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Smallholder Farmers' Resilience in Adapting to Climate Changes in the Southern Highlands of Tanzania

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Abstract

Ensuring food security and increasing crop production in the face of climate change and environmental obstacles pose a pressing concern for smallholder farmers in the southern highlands of Tanzania. Through a combined approach of qualitative and quantitative data collection methods—which includes key informant interviews, focus group discussions, observations, and household surveys—this paper examines the methods employed by smallholder farmers to bolster resilience and reduce vulnerability to environmental shifts. The results suggest that climate change exerts effects on both the village farming system and households by the following percentages of impact: food shortages (38.7% village/farming system, 29.0% household); infestation of uncommon pests (30.6% village/farming system, 27.4% household); diminishing rainfall/drought (22.6% village/farming system, 17.7% household); and crop failure (24.2% village/farming system, 29.0% household). The household farming methods practised by farmers encompass a range of strategies that include: agroforestry (37.1% adoption rate), which promotes the interspersing of trees with crops to enhance biodiversity and provide ecosystem services; and zero/minimum tillage (9.7%) practices, which reduce soil erosion and improve soil health. The challenges smallholder farmers face in adapting to climate change include the lack of appropriate tools, unfamiliarity with techniques, and inadequate support: all of which exacerbate the uncertainty surrounding the future of farmers and agriculture. By building adaptive capacity and promoting climate-smart agricultural practices, the region can improve food security, reduce vulnerability, and enhance the livelihoods of farming communities. Sustained efforts should prioritize smallholder farmers' active participation and empowerment in climate change adaptation initiatives.

***Keywords*:** *smallholder farmers, climate change, adaptation strategies, resilience, southern highlands*

1. Introduction

Climate change has already significantly impacted agriculture, and future projections indicate that its effects will continue to affect agricultural potential in various regions (Gwambene, 2020). Developing countries, in particular, face a substantial threat to agricultural production and food security due to climate change, necessitating adaptive measures to address these potential impacts

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(Bongole et al., 2020; Barasa et al., 2021). Within Sub-Saharan Africa (SSA), changing climate conditions are expected to negatively impact farm-household food security, including declining soil fertility and increased erosion (Obasanjo, 1989; Gebre et al., 2023; OXFARM, 2012; Gwambene et al., 2015). Smallholder farmers, who constitute a significant majority of agricultural producers, are especially vulnerable to climate change due to their reliance on agriculture for their livelihoods and limited resources (Gwambene et al., 2015; CIAT & CARE Tanzania, 2019; Maziya et al., 2024). African agricultural production systems face resource constraints, organizational complexity, and ecological vulnerability, making effective management crucial for sustainability. Small farmers, in particular, require long-term investment resources to acquire various farm implements and machinery, and long-term financial help for purchasing inputs. However, the sector has suffered from severe under-investment, leading to the persistence of outdated and primitive technology that results in production failures (Chona, 1989; Gwambene et al., 2015; CIAT & CARE Tanzania, 2019).

While climate change positively impacts agricultural production in certain regions, smallholder farmers realize the benefits and positive effects through proper adaptation and mitigation measures (Gwambene, 2011; OXFARM, 2012). However, anticipated climate change negatively affects agricultural production for smallholder farmers, including those heavily dependent on natural resources. Urgent action is needed to implement adaptation and mitigation measures, enhancing resilience among smallholder farmers and improving food security (Gwambene & Majule, 2008; CIAT & CARE Tanzania, 2019). The dominant farming systems in Tanzania—characterized by small land sizes, resource limitations, and soil degradation—have exacerbated the impacts of climate change (Zerssa et al., 2021). Smallholder farmers face challenges such as limited cropland, land tenure issues, lack of knowledge about adaptation and production, slow return on investments, and inadequate policies and implementation schemes: all of which hinder the adoption of adaptation practices (Zerssa et al., 2021; Mkonda, 2022). These practices include utilizing degraded lands and improving soil management.

Enhancing smallholder farmers' capacity to increase food production, productivity, and market access is crucial for improving their purchasing power, increasing food availability, and contributing to global food security (Oxfam, 2011; Gwambene et al., 2015; Barasa et al., 2021). However, challenges such as climate variability, poverty, limited access to resources and technology, inadequate financing, and global agricultural policies: all impede the sustainability of agricultural development in Tanzania (Gwambene, 2020; Tilumanywa, 2021). Multiple factors—such as weather information, past experiences with drought, education level, family size, ownership of livestock,

access to credit, and availability of extension services – have influenced the decision-making process of farm households regarding the adoption of adaptation strategies (Amare & Simane, 2017; Ojo et al., 2021). Promoting long-term commitments, raising awareness about challenges, and implementing tailored interventions for different stakeholders are crucial to enhancing agricultural production, food security, and resilience among smallholder farmers. Farmers face a significant challenge in decision-making due to the high risks associated with climate change (Obasanjo, 1989; Chona, 1989; Surminski et al., 2018; Kulyakwave et al., 2023). This risk perception leads to reluctance to invest in farming, undervaluation of the agricultural sector, and underachievement; signalling ineffective leadership (Chona, 1989; Mkonda, 2022). Hence, adaptation strategies are crucial for rural households to address the adverse effects on food security (Gebre et al., 2023).

Smallholder farmers in Tanzania employ various adaptation strategies to mitigate the impacts of climate change, including utilizing local knowledge, diversifying crops, and adopting soil moisture conservation methods (Mlengule, 2019). However, adopting these strategies varies across regions; and is influenced by factors such as education level, labour availability, access to meteorological information, financial services, and extension support (Nisha, 2019; Gwambene, 2020; Kulyakwave et al., 2023). To enhance the capacity of smallholder farmers to increase food production and productivity (Oxfam, 2011; Gwambene et al., 2015; Barasa et al., 2021), and promote widespread adoption of adaptation strategies (including climate-smart agriculture practices), it is crucial to prioritize policies and plans that encourage a combination of interconnected methods, while considering the specific needs and circumstances of smallholder farmers (Bongole et al., 2020).

Policy interventions should promote comprehensive climate-smart agriculture practices, recognize their interconnectedness, and harness their synergistic effects (Bongole et al., 2020). A thorough understanding of the barriers and enabling factors for adaptation practices is essential for developing effective extension messages and agricultural policies that support smallholder farmers in adapting to climate change (Bongole et al., 2020; Mkonda, 2022). A sustainable development of agriculture in Tanzania encounters various challenges, including climate variability, poverty, limited access to non-farm activities, ineffective utilization of improved seeds and fertilizers, limited financing options, global agricultural policies, and diseases (Gwambene, 2020; Tilumanywa, 2021).

