool resources, share knowledge, and support each other in implementing sustainable practices. Married farmers may have increased motivation to adopt CSAPs because of their commitment to securing their family’s livelihood and enhancing long-term resilience against climate variability, ultimately contributing to improved agricultural productivity and sustainability.

Table 2: Demographic Profile of the Respondents

Variable	Category	Frequency	Percentage/Average
Age	18-28	02	09
	29-39	70	35
	40-50	40	43
	>50	08	13
Gender	Male	75	62.5
	Female	45	37.5
Marital status	Not Married	11	09
	Married	109	91
Education	Informal	05	04
	Primary	22	18
	Secondary	57	48
	Tertiary	36	30
Farming Experience	1-5	37	31
	6-10	55	46
	11-15	17	14
	16-20	09	08
	21-25	02	02
Household Members	Minimum	1	3
	Maximum	9	
Farm Size	Minimum	1	1.9
	Maximum	5	
Harvest	Minimum	200	1300
	Maximum	10,000	
Access to training	Accessed	81	-
	Not accessed	39	
Input Availability	Available	93	-
	Not available	27	
Access to Extension	Accessed	83	-
	No accessed	37	

3.1.4. Education level

The education level of the respondents in Table 2 shows a diverse range of educational backgrounds among grape farmers, which plays a significant role in adopting CSAPs. While only 4% of farmers have received informal education and 18% have completed primary education, a more significant proportion have attained secondary education (48%), followed by those with tertiary education (30%). Together, these two groups represent a substantial majority (78%) of the farmers, suggesting a favorable environment for adopting innovative agricultural practices. This educational background equips farmers with the skills and knowledge to engage with extension services, which can provide vital information and support for implementing climate-smart strategies. The results confirm the findings of Ghazalian et al. (2009) and Prokopy et al. (2019), which show a positive correlation between higher education levels and the adoption of agricultural practices. This correlation highlights the essential role of education in facilitating the transition to sustainable farming methods, as educated farmers are more open to new ideas and techniques that enhance agricultural productivity and resilience to climate change.

3.1.5. Farming experience

The distribution of farming experience in Table 2 among respondents reveals relatively inexperienced to moderately experienced grape farmers. With 46% of farmers having only 6 to 10 years of experience and 31% in the 1 to 5 years category, the sector may lack the expertise necessary to implement adaptive practices that mitigate the impacts of climate change. The lower percentages of experienced farmers - only 14% with 11 to 15 years, 8% with 16 to 20 years, and 2% with 21 to 25 years - suggest that few practitioners can mentor less experienced farmers in adopting sustainable methods.

This experience gap concerns the promotion of CSAPs, which often requires a clear understanding of local environmental conditions, pest management, and crop diversification strategies. With the guidance of experienced farmers, more experienced farmers may adopt these innovative practices essential for enhancing resilience against climate variability. The corroboration of these findings with Haryanto (2022) reinforces that both regions face similar challenges in cultivating experienced farming communities.

3.1.6. Household size, farm size and harvest

The data from Table 2 show variability in household sizes, farm sizes, and harvest yields among farming households, with household sizes ranging from one to nine members, farm sizes from one to five acres (average 1.9 acres), and harvest yields from 200 kg to 10,000 kg (average 1,300 kg). This diversity reflects the varying scales of farming operations, which likely influence livelihood strategies and resource management. As observed by Caulfield et al. (2021) in rural Andean households, such variability often correlates with differences in farm management approaches and adaptive strategies, which may have implications for adopting climate-smart practices and farm productivity.

3.1.7. Access to support services (training, extension services, and input)

The data from Table 2 reveal that access to agricultural support services varied among respondents. 81 respondents reported having accessed training opportunities, while 39 had not. Input availability was relatively high, with 93 respondents confirming access, though 27 reported challenges in obtaining farm inputs. Similarly, 83 respondents had access to extension services, while 37 did not. These disparities highlight potential inequalities in access to resources and knowledge, which may influence the adoption of climate-smart agricultural practices and farm productivity. These findings highlight the need to strengthen agricultural support systems, ensuring access to training, inputs, and extension services necessary to improve productivity and adopt sustainable practices. This aligns with Raji et al. (2024), who accentuates the importance of extension services and innovative training in enhancing agricultural productivity. Similarly, Abegunde and Obi (2022) emphasize that strengthening these systems is critical for promoting climate-smart practices in Africa.

3.2. Adoption rates

Table 3 shows farmers' adoption landscape of the CSAPs in the study area. It shows the percentage of farmers who have adopted each practice, highlighting variations in adoption rates.

