# The Effects of Climate Change and Non-climatic Stressors on Crop Production in Bahi District, Tanzania

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**Abstract**

Climate change significantly threatens crop production by reducing yields, increasing pest and disease prevalence, and stunting plant growth. This study examines the combined effects of climate change and non-climatic factors on agricultural production in Bahi District, Tanzania. Grounded in the resilience theory and crop modelling, the study employs a mixed-methods approach, integrating quantitative and qualitative data. Primary data was collected through 254 household surveys, 3 focus group discussions, and 30 key informant interviews. Secondary data was obtained from published and unpublished sources. Quantitative data was analysed using Excel 2010 for descriptive statistics, and SPSS (version 20) for inferential analysis; employing chi-square tests to assess variable relationships. Crop production trends were analysed using the Mann-Kendall test. The findings indicate that climate change is the dominant factor affecting crop production, exacerbating existing vulnerabilities. However, non-climatic stressors such as limited access to capital, inadequate government support, water scarcity, and insufficient agricultural knowledge further constrain farmers' production. The study concludes that strengthening farmers' adaptive capacity through improved financial access, extension services, and climate-resilient farming techniques is crucial. Also, policymakers should promote climate-smart agriculture, enhance rural infrastructure, and facilitate knowledge-sharing initiatives to build resilience and ensure sustainable agricultural production in Bahi District.

**Keywords:** *climate change, crop production, non-climatic factors, agriculture, Bahi District*

## 1. Introduction

Climate change is a serious global concern that considerably impacts agricultural production, food security, and rural lives (Alotaibi, 2023). Human-caused activities—such as deforestation, industrialization, and rising greenhouse gas emissions—have resulted in unprecedented climate change during the last century (Abbas & Mayo, 2021). According to studies on climate, global temperatures have risen by about 0.9°C since the nineteenth century (Kemal et al., 2022; Zalasiewicz et al., 2011); with projections indicating a further increase of up to 1.5°C by 2050 if current environmental degradation and carbon emissions continue (Calzadilla et al., 2013a). This warming trend has exacerbated extreme

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weather events such as protracted droughts, irregular rainfall, heat waves, and flooding: all of which pose significant hazards to global agricultural systems (Gomez-Zavaglia et al., 2020).

Agriculture—the largest consumer of freshwater resources globally—is highly vulnerable to the impacts of climate change (Calzadilla et al., 2013b; Malekela et al., 2022). Long-term changes in precipitation and temperature are expected to significantly affect agricultural production by altering cropping seasons, limiting crop adaptability, and increasing the incidences of pests and diseases (Ajilogba et al., 2021; Kangalawe et al., 2017). These implications are especially concerning for key crops like maize and wheat. By 2030, maize yields in tropical regions could drop up to 24%; while wheat yields may increase by approximately 17%, especially under high greenhouse gas emission scenarios (Alotaibi, 2023). The adverse impacts of climate change will be more noticed in dry and semi-arid environments (IPCC, 2022).

In dry and semi-arid environments, short growing seasons, water scarcity, high temperatures, and heat stress during crop reproductive periods can decrease production by 6 to 18% (Alotaibi, 2023). According to FAO (2018), if current climate trends continue, key cereal crops are expected to incur considerable production losses by 2100, with wheat yields declining by 5 to 50%, maize by 20 to 45%, and rice by 20 to 30%. Such decreases in agricultural yields are projected to increase worldwide food shortages and raise food costs.

Agriculture is the backbone of Tanzania's economy, with crop production being heavily reliant on rainfall (URT, 2021), leaving it extremely sensitive to the effects of climate change. In addition to climate change and variability, Tanzania's agricultural sector faces several economic, social, and policy challenges; all of which have an impact on the resilience and adaptability of farming systems (Batenga et al., 2023; Ilomo et al., 2024; Kangalawe et al., 2013). Limited access to credit and financial services, poor infrastructure, insufficient extension services, insecure land tenure, and insufficient government investment in rural development: all these impede smallholder farmers' ability to adapt to climate change, making it challenging to manage climate risks and maintain agricultural production effectively (Myeya, 2021b; Swai et al., 2012).