Extensive literature and compelling evidence highlight measures to enhance smallholder farmers' capacity to increase food production, improve productivity, and enhance livelihoods. However, despite the wealth of literature on the challenges faced by smallholder farmers in adapting to climate change, there is

still a gap in understanding the specific challenges encountered by smallholder farmers in the southern highlands of Tanzania that needs to be filled. In addressing this gap, this study aims to evaluate the challenges faced by smallholder farmers in this region in adapting to climate change, and explore their perspectives on adaptation measures. Through this investigation, the study seeks to contribute to developing targeted interventions and policies to enhance the resilience and productivity of smallholder farmers in the face of climate variability. Thus, the overarching objective of this study is to assess the challenges and perspectives of smallholder farmers in the southern highlands of Tanzania regarding climate change adaptation, and to identify strategies to improve their resilience and productivity in agricultural practices.

2. Context and Methods

Data for this paper were generated from a study that was conducted in five districts of southern highlands, Tanzania. The region is renowned for its agricultural productivity, and has a significant role in the country's food production. Its diverse climatic conditions, topography, and soil types make it suitable for various crops. Due to its favourable agricultural conditions, the region has gained recognition as a prominent food basket, and a central hub for agricultural production (Gwambene et al., 2015). The study selected five specific areas within the southern highlands to capture a representative sample of farmers' experiences and perspectives in different contexts. Each location had unique characteristics and challenges influencing agricultural practices, climate change adaptation strategies, and overall livelihoods.

In each of the five district selected for this study, the sampling methods encompassed purposive and random sampling techniques, ensuring a comprehensive representation of the community. For the focus group discussions (FGDs), a purposive sampling technique was employed in selecting 8–15 participants per village. Concurrently, the household survey was conducted involving 175 households per village. Additionally, 25 individuals were engaged in informant interviews. These were selected through a combination of purposeful and random sampling techniques. The key informants represented different levels and sectors, including local government, community elders, and professionals in agriculture-related fields, offering expert insights into local practices and challenges. Through a strategic integration of purposive and random sampling techniques, the study facilitated robust data collection and analysis, fostering an understanding of the studied phenomena.

The study also employed a mixed-methods approach to comprehensively understand the research topic, combining qualitative and quantitative data sources. Integrating qualitative and quantitative data sources helped in achieving a more comprehensive and triangulated analysis of the research topic. The

qualitative data provided rich insights into individuals' perceptions, experiences, and attitudes; while the quantitative data offered objective measures and statistical analysis to support and validate the results. By combining these approaches, the study benefited from the strengths of both qualitative and quantitative methods, enhancing the overall validity and reliability of the results.

The household interviews—with the head of each household or a knowledgeable relative—was carried out in a manner that ensured standardized data collection. In addition, FGDs were held in each village to allow an in-depth exploration of the research topic and share experiences and knowledge. Key informant interviews were conducted with individuals from various levels and sectors, including local government representatives, community elders, and professionals in agriculture-related fields. These interviews provided expert perspectives and enriched the study results by offering insights into local practices and challenges. Through transect walks within the study area, observation complemented the data collected from other methods, providing a first-hand understanding of agricultural systems and validating qualitative and quantitative results. Furthermore, a comprehensive literature review synthesized existing knowledge and theories, contributing to a solid theoretical foundation for the study, and guiding data analysis and interpretation.

The data collected through various methods underwent rigorous analysis to derive meaningful insights and support robust conclusions. Qualitative data from FGDs, key informant interviews, and observations were subjected to content and trend analysis techniques. Systematic coding and categorization were carried out in a manner that yielded emerging themes, patterns, and relationships. Quantitative data from household surveys were analysed using the Statistical Package for Social Science (SPSS), and the Microsoft Excel software. Descriptive statistics, inferential analysis, and data visualization techniques—including tables, charts, and figures—were employed to present quantitative results clearly and concisely.

3 Results

3.1 Production Knowledge and Perception of Climate Change

The study's results reveal that a considerable majority of the respondents (89.1%) recognize the impact of climate change on the village/farming system, with 84.5% acknowledging its effects on their households. It is evident from the data that climate change influences various aspects of production, as depicted in Figure 1. Additionally, the statistical analysis conducted using the Pearson Chi-Square test indicates no significant difference in knowledge about climate change across the surveyed districts, as evidenced by the p-value of 0.282. These results suggest that the awareness of climate change is consistent across the Districts included in the survey.

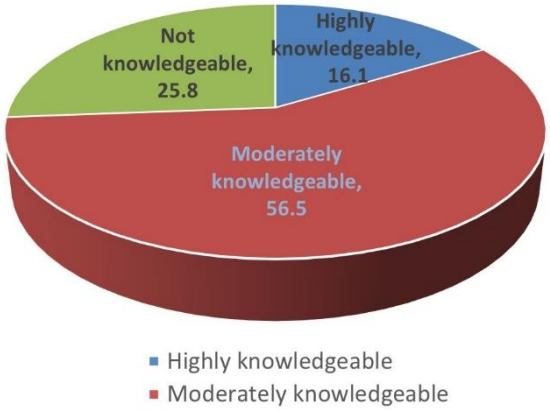

Figure 1: The Knowledge of the Respondent about Climate Change
Source: Field Data

Farm households have experienced a noticeable improvement in production due to adopting new and improved crop varieties, accessing voucher-based fertilizers, and benefiting from increased extension services that provide valuable knowledge on proper farming practices. An example is in Litisha village, where maize harvests have increased from an average of 4–5 bags to 10–12 bags. Although physical activities on the farms may have mostly remained the same, there has been a shift in focus towards implementing more effective and efficient practices. The adaptation strategies employed by farm households in response to climate change have had a positive impact on their food security status. However, it is essential to note that the effect of adaptation on food security is more pronounced for households that actively adopt these strategies than those that do not, as highlighted by Amare and Simane (2017).

Thus, developing and promoting effective adaptation strategies—e.g., planting drought-resistant crops, adjusting planting dates, cultivating early-maturing crops, and diversifying income sources, particularly for vulnerable farm households—is suggested. These measures can help mitigate the adverse impacts of climate change on food security. Yet, adopting these strategies needs to improve as farmers often need more agricultural methods on the same pieces of land. Climate change has wide-ranging impacts on the village/farming system and households, leading to various challenges and disruptions. Figure 2 shows the effects and their respective percentages for the village/farming system and households.

Climate change exerts significant effects on both the village/farming system and households, as evidenced by the following percentages of impact: food shortages (38.7% village/farming system, 29.0% household); infestation of uncommon pests (30.6% village/farming system, 27.4% household); crop failure (24.2% village/farming system, 29.0% household); excessive rainfall (24.2%

