African Research Journal of Education and Social Sciences, 12(3), 36-47
| ISSN: 2312-0134 | Email: arjessjournal@gmail.com | Website: www.arjess.org

ANALYSIS OF FOOD SECURITY ADAPTATION STRATEGIES EMPLOYED BY FARMERS IN LUSHOTO DISTRICT, TANZANIA

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Abstract

The study sought to analyse the existing adaptation strategies employed by farmers in the Lushoto District. Adaptation strategies to climate change resilience are crucial, especially in addressing food security challenges faced by marginalised communities like those in Lushoto District, Tanzania. Also, the study is both appropriate and relevant as climate change continues to threaten agricultural systems and food availability. The study employed a concurrent research design, which involved both quantitative and qualitative techniques. The study targeted 4084 farmers from four divisions. The study employed a concurrent research design, which involved both quantitative and qualitative techniques. Simple random sampling was used to select 364 farmers, whereas purposive sampling was used to select informants. The study used questionnaires, semi-structured interview guides and observation guides to collect data. Quantitative data were analysed using the Statistical Package for the Social Sciences (SPSS, Version 27.0) and presented in tables and figures. Qualitative data were analysed using content analysis and presented thematically. Additionally, farmers reported using various climate change adaptation strategies, including changing planting dates, soil conservation techniques, agroforestry, water harvesting, and crop diversification. They also reported that the effectiveness of applying the adaptation strategies mentioned was affected by limited finances, insufficient institutional and government support, and inadequate farmers' knowledge of adaptation strategies. The study recommends conducting further research on assessing the long-term adaptation strategies on food security, investigating the role of technologies in adaptation practices and evaluating the effectiveness of various adaptation strategies on improving productivity.

Keywords: *Adaptation, Mitigation, Strategies, food security, agriculture, climate change*

ARJESS Journal African Research Journal of Education and Social Sciences, 12(3), 36-49
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INTRODUCTION

Agriculture is vital for social and economic development. It provides essential materials for industrial development. Agricultural products are a source of human nutrients and energy, improving human health (Tudi, 2021). In Sub-Saharan countries, the increase in temperature, unpredictable rainfall, and environmental decline have contributed to a decrease in agricultural production (Rwegima, 2024; IPCC, 2022). The effects resulted in an increase in food prices and the retardation of children's growth. These impacts have led to the development of adaptation strategies to restore the land and increase agricultural production. Stakeholders encourage farmers to adopt strategies that ensure sufficient food for their households (Edward, 2020).

According to IPCC (2021), the modern and improved agricultural practices minimise the negative impacts caused by an increase in temperature and rainfall variation. These are essential in soil water retention, increasing soil fertility, and environmental conservation, ensuring an increase in food production (Edward, 2020). Additionally, tree planting practices enhance soil carbon absorption, improve biodiversity, control soil erosion, and improve water retention (Schneider,2020). Furthermore, trees provide shade, act as carbon sinks, and enhance the microclimate for crop production (Swai et al., 2021).

Adaptation strategies are increasingly perceived as a vital response to climate change. There are growing efforts among governments, researchers, and communities that adaptation has become a necessary investment for securing livelihoods. Developed countries, such as those in North America, Europe, China, and Italy, view adaptation through technology, with an emphasis on innovation in sustainable agriculture, including prior information systems, insurance schemes, and climate-resistant infrastructure (Romm, 2022). Also, the initiative toward environmental conservation is a better way to improve land management and control environmental pollution (Edward,2020).

Asian countries are making efforts to cope with climate change to improve agricultural systems for high crop productivity. These countries are aiming to shift from the traditional way of crop production to the modern way, which copes with temperature increase and unexpected rainfall, which will improve agricultural production (Pickson et al.,2023). Regarding the Lushoto District, few people near rivers or streams practice irrigation during scarce rainfall

According to Gunaratne et al. (2021), the Sri Lankan government encourages farmers to preserve the environment and use sustainable methods of controlling pollution to the environment. Similar action is taken in Australia to conserve ecosystems (Alves et al.,2020). The poverty of most of the community members in the Lushoto District encourages them to continue using charcoal and firewood, which degrades the environment and increases greenhouse gas emissions.

