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Knowledge, Trust, and Resilience: Factors Shaping Climate Adaptation in Zanzibar's Agricultural Sector

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ABSTRACT

Communities that depend on agriculture are seriously threatened by climate change, especially smallholder farmers in low-income countries like Zanzibar. This study examines how farmers in Unguja Island's Central District view climate variability and change, what influences their views, and how Climate-Smart Agriculture (CSA) methods are being adopted. Data were gathered from 396 households in five villages using a mixed-methods approach that included key informant interviews, focus groups, and structured surveys. The majority of farmers reported higher temperatures, less consistent and variable rainfall, and shorter growing seasons, according to statistical analyses using logistic regression and descriptive methods. These factors all contributed to decreased crop yields and increased food insecurity. Education level, farming experience, access to extension services, climate information, and participation in CSA training all had a significant impact on how people perceived climate change. Adoption of CSA practices is still uneven despite widespread awareness, with high adoption of pest management and irrigation techniques but low engagement in crop diversification and planting calendar adjustments. These findings underscore the urgent need for evidence-based, locally-based policies that improve access to climate information, strengthen institutional support, and encourage inclusive CSA strategies to increase the adaptive capacity of smallholder farmers in Zanzibar and similar contexts.

INTRODUCTION

Climate change continues to pose a huge worldwide hazard, harming human well-being, economic activity, health systems, livelihoods, and food supply (Dhimal*et al.*, 2021). Although its detrimental consequences are observed worldwide, developing nations, particularly smallholder farmers living in poverty, are disproportionately affected due to their low capacity to adapt (Hernández-Delgado, 2015). In many nations across Sub-Saharan Africa (SSA), agriculture is prioritized as a strategy to secure accessible and sufficient food supply, given its essential role in achieving food security. However, agriculture is still quite vulnerable to short-term and long-term climate changes. Regretfully, many emerging regions still lack the necessary and robust steps to strengthen this vital sector (Rashid, 2019).

Therefore, neglecting to address climatic variability and change could result in severe food insecurity, with developing countries likely to experience the worst effects (Rashid, 2019). For instance, a 1.5°C increase in temperature is predicted to exacerbate climate-related risks to human safety, livelihoods, food availability, water resources, public health, and economic growth in many low-income nations (Colombini *et al.*, 2023). Due to their heavy reliance on rain-fed crops, smallholder farmers are particularly vulnerable to the effects of climate change. Widespread poverty, inadequate infrastructure, and a lack of technical improvements all contribute to their vulnerability (Mbuli *et al.*, 2021). Due in large part to Tanzania's extreme sensitivity to variations in rainfall, the effects of climate change have presented significant risks to the country's economy and food security (Gwambene & Mung'ong'o, 2023). The agricultural industry, which is still essential to Tanzania's economic growth, has been hampered by these climate changes (Kahimba *et al.*, 2015). With 65–70% of the workforce employed in the agricultural sector (Gupta, 2020) and a GDP contribution of roughly 26–30% (Epaphra & Mwakalasya, 2017), the industry is extremely sensitive to the effects of climate change (Mafie, 2022). Since most farming is rain-fed, crop yields, food security, and rural livelihoods are directly threatened by altered rainfall patterns, protracted droughts, and extreme weather events (Mafie, 2022). The production of important export products, including coffee, cotton, tobacco, cashew nuts, and cloves, which contribute between 30 and 40 percent of the nation's foreign exchange earnings, is similarly impacted by climate change (Epaphra & Mwakalasya, 2017). The agricultural sector is especially vulnerable due to its reliance on natural weather cycles, which presents threats to national development, economic stability, and poverty alleviation (Gwambene *et al.*, 2023). Tanzania's agricultural production and food systems must be protected in the face of climate change by bolstering climate-resilient farming methods, increasing irrigation, and investing in early warning systems and climate-smart agriculture (Komba & Muchapondwa, 2018).

Through adaptive strategies, the agriculture sector has a great deal of potential to improve resilience and mitigate the effects of climate change (Liu *et al.*, 2024). Despite

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being essential to the production of food, the industry contributes significantly to deforestation, which is thought to be the cause of 7–14% of world greenhouse gas emissions, and is also accountable for about 3.7% of global GHG emissions (Filonchyk *et al.*, 2024). However, the industry is extremely vulnerable to the negative effects of climate change, which will especially affect low-income and smallholder farmers who frequently lack the means and ability to adequately respond to climatic shocks (Praveen & Sharma, 2019). Food instability and worldwide poverty are made worse by this susceptibility (Mulugeta, 2023). Therefore, tackling environmental and socioeconomic issues globally requires a dual strategy that reduces agricultural emissions while employing adaptive measures to maintain crop production (Jellason, 2018).

In many places, ecosystems, economic livelihoods, and agricultural output have all suffered as a result of climate change (Praveen & Sharma, 2019). The viability of food production and subsistence methods is seriously threatened by these changes, especially in vulnerable African populations like those in Tanzania (Sieber *et al.*, 2015). To lessen these negative effects, local farmers' ability to adapt to climate unpredictability must be strengthened. This entails putting policies into place that address the root causes of climate change and lessen the vulnerability of crops and subsistence systems to climatic stresses (Bedeke, 2023). Communities' level of adaptation and readiness for climate change is directly related to how vulnerable they are. Smallholder farmers in Sub-Saharan Africa (SSA) account for around 80% of all agricultural activities and represent the backbone of the food systems in the region (Bahri *et al.*, 2021). Even though they have shown remarkable resilience, the speed at which climate change is occurring poses a threat to surpass their present coping mechanisms. These farming systems' susceptibility is further increased by a lack of institutional support, poor market connections, limited financial resources, and limited access to technology (Petersen-Rockney *et al.*, 2021).

The preservation of vital natural resources and the upkeep of important ecosystem services are necessary to guarantee food security while tackling the problems caused by climate change (Telo da Gama, 2023). It is imperative that we move toward more sustainable farming methods, methods that encourage the efficient use of resources while also increasing productivity. By making this change, agricultural outputs become more stable, yield variations are reduced, and resilience to environmental hazards, shocks, and persistent climate variability is strengthened. One of the most effective frameworks for accomplishing these objectives is Climate-Smart Agriculture (CSA) (Karri & Nalluri, 2024). By concurrently increasing output, improving adaptive capacity, and reducing greenhouse gas emissions that fuel climate change, it provides a "triple win" (Islam, 2024; Guillen-Hanson *et al.*, 2018).

Climate-Smart Agriculture (CSA) is a progressive agricultural approach that aims to maximise benefits while minimising trade-offs by considering the unique social, economic, and environmental conditions of each application context. It is intended to improve subsistence farming and food security, with a focus on supporting smallholder farmers (Amejo *et al.*, 2018). Its effectiveness can be greatly increased through the adoption of appropriate technologies and practices across the agricultural value chain—including production, processing, and market access—as well as the sustainable management of natural resources. According to Rodríguez-Barillas *et al.* (2024), farmers' willingness to adopt CSA practices is influenced by their perception of climate-related risks, and it is generally the case that those who perceive greater climatic threats are more likely to implement CSA measures. A variety of factors, such as socio-economic status, geographic and environmental conditions, institutional support, and farm-level characteristics, influence the choice of specific CSA strategies (Thottadi & Singh, 2024).