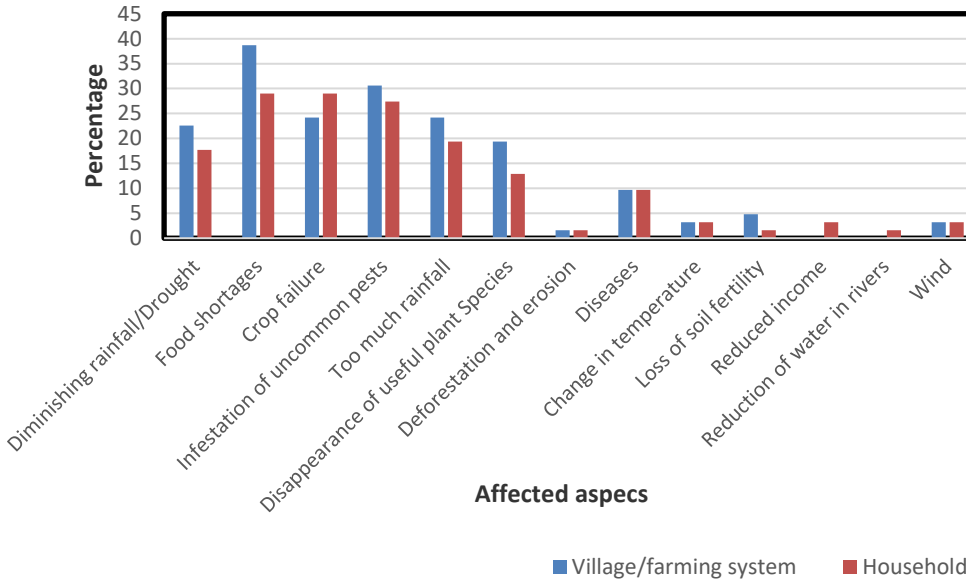

Figure 2: Effect of Climate Change on Village/farming System and Household
Source: Field Data

village/farming system, 19.4% household); diminishing rainfall/drought (22.6% village/farming system, 17.7% household); disappearance of helpful plant species (19.4% village/farming system, 12.9% household); diseases (9.7% village/farming system, 9.7% household); loss of soil fertility (4.8% village/ farming system, 1.6% household); change in temperature (3.2% village/farming system, 3.2% household); wind disturbances (3.2% village/farming system, 3.2% household); deforestation and erosion (1.6% village/farming system, 1.6% household); reduced income (0.0% village/farming system, 3.2% household); and reduction of water in rivers (0.0% village/farming system, 1.6% household).

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These effects posed significant challenges to agricultural productivity, food security, and the overall well-being of farming communities. The production costs of crops are considerably high due to the expenses associated with fertilizers and pesticides, which pose a financial burden for low-income farmers compared to their output. For instance, the high fertilizer and pesticide prices significantly impacted the production costs of round potatoes. Consequently, many small-scale farmers, especially those with low income, have abandoned the cultivation of round potatoes. The challenges in the production of round potatoes include climate change and variability, which contribute to increased pest and disease incidences, and soil exhaustion. Such challenges lead to heightened demand for inputs: costly fertilizers and pesticides.

Due to unpredictable weather conditions, predicting the future of farming activities is challenging. However, farmers anticipate that providing education increases the income of smallholder farmers. The study reveals that smallholder farmers employ both traditional indigenous strategies and conventional measures/strategies to enhance resilience, adaptation, and mitigation of the impact of climate change and variability. In addition to using new and improved seed varieties, fertilizers (through voucher systems), and increased extension services, farmers in the study villages utilize practices such as replanting, pest control, timely farming preparation, early-maturing crop varieties, drought-tolerant crops, and irrigation. Furthermore, rice farmers opt for seedlings instead of seeds. Based on the FGDs, the essential measures to reduce the impact of climate change include tree planting, avoiding farming on steep slopes, restoring natural vegetation, and promoting education and training through NGOs. The effective adaptation strategies highlighted during the FGDs include access to extension services, environmental management/protection (e.g., tree planting), and proper farming methods.

3.2 Farm Characteristics, Practices and Policies

Smallholder farmers can improve their livelihoods and contribute to building a more sustainable and climate-resilient agricultural sector by aligning farm characteristics, practices, and policies with climate-resilient strategies. Ownership of, and production in, small-sized land areas characterize smallholder farmers. The impacts of changing rainfall patterns, temperature variations, and extreme events like floods and droughts, present significant challenges and risks to their agricultural activities. The primary objective of their production is typically for subsistence, with only a few engaging in farming for commercial purposes. Figure 3 provides insights into the farm size

of smallholder farmers in the study area. The small size of farms and prevailing environmental changes necessitate adaptive farming practices to ensure food security and sustainability in the face of evolving climatic conditions. Moreover, it calls for implementing supportive agricultural policies that address the specific needs and vulnerabilities of smallholder farmers in the region. These policies should focus on enhancing access to modern farming technologies, providing climate-resilient crop varieties, promoting efficient water management practices, and fostering capacity-building programs to empower farmers with the knowledge and skills needed to cope with the challenges posed by climate change.

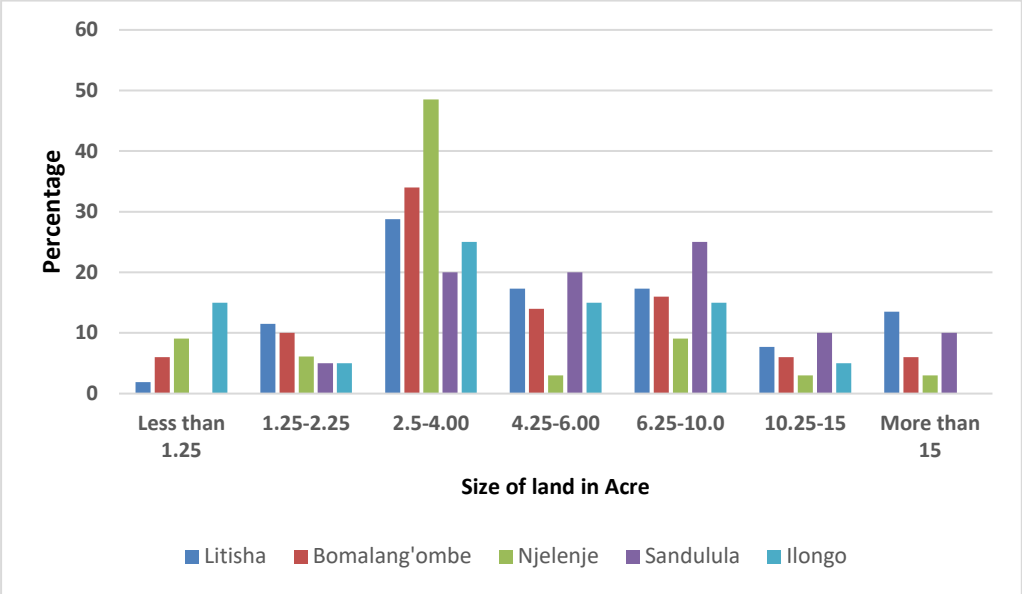

Figure 3: Total land Owned (in acres) in the Study Village
Source: Field Data

Policies, laws, and strategies have significantly impacted all study villages' agriculture, livestock, and natural resources. During the FGDs, smallholder farmers highlighted specific bylaws and policies that have affected them. Some of the issues raised include problems with implementing subsidy policies (*sera ya ruzuku*) and delivering agricultural inputs (*pembejeo*), which are only sometimes suitable for their needs. There were concerns about land distribution, with some individuals owning large tracts that negatively impacted forests and climate conditions. Additionally, some policies were perceived to benefit traders more than farmers, particularly regarding input distribution. Introducing new crops like tea was seen as challenging due to limited available land, as with other crops. Farmers also expressed the need for reduced prices, availability of inputs,

and better support for those farming on hills. In the past, farmers received support from the government, including cattle and pasture; but felt that this assistance as insufficient and needed to be improved.