Baccini's (2023) research, conducted in North America and Europe, reveals that technological development is a major aspect of the impacts of climate change. Adaptation strategies, such as waste management, recycling, composting, and reducing landfill waste, can lower greenhouse gas

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emissions, primarily methane from decomposing organic waste. Proper management of waste systems contributes to resilience to climate change by maintaining a clean environment. Baccini's study was focused on developed countries, whereas the current study was conducted on an underdeveloped country.

Furthermore, the Kenyan government aims to transform unproductive land into more productive areas for the betterment of farmers. Many projects and research are conducted to discover suitable methods of reducing the impacts of climate change and increasing agricultural production. Planting trees on the bare and cleared land helps to rejuvenate the destroyed land into a productive one. The trees are potential in restoring water in the ground, regulating the temperature, adding nutrients to the soil, and maintaining the ecosystems (Cheruiyot et al., 2022).

In Tanzania, several strategies have been introduced to improve agricultural productivity. The practices range from reducing environmental pollution and land conservation to improving soil fertility (Rwegima, 2024). One of the practices is afforestation and reforestation to restore moisture and increase essential nutrients in the soil (Jan 2023).

Tanzania has developed various policies to improve the agricultural sector. One of the policies is the National Agriculture Policy-Kilimo Kwanza (Agriculture first) and the Agriculture and Food Security Investment Plan (TAFSIP) (Rwegima,2024). Also, the government works with NGOs to address food security. The focus was to improve agricultural practices, food assistance, and support the community for sustainable production. Moreover, the government established the National Climate Change Strategy (NCCS) to address the impacts of climate change (Gwambene,2024). The strategies focused on developing the ability of farmers to improve productivity, health, and develop infrastructure for food access and stability.

Lushoto district faces climate change impacts due to increased temperature, changing precipitation patterns, and increased drought, threatening food security. To address the situation, society is encouraged to adopt adaptation and mitigation measures to cope with the impacts of climate change (Mzingula,2020). Climate-Smart Project in Lushoto trains farmers and provides capacity building via village Saving and Credit Cooperative Societies (SACCOs) and encourages the farmers to form their organisations for easy access to resources and subsidies. The project has helped many farmers by providing them with tree plants to plant on their farms (Rwegima, 2024). As such, the current study intended to analyze the adaptation strategies employed by farmers in the Lushoto district, Tanzania

METHODOLOGY

The study employed a concurrent mixed-methods research design, which integrated both quantitative and qualitative approaches. This design was considered appropriate because it allowed for the simultaneous collection and analysis of numerical and descriptive data, thereby providing a comprehensive understanding of the research problem. According to Creswell (2023), the concurrent design enhances the validity of findings by enabling triangulation of data

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from different sources and perspectives. The use of both approaches offered a balanced information into the farmers' experiences and perceptions while ensuring that statistical trends were complemented with in-depth qualitative explanations.

The study targeted a population of 4,084 farmers drawn from four administrative divisions within the Lushoto District. This population was considered sufficient to represent the diverse agricultural practices and socio-economic characteristics of the area. To select participants, the study adopted a simple random sampling technique, which ensures that every member of the target population has an equal opportunity of being included in the study. As Leavy (2022) notes, simple random sampling minimizes selection bias and increases the generalizability of findings. The sample size of 364 farmers was determined using Yamane's (1967) formula, which provides a statistically reliable estimate of sample size based on the total population and the desired level of precision.

Simple random sampling was employed to select 364 farmers from the target population, ensuring that each farmer had an equal and independent chance of being included in the study. This method was appropriate because it minimized selection bias and enhanced the representativeness of the sample, thereby improving the reliability and generalizability of the findings. In addition, purposive sampling was used to identify key informants such as agricultural officers, extension workers, and local leaders who possessed in-depth knowledge and experience relevant to the study. These informants provided valuable qualitative insights that complemented the quantitative data collected from farmers, allowing for a more comprehensive understanding of the research problem.