Scholars—such as Gebre et al. (2023), Kabote et al. (2024) and Sindato et al. (2023)—emphasize the importance of comprehensive and context-specific climate adaptation methods in Tanzania's agriculture sector to increase resilience. Adopting drought-tolerant and pest-resistant seed types, increasing irrigation systems, and supporting agro-ecological practices to promote soil fertility, water retention, and biodiversity: all are important initiatives to be taken (Gebre, et al., 2023; Mwamahonje et al., 2021; Xiong et al., 2020). When these initiatives are combined with community knowledge, supportive institutional frameworks, and adaptive policy measures, they can dramatically improve Tanzania's agricultural systems' resilience and sustainability in the face of changing climate conditions.

Despite the growing body of research on climate change and agriculture, a key knowledge gap remains in understanding the interplay between climate change and non-climatic stressors, and their combined effects on crop production at the local level. Most studies focus on climatic or non-climatic factors, rather than analysing how they interact to shape agricultural outcomes. Therefore, this study aimed to bridge this gap by investigating how climatic and non-climatic stressors influence crop production in Bahi District, Tanzania. Specifically, the study sought to answer the following research questions: (i) What are the implications of climate change on crop production? (ii) What non-climatic factors influence crop production in the study area? (iii) How do climate change and non-climatic factors interact to affect crop production?

The remainder of this article is structured as follows. Section 2 provides the theoretical and conceptual framework, while section 3 details the research methodology. Section 4 presents the results and discussion, and section 5 provides the conclusion and policy recommendations.

## 2. Theoretical and Conceptual Framework

This study integrates the resilience theory and crop modelling to comprehensively understand how climate change and non-climatic stressors affect crop production. The theory explains how farming systems absorb disturbances, adapt, and transform in response to external shocks (Bousquet et al., 2016). In parallel, crop models simulate the impacts of climate variables such as increased temperatures, erratic rainfall, and extreme weather events on crop growth and yields (Pasquel et al., 2022). By combining these theoretical approaches, the conceptual framework focuses on climate change's varied consequences on agriculture, such as increasing temperatures and prolonged dry spells that deplete soil moisture, limit plant development, and reduce yields.

Unpredictable rainfall disrupts planting cycles, causing poor germination and crop loss. Floods and storms degrade vital topsoil, ruin farmland, and spread pests and diseases. Rising production costs, increased investments in irrigation, insecticides, and improved seeds, restricted resource availability, financial constraints, market instability, and insufficient government backing: all these impede the implementation of climate change adaptation strategies. Farmers in Tanzania's Bahi District address these difficulties by adjusting planting seasons, using drought-resistant crops, establishing irrigation systems, and diversifying revenue sources. This integrated framework explains the immediate environmental and socioeconomic effects of climate change on crop production, and directs the creation of policies and actions to strengthen agricultural systems.

## 3. Methodology

### *3.1 Description of the Study Area*

The study was conducted in Bahi District, Dodoma Region, in central Tanzania, between longitudes 35° and 37° east and latitudes 4° and 8° south of the equator.