In promoting adopting climate-smart agriculture (CSA) practices, the focus must be on policies and plans that encourage a combination of interrelated techniques, and capitalize on their synergies (Bongole et al., 2020). The agriculture and livestock sectors should focus on providing technical and advisory services to farmers to increase agricultural output and improve people's living standards (Songea et al., 2012). The aim is to bring extension services closer to the people; and involve farmers, stakeholders, and donors in promoting the sectors. Also, the key objectives should include educating farmers on recommended crop husbandry practices, ensuring the use of appropriate agricultural inputs, promoting integrated pest and disease management techniques, facilitating the use of modern farm machinery, conducting land use planning exercises, training farmers on conservation practices, conducting campaigns against wildfires, and providing irrigation techniques and management training to farmers (Songea et al., 2012). Thus, implementing agriculture and livestock policies and plans is hoped to enhance agricultural productivity and sustainability, and benefit farmers and their communities.

3.3 Smallholder Farmers' Choice of Response Strategies

Since climate change challenges responses to ensures food and livelihood security; it is crucial to provide incentives that influence the choices made by smallholder farmers in crop production. These incentives should aim to maintain and enhance environmental and cultural services, while increasing sustainable productivity and diversifying food production. Figure 4 illustrates smallholder farmers' adaptation and mitigation measures in their production systems. The household farming methods practised by farmers in the study area encompass a range of strategies. These include agroforestry (37.1% adoption rate), which promotes the integration of trees with crops to enhance biodiversity and provide ecosystem services; zero/minimum tillage (9.7%) practices that reduces soil erosion and improve soil health; contour farming (19.4%), which mitigates slope effects on water runoff and soil erosion; terracing (46.8%), which controls and manages soil erosion on hilly terrain; irrigation (24.2%), that ensures adequate crop water supply; mulching (6.5%), which conserves soil moisture and suppresses weed growth; and crop cover (11.3%) that protects soil from erosion and maintains moisture levels. Additionally, crop-residue incorporation (24.2%) involves the adding of crop-residues into the ground to improve organic matter content; while mixed cropping (46.8%) enhances diversity and reduces pest and disease risks; and crop rotation (71.0%) optimizes nutrient cycling and reduces pest pressure. Lastly, crop and livestock farming (43.5%) involves integrating crop and livestock activities to enhance nutrient cycling, and provide multiple sources of income for farmers.

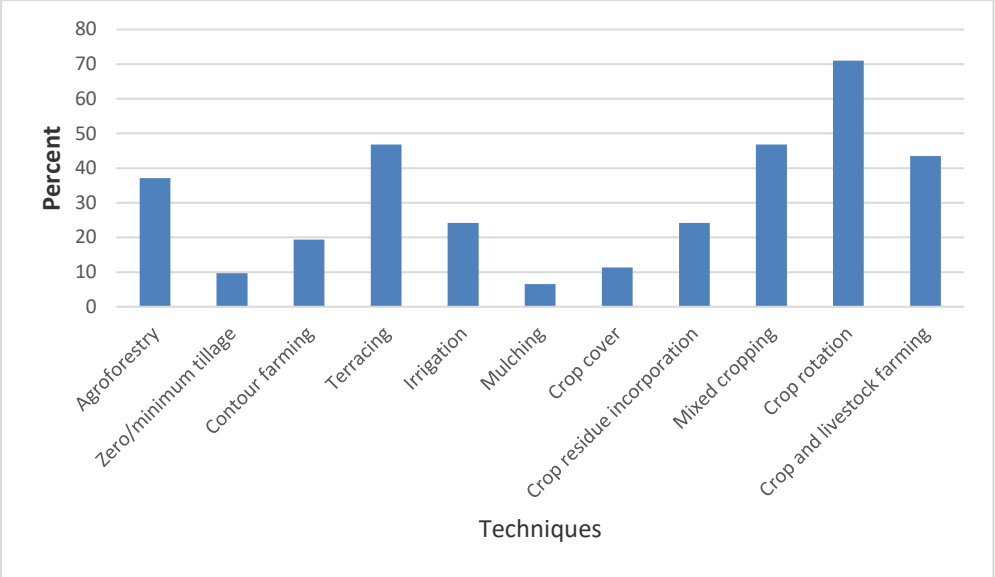

Figure 4: Adaptation and Mitigation Measures
Source: Field Data

These response strategies reflect smallholder farmers' adaptive capacity and resourcefulness in mitigating the impacts of climate change, and ensuring sustainable agricultural production. Through adopting response practices, farmers can enhance the resilience of their farming systems, improve productivity, and diversify their income sources. However, there is still room for further promotion and adoption of these strategies, as their adoption rates vary across different practices. Policymakers and stakeholders should prioritize supporting and incentivizing the adoption of these CSA practices; and providing access to resources, technical assistance, and financial support.

The study results further highlight the influence of farmers' incentives and conditioning factors on adopting adaptation and mitigation measures that can either hinder or promote effective strategies. These measures are crucial in addressing the impacts of climate change, particularly on agricultural practices, crop productivity, and household income. The findings emphasize the need to consider these factors when designing and implementing climate change adaptation policies and interventions. Table 1 highlights the viability of the measures used by smallholder farmers to adapt to climate change and enhance their livelihood resilience. It assesses the effectiveness of each measure in addressing the challenges posed by climate change, and its potential impact on crop productivity and household income. By evaluating the viability of these measures, policymakers and stakeholders can prioritize interventions with the most significant potential for positive outcomes and sustainable impact.

Table 1: Viability of Adaptation Measures to Reduce Climate Change Impacts and Food Shortage

Viability of adaptation measures to food shortage	N	Mean	Std. Deviation	Kurtosis	
	Statistic	*Statistic*	*Statistic*	*Statistic*	*Std. Error*
Use of indigenous crop varieties more resistant to drought	40	1.63	0.868	1.060	0.733
Expansion of agricultural activities	38	1.97	0.944	-0.421	0.750
Collecting and eating wild foods	21	2.43	1.076	-1.272	0.972
The movement to key resource areas	21	2.67	0.913	-0.245	0.972
Casual labour (work for cash)	54	1.78	0.816	0.287	0.639
Casual labour (work for food)	46	1.72	0.834	0.654	0.688
Migrating to other places	23	2.78	1.043	-0.347	0.935
Buying food	56	1.32	0.543	1.326	0.628
Getting assistance from relatives	31	2.23	1.055	-1.393	0.821
Selling household assets to buy food	38	2.00	0.900	-0.648	0.750
Borrowing food	34	1.88	0.880	-0.798	0.788
Reducing the number of meals	39	1.59	0.715	-0.580	0.741
Eating unusual foods	26	2.12	0.952	-1.373	0.887

Source: Field data

The willingness and ability of smallholder farmers to practice various farming methods play a significant role in their adaptation to climate change. The study revealed that certain practices have higher levels of willingness and ability among farmers. For instance, the identified favourable practices include agroforestry, with 49.1% of farmers willing to adopt it; and 35.8% capable of implementing it. Other methods that also showed relatively high levels of willingness and ability included crop rotation, crop-residue incorporation, crop and livestock farming, terracing, and mixed cropping.