3.2.1. Crop diversification

The adoption rate of crop diversification among respondents is 42%, with 50 farmers implementing this practice while 70 farmers do not. The 42% adoption rate reflects a cautious approach that contrasts with the potential benefits of diversified farming. Farmers concentrate on grape production, likely because of a single well-known crop's perceived profitability and manageability. However, this reliance on one crop makes it vulnerable to market volatility and environmental risks, especially as climate conditions shift. In contrast, as Kemboi *et al.* (2020) note, crop diversification offers higher gross margins, promoting greater financial stability. Despite these advantages, diversification remains underutilized because of barriers such as age, education, and limited access to necessary inputs. This contrast shows that overcoming these barriers unlocks diversification’s financial and risk-reduction benefits, promoting resilience despite economic and environmental uncertainties.

3.2.2. Crop rotation

A substantial 71% of the respondents in the current study have adopted crop rotation practices. This rate reflects a growing awareness among grape farmers of the benefits of crop rotation to sustainability and productivity. Using crop rotation contributes to sustainable farming systems by maintaining soil fertility and reducing reliance on chemical inputs. In contrast, Sahu *et al.* (2019) reported low adoption rates of crop rotation practices among farmers, attributing this to a lack of knowledge and various constraints. However, 82% of respondents knew about crop rotation practices, implying that access to training may not be the sole factor affecting adoption. The availability of educational resources and agricultural support programs influences adoption rates by encouraging implementation.

3.2.3. Intercropping

The results reveal that 73% of grape farmers practice inter-cropping, compared to 27% of farmers who do not use it. This trend reflects a substantial shift towards diversification in agricultural practices. It highlights an increasing adoption of strategies that enable farmers to grow multiple crops simultaneously, enhancing resource efficiency, improving pest management, and stabilizing yields, all of which are benefits that are valuable in the face of climate variability and market risks. This adoption rate aligns with the findings of Boora *et al.* (2023) in Haryana, India, where intercropping has got attention. This alignment suggests that farmers in different regions recognize the practical benefits of intercropping as an essential tool for adapting to climate variability and mitigating economic risks.

Table 3: Adoption landscape of Climate-smart agricultural practices in the study area

SN	CSAP	Adopted	Not Adopted	Total
1	Crop diversification	50 (42%)	70 (58%)	120 (100%)
2	Crop rotation	85 (71%)	35 (29%)	120 (100%)
3	Intercropping	87 (73%)	33 (27%)	120 (100%)
4	Water and nutrient management	79 (66%)	41 (34%)	120 (100%)
5	Pest and Disease Management	97 (81%)	23 (19%)	120 (100%)

3.2.4. Water and nutrient management

The results show that 66% of respondents have adopted water and nutrient management practices. Out of these, 79 farmers have implemented these strategies, while 41 have not. This trend highlights the awareness of how such practices enhance grape yield and maintain soil health. However, Ulrich-Schad et al. (2017) found that the level of adoption differs from what was expected. They said the uptake of best management practices for nutrients often falls short of expectations and varies between practices. Similarly, Velasco-Muñoz *et al.* (2022) highlighted that adopting sustainable water management practices remains low because of barriers like high costs and a lack of research. This implies that although farmers recognize the benefits of sustainable practices, persistent challenges, including financial constraints and insufficient research, can impede their implementation.

3.2.5. Pest and disease management

The high adoption rate (81%) of pest and disease management practices among grape farmers reveals a strong commitment to safeguarding crop health, with 97 farmers actively implementing these strategies compared to only 23 who do not. This shows that farmers are aware of and prioritize addressing pest and disease threats. These threats can harm agricultural productivity. This proactive approach recognizes the essential role of effective pest and disease management in achieving sustainable farming practices. The alignment of these findings with Kenfaoui *et al.* (2024), who also reported high adoption rates among grape farmers in Morocco, reinforces the notion that this trend is not isolated but indicative of regional awareness and response among grape farmers to the challenges posed by pests and diseases.

3.3. Factors influencing the adoption of climate smart agricultural practices

The results in Table 4 present the MVP estimates for factors influencing the adoption of CSAPs in grape farming. The Wald test rejected the null hypothesis, showing that at least one regression coefficient differs significantly from zero. Factors influencing adoption include gender, marital status, access to finance, extension services, awareness, input availability, training, and harvest. The MVP model fit was assessed using two statistics: the Wald chi-squared statistic (82.15, 45 degrees of freedom), significant at the 1% level, confirming the model's explanatory power. A likelihood ratio test (chi-squared = 55.25, 10 degrees of freedom) further confirmed significant interdependencies between the equations, enhancing the model’s explanatory power.

The multivariate probit model results reveal that access to finance reduces the probability of crop diversification by 23.52%, statistically significant at the 5% level (p = 0.031). This implies that financial resources enable grape farmers to focus on their primary agricultural activity-grape production, which yields higher returns rather than diversifying into other crops. This contrasts with studies such as Vekariya et al. (2022), which argue that increased income encourages crop diversification. The difference may stem from varying financial objectives and crop values, as grape farmers may view finance as an opportunity to expand within a profitable sector. In contrast, other farmers may use additional funds to invest in diverse crops.