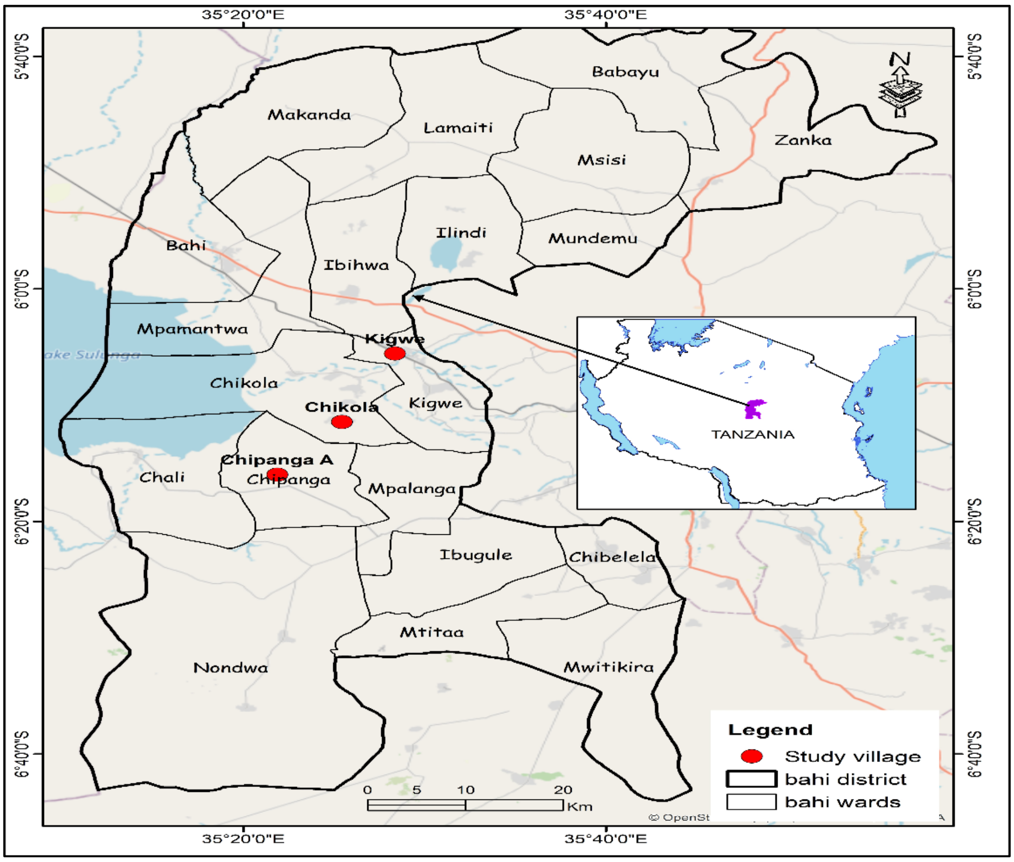


**Figure 1: Geographical Location of the Study Area**
**Source:** IRA GIS Laboratory, University of Dar es Salaam, 2021

The district shares borders with Chemba district to the northeast, and Chamwino and Dodoma districts to the West. The district has a savanna climate with a long, dry season; and annual rainfall ranging from 500-700mm (Myeya, 2021a). The area experiences bimodal rainfall between December and April, lasting 70 to 90 days yearly (URT, 2010). It has an average annual temperature of 22.6°C (Swai et al., 2012). The area was selected for the study because of the district's semi-arid climate, with most of its population (about 80%), relying on agricultural activities, which makes the area vulnerable to the effects of climate change (URT, 2010).

### *3.2 Research Design and Sampling*

This study employed a mixed-methods approach, integrating both quantitative and qualitative research methods to comprehensively assess the impacts of climate change and non-climatic stressors on crop production.

### *3.3 Data Collection*

The study employed primary and secondary data collection techniques to gather comprehensive information. Primary data was collected through household surveys conducted with 254 randomly selected households using structured questionnaires. Three focus group discussions (FGDs) were conducted, one in each village, using participatory tools like historical timelines and seasonal calendars to explore climate change impacts, non-climatic stressors, and adaptation strategies. Key informant interviews (KIIs) with 30 experts provided institutional perspective on climate challenges.

Secondary data provided empirical foundation for analysing crop production trends, ensuring accuracy and contextual relevance. The crop production data was acquired from local government reports, and from published or unpublished research on climate change impacts in Bahi District. We also conducted a comprehensive literature review on climate patterns, adaptation measures, and socio-economic impacts of climate change on agriculture. The reports and literature were synthesized to support and contextualize the findings from the primary data sources. To enhance the validity and reliability of the study, data from household surveys, FGDs, KIIs, and physical observations were systematically triangulated.