Several factors influence the decision-making process for adopting response strategies at the household level. These factors include the education level of farmers, the size of labour force, access to meteorological information, experiences of drought events, availability of financial services—such as credit, farm outputs—and access to extension and technical information. Understanding and addressing these factors are crucial for promoting and adopting adaptation strategies among smallholder farmers. Addressing the underlying incentives and conditioning factors that shape farmers' decision-making is essential to implement these measures successfully. Policymakers must provide appropriate incentives, support, and resources to facilitate adoption; and the scaling-up of effective adaptation strategies. The support can include financial incentives, access to credit and insurance, capacity-building programs, and the provision of extension services and climate information.

Figure 5 presents the willingness and ability of smallholder farmers to practice different farming methods, and a comprehensive overview of the potential for adopting these practices. The formulation of policies and strategies to promote sustainable agriculture, resilient livelihoods, and effective responses to the challenges of climate change need to consider the interplay between incentives, conditioning factors, and the viability of adaptation measures.

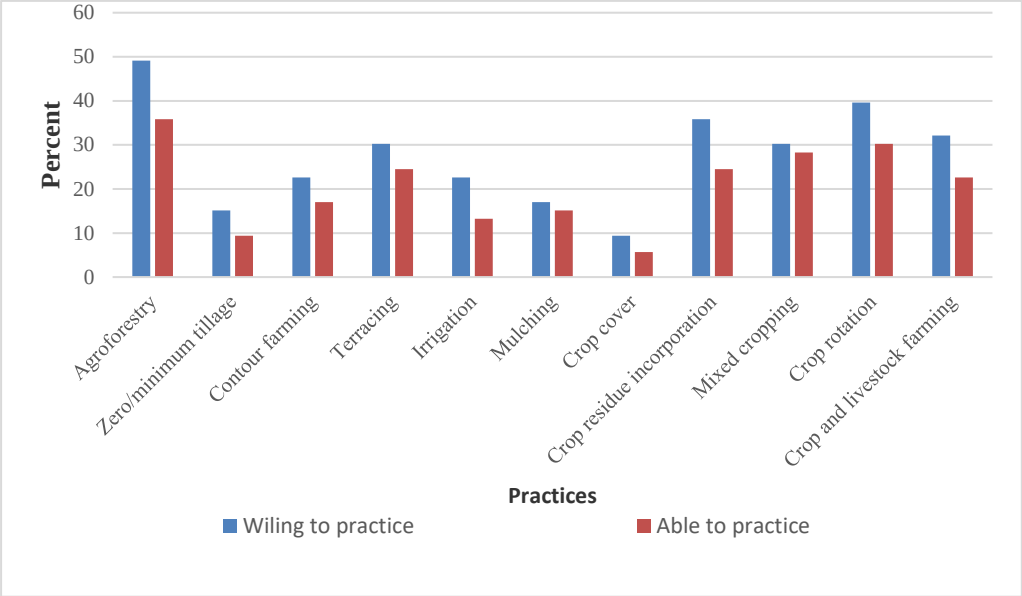

Figure 5: Willingness and Ability to Practice Farming Methods
Source: Field Data

Providing extension services to farmers plays a crucial role in agricultural development by acting as a platform for disseminating technical information to end users. Through extension services, farmers access valuable knowledge, innovative farming practices, and cutting-edge technologies that can enhance their productivity and resilience to various challenges, including climate change. Extension services have successfully bridged information gaps and positively impacted agricultural production by actively reaching out to communal farmers who have been overlooked. Extension services enable farmers to make informed decisions and adopt more sustainable and climate-smart farming practices by equipping them with relevant information and skills. This knowledge transfer improves yields and livelihoods; and contributes to the growth and development of rural communities.

Table 2 shows an essential tool for understanding the experiences of implementing adaptation strategies, and adopting farming practices. It provides valuable insights into the real-life experiences of farmers, showcasing the

effectiveness of different methods and techniques in addressing the challenges posed by climate change. The information is instrumental in designing evidence-based policies and targeted interventions to support and strengthen farmers' capacity to cope with climate change impacts. Moreover, Table 2 aids in identifying areas where additional support and resources are required to facilitate a successful uptake and scalability of climate-resilient farming practices. This, coupled with active involvement of extension services, will ultimately results into a well-informed and data-driven approach to sustainable agricultural development, and hence improved livelihoods for smallholder farmers in an ever-changing climate.

Table 2: Descriptive Statistics on the Years Implemented Farming Methods Practice

Implemented farming methods practice	N	Min.	Max.	Mean	Std.
Agroforestry	23	1	30	8.17	8.569
Zero/minimum tillage	6	2	30	11.50	10.858
Contour farming	10	3	25	10.80	8.753
Terracing	29	1	36	12.41	10.618
Irrigation	14	2	21	6.64	6.234
Mulching	6	2	30	9.67	10.328
Crop cover	6	4	30	17.50	10.672
Crop residue incorporation	12	3	24	12.00	7.398
Mixed cropping	30	1	30	12.57	8.693
Crop rotation	45	1	35	12.29	9.438
Crop and livestock farming	23	2	25	8.91	6.973

Source: Field data

Moreover, the results in Table 2 provide descriptive statistics on the years of implementation of various farming methods and practices. These statistics offer insights into the extent to which farmers have adopted and implemented different strategies to cope with climate change and improve agricultural resilience. Analysing the data presented in Table 2 allows policymakers, researchers, and agricultural stakeholders to assess the effectiveness and longevity of different farming methods. For instance, the mean number of years implemented for agroforestry is 8.17, indicating that farmers have been practising this method for an average of 8.17 years. Similarly, other practices such as zero/minimum tillage, contour farming, terracing, and irrigation have the mean implementation durations of 11.50, 10.80, 12.41, and 6.64 years, respectively. These statistics describe farmers' experience and familiarity with each method. Policymakers can use this information to identify practices successfully implemented over long duration; and consider promoting these methods further. The standard deviation values assess the variability in implementation, providing insights into the challenges, and factors influencing

the adoption and continuity of specific practices. Knowledge-sharing enables the replication of successful experiences, fosters learning among farmers and communities, and contributes to the overall resilience and sustainability of agricultural systems in the face of climate change.

3.4 The Adaptation Challenges Among Smallholder Farmers

The agricultural sector in the Southern Highlands faces many challenges along the value chain, including climate variability, poverty, limited access to resources and technology, and inadequate infrastructure. These challenges significantly hinder the adoption of CSA practices among smallholder farmers in the region. Several reasons contribute to the reluctance of smallholder farmers to adopt CSA practices. Among these, high upfront costs and inadequate technical know-how constitute the prominent barriers that hinder the willingness to adopt these practices; with both factors being cited by 50.0% of respondents. Additionally, cultural unacceptability (25.0%), unsuitability to agro-climatic conditions (25.0%), lack of market for agricultural produce (37.5%), insecurity of land tenure (12.5%), and the opportunity cost of land use (25.0%): all further contribute to the challenges faced by farmers in adopting CSA. These reasons reflect the complex socioeconomic and environmental contexts in which smallholder farmers operate.