On the other hand, access to finance increases the likelihood of adopting crop rotation by 24.96%, statistically significant at the 5% level (p = 0.026). This result shows the positive role of financial resources in supporting sustainable agricultural practices, allowing farmers to invest in inputs and infrastructure needed for effective crop rotation. This aligns with Girma (2022), who found that access to credit supports adopting agricultural technologies, including crop rotation. The results highlight the importance of financial initiatives in fostering sustainable farming practices.

The findings also reveal that input availability reduces the likelihood of crop diversification by 28.8%, statistically significant at the 5% level (p = 0.017). This implies that access to inputs encourages grape farmers to focus on grape farming rather than diversifying into multiple crops, likely because of the efficiency and simplified management of mono-cropping. However, this focus on a single crop may reduce the benefits of diversification, which is crucial for risk management and soil health. This observation is consistent with Adjimoti et al. (2017), who noted that greater input availability could discourage diversification by increasing coordination costs. While inputs may boost productivity for the primary crop, they can limit the advantages of diversified farming systems.

Regarding gender, the MVP analysis shows that male-headed households are 24.72% less likely to adopt crop rotation, which is statistically significant at the 5% level (p = 0.048). This suggests that female-headed households are more likely to prioritise crop rotations, contrasting with the findings of Tanellari et al. (2013), who reported that female-headed households were less likely to adopt new agricultural technologies. The divergence may stem from perceptions of crop rotation as a traditional, resource-conserving practice rather than a capital-intensive innovation. The alignment with sustainability goals may make crop rotation more attractive to female farmers managing household-level agriculture.

The results also show that awareness of CSA practices increases the likelihood of adopting crop rotation by 50.56%, statistically significant at the 1% level (p = 0.002). This highlights the critical role of education and information in promoting CSA practices. Increased awareness of the benefits of crop rotation can encourage adoption, leading to improved agricultural outcomes. These results support what Meshesha et al. (2022) found: Smallholder farmers are much more likely to use CSA practices when they know more about them. This shows how important educational programs are.

Table 4: Results of Multivariate Probit Model Analysis

Variables	Crop diversification		Crop rotation		Inter-cropping		Water and nutrient management practices		Pests and diseases management	
	Coefficient	Std. Err	Coefficient	Std. Err	Coefficient	Std. Err	Coefficient	Std. Err	Coefficient	Std. Err
Gender	.0985364	.263311	-.6176345**	.312856	-.1087789	.2812128	.0826791	.2777121	-.2426986	.2727661
Marital Status	-	-	-.0287282*	.4690864	1.073015**	.4572791	2.016852***	.6358947	.8272004**	.4014732
Household Members	-.1282783*	.0676277	-.0608274	.0662441	.0703505	.0640675	.0239792	.059264	-	-
Farm size	.2416827*	.1416169	-.2658154*	.1442318	.3212883*	.1910455	.1146514	.1685127	.2078508	.1742327
Access to finance	-.5880816**	.2727528	.6243439**	.2803033	-	-	-	-	-	-
Extension	-.3630703	.2764513	.4538706	.3196356	.0873166	.2944317	-	-	.60751**	.2562878
Awareness	-	-	1.263503***	.4047652	.3881217	.3467418	.1391287	.3736292	.2772492	.3546568
Input availability	-.7197001**	.302693	-.682421*	.383596	-	-	-.1506861	.3096022	.4678055	.3033062
Training	.2916297	.2933425	.4979121	.316744	-.902790***	.3396422	-.6609414**	.3161761	-.471289	.2947368
Harvest	-.000134*	.0000693	-.0000815	.0000685	-.0001701**	.0000815	-.0001367*	.0000711	-.0000883	.0000773
Experience	-	-	-	-	.0071598	.0293791	.0569499*	.0326037	.0024752	.0279819
Observations	120									
rho21	-.1136486	.169596								
rho31	.0310001	.1656734								
rho41	.0928604	.1433634								
rho51	.1057683	.1657584								
rho32	-.1935498	.1518861								
rho42	.3034297*	.1567716								
rho52	.3003618**	.1388876								
rho43	.5391678***	.1425206								
rho53	.4480108***	.146657								
rho54	.8233746***	.0922032								
Wald $chi^2(45)$	82.15***									
Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho32 = rho42 = rho52 = rho43 = rho53 = rho54 = 0										
$chi^2(10)$	55.2465***									

Note: *** (P < 0.01); ** (P < 0.05); * (P < 0.10)

Marital status is another significant factor influencing the adoption of CSAPs. Married farmers are 42.92% more likely to adopt intercropping practices ($p = 0.019$), reflecting the cooperative dynamics often present in marital partnerships that encourage resource-enhancing practices. Similarly, married farmers are 80.68% more likely to adopt water and nutrient management practices ($p = 0.002$), emphasizing the role of family considerations in promoting sustainable farming practices. Moreover, married farmers were 33.08% more likely to adopt pest and disease management practices ($p = 0.039$), demonstrating their proactive approach to ensuring food and income security. These findings align with those of Iyilade et al. (2020) and Egho and Enujeke (2012), who observed that married households adopt more sustainable practices, though Acheampong et al. (2023) noted that marriage may not always encourage practices like crop rotation.