Both primary and secondary data sources were utilized in the study. Primary data were collected directly from farmers and agricultural officials through field-based instruments, while secondary data were obtained from government reports, agricultural records, and relevant literature to complement and validate primary findings. The main research instruments included semi-structured questionnaires, interview guides, and an observation checklist. The semi-structured questionnaires were administered to the farmers to gather quantitative data on demographic characteristics, farming practices, and perceptions of agricultural interventions. The interview guides were used to collect qualitative insights from district agricultural officers and other key stakeholders, providing contextual understanding and interpretation of the survey findings. In addition, the observation checklist was employed to document on-site conditions such as farm management practices, infrastructure, and the physical environment.

The data collection process was carefully planned and executed to ensure accuracy and reliability. Questionnaires were distributed to farmers with the assistance of trained research assistants, while interviews were conducted face-to-face to encourage detailed responses. After data collection, all responses were compiled, coded, and organized systematically for analysis. Quantitative data were entered and analyzed using the Statistical Package for the Social Sciences (SPSS) Version 27. Descriptive statistics such as frequencies, percentages, means, and standard

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deviations were computed and presented in tables and figures to enhance clarity and interpretation. Qualitative data from interviews and observations were transcribed, categorized into themes, and analyzed thematically to identify recurring patterns and meanings that complemented the quantitative findings.

The study adhered strictly to established ethical research standards. Participation was voluntary, and respondents were informed of the study's purpose, procedures, and their right to withdraw at any time without penalty. Confidentiality and anonymity were maintained throughout the study by ensuring that no identifying information appeared in the final report. Data collected were securely stored and used solely for academic purposes. Furthermore, the researcher obtained relevant permissions from local authorities before fieldwork commenced, ensuring that the study was conducted with integrity and respect for participants' rights and welfare.

RESULTS

Demographic Characteristics of the Respondents

This section presents the demographic characteristics of the respondents based on information collected through questionnaires, interviews, and observations. The aim was to obtain relevant background information for analyzing the current adaptation strategies employed to address food loss in Lushoto District.

The findings indicate that respondents were drawn from a wide range of age groups. A total of 14.3% were aged between 20 and 30 years, 38.7% were between 31 and 40 years, 37.0% were aged between 41 and 50 years, while 10.1% were above 50 years. This shows that the majority of respondents were middle-aged farmers who actively participate in agricultural activities within the district.

Regarding the type of farming practiced, the results reveal that crop farming is the dominant activity in the study area, accounting for 84.6% of the respondents. Mixed farming, which combines crop cultivation and livestock keeping, is practiced by 14.6% of respondents, while livestock keeping alone accounts for only 0.8%. These demographic findings provide a general overview of the composition and agricultural engagement of the farmers involved in the study.

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Food Security Barriers Faced by Farmers

The study sought to examine the key barriers affecting food security among farmers. Figure 1 presents the distribution of respondents based on the food security constraints they experience in their farming activities.

