Enhancing Agricultural Production through Climate Change Adaptation: A Case of Bahi District, Tanzania

Abstract

This article assesses climate change adaptation strategies' contribution to agricultural production in Chipanga A, Chikola and Kigwe villages, Bahi district, Tanzania. The article used a quantitative method. Primary data collection methods include household interviews and field observations. Secondary data are obtained through a literature review, and meteorological data (rainfall and temperature) are sourced from the Tanzania Meteorological Agency. The research incorporated interviews with 254 households. Quantitative data analysis was done using SPSS version 20, which used Excel 2010 to create graphs and tables for descriptive data. Inferential data, aimed at assessing relationships between variables, were analysed through chi-square and t-tests. Smallholder farmers employed various adaptation strategies in the study area, including improved seeds (drought-tolerant and early-maturing crops), fertilizers, intercropping, mixed farming, crop diversification, and irrigation. These strategies exhibited statistical significance ($p < 0.05$). Notably, these adaptation strategies substantially impacted crop production, with 85% of respondents stating that these strategies significantly enhanced crop production ($p < 0.001$) within the study area. The study recommends the improvement of practical knowledge, improving agriculture extension services, provision of credible information on climate change adaptation strategies and quick assistance when needed by smallholder farmers, provision of capital and credit to farmers, as well as the construction of sound agricultural infrastructure system to enhance smallholder farmers' capacity of adaptation hence increased of agricultural production.

Keywords: Climate change; adaptation strategies; agricultural production; Bahi district.

1. Introduction

Agricultural production significantly contributes to the worldwide economy (Gomez-Zavaglia *et al*., 2020). It ensures global food security, delivering a reliable source of safe and nutritious food to accommodate the demands of our growing world population by addressing hunger and malnutrition (Cafiero *et al*., 2018). Moreover, it creates employment and fosters trade and economic expansion (Smith & Gregory, 2013). Global agriculture, forestry, and fisheries employed 866 million people in 2021, and real value-added contribution rose 78% between 2000 and 2020, reaching USD 3.6 trillion (FAO, 2022).

However, Climate change is the biggest threat to agricultural production worldwide (FAO *et al*., 2018). Climate change may shorten growing seasons and force large areas of marginal agricultural potential out of production (IPCC, 2022). Others are changing production seasons and increased pests and diseases, which decrease agricultural production and community livelihood (Edame *et al*., 2011). By 2050, seasonal total precipitation, intra-seasonal temperature, and precipitation variability may affect crop production (Rowhani *et al*., 2011). Domestic agricultural production has already dropped by 10% in certain sub-Saharan African nations and is expected to drop by 50% in others by 2020 (Kangalawe & Lyimo, 2013). In sub-Saharan Africa (SSA), maize, rice, and wheat production is expected to increase to 70% by 2050 to feed the growing population, but instead, it will decrease by 14%, 5%, and 22% respectively (IPCC, 2007). The World Bank also issues a warning, predicting that by 2050, up to 86 million people in sub-Saharan Africa may migrate due to climate change within their nations. With a substantial amount, about 38.5 million, coming from countries in the Lake Victoria region, including Kenya, Tanzania, and Uganda, this would drive individuals, families, and communities to look for more secure living locations (Rigaud *et al*., 2021).

Therefore, adaptation is the global solution to climate change's implications for agricultural production (Klein *et al*., 2015). These adaptation practices typically reduce the risks of exposure to natural hazards associated with climate change and the severity of damages caused. Thus, farmers using climate change adaptation strategies are more likely to be food secure than those not adopting any strategy (Rahman *et al*., 2021). Adaptation to climate change includes growing drought-tolerant crops, early planting, diversifying crop varieties, harvesting rainwater, adjusting to market dynamics through credit and income programs, improving meteorological forecasting, and facilitating access to agricultural markets and information. Africa has the most significant climate change adaptation capacity gap (Antwi-agyei & Dougill, 2013) because of poor infrastructure, technology, corruption, poverty, skills, and institutional capacity (Ajilogba & Walker, 2021). Thus, most smallholder farmers had less capacity to adapt to climate change in their agricultural activities (Frayne *et al*., 2013; Id *et al.*, 2019; Rahman *et al*., 2021).