The study further reveals that an increase in grape yield reduces the likelihood of adopting intercropping by 0.0068%, statistically significant at the 5% level ($p = 0.037$). This slight reduction shows that as grape productivity increases, farmers may feel less inclined to adopt intercropping, seeing it as unnecessary for optimizing resource use and increasing yields. This translates to the context that higher grape yields may make farmers more focused on maintaining or improving their current productivity rather than diversifying through intercropping. This aligns with Michler et al. (2018), who observed that yield increases alone do not always drive the adoption of agricultural innovations, as economic returns and perceived benefits play a crucial role in decision-making.

The results show that access to training significantly reduces the likelihood of adopting intercropping and water management practices. Specifically, access to training reduces the probability of adopting intercropping by 36.12% ($p = 0.008$), suggesting that current training programs may lead grape farmers to adopt alternative practices instead. This raises concerns about the content and focus of these training programs. Similarly, access to training decreases the likelihood of adopting water management practices by 26.44% ($p = 0.037$). This indicates that the training may focus on other agricultural practices, leaving water and nutrient management insufficiently addressed. These findings are consistent with Ward et al. (2015), who argued that training alone may not promote the adoption of intercropping, and Dhehibi et al. (2018), who found similar results for soil and water conservation practices in Tunisia. These findings highlight the limitations of training programs that do not prioritise resource management practices.

The findings reveal that access to extension services increases the likelihood of adopting pest and disease management practices by 24.32%, statistically significant at the 5% level ($p = 0.018$). This emphasizes the vital role of extension services in educating farmers about effective pest and disease management strategies. Extension services enable farmers to adopt best practices that enhance grape productivity and mitigate risks from pests and diseases. These results are in line with those of Ali and Rahut (2013), who found that extension services make it much easier for farmers to use new technologies, and Toepfer et al. (2020), who highlighted how important it is to improve extension services for long-term pest and disease control.

4. Conclusion and Recommendations

4.1. Conclusion

This study examines the factors influencing the adoption of CSAPs by smallholder grape farmers in Dodoma, Tanzania. Using a multivariate probit model, this study identified significant factors that affect the likelihood of adopting specific CSAPs, such as crop rotation, intercropping, water and nutrient management, and pest and disease management. The results reveal that factors such as access to finance, farmer awareness of CSAPs, gender, and marital status substantially influence the adoption of these practices. Access to financial services and awareness of CSAPs enhances adoption rates, highlighting the importance of resources and information in encouraging sustainable practices. Gender disparities highlight that female-headed households are more likely to adopt crop rotation, likely reflecting a commitment to land management practices that promote long-term soil health. The findings illustrate the need for policies and interventions. Programs that improve financial accessibility, increase farmer awareness, and address gender-specific challenges could promote CSAP adoption. Focusing on family-centered support and improving extension services could help these practices catch on with more people, ultimately making regional agriculture more resilient.

4.2. Recommendations

Policymakers should implement family-centered agricultural support initiatives that address household decision-making dynamics. Agricultural programs can design content and resources that emphasize the role of CSAPs in enhancing family welfare and food security. To increase the adoption of sustainable agricultural practices, these initiatives should emphasize their contribution to the family's well-being, thus encouraging household cooperation.

Financial institutions should introduce incentives to encourage crop diversification and reduce the over-reliance on grape farming. Low-interest loans or grants targeted at multi-crop farming can provide grape farmers the resources to incorporate diverse crops alongside grape production. This approach will help mitigate financial risk, improve resilience, and promote sustainable farming practices. Farmers can benefit from the risk-spreading advantages of diversified farming without compromising profitability by reducing dependency on a single crop.

Development practitioners should prioritise gender-sensitive approaches to promoting crop rotation. Training and outreach programs should address gender-specific perspectives to highlight crop rotation's benefits. This approach will ensure the inclusivity of CSAPs, contributing to long-term agricultural sustainability and empowering women in agricultural decision-making.

Current training programs should be refocused to emphasize water and nutrient management practices. Integrating custom modules on water efficiency, soil health, and nutrient optimization can enhance training programs, equipping farmers with practical knowledge essential for sustainable resource management. This focus will help grape farmers increase productivity and enhance resilience to climate variability.