Smallholder farmers are the primary drivers of the agricultural industry in Zanzibar Island's Central District, making significant contributions to both local food security and economic stability. Despite playing a crucial role, little empirical research has been done on how farmers view climate variability and change, two aspects that have a significant impact on the adoption of Climate-Smart Agriculture (CSA) techniques for resilience and adaptation. This knowledge gap makes it more difficult to develop evidence-based policies, make calculated investments, and carry out locally customised interventions that would increase the farming community's capacity for adaptation. In light of this, the purpose of this study is to methodically investigate farmers' awareness, attitudes, and reactions to stresses associated with climate change in the Central District. It is anticipated that the results would produce empirical insights that will help establish institutional policies, improve extension services, and pinpoint scalable CSA approaches appropriate for Zanzibar's agro-ecological circumstances and similar settings.

MATERIALS AND METHODS

Study Area

The Central District (Wilaya ya Kati) is one of six districts on Unguja Island in the United Republic of Tanzania's Zanzibar Archipelago (Figure 1). Approximately between latitudes 6°13' and 6°25' South and longitudes 39°20' and 39°35' East, the district is situated in the central-eastern region of Unguja Island. It shares boundaries with the West District to the west, South District to the south, the North A District to the north, and the Indian Ocean to the east. The district comprises several shehias (wards) that serve as units for administrative, developmental, and statistical purposes. The district experiences a tropical climate characterized by two rainy seasons: the long rains (Masika) from March to May and the short rains (Vuli) from October to December. Mean annual rainfall ranges between 1,000 mm and 1,600 mm, with average temperatures hovering between 24°C and 32°C throughout the year (RGoZ, 2013). However, recent years have witnessed a noticeable increase in climate variability and extreme weather events, including irregular rainfall patterns, prolonged dry spells, and occasional flash floods (URT, 2022). The majority of the population in the Central District depends on subsistence agriculture as their primary livelihood. Rice, bananas, sweet potatoes, cassava, and spices like black pepper, cinnamon, and cloves are examples of common crops (URT, 2022). These farming systems are extremely susceptible to drought and unpredictable rainfall because they are mostly rain-fed and have little irrigation infrastructure. Petty trading, small-scale fishing, and subsistence animal rearing are ways that smallholder farmers augment their incomes. Ecologically vulnerable regions, including as portions of the Jozani-Chwaka Bay National Park, which is home to Zanzibar's only surviving natural forest, are also located in the Central District. In addition to having large mangrove forests and wetlands that help store carbon, protect the shoreline, and conserve biodiversity, this region is home to a variety of endemic and endangered species, such as the Zanzibar red colobus monkey (Piliocolobus kirkii) (RGoZ, 2014).

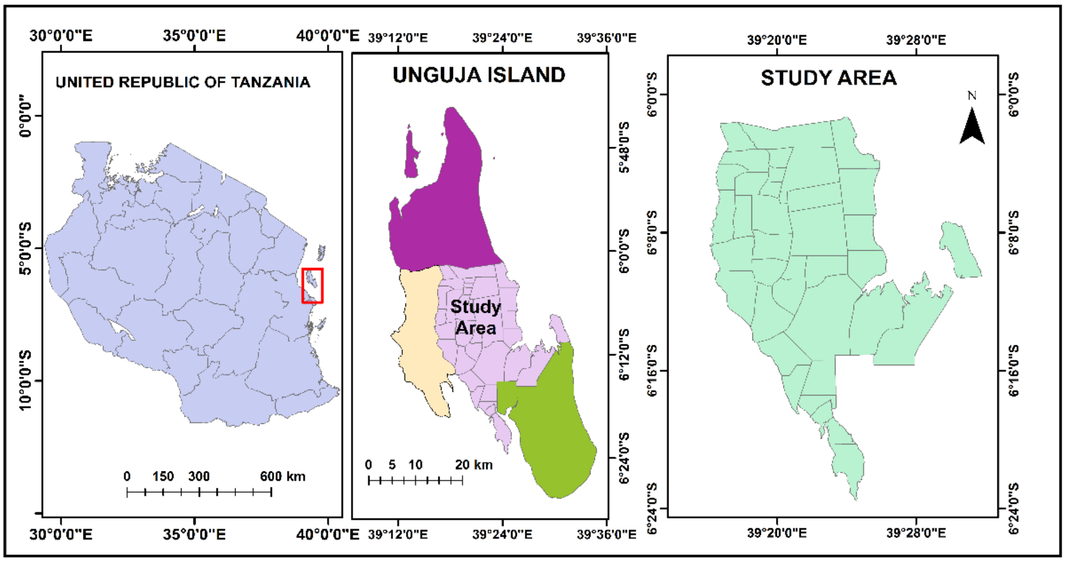

Figure 1: Study area

Sampling Techniques and Data Collection

To guarantee a representative selection of the target household population throughout the study area, a stratified multi-stage random sampling approach was used. A structured questionnaire that was rigorously pre-tested to evaluate its validity, reliability, and internal consistency served as the main tool for gathering data. To make it easier to gather both quantitative and qualitative data, the questionnaire included both open-ended and dichotomous items. Prior to the primary data collection effort, a pre-testing phase was carried out on a pilot group of farmers in the study location in order to find and address ambiguities and improve contextual relevance. Three focus group discussions (FGDs) were arranged in easily accessible locations inside each chosen ward in order to supplement the survey data and improve triangulation. Eleven people participated in each FGD. Key community stakeholders that were chosen for the FGDs based on their familiarity with locality agricultural practices and institutional dynamics included religious leaders, village elders, and members from women's and youth associations.

Semi-structured key informant interviews (KIIs) were carried out with 32 employees from pertinent governmental and non-governmental organisations in order to gather institutional viewpoints and enhance comprehension of adaptive techniques advocated to assist local farmers. These included academicians from Zanzibar's higher education institutions as well as representatives from the Tanzania Meteorological Authority, the Ministry of Agriculture, and the Zanzibar Agriculture Research Institute. Using Cochran's sample size determination formula (Heinisch & Cochran, 1965), 396 households were selected from five villages in the central district (Chwaka, Binguni, Fuoni, Mwera, and Bambi). This allowed for proportionate distribution among the three wards in accordance with population distribution data. In order to optimise data timeliness and relevance, the research's empirical phase was conducted over two months, from February to March 2025, which corresponded with the main agricultural season.

Data Analysis

IBM SPSS Statistics software (version 23), which is well known for its resilience when working with social science datasets, was used to do quantitative data analysis (Bala, 2016). The main variables of interest were summed up using descriptive statistical methods, such as frequencies, percentages, means, and standard deviations. These included the respondents' socioeconomic characteristics (e.g., age, household size, income sources, and education level), institutional factors (e.g., membership in agricultural cooperatives or access to extension services), farmers' perspectives on climate change and variability, and the particular climate-smart agriculture (CSA) practices implemented. A logistic regression model was used to investigate the underlying elements impacting farmers' views of climate change. The likelihood that a farmer would perceive climate change in general, an increase in temperature, or a decrease in rainfall—each represented as a separate dependent (dummy) variable—was estimated using this model, which is appropriate for analysing binary (yes/no) outcomes (Song *et al.*, 2021). A variety of demographic, social, and institutional elements that were thought to influence people's perceptions were included as independent variables in the model.