### *3.4 Data Analysis and Interpretation*

The data from the household survey was analysed using the SPSS (20th edition) and Excel 2010 softwares to process descriptive and inferential statistics. Descriptive statistics, such as frequencies, means, and percentages, were used to summarize the effects of climate and non-climatic stressors on crop production. Inferential statistics were applied to examine the relationships between climate change and non-climatic stressors, and their effects on crop production. Qualitative data obtained from FGDs and KIIs were analysed using content analysis, where responses were categorized into themes based on recurring patterns. The findings from participatory assessments—such as historical timelines and seasonal calendars—were also analysed during group discussions, ensuring that community narratives were systematically interpreted and triangulated with the survey results.

The Mann-Kendall test and simple linear trends were employed to analyse agricultural production trends. The test is a non-parametric statistical test used to detect trends in time-series data without assuming a specific distribution. It assesses whether there is a significant increase or decrease in crop production trends over time. A p-value $\leq 0.05$ indicates a statistically significant trend, suggesting a meaningful upward or downward shift in agricultural production due to climate or non-climate factors. Conversely, a p-value $> 0.05$ suggests the trend is not statistically significant.

Additionally, a simple linear trend analysis was used to determine the rate and direction of change in agricultural production. The intercept in this analysis represents the expected value of crop production when all independent variables (such as climate and non-climate stressors) are held at zero. If the intercept is high, it suggests that baseline production levels are stable even without external changes. However, a low or negative intercept may indicate pre-existing challenges affecting production.

## 4. Results and Discussion

### *4.1 Effects of Climate Change on Crop Production*

Climate change and the increasing frequency of extreme weather events threaten crop yields and agricultural stability in Bahi District (Table 1). Statistical analyses confirm the significant impact of climate change on agricultural production. Results from the chi-square test show that farmers' perceptions of climate-related effects differ significantly across villages ($p = 0.002$). Approximately 37.5% of the respondents reported reduced crop yields, with village-specific figures of 39.1% in Chikola, 38.9% in Chipanga A, and 35.1% in Kigwe (Table 1).

**Table 1: Percentage of Response to the Effects of Climate Change on Crop Production**

| Effects (multiple answers) | Chikola (*n*=88) | Chipanga A (*n*=72) | Kigwe (*n*=94) | Total (*n*=254) |
|---|---|---|---|---|
| Reduced crop production | 39.1 | 38.9 | 35.1 | 37.5 |
| Crop shifting and abandoned | 8 | 9.7 | 13.8 | 10.7 |
| Increased pest and diseases | 21.8 | 16.7 | 16 | 18.2 |
| Crop retardation | 6.9 | 5.6 | 8.5 | 7.1 |
| Decreased household food availability | 12.6 | 12.5 | 12.8 | 12.6 |
| Reduced water sources | 10.3 | 9.7 | 10.6 | 10.3 |
| Non-farm work | 2.3 | 1.4 | 3.2 | 2.4 |
| Reduced pastures, livestock/ milk | 14.9 | 15.3 | 13.8 | 14.6 |

**Source:** Field survey, 2021

The FGDs reported that the changing climate impacted crop production as farming activities depended much on rainfall and temperature; thus, when rain and temperature were below or above the requirements of the crops, production was reduced, resulting in crop destruction and low production. An agriculture officer X, from Kigwe village, disclosed that crop production declined daily due to prolonged drought associated with the drying of crops. The findings indicated generally that all the crop production in Bahi District decreased. Maize production decreased even more due to low rainfall, prolonged drought, late onset of rainfall, and early cessation of rainfall: all of which prevented maize from maturing or drying up. Thus, many farmers stopped cultivating maize, especially in Chikola and Kigwe villages. One key informant in Kigwe explained this situation thus:

> *"Crop production was decreasing day-by-day, especially maize in Kigwe Village, where almost all farmers had abandoned cultivation due to drought, late onset of rain or early cessation; which affected the growth of maize. Maize production was low as this particular crop has low capacity to tolerate drought conditions. The more suitable the amount of rainfall, the higher the production. Other crops, such as millet and sorghum, require high inputs to grow adequately, but their production was also very low."* ***(KII Participant M in Kigwe Village, October 15, 2021).***

The findings correlate with Clottey et al. (2015), who reported that the average rainfall requirements for maize production are between 800mm and 1500mm per year, so the low average rainfall in the Bahi District lead to low maize production. Kangalawe et al. (2013) reported an average decrease in maize production in Tanzania at 33%. However, in Central Tanzania, especially in Dodoma and Tabora, there was an average decrease of 84% due to increased temperature. Yanda et al. (2010) reported similar results in Moshi Rural District, where climate change resulted in low banana yields.