Climate change is hurting Tanzania's agricultural sector, which has driven the country's economy (Khanal *et al.*, 2018). Climate change caused pests, illnesses, droughts, and floods in some parts of Tanzania, resulting in low agricultural production (Kangalawe *et al*., 2017). About 80% of rural Tanzanians depend on rain-fed agriculture for food and income, and 40% of its land is semi-arid, making it more vulnerable to climate change (Augustino *et al*., 2013; Clapp *et al*., 2018). According to the National Adaptation Plan for Action, climate change will harm large areas of the economy, food security, and how people make a living(Paavola, 2008). Low agricultural production is caused by protracted dry seasons, drought, irregular rainfall, cropping patterns, weeds, pests, and illnesses (Shemsanga *et al*., 2010). Adaptation is agreed to reduce the impacts of climate change on agricultural production (Komba & Muchapondwa, 2012). Thus, Most Tanzanian rural families adopt climate change adaptation strategies to enhance agricultural production and subsistence farmer livelihoods in vulnerable conditions (Ndiritu & Muricho, 2021; Klein *et al*., 2015).

Tanzanian climate change adaptation options include soil erosion prevention, improved seeds, fertilizer, mulching, planting date adjustments, mixed agricultural irrigation, water conservation, and agroforestry (Urwin & Jordan, 2008). These adaptation strategies are expected to reduce the adverse effects of climate change on agricultural production and improve food security in a community, but their performance varies by place and time due to socio-economic, socio-cultural, geographical location, institutional feasibility, and environmental factors (IPCC, 2022; Lobell *et al*., 2008; Marie *et al*., 2020; Rowhani *et al*., 2011).

Several studies have been conducted discussing climate change and adaptation to agriculture activities by different researchers Worldwide (Antwi-agyei & Dougill, 2013; Malekela & Lusiru, 2022; Kangalawe *et al*., 2017; Jha & Gupta, 2021; Alemu & Mengistu, 2019; Mongi *et al*., 2010) Although the existing vulnerability studies have limitations, with a need for a broader scope. Climate change varies within countries, demanding higher-resolution data for adaptation policies, even at sub-national levels. These studies often rely on small household surveys in limited geographic areas. To overcome these limitations, more extensive research is required. Therefore, this research aims to enrich the existing literature by exploring the role of adaptive strategies within Bahi district. A robust empirical connection between adaptation strategies and the improvement of agricultural production established by addressing the aim by answering two questions: 1) What do smallholder farmers conduct the current adaptation strategies in the study area, and 2) what is the contribution of those adaptation strategies in enhancing agricultural production? Our discoveries carry significant implications for policy initiatives designed to promote and support climate change adaptation in Bahi district and similar semi-arid regions, as they shed light on how it contributes to improving agricultural production. Moreover, documentation of a comprehensive record of the effective contribution of adaptation strategies provides a roadmap for long-term planning.

2. Research Methodology

2.1 Descriptions of the study area.

This study was conducted in Bahi District, in Dodoma region - Tanzania. The district is among six districts found in Dodoma region of central Tanzania. It is located between Longitudes 35° and 37° East and between Latitudes 4° and 8° South of the Equator (Swai et al., 2012). The district is bordered by Chemba District in the North, East by Chamwino and Dodoma Districts, and in the West, it is bordered by Singida Region. Bahi District is subdivided into four divisions, constituting 20 wards and 56 villages (URT, 2010).