To find out how farmers who used CSA techniques differed from those who did not, comparative analyses were conducted. For these comparisons, a number of inferential statistical tests were used. While the chi-square (χ^2) test evaluated relationships between categorical variables, the analysis of variance (ANOVA) and the F-test were utilised to compare means across groups. Mean comparison tests shed more light on the factors that influence CSA adoption by elucidating statistically significant variations in important variables between adopter and non-adopter groups. The Cronbach's alpha test, a statistical indicator of internal consistency, was used to evaluate the questionnaire's reliability. The questionnaire items showed adequate internal coherence and were probably assessing the intended constructs reliably across the sample, as evidenced by the Cronbach's alpha value of 0.730, which is higher than the generally accepted threshold of 0.70.

Ethical Considerations

Ensuring that every participant understood the goal and nature of the study was crucial before starting the data gathering procedure. In order to do this, each respondent gave their informed consent. This required giving thorough and understandable explanations of the study's goals, the kinds of data that would be gathered, and the intended uses of the data. Respondents were given the opportunity to ask questions and were guaranteed the freedom to choose to participate in the study at any time without facing any repercussions. The study's participants' rights to confidentiality and privacy were protected throughout the consent process, which was conducted in accordance with ethical research norms. The data was collected only after their express agreement was obtained.

RESULTS AND DISCUSSION

Results

Socioeconomic and Demographic Profiles of Smallholder Farmers

According to the demographic profile of the populations of Chwaka, Binguni, Fuoni, Mwera, and Bambi, the majority of the population is Muslim, with percentages averaging 98.8% and ranging from 97.3% in Mwera to 100% in Binguni (Table 1). In comparison, the percentage of Christians is rather low, averaging around 1.2%. The proportion of genders is fairly balanced, with 50.7% of the population being female and 49.3% being male. A population of seasoned farmers is shown by the age distribution, with the largest percentage of people in the 50–59 age range (average 54.2%) and a significant presence in the 40–49 age range (30.8%). Although still present, the 60+ age group makes up only 15% of the population, with Bambi having the lowest number (5.8%). Data on marital status reveals a low divorce rate (4.5%) and a moderate percentage of widowed people (4.8%), together with high marriage rates (90.7% on average).

Additionally, research shows that only 3.6% of people have finished higher education, indicating inadequate access to university education. With an average of 54.0%, secondary education is more prevalent, especially in Binguni (70.5%). With an average of 42.4%, primary education is the most common educational level, with Chwaka having the largest percentage (56.4%). According to household size data, the majority of households (59.6% on average) are between six and ten people, with Chwaka having the largest households (70.3%). With an average of 25.5%, households with one to five people are less prevalent than those with ten or more people, which make up 15% of the population. These results imply that the population is made up of a well-established group of seasoned farmers who have larger families and comparatively little formal education beyond secondary school.

Table 1: Socioeconomic and demographic variables of participants in the study areas

Variable	Sub-Category	Chwaka (%)	Binguni (%)	Fuoni (%)	Mwera (%)	Bambi (%)	Average (%)
Religion	Muslims	99.1	100	99.6	97.3	98.2	98.8
	Christians	0.9	0	0.4	2.7	1.8	1.2
Gender	Male	48.4	49.8	47.5	46.7	54.2	49.3
	Female	51.6	50.2	52.5	53.3	45.8	50.7
Age	40–49	22.3	34.5	33.2	38.4	25.5	30.8
	50–59	56.3	50.6	52.2	43.2	68.7	54.2
	60+	21.4	14.9	14.6	18.4	5.8	15.0
Marital Status	Married	90.2	83.5	94.3	92.4	93.3	90.7
	Widowed	8.2	5.4	1.1	4.2	5.1	4.8
	Divorced	1.6	11.1	4.6	3.4	1.6	4.5

Education Level	Tertiary	3.2	4.3	2.7	1.6	6.3	3.6
	Secondary	40.4	70.5	50.6	48.2	60.3	54.0
	Primary	56.4	25.2	46.7	50.2	33.4	42.4
Household Size	1–5 members	15.3	18.4	25.2	38.3	30.1	25.5
	6–10 members	70.3	68.5	60.2	43.5	55.4	59.6
	10+ members	14.4	13.1	14.6	18.2	14.5	15.0

Agricultural Access and Support Indicators of Smallholder Farmers

The study used Chi-square (χ^2) tests to analyse ten binary (yes/no) indicators in order to investigate spatial differences in farmers' access to basic agricultural services across five communities: Chwaka, Mwera, Fuoni, Bambi, and Binguni. There were notable variations in a number of categories (Table 2). For example, farmers in Fuoni and Mwera reported having access to agricultural advising services at rates of 34.8% and 34.6%, respectively, whereas only 24.1% and 19.7% of farmers in Chwaka and Binguni, respectively, reported having such services. At the 1% level, significance was shown by the comparable χ^2 value of 16.8. The biggest difference was also shown in access to extension officer visits, with only 2.8% of farmers in Chwaka reporting visits, compared to 31.0% in Fuoni and 29.1% in Mwera. This indicator showed a very unequal distribution of public extension services with a χ^2 value of 35.2, which was also significant at the 1% level.

Some services did not exhibit considerable spatial variation and showed consistently low access across all areas. With a non-significant χ^2 value of 4.6, access to agricultural credit or loans was less than 20% in every community, ranging from 11.9% in Binguni to 19.6% in Chwaka. Likewise, there was often little access to irrigation or dependable water sources; Fuoni reported the highest percentage at 32.5%, while Chwaka reported the lowest at 12.7% (χ^2 = 5.8). Even fewer farmers in Chwaka and Mwera received early warning systems for weather-related hazards, with just 6.0% and 12.9% of farmers, respectively, receiving such information ($\chi2$ = 2.9). These low numbers and statistically insignificant differences point to systemic impediments that may be caused by institutional flaws and inadequate infrastructure in all locations assessed.

Other services displayed differing levels of importance. A χ^2 value of 7.9, which indicates significance at the 10% level, showed that the percentage of participants in climate-smart agriculture training varied from 29.3% in Bambi to 42.6% in Fuoni. This points to slight regional differences in the reach of climate adaption initiatives. Bambi had a higher percentage of members in farmer cooperatives or groups (35.2%) than Mwera (19.4%) and Chwaka (20.2%). The χ^2 score in this case was 10.5, which is significant at the 5% level and indicates that organisational participation may be influenced by external support or local community engagement. The percentage of Binguni and Fuoni that had access to inputs, including seeds, fertiliser, and tools, varied from 29.6% to 41.0%; however, the χ^2 value of 3.9 showed no discernible spatial variations.

Significant variations in market proximity were noted, despite the fact that overall market access was high, ranging from 70.5% in Binguni to 87.2% in Fuoni (χ^2 = 6.2, not significant). Only 54.0% of farmers in Bambi and 58.2% in Binguni said that marketplaces were within tolerable travel time, compared to nearly 80% of farmers in Chwaka, Mwera, and Fuoni. Significant locational disadvantages were indicated by this indicator's χ^2 value of 22.4, which was significant at the 1% level. For farmers in more remote locations, these geographic restrictions may limit their capacity to participate in markets, weaken their negotiating position, and decrease their profitability.