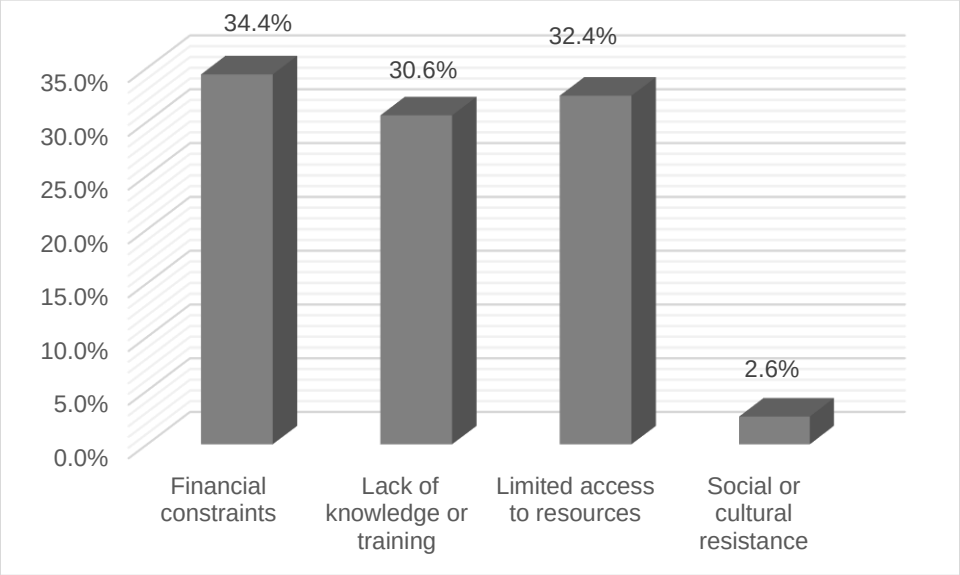

Figure 1: The barriers faced by farmers

The findings reveal the most significant obstacles to implementing the strategies as financial constraints, limited access to resources, and insufficient knowledge or training. The farmers' responses reveal that financial issues challenges are widely acknowledged, with scores of 34%, limited access to resources has a rate of 32%, and insufficient knowledge or training has a rate of 31%, respectively (Figure 1). According to the findings, a significant barrier to the implementation of the adaptation and mitigation measures is financial resources, which hinder access to the resources necessary for resilience to climate change. Moreover, insufficient knowledge or technique training among farmers and local stakeholders hinders the adaptation of the strategies.

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The strategies employed by farmers

The study further sought to identify and document the various strategies employed by farmers to mitigate and adapt to food loss in Lushoto District. Figure 1 shows the distribution of the respondents

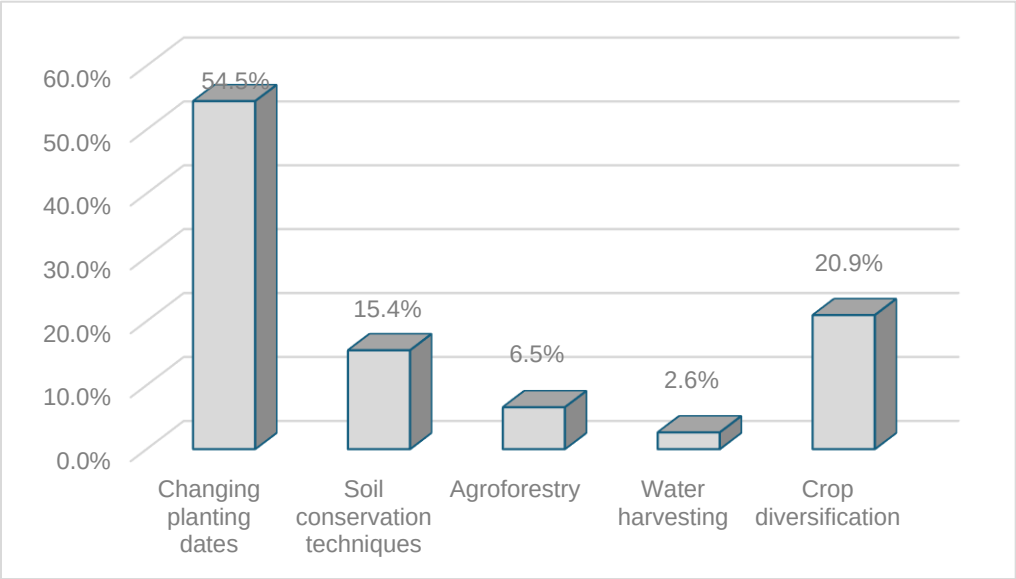

Figure 2: Adaptation practices adopted by the communities

The findings revealed that 54% adopted changing planting dates, 21% crop diversification, and 15% soil conservation techniques. Other practices, such as agroforests 7% and water harvesting 3% also adopted by farmers to create climate resilience (Figure 2). For farmers to build resilience to climate change, they adopted changing planting dates in response to shifting rainfall patterns and temperature regimes. This strategy involves altering the traditional calendar for sowing crops based on current weather conditions as informed by local observation, seasonal climate forecasts, or indigenous knowledge. Moreover, crop diversification is the most common strategy adopted by farmers, from monoculture to growing a variety of crops.