In addition to declining yields, other reported impacts include increased pest and disease incidences. Farmers in Bahi District noted a strong link between increased agricultural pests and diseases and climate change. They observed that increasing temperatures had produced ideal conditions for the spread of pests, weeds, and crop diseases. The pests and diseases frequently reported were stalk borers in maize, aphids in sorghum and cowpeas, cutworms in millet, and leaf spot diseases in sorghum and groundnuts. Farmers in groundnut production areas notably reported a considerable increase in seed rot and seedling blight, particularly during the 2019/2020 season, when severe rains caused flooding and waterlogged conditions. Also, high moisture levels generated suitable conditions for fungal infections, resulting in a widespread rotting of peanut seeds and young plants, thereby reducing crop yields.

Water shortage was a key setback in the study area, caused mostly by rising temperatures and increasingly unpredictable rainfall patterns. These changes drastically lowered the availability and dependability of water supplies for irrigation. The FGDs revealed that wetlands, which were once crucial for irrigation, had dried up owing to prolonged dry spells and increased evaporation rates caused by climate change. Benson et al. (2015) had similar findings in Yatta, Kenya, where environmental degradation, combined with climate-induced droughts, resulted in severe water shortages, significantly affecting agriculture.

An average of 10.7% of the respondents noted crop shifting or abandonment: 8% in Chikola, 9.7% in Chipanga A, and 13.8% in Kigwe. This suggests that farmers were beginning to adjust—or even abandon—traditional cropping practices due to changing climate conditions; reflecting the increasing unsuitability of certain crops under prolonged temperature and precipitation variability. Beyond crop impacts, smallholder farmers also reported broader climate-related livelihood challenges. Approximately 12.6% of the respondents across the villages reported reduced household food availability, indicating emerging food insecurity risks. Water availability for farming also declined, with 10.3% of the respondents citing reduced access directly affecting irrigation and crop performance.

Furthermore, off-farm employment was reported by a modest percentage (averaging 2.4%), suggesting early signs of livelihood diversification in response to agricultural uncertainties. These findings suggest that climate stressors—particularly high temperatures, unpredictable rainfall, and extreme weather events—disrupt crop growth, reduce production, and increase vulnerability to pests and diseases. Similar to global patterns, these changes threaten the resilience of farming systems; and may lead to the loss of crop varieties and their associated genetic resources if they are no longer cultivated (Gitz et al., 2016). These findings show how climate change alters agricultural production and rural livelihoods in Bahi District via direct and indirect channels. They also highlight the critical need for localized and integrated adaptation strategies that address these climatic and socioeconomic challenges of the communities.

A time-series analysis—using the Mann-Kendall test (Table 2, Figures 2, 3 and 4)—further supports these findings. The data trends show that while millet production increased significantly (Sen's slope of 1252.667, p = 0.005), and maize shows a rising tendency (Sen's slope of 1933.160, p = 0.064), rice and cassava yields were declining (p = 0.837 for both). Sorghum exhibits a modestly positive trend (Sen's slope of 532.876, p = 0.077).