Table 2: Spatial Distribution of Farmer Access to Agricultural Services in the study areas

Farmer Access Indicators (yes/no questions)	**Responses across wards (%)**										**χ^2 - Value**
	Chwaka		**Mwera**		**Fuoni**		**Bambi**		**Binguni**		
	Yes	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	
Access to advisory services	24.1	75.9	34.6	65.4	34.8	65.2	21.7	78.3	19.7	80.3	16.8
Extension officer visit	2.8	97.2	29.1	70.9	31.0	69.0	25.9	74.1	18.4	81.6	35.2
Access to credit/loans	19.6	80.4	17.5	82.5	16.4	83.6	13.1	86.9	11.9	88.1	4.6
Climate-smart training/info	36.9	63.1	34.7	65.3	42.6	57.4	29.3	70.7	30.3	69.7	7.9
Market accessibility	78.5	21.5	81.0	19.0	87.2	12.8	71.6	28.4	70.5	29.5	6.2
Proximity to market	81.3	18.7	84.3	15.7	83.7	16.3	54.0	46.0	58.2	41.8	22.4
Access to irrigation/water	12.7	87.3	27.8	72.2	32.5	67.5	23.6	76.4	26.1	73.9	5.8
Membership in a farmer group	20.2	79.8	19.4	80.6	21.6	78.4	35.2	64.8	21.8	78.2	10.5
Access to inputs	34.6	65.4	38.2	61.8	41.0	59.0	31.8	68.2	29.6	70.4	3.9
Weather early warning access	6.0	94.0	12.9	87.1	11.4	88.6	9.5	90.5	8.3	91.7	2.9

Note: $\chi^2 \geq 13.28$ → Significant at 1%, $\chi^2 \geq 9.49$ → Significant at 5%, $\chi^2 \geq 7.78$ → Significant at 10%, $\chi^2 < 7.78$ → Not significant

Perceptions of Climate Variability and Change Among Smallholder Farmers

Small-scale farmers from five Zanzibari villages—Chwaka, Mwera, Fuoni, Bambi, and Binguni—perceive climate change indicators and their effects on agricultural practices and productivity, according to the data given (Figure 2). In order to find indications of climatic changes, farmers compared the weather patterns of today to those of 20 to 30 years ago using local indicators that could be observed. Perceived decreases in total rainfall amounts were indicated by a large percentage of respondents in all five wards, with Fuoni (75.6%) and Chwaka (70.4%) expressing the greatest worry. While Bambi (45.2%) and Binguni (52.5%) indicated lesser perceptions, Chwaka (80.1%) and Fuoni (78.4%) reported the most prevalent perceptions of the delayed commencement of the rainy season. Traditional planting calendars are upset by these delays, which frequently result in inconsistencies between crop growth phases and water availability.

Many people also thought that the rainy season ended early and that the amount of rainfall was shorter, particularly in Chwaka (65.5% and 85.9%, respectively) and Fuoni (60.7% and 82.2%). According to these impressions, farmers are having shorter growing seasons, which can impede crop growth and lower yields. One of the most strongly perceived indicators, especially in Binguni (94.2%), Mwera (88.1%), and Bambi (86.8%), was the increased frequency of dry periods during the wet season. Since sporadic dry spells harm crops and reduce soil moisture, this unpredictable intra-seasonal rainfall variability probably presents one of the biggest obstacles to maintaining consistent agricultural production. More than half of respondents reported more intense rainfall episodes in most wards, with Mwera (65.0%) reporting the greatest, despite a comparatively lesser percentage perceiving such incidents. This points to a trend towards more intense and erratic precipitation, which can exacerbate soil erosion and flooding. At the same period, farmers noticed higher average daytime and nighttime temperatures, especially in Chwaka (85.2% and 78.4%) and Fuoni (88.3% and 80.2%).

Farmers have observed an increase in the frequency of floods and droughts, which reflects the dual nature of climate extremes: both excess and scarcity of water are becoming more prevalent. Mwera (72.4%) and Fuoni (75.0%) showed the most evidence of this. The biggest percentage of respondents expressed significant concern about the perceived changes in planting and harvesting dates brought on by weather variability in Binguni (62.0% planting; 49.1% harvesting). Although the degree of adaptation may be constrained by information or resource availability, these developments show that farmers are modifying their agronomic calendars in response to changing meteorological conditions. Changes in climate patterns were blamed by respondents for lower crop yields, particularly in Chwaka (72.6%) and Fuoni (70.7%). Food security is at risk due to the combined effects of the previously stated climatic indicators, which work together to produce unfavourable growth conditions.

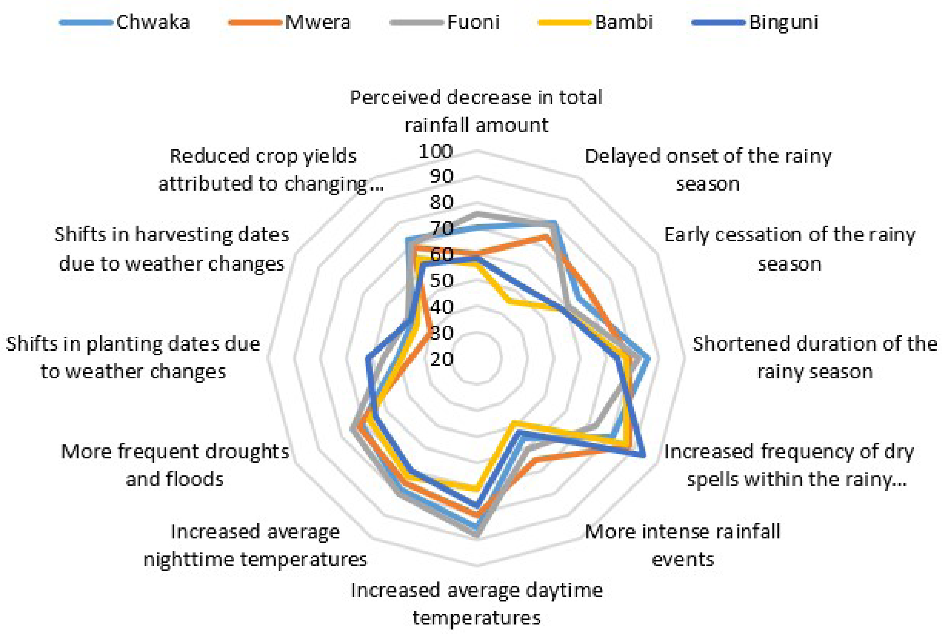

Figure 2: Smallholder farmers' perceptions of climate variability in agriculture

Determinants Shaping Smallholder Farmers' Perceptions of Climate Variability and Change

Important information about the variables affecting smallholder farmers' views of climate variability and change in Zanzibar is revealed by the regression analysis. The results show that farmers' awareness and interpretation of climatic dynamics are significantly shaped by a variety of sociodemographic, institutional, informational, and cognitive factors (Table 3). The findings indicate that education level is a significant driver of whether or not people perceive that the climate has changed. Higher educated farmers were substantially more likely to believe that climate change is happening (Odds Ratio = 1.82, 95% CI: [1.10, 3.01]). Furthermore, this perception was positively impacted by years of farming experience (OR = 1.07), indicating that farmers who have been involved in agricultural operations for a longer period of time are better able to detect subtle changes in the climate. Institutional backing is also very important. Climate change was more likely to be reported by farmers who had access to extension services (OR = 2.13), received climate information (OR = 3.45), or participated in climate-related workshops (OR = 2.50). Furthermore, the likelihood of recognising climate change was considerably raised by dependence on traditional knowledge systems (OR = 2.01), membership in farmer cooperatives (OR = 1.90), and strong trust in the accuracy of climatic information (OR = 1.85).