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Climate mitigation measures

The study further sought to identify and document the various climate mitigation measures employed by farmers to mitigate and adapt to food loss in Lushoto District. Figure 2 shows the distribution of the respondents

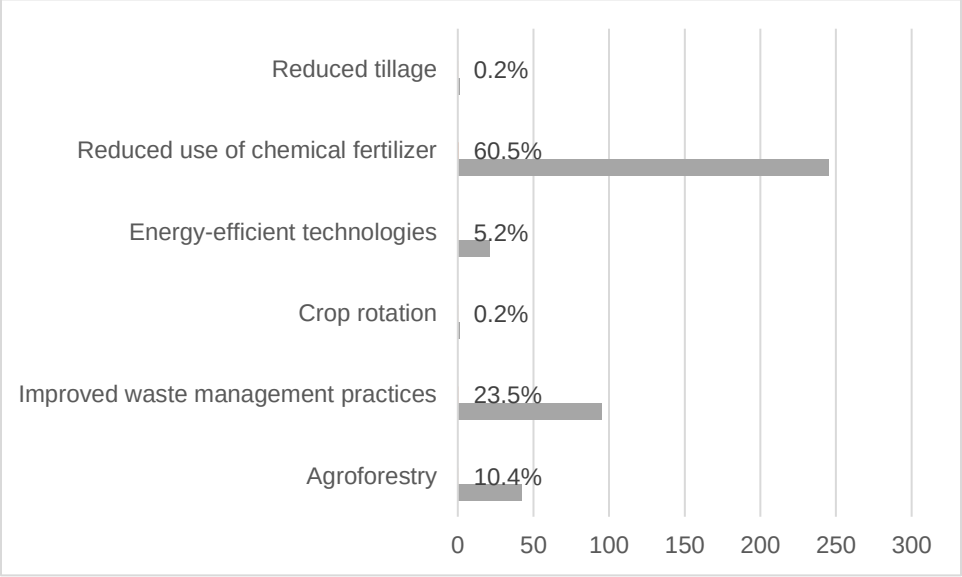

Figure 3: Climate mitigation measures.

The finding revealed that farmers have adopted mitigation practices, such as reduced use of chemical fertilisers 61% of respondents, improved waste management 24%, agroforestry 10% and use of energy-efficient technology 5%.

The reduced use of chemical fertilisers is increasingly being adopted by farmers in the Lushoto District, with 61% of the respondents. The strategy plays a crucial role in improving soil structure and fertility. The use of compost manure improves soil structure, water retention and infiltration, as well as soil fertility to withstand periods of low rainfall and insufficient water. Moreover, the farmers have improved waste management practices by 24%. (Figure 3). Organic waste from the kitchen, animals, and crop residues is converted into compost and used as a natural fertiliser. Moreover, agroforestry is also adopted by farmers, accounting for about 10% of the respondents. The measure is significant in reducing greenhouse gas emissions and encourages carbon sequestration. This method helps farmers improve soil fertility and water retention, facilitate crop production and environmental conservation for sustainable agriculture.

The study further assessed climate adaptation practices used by farmers in the study area, which revealed that the change of crop diversification was most adopted by farmers, accounting for 54% of the questionnaire respondents. Farmers reported altering traditional weather forecasting methods and diversifying crops and the economy to ensure food stability. Their crop

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diversification enhances agricultural productivity and fosters agricultural development. The finding is affirmed by Kumar et al. (2022) and Vaishali et al. (2024), who argued that utilising various crop varieties contributes to food stability, improves soil health, enriches food sustainability, and strengthens food security.

On the other hand, changing planting dates was reported to be adopted by 21% of respondents, water harvesting by 3 %, soil conservation techniques by 15%, and agroforestry by 7%, which implies limited awareness of these methods. The finding also aligns with Detelinora et al. (2023), who argued that soil conservation, crop-tolerant seed, irrigation methods, and agroforestry were adopted, especially in arid and semi-arid regions. The interviewed respondents also reported that crop diversification, irrigation, and changing planting dates are the main strategies employed by farmers in the Lushoto district. Additionally, farmers can adopt rainwater harvesting techniques to store water for irrigation during dry seasons, resulting in increased yields (Sharifi, 2021).

Conversely, 5% of farmers are reported to use energy-efficient technologies, while no farmers reported using reduced tillage and crop rotation. With advancements in science and technology, innovative irrigation methods like drip irrigation and rainwater harvesting can be utilised. The findings affirm the study conducted by Murphy (2021) in Benin and Mali, which revealed that solar-powered irrigation has enhanced productivity and boosted social welfare by improving families' access to education, food, and healthcare. Additionally, water-use-efficient technology has shown promising results in water-deficient regions of Africa and South Asia. These technologies and services have improved food security in areas prone to climate change (Diallo,2020; Fan et al.,2020).