The climate of Bahi district is characterized by a savanna type of climate having long, dry seasonal (Myeya, 2021a); the annual rainfall is around 500-700mm, and has bimodal rainfall from December to April for 70 to 90 days in a year, (URT, 2010). Rainfall amount is low, unpredictable in frequency, amount, and distribution, and sometimes it is characterized by a heavy storm resulting in a flood. The annual average temperature is 22.6°C, having a semi-arid climate characteristic with warm temperatures all over the year (Swai *et al*., 2012)**.**

Bahi's economy is 80% agricultural. Smallholder farmers run the sector. Other economic activities include livestock, fishing, and wildlife. Salt mining at Mpamantwa, Lamaiti, Chali, Kigwe, and Ilindi wards and gold at Mafurungu hills may boost the district economy. Bahi district is 13% of Dodoma Regional. 378,207 hectares (70%) of 544,842 are arable. 164,637 (44%) of arable land is used, indicating that much of it is underutilized (URT, 2010).

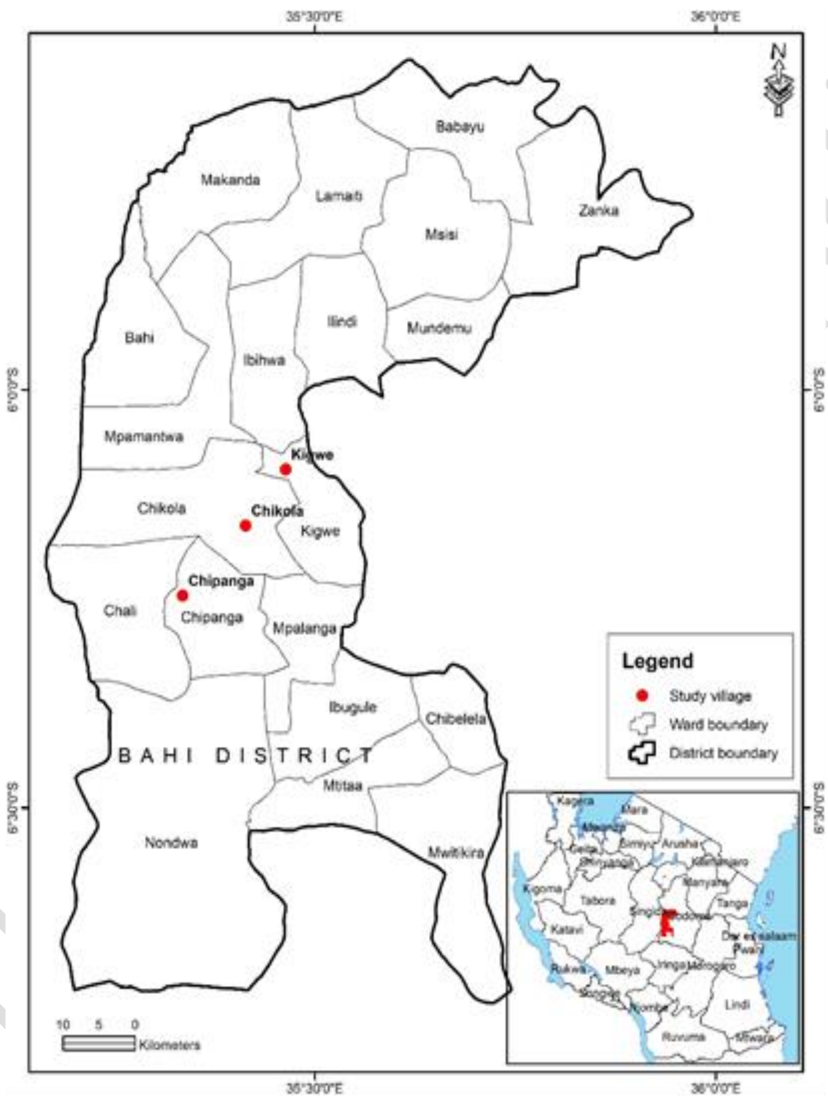

Figure 1: Geographical location of the study area.
Source: Institute of Resources Assessment GIS laboratory, University of Dar es Salaam (2021).