Education continues to be a major influence in perceptions of decreased rainfall (OR = 1.76), demonstrating the ongoing significance of formal education in understanding climate change. This view was also impacted by farm size (OR = 1.58), indicating that farmers overseeing larger plots might be more aware of and subject to variations in rainfall. Significantly, there was a negative correlation (OR = 0.52) between livelihood diversification and rainfall, suggesting that farmers who have several sources of income may be less reliant on rain-fed agriculture and, thus, less sensitive to variations in rainfall. Perceiving a decrease in rainfall was also strongly influenced by information-related factors, including participation in workshops (OR = 2.12), access to extension services (OR = 1.92), and availability of climatic information (OR = 2.98). Furthermore, radio transmission of climate information (OR = 1.81) was found to be a significant influence, highlighting the role of mass media in raising awareness in rural areas.

Education (OR = 1.50) and agricultural experience (OR = 1.09) were also significant when it came to experiencing extreme weather occurrences, supporting the idea that knowledgeable and experienced farmers are more likely to identify and report climatic impacts. Cooperative-affiliated farmers were also more likely to report these experiences (OR = 2.01), possibly as a result of peer conversations and shared learning. Direct exposure to organised information significantly improves farmers' capacity to identify and describe extreme weather events, as evidenced by the highest impacts of access to climate information (OR = 3.71) and workshop participation (OR = 2.88). Additionally, farmers were more likely to report experiencing extreme weather if they had high trust in government climate actions (OR = 1.88), and if they trusted the accuracy of climate information (OR = 2.06), indicating that trust in institutions reinforces the perceived relevance of climate events.

Table 3: Logistic Regression of Factors Influencing Smallholder Farmers' Perceptions of Climate Change

Variables	**(1) Climate has changed**		**(2) Rainfall decreased**		**(3) Experience with extreme weather events**	
	Odds Ratio	**95% CI**	**Odds Ratio**	**95% CI**	**Odds Ratio**	**95% CI**
Age of farmer (proxy for long-term observation)	1.04	[0.98, 1.11]	1.02	[0.95, 1.10]	1.01	[0.95, 1.09]
Education level (primary, secondary, tertiary)	1.82*	[1.10, 3.01]	1.76*	[1.02, 3.03]	1.50*	[1.01, 2.45]
Years of farming experience	1.07*	[1.01, 1.14]	1.03	[0.97, 1.10]	1.09	[1.02, 1.17]
Farm size (acres, log transformed)	1.2	[0.82, 1.77]	1.58*	[1.05, 2.39]	1.44	[0.91, 2.27]
Household size	0.91	[0.71, 1.18]	1	[0.78, 1.30]	0.95	[0.75, 1.21]
Livelihood diversification (1 = yes)	0.68	[0.36, 1.29]	0.52*	[0.28, 0.97]	0.6	[0.31, 1.17]
Member of farmer cooperative (1 = yes)	1.90*	[1.01, 3.58]	1.45	[0.78, 2.67]	2.01*	[1.02, 3.95]
Access to extension services (1 = yes)	2.13*	[1.15, 3.94]	1.92*	[1.00, 3.66]	1.88	[0.97, 3.65]
Access to climate information (1 = yes)	3.45*	[1.92, 6.20]	2.98*	[1.68, 5.30]	3.71*	[2.02, 6.80]
Source of information: Radio (1 = yes)	1.66	[0.89, 3.11]	1.81*	[1.02, 3.20]	1.73	[0.93, 3.24]
Attended climate/environment workshops (1 = yes)	2.50*	[1.40, 4.46]	2.12*	[1.18, 3.83]	2.88*	[1.52, 5.46]
Perceived reliability of climate info (1 = high trust)	1.85*	[1.08, 3.18]	1.44	[0.81, 2.56]	2.06*	[1.15, 3.70]
Trust in government climate action (1 = high)	1.42	[0.76, 2.67]	0.95	[0.50, 1.79]	1.88*	[1.01, 3.50]
Trust in local/traditional knowledge (1 = high)	2.01*	[1.10, 3.68]	1.28	[0.70, 2.35]	1.91	[0.98, 3.73]
Religious/cultural beliefs about nature (1 = yes)	0.72	[0.40, 1.28]	0.84	[0.48, 1.50]	0.69	[0.36, 1.31]
Number of observations	396		396		396	

*Remarks: *significant at the 5% level, significant at the 10% level, and ***significant at the 1% level. The reference category for education is secondary education; for livelihood diversification, it is non-diversified; for cooperative membership, it is non-member; for extension services, it is not available; for climate information, it is not available; for information sources, it is not radio; for workshops, it is not present; for trust variables, it is low; and for religious/cultural beliefs, it is not. Dependent variables are dummy variables that measure how people perceive climate change: (1) an overall shift in the climate, (2) a decrease in rainfall, and (3) exposure to extreme weather occurrences. The 95% Confidence Intervals (CI) for the odds ratios are provided in parenthesis. 396 observations were made.*

Smallholder Engagement with Climate-Smart Agriculture Practices

Improving farmers' ability to adapt is still essential to mitigating the negative consequences of climate change and variability. Smallholder farmers' adoption of climate-smart agricultural (CSA) techniques, which seek to increase resilience and stabilise yields, is heavily influenced by their perceptions of climate-related shifts (Figure 3). There is ample evidence that changing climatic circumstances are having an effect on agricultural production, since many farmers in the research reported decreasing crop yields. In particular, 82.1% of those surveyed reported fewer food crops were collected in the previous seasons. Only a small percentage of farmers are unaffected or have successfully adapted, as estimated by 10.4% of farmers who reported higher yields and 7.5% who saw no discernible change. More than half of the respondents (53.8%) described their losses as moderately severe, indicating consistent but not catastrophic disruptions in food production. The quantity of losses further supports this tendency. In the meantime, 30.6% of farmers suffered extremely severe crop losses, indicating that a sizable portion of the farming population is highly vulnerable. Relatively few households have been able to protect themselves from climatic stressors, since only 15.6% of them categorised their losses as not severe.

Focus Group Discussion (FGD) participants stated that tackling the effects of climate change and variability on agriculture requires enhancing farmers' capacity for adaptation. About 81.3% of respondents reported that they had harvested fewer food crops in the most recent seasons, which they attributed to unpredictable weather and protracted dry spells. Just 9.4% of responders said their yields had improved, while 9.2% said their harvests had not changed much. 52.7% of individuals classified their crop losses as somewhat serious when asked how terrible they were, indicating common but manageable difficulties. Another 31.6% said their losses were very bad, which frequently led to almost complete crop failures. However, just 16.9% of participants said their losses were little or no severe, indicating that only a tiny percentage of farming households had successfully adjusted to or were less impacted by the difficulties associated with climate change.