DISCUSSION

The study revealed that the adoption of strategies varies among individual farmers. The major factor for the difference is the understanding of the strategies, awareness, and economic status. The farmers adopt a variety of strategies according to their capabilities and the availability of the resource.

The findings showed that changing planting date strategy was the most widely used in response to shifts in rainfall patterns and temperature regimes. Farmers utilise local observations, seasonal climate forecasts, or indigenous knowledge to cope with the changing climate. The finding reveals that the strategy is adopted by 54% of respondents. In Ethiopia, the focus on adaptation to the calendar for farming has helped food availability (Marie et al., 2020). The idea to change the planting date to the farmers provide a room for food production in Lushoto District.

Farmers are shifting from monoculture to growing a variety of crops, including drought-tolerant species such as sorghum, millet, and sweet potatoes. Crop diversification was adopted by farmers, with 21% of the questionnaire respondents. Farmers reported altering traditional weather

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forecasting methods and diversifying crops and the economy to ensure food stability. The findings are affirmed by Kumar *et al*. (2022) and Vaishali *et al.* (2024), who argued that utilising various crop varieties contributes to food stability, improves soil health, enriches food sustainability, and strengthens food security. in Pakistan, the growth varieties of crops like vegetables, citrus fruits, and orchards benefited the farmers economically (Hussain et al.,2020). The strategy is crucial to the farmers in Lushoto to ensure individual social-economic improvement and food availability.

Reduced chemical fertilisers were the most prevalent method, accounting for 61% of the total respondents. The farmers adopted the strategy for more sustainable soil fertility management practices. The use of organic fertilisers to adapt to climate change has been reported by farmers at a rate of 32.8%. Gamage et al. (2023), survey research done at the University of California, Pacific and New Zealand islands reveals that organic farming from plants and animal waste is essential in improving soil fertility by releasing nutrients to encourage the development of soil structure. The adaptation of these strategies to the farmers in the Lushoto District will improve soil fertility and encourage crop production.

The effectiveness of the strategies varies among individual farmers. Those who have adopted have experienced changes in crop yield production. The finding indicates 54.8% (54.1% somewhat increased and 0.3% gently increased). However, 23.5% reported no change, yet 21.6% observed some decreases in farmers' resilience to climate-related events. Most respondents, approximately 61.3%, reported the practices as somewhat successful, while 0.3% indicated they were very successful. In contrast, 35.3% of respondents reported being somewhat unsuccessful, and 3.1% expressed neutral views. The effectiveness of these strategies depends on farmers' understanding of them and their capacity to afford them. (Gambwene & Saria, 2024). The study supported by the people who have managed to adopt agro-silvo-pastoralism strategies in vulnerable areas along the wetlands. The government has implemented sustainable management of natural resources such as coastal trees and flood breakers (Guja,2024). The strategy is important to the farmers in Lushoto in conserving the wetlands for improving production.

CONCLUSION

This study assessed climate change adaptation and measures to ensure food security in the Lushoto District of Tanzania. The results showed that climate change significantly affects food security, with erratic rainfall patterns, increased temperature, floods, and drought. The study sample in Lushoto, consisting of 364 participants, reported implementing different climate mitigation strategies, including agroforestry, using organic fertilisers, crop rotation, and reduced tillage. Additionally, farmers reported changing planting dates, soil conservation techniques, agroforestry, water harvesting, and crop diversification as climate change adaptation strategies. The farmers also revealed that the effectiveness of the adopted strategies varies from one person to another. The effectiveness of the strategies depends on knowledge, financial resources, and access to resources. However, the participants reported that the effectiveness of applying the mentioned mitigation and adaptation strategy was affected by limited finances, insufficient institutional and government support, and inadequate farmers' knowledge of adaptation and mitigation strategies. While

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respondents reported adopting different climate adaptation strategies, 57% reported noticing an improvement in crop yield since implementing adaptation strategies.

Based on the findings, the researcher recommended increasing the number of trained agricultural extension officers and providing capacity-building workshops for farmers on climate-smart practices. Since the strategies are very crucial for climate change resilience and the improvement of food production, the researcher recommended the integration of traditional knowledge and scientific knowledge to increase production. Also, educating and raising awareness among farmers will enhance the effectiveness and sustainability of the existing adaptation and mitigation strategies employed by farmers.