Figure 6 indicates the adoption challenges, barriers and constraints farmers face in implementing adaptation measures; which in turn necessitate that tailored interventions and support are needed to enhance the adoption of sustainable and resilient agricultural practices among smallholder farmers in the Southern Highlands.

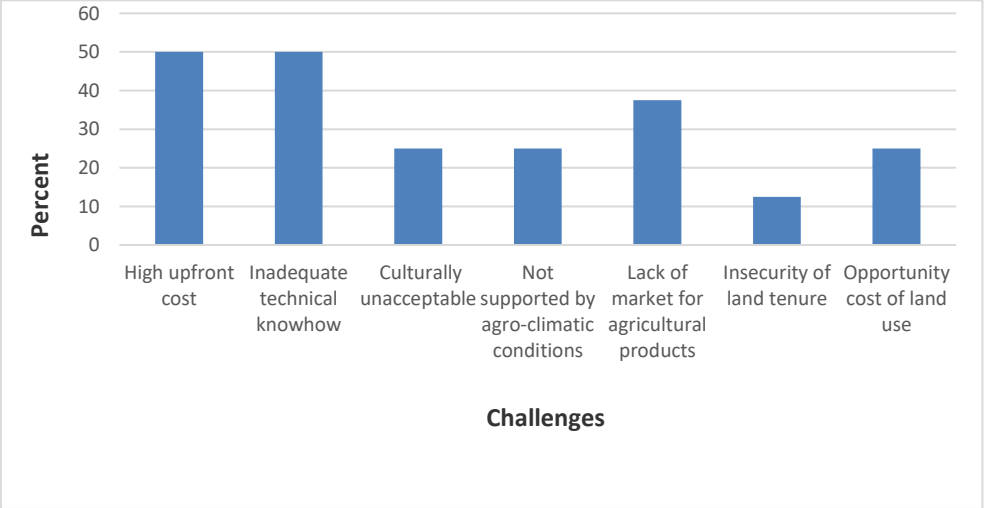

Figure 6: The Adoption Challenges Among Smallholder Farmers
Source: Field Data

Adaptation practices in agriculture are crucial for addressing challenges related to drought resilience, stable crop yields, carbon sequestration, greenhouse gas mitigation, and higher household income. However, various factors often limit the adoption of these practices among smallholder farmers. Key barriers include the shortage of cropland, land tenure issues, inadequate knowledge about adaptation strategies, slow return on investments, and insufficient policy and implementation schemes (Zerssa et al., 2021). To overcome these challenges, it needs measures that promote the utilization of degraded and marginal lands, improve soil organic matter management, provide capacity-building opportunities and financial support, and measures that develop specific policies tailored to the needs of smallholder farmers. These measures aim to enhance the feasibility and viability of adaptation practices, enabling farmers to effectively address food shortages and build resilience in the face of climate change.

Table 3 provides descriptive statistics indicating the effectiveness of the measures used to address food shortage. The values of skewness and kurtosis reflect the distribution characteristics of the data. For example, the skewness value of the indigenous group (n=40) is 1.328, with a standard error of 0.374; and the kurtosis value of 1.060 with a standard error of 0.733. Similarly, for the conventional group (n=56), the skewness value is 1.473 with a standard error of 0.319, and the kurtosis value is 1.326 with a standard error of 0.628. These statistical indicators provide insights into the effectiveness and suitability of measures in addressing food shortage among smallholder farmers. Thus, by understanding the barriers to adoption and implementing appropriate measures, policymakers and stakeholders can work together to overcome challenges, support farmers in adopting adaptation practices, and promote sustainable agricultural development. This holistic approach is crucial for building the resilience of smallholder farmers, and ensuring food security in the face of climate change.

Table 3: Descriptive Analysis for Adaptation Measures to Food Security

Descriptive Statistics	N	Mean	Std	Variance	Skewness		Kurtosis	
				Statistic	*Statistic*	*Std. Error*	*Statistic*	*Std. Error*
Migrating to other places	23	2.78	1.043	1.087	-0.842	0.481	-0.347	0.935
The movement to key resource areas	21	2.67	0.913	0.833	-0.549	0.501	-0.245	0.972
Collecting and eating wild foods	21	2.43	1.076	1.157	-0.196	0.501	-1.272	0.972
Getting assistance from relatives	31	2.23	1.055	1.114	0.061	0.421	-1.393	0.821
Eating unusual foods	26	2.12	0.952	0.906	0.056	0.456	-1.373	0.887
Selling household assets to buy food	38	2.00	0.900	0.811	0.469	0.383	-0.648	0.750
Expansion of agricultural activities	38	1.97	0.944	0.891	0.665	0.383	-0.421	0.750
Borrowing food	34	1.88	0.880	0.774	0.524	0.403	-0.798	0.788
Casual labour (Work for cash)	54	1.78	0.816	0.667	0.869	0.325	0.287	0.639
Casual labour (Work for food)	46	1.72	0.834	0.696	1.064	0.350	0.654	0.688
Use of indigenous crop varieties more resistant to drought	40	1.63	0.868	0.753	1.328	0.374	1.060	0.733
Reducing the number of meals	39	1.59	0.715	.511	0.805	0.378	-0.580	0.741
Buying food	56	1.32	0.543	0.295	1.473	0.319	1.326	0.628

Understanding the barriers and facilitating factors related to adopting adaptation practices is crucial for effectively designing extension messages and agricultural policies. This knowledge enables policymakers to accelerate the dissemination of adaptation strategies, and contribute to protecting farm production and food security. Agricultural policymakers should prioritize the improvement of smallholder farmers' household characteristics by evaluating existing farmer extension programs. By customizing extension services to meet the specific needs of farming households, policymakers can develop a comprehensive package that addresses the actual needs of farmers as they perceive them. Moreover, it is essential to acknowledge smallholder farmers' diverse markets and contexts, and ensure that the implemented strategies align with their unique circumstances.

Figure 7 presents insights on the adoption of crop varieties that cover policy, technical, and sociocultural factors. Understanding the barriers and facilitating conditions for adopting adaptation practices is crucial for designing effective extension messages and agricultural policies. This awareness enables an accelerated dissemination of adaptation strategies, thereby contributing to the protection of farm production and food security. Agricultural policymakers should prioritize enhancing smallholder farmers' household characteristics by reviewing farmer extension programs. Furthermore, they should designing farm management programs based on farmers' household characteristics, such as education, gender, livestock ownership, and membership in social groups: all of which can assist in meeting their specific requirements (Bongole et al., 2020).