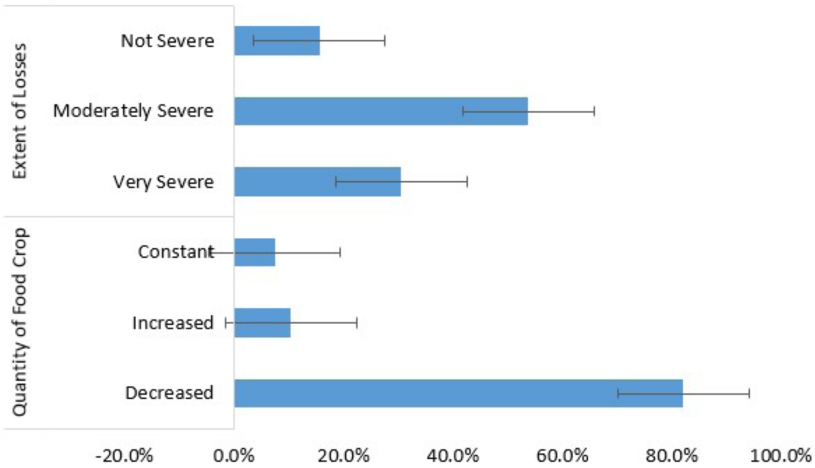

Figure 3: Perceived extent of food crop losses and changes in crop quantity

The evaluation of Zanzibari farmers' adoption of Climate Smart Agriculture (CSA) shows a wide range in the use of these practices, indicating both positive advancements and enduring challenges in the transition to sustainable, climate-resilient agriculture (Table 4). While certain CSA programs have seen significant adoption among the farming community, others are still underutilised. For example, just 16.3% of respondents reported crop diversity, a crucial tactic for protecting against climate-related shocks. This suggests that monoculture systems, which increase vulnerability to droughts, pests, and other climatic stresses, are still preferred. Similarly, just 20.9% of farmers changed their planting schedules, and 22.4% used crop rotation or mixed crops, even though these strategies have been shown to be cost-effective in increasing resilience to climatic variability. On the other hand, some practices have become increasingly popular. 35.7% of farmers had adopted improved crop varieties, and 31.1% of farmers reported applying organic manure, indicating growing knowledge of the benefits of these crop varieties for climate adaptation and productivity.

Additionally, a number of other practices showed a moderate level of adoption: 43.9% of respondents practiced soil conservation techniques, such as mulching and terracing, indicating a growing appreciation for managing soil health; 48.0% of farmers had diversified their livelihoods, such as by farming seaweed; 41.6% reported using climate and weather data to inform farming decisions; and 56.9% of respondents adopted agroforestry, which involves integrating trees into agricultural systems, indicating a moderate level of uptake of sustainable land-use practices. A number of CSA tactics showed comparatively high adoption rates. 51.0% of the farmers reported better livestock management, which included using better breeds and zero-grazing methods. Perhaps in reaction to diminishing yields and changing climate conditions, a significant percentage (63.8%) had increased the area of their farmed land.

The notably high acceptance rate of 75.0% for Integrated Pest Management (IPM) could be attributed to either reliance on traditional ecological knowledge or competent extension services. With 81.6% of farmers using irrigation or rainwater harvesting techniques, water-related solutions were particularly prevalent, highlighting the critical role that water management plays in climate adaptation.

A sizable majority (88.8%) stated that they had reduced the amount of land under cultivation, which could be attributed to changing land use patterns, salinisation, or soil degradation. However, this finding might also be a reflection of more general adaptive strategies. The transition of 29.4% of farmers from crop to livestock farming was one CSA practice with varying adoption rates. A lack of infrastructure to support livestock-based systems, restricted access to essential inputs, or sociocultural norms could all have an impact on this comparatively low rate.

According to key informants (KI), smallholder farmers in Zanzibar have different views on Climate Smart Agriculture methods. Of the farmers who responded to the survey, 14.2% believe that crop diversification is the most important strategy, followed by 11.7% who value adjusting planting timings to deal with unpredictable rains, 10.3% who prioritize crop rotation and mixed cropping to increase soil productivity, 9.6% who believe that using manure is essential, 8.4% who believe that using improved crop varieties is essential, and 7.9% who emphasize the importance of soil protection techniques. Among adaptation strategies, 3.2% of KI perceive less land under cultivation, whereas only 4.3% report more; 4.8% of KI perceive integrated pest management to be practiced in the district; 5.6% believe irrigation and water harvesting to be practiced in the district; 3.6% believe farmers have switched from crop cultivation to livestock farming; 1.0% believe farmers actively use climate and weather data to inform their decisions; and 2.8% value agroforestry approaches. Diversification of livelihoods accounts for 6.5% of KI, while 6.1% consider improving animal raising as a crucial adaptation.

Table 4: Climate Smart Agriculture Practices among smallholder farmers in Zanzibar

CSA Practice	% Practicing	% Not Practicing
Crop Diversification	16.3%	83.7%
Change of Planting Time	20.9%	79.1%
Crop Rotation and Mixed Cropping	22.4%	77.6%
Use of Manure	68.9%	31.1%
Change of Crop Varieties	64.3%	35.7%
Soil Conservation Measures	43.9%	56.1%
Livelihood Diversification	48.0%	52.0%
Enhancing Animal Rearing Practices	51.0%	49.0%
Increase in Land under Cultivation	63.8%	36.2%
Use of Integrated Pest Management (IPM)	75.0%	25.0%
Irrigation/Water Harvesting	81.6%	18.4%
Reduction in Land under Cultivation (as adaptation)	88.8%	11.2%
Switch from Crop Farming to Livestock	29.4%	70.6%
Agroforestry (e.g., planting trees with crops)	56.9%	43.1%
Use of Weather and Climate Information	41.6%	58.4%

Discussion

Socioeconomic and Demographic Profiles of Small-Scale Farmers

The Central District of Zanzibar's smallholding farmers' ability to adjust to Climate Smart Agriculture (CSA) is significantly influenced by the demographics of the communities in Chwaka, Binguni, Fuoni, Mwera, and Bambi. The majority of the population is Muslim, and Islam is represented almost everywhere in the region. This represents a strong cultural and theological framework that may have an impact on sustainable agriculture practices and attitudes. Cultural norms, particularly religious beliefs, have a substantial impact on how communities adapt to climate change (Murphy *et al.*, 2016). In this situation, the common religious identity may encourage group efforts and community-based projects to apply CSA techniques, which frequently depend on ecological knowledge and social cohesiveness (Guragain, 2024). An ageing farming population that may possess a lot of traditional knowledge but may find it difficult to accept modern technology is indicated by the age distribution of farmers, with a significant part (average of 54.2%) in the 50–59 age range. In contrast to younger generations, older farmers are generally less willing to adopt innovations and more risk-averse (Dadzie *et al.*, 2022). This is especially true for CSA operations, which frequently call for farmers to implement cutting-edge methods like new pest control techniques or crop varieties that are climate resilient. However, research by Wang *et al.* (2024) emphasises the importance of intergenerational knowledge transfer in fostering adaptive capacity, so involving both older and younger farmers in

CSA programs may increase the effectiveness of these initiatives (Zakaria *et al.*, 2020). The presence of younger farmers in the 40–49 age group (averaging 30.8%) could be viewed as an opportunity to bridge the generational gap.

Although education is essential for adopting sustainable agricultural practices because it gives farmers the skills and knowledge to implement creative solutions, the relatively low level of formal education, 3.6% with tertiary education and 54% with secondary education, presents both a challenge and an opportunity for CSA adaptation. However, the limited access to higher education may make it more difficult for farmers to engage with more technical CSA practices, like precision agriculture or climate modelling (Sisay *et al.*, 2023). However, Gemtou *et al.* (2024), who stress the need for accessible, context-specific educational interventions in rural farming communities, suggest that secondary education, which is more common in areas like Binguni (70.5%), provides a basis on which training programs could be constructed. With an average of 6–10 people (59.6%), the large household sizes have a big impact on the adoption of CSA practices. The labor needed to execute labor-intensive activities, such managing soil fertility or conserving water, can be supplied by larger households (Mosissa, 2019).