**Table 2: Trend Analysis of Crops in Bahi District**

| Crop Type | S | $R^2$ | Mann-Kendall Test Z | p-value | Sen's slope Q |
|---|---|---|---|---|---|
| Millet | 42 | 0.4701 | 2.81 | 0.005 | 1252.667 |
| Maize | 28 | 0.4043 | 1.85 | 0.064 | 1933.160 |
| Rice | -4 | 0.026 | -0.21 | 0.837 | -278.034 |
| Cassava | -4 | 0.0891 | -0.34 | 0.837 | -61.200 |
| Sorghum | 44 | 0.3261 | 1.77 | 0.077 | 532.876 |

**Source:** Bahi District Office, 2021

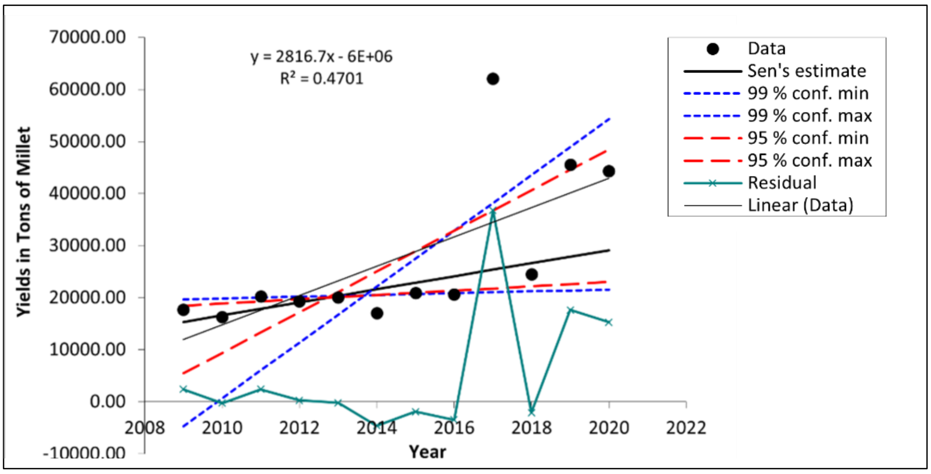


**Figure 2: Production Trend of Millet in Bahi District (2009–2020)**
**Source:** Bahi District Office (2021)

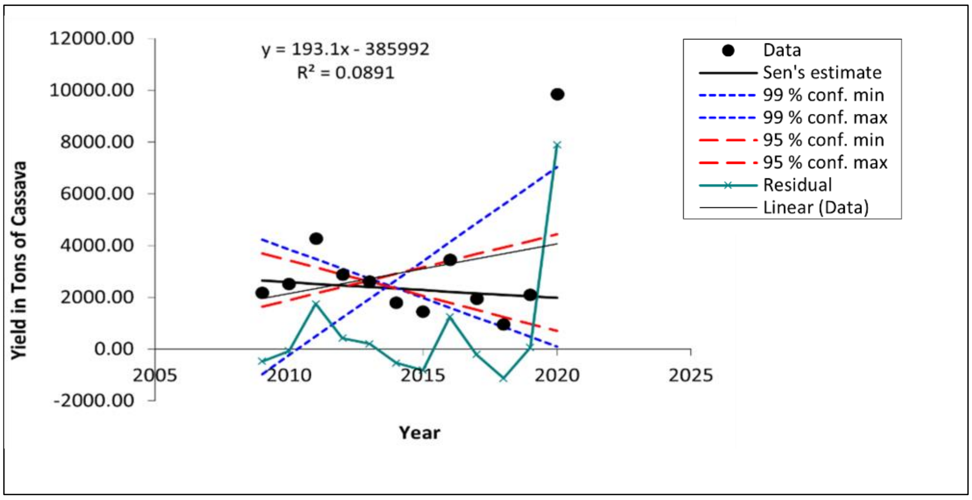


**Figure 3: Production Trend of Cassava in Bahi District (2009–2020)**
**Source:** Bahi District Office (2021)

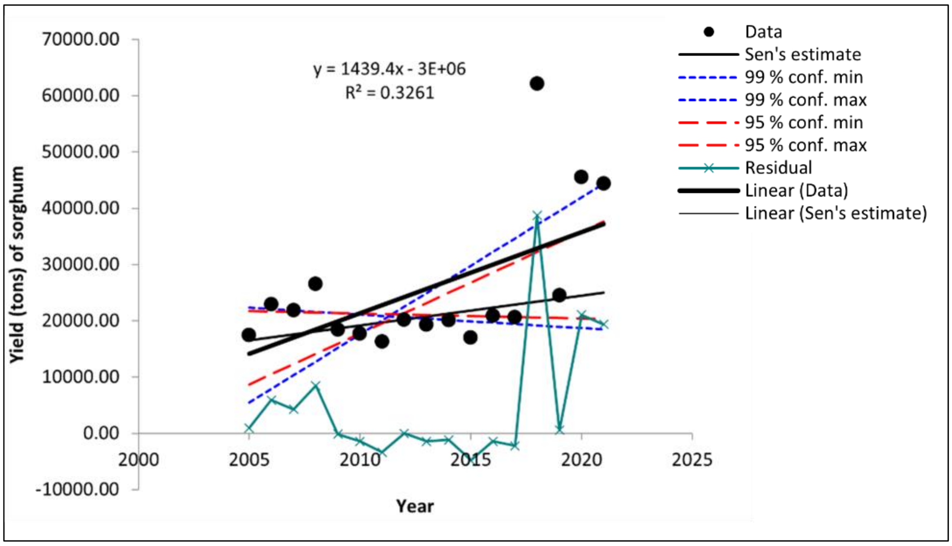


**Figure 4: Production Trend of Sorghum in Bahi District (2009–2020)**
**Source**: Bahi District Office (2021)

Furthermore, the Mann-Kendal analysis also show increased production trends for millet, sorghum, and maize. It was reported that the increased crop production trends were associated with farm expansion and different adaptation strategies; and not by increase in output per unit area.

### *4.2 Effects of Non-climatic Stressors on Crop Production*

Non-climatic stressors in Bahi District significantly influence agricultural production, intensifying the impacts of climate change and limiting farmers' adaptive capacity. The study identified several key non-climatic challenges affecting crop production in Chikola, Chipanga A, and Kigwe villages. One of the reported major stressor was limited access to reliable markets; with Chipanga A being the most affected (51.4%) due to its remoteness. Farmers lacked permanent marketplaces and struggled to find buyers, often selling