2.2 Research design, sampling procedure and sample size

The research adopted a quantitative approach, incorporating descriptive and inferential design strategies. This approach was employed to understand better how climate change adaptation strategies enhance agricultural production. Descriptive and inferential studies in research not only aim to uncover factual information but also have the potential to establish fundamental principles of knowledge and offer solutions to substantial problems, as Neuman (2007) suggested.

Probability and non-probability sampling techniques used to select respondents for quantitative data collection, aiming to minimize errors and ensure study reliability. The study chose an average sample size of 10% of all households across three villages (Chipanga A, Chikola and Kigwe villages), supported by Cresswell (2014) assertion that this provides sufficient statistical significance. Kothari (2004) recommended a minimum 5% representative sample size which have at least 30 units. With 2,527 households across the villages, the study selected 254 households (72, 88 and 94 households from Chipanga A, Chikola and Kigwe villages respectively) through random sampling, ensuring fairness and equal representation in the sample. This approach balanced resource constraints with research objectives, allowing for meaningful insights.

2.3 Data collection

Primary data collected through survey method using household questionnaire survey technique whereby semi-structured household questionnaire employed as a tool to obtain information on the existing and potential contributions of climate change adaptation strategies to enhancing agricultural production. Secondary data collected through literature survey using document review technique whereby published and unpublished archive information from relevant offices and internet utilized.

2.4 Data analysis

The quantitative data from the household survey were organized and analyzed statistically using Statistical Products and Service Solution (SPSS IBM Statistics, 20 edition) and Excel 2010 softwares. Descriptive statistical analysis conducted to obtain measures of central tendencies and dispersions. Inferential statistical analysis conducted to see relationship between variables using chi-square and T-tests. Analysed data were presented through statements, tables, and graphs.

3. Results

3.1 Types of Adaptation strategies used in the study area.

The household sample demographics encompassed 32.4% women and 67.6% men, aged 20 to 78 years and an average age of 44. Regarding education, the majority (59.4%) had completed primary school, 12.1% had secondary education, 3.8% had tertiary education, and 24.6% were not attending school. The results show that 89.5% of the respondents applied at least one adaptation strategy to reduce climate change's impacts on their agricultural activities. The existing adaptation strategies identified in the study area are shown in Table 1. Results show that improved seeds, intercropping and mixed farming, and early maturing crops are commonly adopted climate change adaptation strategies across all three villages; also, the prevalence of specific strategies differed. Chipanga A Village, for example, had higher adoption rates for uses of fertilizer and irrigation; Kigwe showed a higher percentage of respondents using drought-tolerant crops and early maturing crops, while Chikola showed the adoption of Intercropping and uses of improved seed. These results highlight the localized nature of adaptation strategies based on village-specific conditions and needs.

These strategies show relatively high percentages, indicating their significance in mitigating the impacts of climate change on agricultural activities. Conversely, irrigation, tillage, and crop rotation are less commonly practiced in all three villages, with lower percentages. The chi-squared test results and p-values indicate the significance of differences in the villages' adoption of these strategies. For example, using fertilizers and crop rotation significantly differ among villages, as low p-values indicate.

Table 1: Existing Climate change adaptation strategies in study areas

CC Adaptation strategies	Chikola	Chipanga A	Kigwe	Total	X^2	P-value
Uses of fertilizers	44.3	68.1	24.5	41.3	29.212	0.000
Improved seeds	80.7	93.1	91.5	75.6	7.381	0.025
Drought tolerant Crops	56.8	70.8	75.5	68.1	7.727	0.021
Early maturing crops	62.5	72.2	80.9	71.8	7.602	0.222
Irrigation	6.8	34.7	3.2	12.5	3.0080	0.022
Crops rotation	25	9.7	11.7	15.7	16.236	0.000
Inter and mixed	87.5	59.7	86.2	79.1	7.040	0.002
Planting dates	29.5	4.2	12.8	16.1	23.451	0.000
Crop diversification	38.6	18.1	26.6	28.3	9.333	0.009
Tillage	3.4	5.6	9.6	6.3	9.333	0.009
Mulching	16.8	14.2	18.5	16.5	5.901	0.012

Source: Household field survey, (2021).