However, the availability of resources, including capital and land, must be weighed against the labor supply. The economic sustainability of CSA can also be impacted by household size, especially if resources are distributed among several family members, according to Muriithi *et al.* (2023). Large households may therefore have the workforce to implement CSA, but they may also be limited in their ability to invest in CSA technologies without outside assistance due to land and financial constraints.

Agricultural Access and Support Indicators of Smallholder F.armers

Significant differences were found when the spatial variations in farmers' access to agricultural services among the five communities (Chwaka, Mwera, Fuoni, Bambi, and Binguni) were analyzed. These differences were especially evident in services pertaining to agricultural advice and visits from extension officers. For example, Chwaka had significantly lower outreach from extension officers (2.8%) than Fuoni (31.0%) and Mwera (29.1%), a difference that was corroborated by statistically significant Chi-square values. These tendencies are consistent with more general patterns seen throughout sub-Saharan Africa, where regions with better institutional capacities and infrastructure are typically given preference when it comes to the distribution of extension services. Similar results were observed by Madan and Maredia (2021), who emphasized that administrative and logistical limitations frequently contribute to the unequal distribution of extension staff. According to Imran *et al.* (2024), extension programs are often restricted to more accessible locations due to a lack of funding and human resources, underserving outlying communities.

On the other hand, there were no appreciable statistical disparities in the accessibility of services like early warning systems, irrigation infrastructure, and agricultural financing across all study areas. For example, credit access was still less than 20% in all communities, highlighting a pervasive issue that is not region-specific. These consistently low access levels most likely indicate flaws in the system. According to Fanadzo and Ncube (2018), these limitations are caused by structural problems, such as weak rural banking institutions and a lack of funding for irrigation and other agricultural infrastructure. Early warning systems' restricted reach is also a reflection of a larger lack of climate communication networks, which is becoming a more pressing problem for adaptive responses to climate variability (Islam *et al.*, 2025).

There were moderate spatial disparities in a few agricultural services. Climate-smart agriculture (CSA) training participation was statistically significant at the 10% level and varied from 29.3% in Bambi to 42.6% in Fuoni. Similarly, there was a wide range in farmer cooperative membership, with a high of 35.2% in Bambi and a low of 20.2% in Chwaka. These results are in line with those of Bullock *et al.* (2020), who pointed out that locations where non-governmental organizations or development agencies are actively involved tend to have higher levels of participation in CSA projects and farmer groups. Additionally, Hartmann *et al.* (2023) contend that institutional networks and local social capital have a major impact on program participation.

Although there was a reasonably modest amount of availability to basic inputs including seeds, fertilizer, and equipment (between 29.6% and 41.0%), the spatial disparities were not statistically significant, suggesting a more equal distribution or shared difficulties throughout groups. Nonetheless, there were notable and statistically significant differences in the physical closeness to marketplaces ($\chi^2 = 22.4$). In contrast to more over 80% in Chwaka, Mwera, and Fuoni, farmers in Bambi (54.0%) and Binguni (58.2%) reported having limited access to local markets. Farmers' capacity to sell produce effectively and profitably is impacted by this regional difference in market proximity, which makes it crucial. According to Ma *et al.* (2024), remote farmers frequently face major disadvantages because of the substantial impact that distance to markets has on transaction costs, market participation, and income potential.

Overall, this study's conclusions about spatial dynamics are consistent with those found in other African contexts, including Ghana and Nigeria. Agricultural services frequently concentrate in more economically established or politically linked locations, marginalizing periphery populations, according to studies by Rotz *et al.* (2024) and Thomas *et al.* (2019). These findings imply that spatially sophisticated policy actions are necessary. In order to address locational inequities, particular investments and customized service delivery plans that take into account each community's unique institutional and infrastructure constraints are needed.

Smallholder Farmers' Observations of Climatic Shifts and Variability

In terms of smallholder farmers' reactions to climate change, the research findings from the five Zanzibari villages—Chwaka, Mwera, Fuoni, Bambi, and Binguni—reflect an expanding corpus of empirical and perception-based studies carried out throughout sub-Saharan Africa. According to studies conducted in rural Ethiopia, Kenya, Tanzania, and Ghana, farmers use decades of accumulated ecological memory to assess long-term changes in weather patterns. This approach is consistent with the use of local climatic indicators and experiential knowledge (Gezie, 2019; Vaughan *et al.*, 2019; Gebremariyam, 2021). The apparent drop in overall rainfall in Zanzibar, especially in Fuoni and Chwaka, is consistent with a study conducted in Tanzania by Makame & Shackleton (2021), which discovered a correlation between decreased maize yields in semi-arid and sub-humid regions and decreasing rainfall trends. According to similar findings, traditional agricultural cycles in Malawi and Uganda have been significantly interrupted by decreased rainfall (Lunyolo *et al.*, 2021; Amare *et al.*, 2023). These views, which emphasize the extensive effects of changing rainfall regimes, are corroborated by climatological data as well as farmer testimony in several African contexts (Sinore & Wang, 2025).

Widely held beliefs in Chwaka and Fuoni regarding the rainy season's delayed start and early end are consistent with research conducted in Ethiopia by Alemu & Dioha (2020), which found that uncertain rainfall onset shortened growing seasons and raised farming hazards. Similar experiences were documented by farmers in Senegal and Nigeria, who reported more unpredictable rainfall initiation and termination, which resulted in crop failure and decreased food supply (Onwutuebe, 2019). Compressed growing seasons are the result of these changes along with shorter rainfall durations, which are particularly noticeable in Chwaka and Fuoni. This significantly limits farmers' capacity to control planting schedules and leads to subpar crop performance, as Zhang & Swaminathan (2020) point out.

Another important signal that has been frequently noted in research throughout East Africa is the increased frequency of dry spells during rainy seasons, which are most strongly recorded in Binguni and Mwera. Onwutuebe (2019) asserts that intra-seasonal dry spells, especially in maize-based systems, might result in complete crop loss, especially during crucial phases of crop development (such as blooming). Chronic food insecurity is exacerbated by longer and more unpredictable dry spells, according to farmers in Malawi and Zimbabwe (Chimimba *et al.*, 2023). Their prevalence, particularly in Mwera (65.0%), indicates knowledge of the growing frequency of extreme weather occurrences, a trend supported by multiple climate model projections, even though fewer respondents reported experiencing more heavy rainfall episodes. Studies conducted in Kenya and Rwanda, for instance, have shown an increase in periods of heavy precipitation that cause flash floods, topsoil erosion, and infrastructure devastation (Lydie, 2022). These alterations reveal a twofold vulnerability in which farmers must deal with unexpected surpluses as well as water constraints, making management choices more difficult.

Perceptions from respondents provide ample evidence of the observed increase in average daytime and nighttime temperatures, particularly in Fuoni and Chwaka. Rising temperatures in East and Southern Africa were identified by Bakala *et al.* (2024) and Ayal (2021) as one of the most frequently mentioned climatic stressors, especially for heat-sensitive crops like maize and beans. A larger tendency of climate extremes noted in assessments by Allan *et al.* (2023) is reflected in the increased frequency of droughts and floods, which are especially noticeable in Fuoni and Mwera. According to studies conducted in Madagascar and Mozambique, the same communities are quickly suffering from both flood-related devastation and drought-induced crop failures, which weakens their ability to bounce back and recover (Holleman *et al.*, 2020). Farmers in Ghana and Burkina Faso report modifying crop calendars in response to local weather signals, which is consistent with moderate levels of perception in Zanzibar regarding changes in planting and harvesting dates (Yang *et al.*, 2019). But much like in Zanzibar, a lot of farmers do not have access to trustworthy seasonal forecasts, technologies, or extension services, which limits their ability to make the best agronomic choices (Salum *et al.*, 2021). According to modeled forecasts, agricultural yields in East Africa are predicted to decrease by 10–20% by 2050 under current warming trajectories. This decrease is especially evident in Chwaka and Fuoni. (Guido *et al.*, 2020).