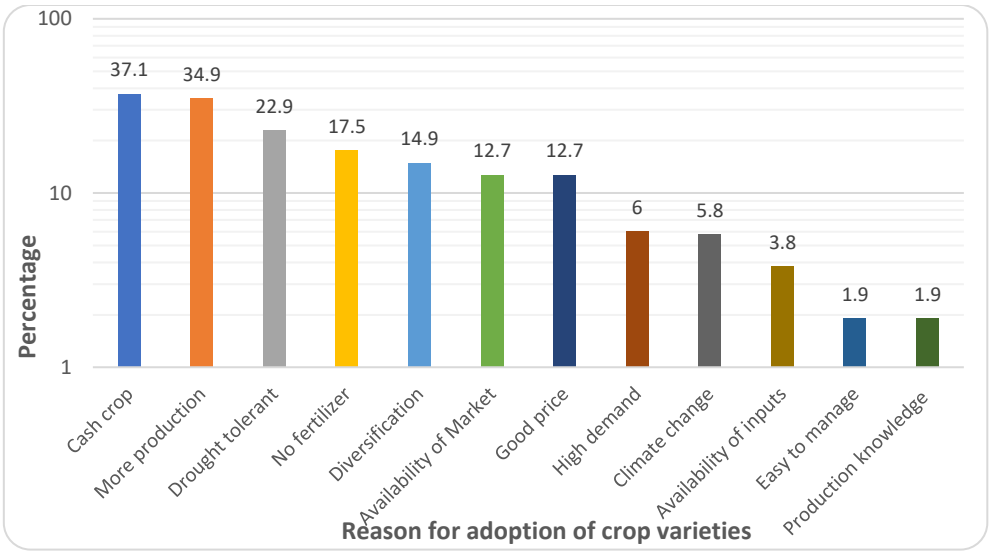

Figure 7: Reason for the Adoption of Crop Varieties
Source: Field Data

Figure 7 further shows why farmers choose to adopt specific crop varieties. These reasons encompass various factors that drive farmers' decisions in selecting and cultivating particular crops. Some of the main reasons for adopting crop varieties include the potential for cash crop production, the ability to achieve high yields, drought tolerance, access to necessary inputs, the need for diversification, market demand, favourable prices, and the availability of production knowledge. The inclusion of cash crops in the farmers' choices signifies their desire to generate income and improve their economic well-being by cultivating crops with high market values. High production potential is another significant factor, indicating that farmers prioritize varieties that offer the potential for abundant yields. Drought tolerance is crucial in regions prone to water scarcity, as it allows farmers to mitigate the risks associated with changing climatic conditions and ensure crop survival. Also, access to inputs, such as quality seeds and fertilizers, is essential for farmers to achieve optimal crop performance and productivity.

Other reasons include diversification, which is driven by reducing risk and ensuring a more stable income through cultivating various crops with different market demands. Market-oriented considerations, such as demand and reasonable prices, play a role in farmers' decisions as they seek to align their production with consumer preferences to maximize their profitability. Lastly, the availability of production knowledge is a vital factor, indicating that farmers are more likely to adopt crop varieties when they have access to information, training, and technical assistance regarding the cultivation and management of these crops. Understanding these reasons for adopting crop varieties is crucial for policymakers, researchers, and agricultural stakeholders. It enables them to develop targeted interventions, extension services, and policies that support and promote the adoption of appropriate crop varieties based on farmers' needs and the prevailing market conditions. Through agricultural strategies with the motivations and objectives of farmers, it becomes possible to enhance agricultural productivity, improve farmers' livelihoods, and contribute to sustainable and resilient food systems.

3.5 Enhancing Resilience and Adoption Capacity Among Smallholder Farmers

Significant changes in policy and practice are crucial to enhancing resilience and adoption capacity among smallholder farmers. These changes aim to improve the adaptation and resilience of smallholder farmers in the face of changing climatic conditions, and create an enabling environment that promotes their ability to adapt. Figure 8 illustrates the measures needed to enhance smallholder farmers' adaptation capacity. One key aspect is developing and disseminating appropriate agricultural technologies and adaptation strategies. It is essential to have a comprehensive understanding of why farmers make confident decisions, and how they can improve their practices to achieve better results regarding productivity, cost-effectiveness, and reduced effort. Through training and

knowledge transfer, small-scale farmers can acquire the skills and understanding necessary to implement effective adaptation and mitigation strategies that align with their specific capacities and resources.

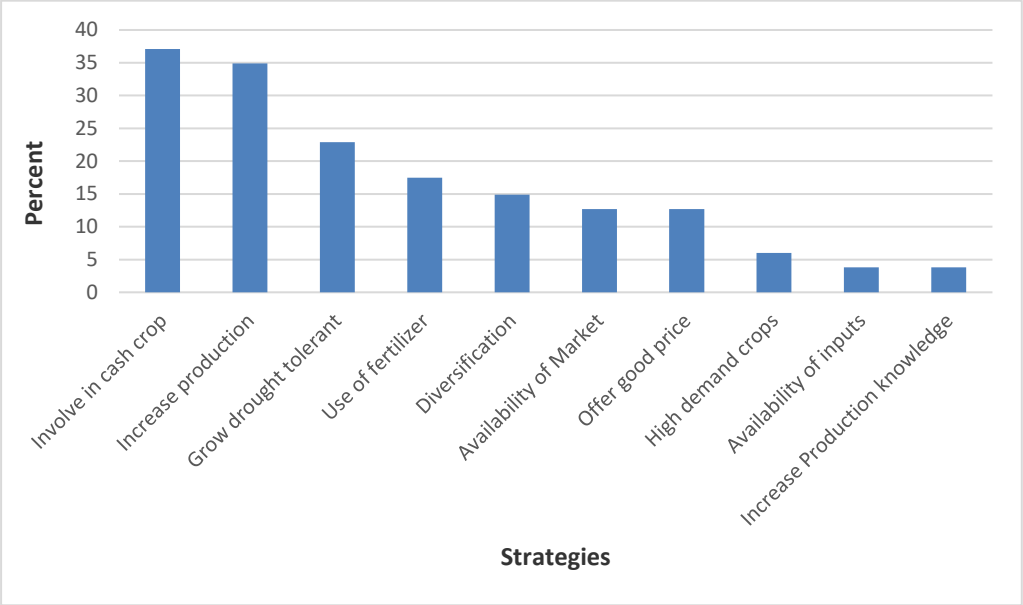

Figure 8: Strategies to Improve Adaptation Capacity of Smallholder Farmers
Source: Field Data

The findings reveal several strategies recommended to enhance the adaptive capacity of smallholder farmers in response to climate change. These strategies include engaging in cash crop cultivation (37.1%), increasing overall production (34.9%), cultivating drought-tolerant crops (22.9%), utilizing fertilizers (17.5%), diversifying crop varieties (14.9%), accessing markets (12.7%), securing favourable prices (12.7%), prioritizing high-demand crops (6.0%), ensuring the availability of necessary inputs (3.8%), and improving knowledge related to production techniques (3.8%).