Strengthening extension services to support pest and disease management is crucial for improving grape farming outcomes. Local governments and agricultural organizations should enhance outreach, particularly in remote areas, by providing regular, practical training on sustainable pest and disease management techniques. This approach will enable farmers to adopt effective practices that protect crop health, increase productivity, and bolster resilience to pest and disease threats.

Data availability statement
Data will be made available on request.

Conflicts of interest
The authors declared that there is no conflict of interest regarding the publication of this article.

References

Abegaz, A., Abera, W., Jaquet, S., and Tamene, L. (2024). Adoption of climate-smart agricultural practices (CSAPs) in Ethiopia. *Climate Risk Management*, *45*, 100628. https://doi.org/10.1016/j.crm.2024.100628.

Abegunde, V. O., and Obi, A. (2022). The Role and Perspective of Climate Smart agriculture in Africa: a scientific review. *Sustainability*, *14*(4), 2317. https://doi.org/10.3390/su14042317.

Acheampong, P. P., Yeboah, S., Adabah, R., Asibuo, J. Y., Nchanji, E. B., Opoku, M., Toywa, J., and Lutomia, C. K. (2023). Gendered perceptions and adaptations to climate change in Ghana: What factors influence the choice of an adaptation strategy? *Frontiers in Sustainable Food Systems*, *7*. https://doi.org/10.3389/fsufs.2023.1091812.

Adjimoti, G. O., Kwadzo, G. T., Sarpong, D. B., and Onumah, E. E. (2017). Input Policies and Crop Diversification: Evidence from the Colline Region in Benin. *African Development Review*, *29*(3), 512–523. https://doi.org/10.1111/1467-8268.12286.

Agus, F., Husnain, H. and Yustika, R. D. (2015). Improving Agricultural Resilience to Climate Change through Soil Management. *Jurnal Penelitian Dan Pengembangan Pertanian*, *34*(4), 147. https://doi.org/10.21082/jp3.v34n4.2015.p147-158.

Agyekum, T. P., Antwi-Agyei, P., Dougill, A. J., and Stringer, L. C. (2024). Benefits and barriers to the adoption of climate-smart agriculture practices in West Africa: A systematic review. *Climate Resilience and Sustainability*, *3*(3). https://doi.org/10.1002/cli2.79.

Ali, A., and Rahut, D. B. (2013). The Impact of Agricultural Extension Services on Technology Adoption and Crop Yield: Empirical Evidence from Pakistan. *Asian Journal of Agriculture and Rural Development*, *3*(11), 801–812. https://doi.org/10.22004/ag.econ.198306.

Aryal, J. P., Rahut, D. B., Maharjan, S., and Erenstein, O. (2018). Factors affecting the adoption of multiple climate-smart agricultural practices in the Indo-Gangetic Plains of India. *Natural Resources Forum*, *42*(3), 141–158. https://doi.org/10.1111/1477-8947.12152.

Boora, S., Kaur, B., Tyagiq, R., Bishnoi, D. K., k, M., and k, R. (2023). Extent of adoption of intercropping practices among farmers of Haryana. *Indian Journal of Extension Education*, *59*(1), 24–27. https://doi.org/10.48165/ijee.2023.59105.

Caulfield, M. E., Hammond, J., Fonte, S. J., Florido, M. A., Fuentes, W., Meza, K., Navarette, I., Vanek, S. J., and Van Wijk, M. (2021). Unpicking the inter-relationships between Off-Farm livelihood diversification, household characteristics, and farm management in the rural Andes. *Frontiers in Sustainable Food Systems*, *5*. https://doi.org/10.3389/fsufs.2021.724492.

Chacky, Z. S., and Pande, V. S. (2022). Benefits associated with smallholder farmers' participation in grapes value addition: a case of Dodoma City jurisdiction, Tanzania. *East Africa Journal of Social and Applied Sciences*, *4*(1), 30-40.

Costa, E., Martins, M. B., Vendruscolo, E. P., Da Silva, A. G., Zoz, T., Da Silva Binotti, F. F., Witt, T. W., and De Castro Seron, C. (2020). Greenhouses within the Agricultura 4.0 interface. *Ciência Agronômica/Revista Ciência Agronômica*, *51*(5). https://doi.org/10.5935/1806-6690.20200089

Dhehibi, B., Zucca, C., Frija, A., and Kassam, S. N. (2018). Biophysical and Econometric Analysis of Adoption of Soil and Water Conservation Techniques in the Semiarid Region of Sidi Bouzid (Central Tunisia). *New Medit*, *XVII* (2), 15–28. https://doi.org/10.30682/nm1802b.