REFERENCES

Baccini, P., & Brunner, P.H. (2023). Metabolism of the anthroposphere: analysis, evaluation, and design. MIT Press

Conte, C. (2021). The Usambara Knowledge Project: Place as archive in a Tanzanian Mountain Range History in Africa, 48,83-102.

Creswell, W.J. & Creswell, D.J. (2023). Research Design. Qualitative, Quantitative, and Mixed Approaches. Science (General)- Research and Development. Pg. 100-150.

Edwards, C.A. (2020). The importance of integration in sustainable agricultural systems. In sustainable agricultural systems (pp.249–2640. CRC Press

Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, N., Kodikara, N., Suraweera, P& Merah, O. (2023). Role of organic farming for achieving sustainability in agriculture. Farming system, 1(1)100005.

Gwambene, B. & Saria, J. (2024). Smallholder Farmers' Resilience in Adaptation to Climate Change in the Southern Highlands of Tanzania. Journal of the Geographical Association of Tanzania 44 (1)- DOI: 1056279/jgat.v 44i1.277.

Guja, M.M. & Bedeke, S.B. (2024). Smallholders' climate change adaptation strategies: exploring effectiveness and opportunities to be capitalised. Environment, Development, and Sustainability, 1-30

Hussain, M., Butt, A.R., Uzma, F., Ahmed, R., Irshad, S., Rehman, A., &Yousaf, B. (2020). A comprehensive review of climate change impacts, adaptation, and mitigation on environmental and natural calamities in Pakistan. Environmental monitoring and assessment, 192 (1),48.

African Research Journal of Education and Social Sciences, 12(3), 36-49
| ISSN: 2312-0134 | Email: arjessjournal@gmail.com | Website: www.arjess.org

IPCC (2021). Climate change and land. An IPCC Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Cambridge University.

IRENA (2021). Renewable Energy Outlook: Tanzania

Kumar, P., Pandey, A.K., Singh, S.K., Singh, S.S., & Singh, V.K. (2022). Sustainable agriculture systems and technologies. John Wiley & Sons, Incorporated, pp 63–200.

Leavy, P. (2022). Research design. Quantitative, Qualitative, Mixed methods, Arts-Based, and community-based participatory Research Approaches, pp.30-50.

Marie, M., Yirga, F., Haile, M. & Tquabo, F. (2020). Farmers' choices and factors affecting the adaptation of climate change adaptation strategies. Evidence from northwestern Ethiopia. Heliyon, 6(4).

Maro, F., Tenge, A. &Haule, K. (2023). Smallholder farmers' adaptation to climate change: the struggle of adaptive capacity among Ndiwaland Chamazi farmers in Usambara highlands, Tanzania. *Journal of the geographical association of Tanzania, 43(2), 1-23.*

Mkonda, M.Y. (2022). Awareness and adaptations to climate change among the rural farmers in different agro-ecological zones of Tanzania. Management of environmental quality: *An international Journal, 33(6), 1502-1527.*

Ogada, J.M., Radeny, M., Recha, J., & Solomon, D. (2021). Adaptation of complementary climate-smart agricultural technologies: lessons from Lushoto in Tanzania. Agriculture and food security, 10 (1), 55

Rwegima, P.C. (2024). Sustainable development through effective leadership and cultural democracy in East Africa (EAC). Reviewed International Journal of Political Science and Public Administration, 5 (1), 15-34.

Schneider, P. & Asch, F. (2020). Rice production and food security in Asian Mega-deltas: Review on characteristics, vulnerabilities, and agricultural adaptation options to cope with climate change. *Journal of Agronomy and Crop Science, 206 (4), 491-503.*

Swai, O.W., & Mbwambo, J.S. (2021). Agroecological adaptation to climate change in the Usambara Mountains of Tanzania. *Journal of Agriculture and Environment.*

Tudi, M., Daniel Ruan, H., Wang, L., Lyu, J., Sadler, R., Connell, D., &Phung, D.T. (2021). Agriculture, Development, pesticide application and its impact on the environment. *International journal of environmental research and public health, 18(3), 1112*