Moreover, policymakers and stakeholders must consider the socioeconomic context in which smallholder farmers operate. This context addresses resource access, market opportunities, and financial support issues. Smallholder farmers often face challenges accessing land, credit, inputs, and markets. Therefore, it is crucial to provide them with the necessary support and resources to overcome these constraints and enhance their capacity to adapt. Incorporating the voices and experiences of smallholder farmers in developing and implementing policies is paramount. Engaging with farmers, comprehending their needs and

perspectives, and involving them in decision-making processes is vital. This participatory approach ensures that policies and interventions are context-specific, responsive to local realities, and capable of effectively addressing the challenges faced by smallholder farmers.

4. Discussion

Smallholder farmers in the Southern Highlands of Tanzania confront significant challenges; and face risks from shifting rainfall patterns, temperature fluctuations, and extreme events such as floods and droughts. These farmers employ diverse adaptation strategies, including local knowledge and conventional measures, to mitigate their vulnerability to climate variability. However, the adoption of these strategies varies across different regions. Factors such as education level, labour force size, access to meteorological information, past experiences with droughts, availability of financial services, farm outputs, and access to extension and technical information: all these influence the adoption of strategies.

Reducing the risks associated with climate change in the agricultural sector necessitates building resilience and adapting to the negative impacts of climate variability and environmental change. However, the low adaptive capacity among smallholder farmers in rural areas needs to improve the implementation of measures to enhance resilience. Similar findings have been observed by Mlengule (2019), Nisha (2019), Bongole et al. (2020), Gwambene (2020), and Kulyakwave et al. (2023).

Improving farmers' adaptive capacity and enhancing their resilience to climate change requires addressing challenges related to land use, food security, biodiversity, ecosystem management, and other pertinent factors. Therefore, it is crucial to prioritize policies and plans that promote comprehensive CSA practices tailored to smallholder farmers' specific needs and characteristics. The findings of this study indicate that smallholder farmers in the study area utilize a combination of traditional indigenous strategies and conventional measures to enhance resilience and mitigate vulnerability to environmental changes and climate variability. Various incentives and conditioning factors influence the effectiveness of these adaptation measures. Moreover, the study findings have shown that alterations in agricultural practices have notable impacts on crop productivity and household income. Also, when designing interventions to support smallholder farmers' adaptation to climate change, it is crucial to recognize their unique socio-ecological characteristics, resources, and cultural aspects. The choice of adaptation strategies depends on the local context, education level, labour force size, access to meteorological information, experiences with drought events, access to financial services, and the availability of extension and technical knowledge.

Furthermore, farmers predominantly employ on-farm strategies, such as the utilization of improved crop varieties, fertilizers, pesticides, soil and water conservation techniques, and adjusted planting dates. These findings align with Gwambene (2020) and Tilumanywa (2021), who suggest that enhancing resilience, improving food security, and increasing income for smallholder farmers require substantial changes in policy and practice. Therefore, it is essential to implement hefty policy and practice changes to promote resilience, enhance food security, and improve income for smallholder farmers.

The government plays a vital role in fostering resilience in the agricultural sector by implementing policies, facilitating agricultural produce marketing, and designing projects involving marginalized groups (CIAT & CARE Tanzania, 2019). However, challenges are associated with limited resources, inadequate infrastructure, and the lack of financial and human resources for collecting and disseminating climate information. The adoption rates of adaptation strategies, particularly among women farmers, still need to improve due to various barriers such as financial constraints, limited market access, and the need for more reliable information. These study findings are consistent with previous research on the factors influencing the choices of farm households in adapting to climate change (e.g., Oxfam, 2011; Gwambene et al., 2015; Nisha, 2019; Barasa et al., 2021; Ojo et al., 2021; Gebre et al., 2023).

Establishing solid linkages between critical components—such as early maturing crops, early planting, drought-tolerant varieties, savings, income diversification, and asset sales—is crucial for enhancing smallholder farmers' adaptive capacity and resilience. Organizations have emphasized improving farmers' adaptive ability and strength to promote food security and increase agricultural productivity. Providing extension services to farmers is of utmost importance as it facilitates the dissemination of technical information, and helps reach previously overlooked sectors, thereby positively impacting agricultural production. Also, exploring more efficient and appropriate agricultural technologies to address labour shortages and improve overall efficiency is crucial. Studies by Gwambene (2011) and Nisha (2019) highlight that smallholder farmers employ multiple adaptation strategies to respond to, and mitigate, the impacts of climate change. While mechanization may be introduced on a broader scale later, developing other suitable technologies for various agricultural operations is necessary. Equally, increasing investments in agricultural research plays a vital role in enhancing the generation and transfer of agricultural technology.

Recommended strategies for achieving resilient and productive agricultural systems include ensuring the effectiveness and broad coverage of extension services, conducting collaborative surveys, promoting enterprise diversification, implementing intercropping practices, providing civic education, encouraging

mixed cropping, and offering fertilizer recommendations specific to different regions. Collaboration among political leaders, community leaders, and research stations; and the promotion of sustainable practices, are also essential.

While widespread mechanization may only be feasible after some time, developing appropriate technologies for various agricultural operations such as planting, threshing, drying, milling, and storage is essential. Furthermore, increasing investments in agricultural research, coupled with effective extension services and broad coverage, are crucial for advancing the generation and transfer of agricultural technology. Collaborative surveys involving research scientists, extension staff, and farmers can help identify socioeconomic conditions, and prioritize interventions accordingly. Recommended strategies include promoting enterprise diversification, intercropping, public education, mixed cropping, and providing area-specific fertilizer recommendations. Collaboration among political leaders and community leaders, facilitating visits to research stations, and promoting sustainable practices are necessary to achieve resilient and productive agricultural systems.

Therefore, to tackle the challenges smallholder farmers encounter in adapting to climate change and environmental changes, it is essential to implement comprehensive policies, boost investment in agricultural research, provide practical extension services, and foster collaboration among stakeholders. By promoting measures that enhance resilience, strengthen adaptive capacity, and support adopting suitable adaptation strategies, smallholder farmers can improve their food security, augment their income, and sustain agriculture development.

5. Conclusions and Recommendations

The study highlighted the challenges confronting smallholder farmers amid the complexities of climate change; ranging from unpredictable rainfall patterns to temperature shifts and extreme climatic events. Despite employing a spectrum of adaptation strategies, their adoption is influenced by factors such as education levels and resource accessibility. Addressing these challenges demands a holistic approach, integrating robust awareness campaigns, targeted training initiatives, and improved accessibility to climate data. Effective collaboration among stakeholders and empowering farmers through technological advancements and supportive policy frameworks are paramount for building resilience, and facilitating a widespread adoption of climate adaptation measures. Encouraging mechanisms like long-term land agreements, and providing training in environmental management, can serve as catalysts for incentivizing sustainable agricultural practices, thereby bolstering food security and ensuring a long-term viability of agriculture in the region. In essence, concerted and multidimensional interventions are essential to empower farmers foster inclusive adaptation strategies, and fortify agricultural resilience in the face of evolving environmental dynamics.

Competing interests
The authors do not have any competing interests in this paper.

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