Egho, E. O., and Enujeke, E. C. (2012). Integrated Pest Management (IPM) Adoption among Farmers in the Central Agro-Ecological Zone of Delta State, Nigeria. *Agricultura*, *83*. https://doi.org/10.15835/arspa.v83i3-4.9078

FAO, (2010). Climate-smart agriculture: policies, practices, and financing for food security, adaptation, and mitigation. In *Hague Conference on Agriculture, Food Security and Climate Change*.

FAO, (2013). Climate-smart agriculture sourcebook. Food and Agriculture Organization of the United Nations.

Gemtou, M., Kakkavou, K., Anastasiou, E., Fountas, S., Pedersen, S. M., Isakhanyan, G., Erekalo, K. T., and Pazos-Vidal, S. (2024). Farmers' Transition to Climate-Smart Agriculture: A Systematic Review of the Decision-Making Factors Affecting Adoption. *Sustainability*, *16*(7), 2828. https://doi.org/10.3390/su16072828.

Ghazalian, P. L., Larue, B., and West, G. E. (2009). Best Management Practices to Enhance Water Quality: Who is Adopting Them? *Journal of Agricultural and Applied Economics*, *41*(3), 663–682. https://doi.org/10.1017/s107407080000314x.

Girma, Y. (2022). Credit access and agricultural technology adoption nexus in Ethiopia: A systematic review and meta-analysis. *Journal of Agriculture and Food Research*, *10*, 100362. https://doi.org/10.1016/j.jafr.2022.100362.

Greene, W. H. (2008). Econometric Analysis, 6th Ed. New York, NY University, Upper Saddle River, NJ, 07458.

Gudina, M. H., and Alemu, E. A. (2024). Factors influencing small holder farmers adoption of climate SMART agriculture practices in Welmera Woreda, Central Ethiopia. *Frontiers in Climate*, *6(12)*. https://doi.org/10.3389/fclim.2024.1322550.

Gumbi, N., Gumbi, L. and Twinomurinzi, H. (2023). Towards Sustainable Digital Agriculture for Smallholder Farmers: A Systematic Literature Review. *Sustainability*. *15*(16), 12530. https://doi.org/10.3390/su151612530.

Haryanto, L. I., (2022). Farmer perspectives on the livelihoods of the grape community in South

Tangerang City. *Jambura Agribusiness Journal*, *4*(1), 23–32. https://doi.org/10.37046/jaj.v4i1.14361

Hossain, S. M., Atibudhi, H., and Mishra, S. (2023). Agricultural Vulnerability to Climate Change: A Critical review of evolving assessment approaches. *Grassroots Journal of Natural Resources*, *6*(1), 141–165. https://doi.org/10.33002/nr2581.6853.060107.

IPCC (Intergovernmental Panel on Climate Change) (2014). Climate Change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. Contribution of working group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. *Integrated Taxonomic Information System (ITIS)*, 2021.

Iyilade, A. O., Alalade, O. A., Longe, M. P., Alokan, A. O., and Akinola-Soji, B. (2020). Factors influencing the adoption of sustainable soil and water conservation practices among smallholder farmers in Kwara State, Nigeria. *Journal of Agricultural Extension*, *24*(4), 113–121. https://doi.org/10.4314/jae.v24i4.12.

Kassa, B. A., and Abdi, A. T. (2022). Factors influencing the adoption of Climate-Smart agricultural practice by Small-Scale farming households in Wondo Genet, southern Ethiopia. *SAGE Open*, *12*(3), 215824402211216. https://doi.org/10.1177/21582440221121604.

Kemboi, E., Muendo, K., and Kiprotich, C. (2020). Crop diversification analysis amongst smallholder farmers in Kenya (empirical evidence from Kamariny ward, Elgeyo Marakwet County). *Cogent Food and Agriculture*, *6*(1), 1834669. https://doi.org/10.1080/23311932.2020.1834669.

Kenfaoui, J., Lahlali, R., Laasli, S., Lahmamsi, H., Goura, K., Taoussi, M., Mennani, M., Fardi, M., Tahiri, A., Amiri, S., and Ghadraoui, L. E. (2024). Farmer's knowledge, perception, and practices in managing insect pests and diseases of grapevine in Morocco. *International Journal of Pest Management*, 1–18. https://doi.org/10.1080/09670874.2024.2361365.

Kiggundu, N., Wanyama, J., Mfitumukiz, D., Twinomuhangi, R., Barasa, B., Katimbo, A., and Kyazze, F.B. (2018). Rainwater harvesting knowledge and practises for agricultural production in a changing climate: A review from Uganda's perspective. *Agricultural Engineering International: The CIGR Journal, 20*, 19-36.

Kimaro, N., Timothy, S., and Mgale, Y. J. (2024). Exploring Consumer Preferences for Locally Produced Wine in the Tanzanian Market: Evidence from Wine Consumers in Dodoma City. *Research on World Agricultural Economy*, *5*(1), 19–31. https://doi.org/10.36956/rwae.v5i1.965.