Factors Influencing Smallholder Farmers' Understanding of Climate Variability and Change

Complex connections between sociodemographic, institutional, and cognitive elements and smallholder farmers' perspectives on climate change in Zanzibar are revealed by the regression analysis. Education level was found to be a significant predictor of perceptions of climate change (OR = 1.82, CI: [1.10, 3.01]), supporting findings from research in Nigeria (Azeez *et al.*, 2024) and Kenya (Yvonne *et al.*, 2020), where a higher level of education increased awareness of long-term climate changes. Evidence from Moutouama *et al.* (2022) in Africa, who contend that farmers acquire "environmental memory" through years of interacting with their land and weather patterns, was also supported by the finding that farming experience (OR = 1.07) positively influenced perceptions of climate change. The likelihood of noticing climate change was considerably raised by institutional support, which was provided through extension services (OR = 2.13), access to climate information (OR = 3.45), and workshop participation (OR = 2.50). These results are in line with Antwi-Agyei & Stringer (2021) in Ghana, who emphasize that farmers who receive information through organized channels are more likely to perceive and adapt to climate risks; farmers in cooperatives (OR = 1.90) benefited from shared learning, which is in line with findings from Bwalya *et al.* (2023) in Zambia, where collective membership improved knowledge exchange; and farmers who trusted traditional/local knowledge (OR = 2.01) and thought climate information was reliable were more likely to perceive climate change. These findings highlight the dual value of scientific and indigenous knowledge systems, which is in line with Cebrián-Piqueras *et al.* (2020), who stress the complementarity of local and formal knowledge in forming climate perceptions.

Additionally, education (OR = 1.76) and farm size (OR = 1.58) had a significant impact on how people perceived decreasing rainfall. According to research by Abid *et al.* (2019) in Pakistan, larger landholders might be more dependent on and aware of variations in precipitation patterns. Interestingly, there was a negative correlation (OR = 0.52) between livelihood diversification and the perception of a drop in rainfall. This shows that farmers who have other sources of income might be less vulnerable to climate-related agricultural disturbances, as Ricart *et al.* (2025) observed. Perception was again strongly influenced by access to climate information (OR = 2.98), extension services (OR = 1.92), and workshops (OR = 2.12), highlighting the significance of formal information channels. The importance of radio (OR = 1.81) as a medium is consistent with research conducted in Cameroon by Elvis (2024), which emphasized the effectiveness of radio in rural climate communication.

The results of the research demonstrated that farmers' detection of extreme occurrences was significantly influenced by their level of education (OR = 1.50) and agricultural experience (OR = 1.09), confirming that knowledge and familiarity with the environment improve the ability to identify and understand climatic anomalies. These findings are consistent with those of Ricart *et al.* (2025) in Italy. The reported experiences were significantly shaped by cooperative participation (OR = 2.01), information availability (OR = 3.71), and training/workshops (OR = 2.88). These results corroborate Rajesh's (2024) assertion that organized and group information-sharing systems can raise awareness of extreme climatic occurrences. In line with Arjomandi *et al.* (2023), who contend that institutional trust is a crucial determinant of risk perception and adaptive response, perceptions of extreme weather were significantly influenced by trust in government initiatives (OR = 1.88), as well as trust in the reliability of climate information (OR = 2.06). Farmers are more likely to internalize and act upon messages about climate risks when they have faith in government and scientific institutions.

Adoption of Climate-Smart Agriculture by Smallholder Farmers

Research from sub-Saharan Africa, Asia, and Latin America consistently shows how important smallholder farmers' perceptions of climate change are in determining their adaptive behavior. The findings from Zanzibar, which show varying adoption of Climate Smart Agriculture (CSA) practices and notable crop yield declines attributed to climate variability, are consistent with an increasing body of global evidence highlighting the importance of farmer perceptions and adaptive capacity in the face of climate change. For instance, in a cross-country study conducted in Africa, Paul *et al.* (2023) discovered that farmers were far more likely to implement adaptive methods if they sensed long-term changes in rainfall and temperature. In a similar vein, Bedo *et al.* (2024) found a direct correlation between the likelihood of implementing conservation agriculture and other resilience-enhancing activities and the perceived severity of climate impacts in Ethiopia.

Evidence from areas like the Sahel in West Africa, where periodic droughts have resulted in comparable yield losses, is strongly consistent with data from Zanzibar, where 82.1% of farmers reported a decrease in food crop yields (Sultan *et al.*, 2019). Only 10.4% of Zanzibari farmers reported higher yields, and only 7.5% reported no change. This reflects trends in smallholder systems around the world, where adaptation success is still only achieved by a select few farmers who have greater access to resources, information, and institutional support (Azadi *et al.*, 2021). The magnitude of Zanzibar's reported crop losses also mirrors global trends. In Tanzania, more than 60% of smallholder farmers reported moderate to severe yield losses as a result of climate stressors, specifically unpredictable rainfall and pest outbreaks, according to a study by Gwambene *et al.* (2023). This is also true in Kenya (Kalia, 2024). The study found that 30.6% of farmers experienced very severe impacts and 53.8% of farmers reported moderately severe losses. These numbers are nearly identical to these regional trends, suggesting that rain-fed agricultural communities are generally vulnerable.

Although Zanzibar has moderate to high adoption rates for agroforestry and water harvesting (56.9% and 81.6%, respectively), adoption rates elsewhere in the world differ significantly. For example, land fragmentation and institutional limitations contribute to the limited adoption of water harvesting in South Asia, despite the region's considerable sensitivity to water-related stress (Rani, 2025). Agroforestry, on the other hand, has gained traction in Rwanda due to strong extension assistance and farmer cooperatives that encourage tree-based systems (Rwaburindi, 2024). Another difference is Zanzibar's comparatively low adoption rate of agricultural diversification (16.3%). Diversification is more prevalent in areas like Southeast Asia and the Andean highlands, where it is frequently motivated by both market incentives and objectives related to climate resilience (Beltrán-Tolosa *et al.*, 2022). The prevalent monocultural customs, lack of extension services, and socioeconomic obstacles in Zanzibar may be the cause of this discrepancy.

CONCLUSION

This study emphasizes how vulnerable smallholder farmers in the Central District of Zanzibar are to climate variability, such as decreasing rainfall, increasing temperatures, and changing weather patterns, which have resulted in lower crop yields and altered agricultural methods. Due to restricted access to credit, extension services, and accurate climate information, some Climate-Smart Agriculture (CSA) practices—including crop diversification and modified planting calendars—remain underutilized, even if others, like water harvesting and agroforestry, have gained popularity. Education, experience, institutional support, and confidence in both traditional and scientific knowledge all have a significant impact on farmers' perspectives of climate change. . In order to provide more resilient and sustainable agricultural systems throughout Zanzibar, strengthening adaptive ability will necessitate focused policy interventions that increase Community-Based Adaptation training, enhance infrastructure, and encourage equitable access to climate resources.

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