produce at low prices, or incurring post-harvest losses. The FGDs revealed that limited market access reduced farmers' bargaining power, limited price information, and increased risks of unsold produce (see Table 3). The KIIs also confirmed that buyers primarily set prices, and many farmers sold immediately after harvest to recover costs, leaving them without sufficient food or income for use later in the year. Similar findings were reported by Majule et al. (2013) in Nzega District, where weak market systems undermined agricultural production.

**Table 3: Socio-economic Factors Hindering Agriculture Production**

| Socio-economic factors | Chikola | Chipanga A | Kigwe | Total | $X^2$ | P-value |
|---|---|---|---|---|---|---|
| Lack of market | 40.9 | 51.4 | 31.9 | 40.6 | 6.421 | 0.04 |
| Inadequate infrastructure and transport | 31.8 | 18.1 | 30.9 | 27.6 | 4.567 | 0.102 |
| Inadequate government support | 38.1 | 42.6 | 39.4 | 40.0 | 9.353 | 0.009 |
| Lack of credit | 45.5 | 62.5 | 30.9 | 44.9 | 16.756 | 0.000 |
| Edaphic factor | 28.4 | 16.7 | 34 | 27.2 | 6.327 | 0.042 |
| Lack of water | 69.3 | 34.7 | 69.1 | 57.4 | 25.485 | 0.000 |
| Lack of farming knowledge and tools used | 54.5 | 68.1 | 22.3 | 46.5 | 37.796 | 0.000 |

**Source:** Household field survey, 2021

Moreover, limited access to credit affected 44.9% of the respondents, particularly in Chipanga A (62.5%). As KIIs in Kigwe pointed out, many smallholder farmers were discouraged from official banking services due to high loan rates and severe collateral requirements. This lack of access hampered agricultural production by disabling farmers from acquiring quality seeds, fertilisers, tools, hiring labour, or investing in better farming techniques: all resulting in low yields and lower household income.