Kizito, F., Chikowo, R., Kimaro, A., and Swai, E. (2022). Soil and water conservation for climate-resilient agriculture. In *CABI eBooks* (pp. 62–79). https://doi.org/10.1079/9781800621602.0005.

Kulwijila, M., Makindara, J., and Laswai, H. (2018). Grape value chain mapping in Dodoma region, Tanzania. *Journal of Economics and Sustainable Development*, *9*(2), 171–182. https://iiste.org/Journals/index.php/JEDS/article/download/40701/41856.

Lwelamira, J. (2015). Grapevine Farming and its Contribution to Household Income and Welfare among Smallholder Farmers in Dodoma Urban District, Tanzania. *American Journal of Agriculture and Forestry*, *3*(3), 73. https://doi.org/10.11648/j.ajaf.20150303.12.

Makate, C., Makate, M., Mutenje, M., Mango, N., and Siziba, S. (2019). Synergistic impacts of agricultural credit and extension on adoption of climate-smart agricultural technologies in southern Africa. *Environmental Development* 32, 100458. https://doi.org/10.1016/j.envdev.2019.100458.

Meshesha, A. T., Birhanu, B. S., and Ayele, M. B. (2022). Effects of perceptions on the adoption of climate-smart agriculture innovations: empirical evidence from the upper Blue Nile Highlands of Ethiopia. *International Journal of Climate Change Strategies and Management*, *14*(3), 293–311. https://doi.org/10.1108/ijccsm-04-2021-0035.

Michler, J. D., Tjernström, E., Verkaart, S., and Mausch, K. (2018). Money Matters: The role of yields and profits in agricultural technology adoption. *American Journal of Agricultural Economics*, *101*(3), 710–731. https://doi.org/10.1093/ajae/aay050.

Mutengwa, C. S., Mnkeni, P., and Kondwakwenda, A. (2023). Climate-Smart Agriculture and Food Security in Southern Africa: A review of the vulnerability of smallholder agriculture and food security to climate change. *Sustainability*, *15*(4), 2882. https://doi.org/10.3390/su15042882.

Nalyoto, A., and Ngaruko, D. D. (2023). Analysis of profit efficiency of grape production: a case of smallholder grape farmers in Dodoma, Tanzania. *Huria Journal of the Open University of Tanzania*, *29*(1). https://doi.org/10.61538/huria.v29i1.1228.

Naulleau, A., Gary, C., Prévot, L., and Hossard, L. (2021). Evaluating Strategies for Adaptation to Climate Change in Grapevine Production: A Systematic Review. *Frontiers in Plant Science*, *11*. https://doi.org/10.3389/fpls.2020.607859.

Ndlovu, S., Mathe, B., Phiri, K., and Nyathi, D. (2020). Factoring water harvesting into climate change adaptation: Endogenous responses by smallholder farmers in Gwanda district, Zimbabwe. *Cogent Social Sciences*, *6*(1). https://doi.org/10.1080/23311886.2020.1784652.

Ndung'u, S., Ogema, V., Thiga, M., and Wandahwa, P. (2023). Factors influencing the adoption of climate smart agriculture practises among smallholder farmers in Kakamega County, Kenya. *African Journal of Food Agriculture Nutrition and Development*, *23*(10), 24759–24782. https://doi.org/10.18697/ajfand.125.23400.

Negera, M., Alemu, T., Hagos, F., and Haileslassie, A. (2022). Determinants of adoption of climate smart agricultural practises among farmers in the Bale-Eco region, Ethiopia. *Heliyon*, *8*(7), e09824. https://doi.org/10.1016/j.heliyon.2022.e09824.

Nyang'au, J. O.; Mohamed, J. H.; Mango, N.; Makate, C.; Wangeci, A. N. and Ahenda, S. O. (2020). Determinants of smallholder farmers' choice of climate Smart agriculture practises to adapt to climate change in Masaba South Sub-County, Kisii, Kenya. *Asian Journal of Agricultural Extension Economics and Sociology* 29–41. https://doi.org/10.9734/ajaees/2020/v38i530345.

Ogisi, O. D., and Begho, T. (2023). Adoption of climate-smart agricultural practices in sub-Saharan Africa: A review of the progress, barriers, gender differences, and recommendations. *Farming System*, *1*(2), 100019. https://doi.org/10.1016/j.farsys.2023.100019.

Ouédraogo, M., Houessionon, P., Zougmoré, R. B., and Partey, S. T. (2019). Uptake of Climate-Smart Agricultural Technologies and Practises: actual and potential adoption rates in the Climate-Smart Village site of Mali. *Sustainability*, *11*(17), 4710. https://doi.org/10.3390/su11174710.