3.2 The contribution of adaptation strategies in enhancing agricultural production.

The T-test paired sample analysis results demonstrate a highly significant increase in crop production after implementing various adaptation strategies across the study area, as shown in Table 2. All tested adaptation strategies, including the use of fertilizer, improved seeds, mulching, inter/mixed cropping, crop diversification, and irrigation, show statistically significant increases in crop production.

The p-value of 0.001 for each adaptation strategy indicates a strong significance level, suggesting that the differences in crop production before and after implementing these strategies are not due to random chance.

All adaption options increased mean agricultural production significantly when comparing mean and Standard deviation agricultural production before and after practicing adaptation strategies see Table 2. Fertilizers increased productivity significantly, with the mean production standing out. Mean production levels increased with improved seed, mulching, inter/mixed cropping, crop diversification, and irrigation. However, these strategies' standard deviation (SD) of output outcomes differed. Irrigation had the largest SD, implying more significant outcome variability for adopters. Concerning outcomes, these data show that various adaptive strategies improve agricultural production.

Table 2: T-test Paired sample analysis result on production after and before using adaptation strategies

	PB Mean	**SD**	**lower**	**upper**	**PA Mean**	**SD**	**lower**	**upper**	
Fertiliser	7.68	1.86	7.2	8.15	14.74	4.5	13.59	15.89	0.001
Improved seed	7.61	1.6	7.29	7.93	15.61	3.72	14.93	16.31	0.001
Mulching	7.86	2.36	7.09	8.64	16.18	3.78	14.94	17.42	0.001
Inter/Mixed cropping	8.21	2.17	7.49	8.92	15.05	2.55	14.21	15.89	0.001
Crop diversification	7.53	1.73	6.88	8.18	16.23	2.38	15.34	17.12	0.001
Irrigation	17.03	3.82	15.58	18.49	30.17	4.43	28.52	31.89	0.001

CLD = Confidence level of differences**, SD =** Standard deviation, **PB** = Production before, **PB** = Production before

Source: Household field survey, (2021).

Note: To synthesise the results of Table 2 and make them simpler to interpret, we take total agricultural production in bags (1 bag = 100 kg) before practicing adaptation strategies by calculating its mean and Standard deviation and comparing them to the Mean and standard deviation of the agricultural production after practicing adaptation strategies per season.

4. Discussions

Confirming varied adaptation strategies among Bahi district smallholder farmers and their favorable impact on agricultural production is crucial. This diversity recognizes the necessity for localized climate change solutions. These methods boost agricultural production, which is essential for food security and farming communities' climate resilience. This research can inform policy decisions and support mechanisms, allowing governments and organizations to scale up effective adaptation measures and create more resilient and sustainable agricultural systems. According to Table 1, agriculture's climate change adaption strategies vary widely across study areas. These differences reflect local conditions, resources, and farmer preferences. It is vital to recognize that climate change adaptation has no single solution. Strategies should be context-specific to solve local problems.

Improved seeds are the most extensively utilized adaptation strategies across all research areas. The substantial adoption of better seed types demonstrates that farmers appreciate their importance in minimizing climate change's effects on agricultural production. Agricultural resilience is improved through breeding seeds with drought tolerance, disease resistance, and higher yields. This improvement in crop yield indicates that improved seeds significantly impacted agricultural productivity in the study area. It was noted that despite other supporting factors in drought conditions, using quality seeds of high-yielding varieties was the main factor in increasing agricultural production and enhancing household food security. A similar finding from *Singh et al*. (2013) reported that improved seed was crucial in agricultural communities due to the climatic situation, as many farmers acknowledged that it increased food security through improved crop productivity. Also, Bekele (2017) reported that through improved seeds in Southern Ethiopia, there was evidence of an increase in crop production, an improvement in household income, and the sustainability of food security.