Inadequate farming knowledge and reliance on traditional tools were cited by 46.5% of the respondents as the other constraints. Chipanga A reported the highest impact (68.1%), while Kigwe was least affected (22.3%). Over a half of the farmers (57.8%) used hand hoes, and only 0.4% used tractors. The FGDs revealed that few owned ox-ploughs; and the majority had to borrow or rent them. A KII responder in Kigwe stated that limited access to modern tools affected farm size and yields. Furthermore, the survey discovered extensive gaps in scientific knowledge, with farmers frequently ignoring recommended procedures. Many smallholder farmers had become inactive in their farming practices. These variables jointly impeded crop production by limiting efficiency, diminishing cultivable land, and lowering yield quality and quantity due to inadequate agronomic practices. This finding aligns with Jackson et al. (2018), who reported similar challenges in Manyoni District.

Inadequate government support further exacerbated the production constraints. The study participants reported that farmers often lacked timely access to essential inputs, technical advice, and subsidies. The FGDs further revealed delayed delivery of seeds and fertilisers, high input prices, and poor transmission of meteorological information, which was frequently replaced by untrustworthy informal sources. The KIIs revealed that government support was minimal during production shortages, thus increasing household vulnerability.

Infrastructure limitations also posed serious challenges. In Chikola (31.8%) and Kigwe (30.9%), respondents reported that accessing farms and markets was difficult due to poor road conditions during the rainy season. Most farmers (86.1%) travelled on foot, and the lack of paved roads hampered the transportation of inputs and produce. A KII respondent in Chikola noted that seasonal flooding rendered some roads impassable, thereby discouraging the use of distant but fertile lands. About 27.2% of the respondents noted soil-related (edaphic) constraints, particularly in Kigwe (34%). Poor soil fertility, erosion, and nutrient depletion were prevalent in the Bahi District due to high temperatures and minimal rainfall. Soil salinity also exacerbated moisture loss and salt accumulation. The KIIs cited climate fluctuation and unsustainable land use as the causes of these conditions.

### *4.3 Insights on Climate Change and Non-climatic Stressors on Crop Production*

The study found that climate change dramatically lowers crop productivity, reduces yields, alters cropping patterns, and causes vulnerability to pests and diseases. These climate pressures are supported by statistical analysis and trend measurements, which show significant and quantitative effects on agricultural productivity. Likewise, negative consequences of non-climatic stressors—such as restricted access to capital, markets, and government support—exacerbate smallholder farmers' vulnerabilities. These socioeconomic constraints limit farmers' ability to implement effective climate adaptation strategies, including adjusting planting seasons, employing drought-resistant crops, and expanding farm acreage.

The FGDs and KIIs provided further insights, with community members and local officials noting that the observed declines in crop production were linked to climatic disturbances, and the failure of complementary support systems. For example, over 69% of the respondents in some villages reported reduced water availability for irrigation, which is directly linked to climate change. This depletion of water sources exacerbates agricultural challenges and threatens food security. Although certain crops—like millet and maize—show positive trends in some areas, these improvements are likely driven by farm expansion and specific adaptation strategies rather than general improvement in production efficiency.

The findings highlight the necessity for comprehensive policy initiatives addressing environmental and socioeconomic restrictions. An integrated approach that addresses climate adaptation and socioeconomic support is required to strengthen the resilience of Bahi District's smallholder farmers.

## 5. Conclusion and Recommendations

The findings from this study confirm the harmful effects of climate change on crop production, and reveal that non-climatic factors significantly exacerbate these challenges. An integrated approach that simultaneously addresses both sets of stressors is critical for enhancing the resilience and sustainability of agriculture in Bahi District. Climate-induced alterations in temperature and precipitation have led to lower yields, increased food poverty, and higher incidences of pest and disease outbreaks. These environmental pressures are compounded by non-climatic challenges such as low government support, limited access to loans and credit, and inadequate farming knowledge and equipment. Potential adaptation strategies have been identified, including crop diversification, enhanced government support, improved water management, and community-driven initiatives like Village Community Banks (VICOBA). In moving forward, joint efforts are essential to develop and implement holistic adaptation plans that integrate scientific knowledge, local experience, and community engagement to build a more resilient and sustainable agricultural sector in Bahi District.

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