Prokopy, L., Floress, K., Arbuckle, J., Church, S., Eanes, Gao, Y., Gramig, B., R., P., and Singh, A. (2019). Adoption of agricultural conservation practises in the United States: Evidence from 35 years of quantitative literature. *Journal of Soil and Water Conservation*, *74*(5), 520–534. https://doi.org/10.2489/jswc.74.5.520.

Raji, N. E., Ijomah, N. T. I., and Eyieyien, N. O. G. (2024). Improving agricultural practices and productivity through extension services and innovative training programs. *International Journal of Applied Research in Social Sciences*, *6*(7), 1297–1309. https://doi.org/10.51594/ijarss.v6i7.1267.

Sahu, G. T., Kaur, S., and Singh, G. (2019). Knowledge level of farmers and constraints faced in adoption of crop rotation system. *Current Journal of Applied Science and Technology*, 1–6. https://doi.org/10.9734/cjast/2019/v38i130349.

Sanogo, K., Touré, I., Arinloye, D. A., Dossou-Yovo, E. R., and Bayala, J. (2023). Factors affecting the adoption of climate-smart agriculture technologies in rice farming systems in Mali, West Africa. *Smart Agricultural Technology*, *5*, 100283. https://doi.org/10.1016/j.atech.2023.100283.

Sewando, P. T., Utonga, D., and John, S. (2022). The contribution of carrot farming on livelihood improvement at household levels in Arumeru district, Arusha Tanzania. *International Journal of Science and Management Studies (IJSMS)*, 87–93. https://doi.org/10.51386/25815946/ijsms-v5i2p111.

Silva, M. F. E., Van Schoubroeck, S., Cools, J., and Van Passel, S. (2024). A systematic review identifying the drivers and barriers to the adoption of climate-smart agriculture by smallholder farmers in Africa. *Frontiers in Environmental Economics*, *3*. https://doi.org/10.3389/frevc.2024.1356335.

Singh, A. S. and Masuku, M. B. (2014). Sampling Techniques and Determination of Sample Size in Applied Statistics Research: An Overview. *International Journal of Economics, Commerce, and Management*, 2, 1-22.

Tanellari, E., Kostandini, G., and Bonabana-Wabbi, J. (2013). Gender Impacts on Adoption of New Technologies: Evidence from Uganda. *RePEc: Research Papers in Economics*. https://doi.org/10.22004/ag.econ.143204.

Toepfer, S., Zhang, T., Wang, B., Qiao, Y., Peng, H., Luo, H., Wan, X., Gu, R., Zhang, Y., Ji, H., and Wan, M. (2020). Sustainable Pest Management through Improved Advice in Agricultural Extension. *Sustainability*. *12*(17), 6767. https://doi.org/10.3390/su12176767.

Ulrich-Schad, J., De Jalón, S. G., Babin, N., Pape, A., and Prokopy, L. (2017). Measuring and understanding agricultural producers' adoption of nutrient best management practises. *Journal of Soil and Water Conservation*, *72*(5), 506–518. https://doi.org/10.2489/jswc.72.5.506

Utonga, D. (2022a). Analysis of Maize Profitability among Smallholder Farmers in Mbinga District, Tanzania. *International Journal of Research Publication and Reviews*, 1031–1035. https://doi.org/10.55248/gengpi.2022.3.2.13.

Utonga, D. (2022b). Determinants of Maize Yields among Small-Scale Farmers in Mbinga District, Tanzania. *Asian Journal of Economics Business and Accounting*, 49–58. https://doi.org/10.9734/ajeba/2022/v22i730578.

Utonga, D., and Kamwela, L. J. (2024). Towards Sustainable Maize Farming in Tanzania: Understanding Yield Predictors among Smallholder Farmers. In Contemporary Research in Business, Management, and Economics (Vol. 4, pp. 78–90). BP International. https://doi.org/10.9734/bpi/crbme/v4/3435g.

Vekariya, D. J., Vekariya, S. B., and Nagani, C. M. (2022). Factors affecting crop diversification. *Gujarat Journal of Extension Education*, *34*(1), 46–49. https://doi.org/10.56572/gjoee.2022.34.1.0009.

Velasco-Muñoz, J. F., Aznar-Sánchez, J. Á., López-Felices, B., and Balacco, G. (2022). Adopting sustainable water management practices in agriculture based on stakeholder preferences. *Agricultural Economics (Zemědělská Ekonomika)*, *68*(9), 317–326. https://doi.org/10.17221/203/2022-agricecon.

Wakweya, R. B. (2023). Challenges and prospects of adopting climate-smart agricultural practises and technologies: Implications for food security. *Journal of Agriculture and Food Research*, *14*, 100698. https://doi.org/10.1016/j.jafr.2023.100698.

Ward, P., Bell, A., Parkhurst, G., Droppelmann, K., and Mapemba, L. (2015). Heterogeneous preferences and the effects of incentives in promoting conservation agriculture in Malawi. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2635476.