Irrigation is not commonly used in these areas due to the absence of wetlands. Water scarcity poses a significant challenge in the villages of Kigwe and Chikola due to excessive drought and declining rainfall. However, farmers in these villages acknowledge that irrigation can be a highly effective strategy for mitigating the impacts of climate change on their crops. They view irrigation as a proactive approach to addressing the challenges of changing climate conditions. In Chipanga, A village, they partially practiced irrigation using traditional methods and water pumps, demonstrating farmers' adaptability to utilize available resources. These findings align with previous research by Levira (2009) and Finger *et al*. (2011), which emphasizes the importance of adopting irrigation in reducing the vulnerability of small-holder farmers to drought and enhancing food security.

As evident in Table 1, intercropping and mixed farming strategy entails cultivating different crops concurrently on a single piece of land, such as sorghum/millet alongside groundnuts or lablab, sunflower with green peas, and maize with groundnuts in the study area. Its primary objective is to minimize the risks associated with crop failures resulting from unfavorable weather conditions or pest infestations. The consistent findings from Myeya (2021b) in Bahi and Kongwa districts corroborate the widespread adoption of intercropping and mixed farming among smallholder farmers to bolster food security and reduce crop-related risks. Furthermore, this practice yields environmental benefits, including improved soil moisture, nutrient levels, structure enhancement, and natural weed control. Incorporating legumes into this approach provides green manure, fostering better plant growth. A similar finding was reported by (Thornton *et al*. (2014) that mixed crops played a significant role in reducing the severity of the effects of climate change on food security in developing countries as they helped increase crop production. Thus, mixed farming was very much needed in developing countries to sustain food security from the effects of climate change for a growing population (Thornton *et al*., 2010).

Organic manure fertilizer, mainly applied to rice and maize crops and commonly practiced in Chipanga A, compared to Kigwe and Chikola villages, significantly contributed to soil fertility and increased yields, improving agricultural production. This aligns with previous research, including studies by (Yanda *et al.*, 2010) and Altieri *et al*. (2015), which emphasize the positive impact of organic manure on soil health and crop production. Additionally, the combination of mulching and manure application showed potential for carbon sequestration and enhanced yields, in line with findings by Clottey *et al*. (2015) highlighting the benefits of using fertilizer to increase agricultural production rates by 60 to 70%. Moreover, Boulanger *et al*. (2022) argued that applying fertilizer in farms for crop production was crucial in doubling crop production, facilitating the increase of household income and food security in Kenya. Also, Stewart & Roberts (2012) held the same opinion as the findings from this study; they argued that fertilizers had a crucial role in boosting crop production, especially cereal crops, but needed to provide an appropriate and balanced supply of all nutrients.

4. Conclusion and recommendation

This changing climate has significantly affected agricultural production and other livelihood activities in the study area. Different climate change adaptation strategies were conducted by smallholder farmers to reduce the impacts of climate change, such as the use of improved seeds, which involves planting drought-tolerant crops, planting of early maturing crops, use of fertilizers, intercropping and mixed farming, crop diversification, and irrigation, were significant ($p< 0.05$). The statistical analysis of the performance of climate change adaptation strategies in the study area showed a significant increase in crop production after implementation ($p<0.001$). These findings suggest that these adaptation strategies positively and significantly impact agricultural production in the study area, which is crucial for addressing the challenges posed by climate change. Farmers who implemented these strategies experienced substantial improvements in crop yields, as indicated by the significant differences in mean crop production before and after implementation. The study recommends empowering smallholder farmers to practice climate change adaptation strategies by providing practical knowledge and capital support. Moreover, the government should prioritize mitigation policy to address climate change and invest in sustainable farming technology. For agricultural production success, prioritize adequate watering. Thus, policies should focus on building effective irrigation facilities.

5 Compliance with ethical standards

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