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The Potentials of Organic Cotton Farming to Smallholder Farmers' Resilience Enhancement to Climate Change Adaptation in Semi-Arid Areas of Tanzania: A case of Meatu District

Henry George Mung'ong'o [a*]

[a] *Department of Governance, Peace and Security Studies, Institute of Accountancy Arusha, P.O. Box 2798 Njiro Hill, Arusha, Tanzania.*

Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Climate change has become a threat to a wide range of local community's livelihoods particularly cotton farming system of semi-arid areas experiencing changing in precipitation patterns, pests and diseases, and rising input costs. Therefore, while organic cotton farming is increasingly adopted as pontential adaptation strategy, the extent of its contribution to climate change resilience remains understudied. Thus, this study assessed the role of organic cotton farming for smallholder farmers as an adaptation to climate change in Meatu district specifically aim to examine the trend and patterns of climate change, examining the impacts on smallholder farmers and explore the contribution of organic cotton farming to adaptation. The study employed mixed method approach.

**Corresponding author: E-mail: mungongo82@gmail.com;*

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Simple random and purposive samplings were used to select respondents for the study. Household survey, in-depth interviews, observation and document review methods were used to collect data. The household survey included 246 heads of households. Data on rainfall and temperature was collected from the Tanzania Meteorological Agency (TMA), while linear analysis was used to determine the trends of rainfall and temperature. The study findings highlighted significant trends and patterns of climate change in the Meatu district, including decreasing rainfall and increasing temperatures, which pose challenges to agricultural activities and livelihoods while impacting smallholder farmers ranging from reduced crop yields to changes in traditional farming practices, underscoring the urgent need for proactive adaptation strategies. Organic cotton farming emerges as a promising adaptation strategy, with high adoption rates and a range of benefits, including improved soil health, enhanced crop yield, and increased market opportunities. To conclude, climate change is real and has caused severe impacts on cotton smallholder farmers. However, through the adoption of organic farming smallholder farmers have been able to respond significantly to the impact of climate change. Therefore, it is recommended that organic farming be promoted through the provision of organic farming education, providing support for organic farming initiatives, and strengthening market linkages.

Keywords: Smallholder farmers; organic cotton farming; resilience; climate change adaptation.

1. INTRODUCTION

"It is reported that the farming sector contributes about 40% of the gross domestic product (GDP) of Sub-Saharan Africa creating 62% of employment to the entire the population" (Alshenqeeti, 2014; Asiamah et al., 2017). "There is a significant contribution of agriculture on the livelihoods of smallholder farmers; but, the majority of them rely on rain-fed agriculture, which pose a major challenge. The IPCC report stresses that rural communities in SSA are the most vulnerable to climate change impacts as they derive their livelihoods activities mainly from nature-dependent and climate-sensitive sectors such as agriculture" (Bachmann, 2012).

"Climate change is one of the substantial global challenges in the twenty-first century" (Bartol, 2023). "As stipulated in the IPCC Fifth Assessment Report, changes in rainfall seasons and temperature patterns are anticipated to cause an greater impacts on crop production (Basasola et al., 2018). The report forecasts that mean annual global surface temperature is expected to increase by 1–3.50C by the year 2100, and the global mean sea level is expected to rise by 15–95cm" (Bendjebbar & Fouilleux, 2022). "The projected increase in global average surface temperature is expected to increase spatial and temporal variations in patterns of precipitation" (Creswell, 2019). "These changes are expected to have far-reaching ramifications on the vulnerability and responses to climate change, especially in the Global South" (Liu et al., 2022). Hence, semi-arid dry lands which support over 50% of the world's crop farming which contributes 20 to 30% of Africa's gross domestic product (GDP) and 55% of the total value of African exports, with 70% of the continent's population depending on the sector for their livelihood are all under stress due to global environmental climate.

FAO and ECA (2018) justify that "adverse climate conditions have led to a decline in Africa's agriculture, which is important for future youth employment; and this has threatened food security, health and livelihoods of people. The high vulnerability of Africa's agriculture to climate change is associated with, as mentioned earlier, heavy reliance on rain-fed systems". Authors like Nelson et al*.*, (2019), as quoted in Ombogoh et al*.,* (2021), project that "climate change is anticipated to reduce crop production to between 10 and 35% by the year 2050 because of decreases in rainfall patterns, and increases in temperature and extreme events" (Martins et al., 2018). "The effects of climatic changes are expected to be particularly severe in SSA where poverty rates make populations more vulnerable than in other parts of the world" (Mwasha, 2021). Forexample, the noted impacts are fall in crop yield estimated at 10-20% by 2050 (Mkonda, 2022), about 90% of people are prone to famine in the semiarid reside in Asia and Sub-Saharan Africa.

Devereux and Edward (2014) argue that "East Africa is already among the most food-insecure parts of the world, and climate change continues to affect life in rural communities as the majority of the people are smallholder farmers who depend on rain-fed agriculture". "In Tanzania, crop production is the leading economic activity,

especially for smallholder farmers. Similarly, it has been frequently affected by climate change and variability Predictions by Tanzania National Adaptation Programme of Action (NAPA) indicate that the mean daily temperature will rise by three to five degrees Centigrade throughout the country" (Mohajan, 2017). "Annual rainfall is expected to decrease by 5% to 15% in areas that receive unimodal rainfall, and a decrease of 5% to 45% in areas that receive bimodal rainfall" (Moon et al., 2016). "The primary food producers in Tanzania are smallholder farmers in rural areas, and these are the most vulnerable group to climate change and extreme climatic events. The impacts of climate change have mostly affected the livelihoods of poor communities because of their low adaptive capacity and high dependence on rain-fed agriculture" (Palmer & Bolderston, 2006).

Globally cotton production has been also affected by environmental changes climate change in particular causing dropping in yields to smallholder farmers. In Southeast Europe particularly in Turkey where cotton is grown, the impact of climate change observed since1950s ITC (2011). Including the increase in summer temperatures, decrease in rainfall, and prolonged dry season, this poses significant challenges and risks for the conventional cotton sector. Climate change affects the availability and quality of water resources UNDP (2021) hence this led to the development of organic cotton in Turkey as an adaptation to climate change, in the 1990s.

Organic farming is defined as "…an agricultural approach that emphasizes the use of natural methods, excluding synthetic pesticides or fertilizers, to cultivate crops and raise livestock. It involves sustainable practices such as crop rotation, composting, and biological pest control, promoting soil health and biodiversity (Gamage et al., 2023). It is a farming system that prioritizes ecological balance, relying on organic inputs and avoiding Genetically Modified Organisms (GMOs) and synthetic chemicals (Meemken and Qaim 2018). "It has been practised in many parts of the world as a way to maximize land productivity in a small area by improving the intensity of land and labour use for better profit and stabilization of farm income (Saunders, 2016). Recently, some interest has been generated on the organic farming system as one of the viable and potential climate change adaptation strategies" (Sawe, 2022). In China, Organic farming is increasingly recognized as an adaptation measure to support sustainable livelihoods under a changing climate. Adaptation based on organic cotton farming development builds on well-established traditional Chinese peasant practices because organic farming has been a sustainable livelihood strategy for thousands of years in China (Jin et al., 2015). Organic cotton farming holds significant potential for smallholder farmers in China amidst climate change offering both economic and environmental benefits.

The study conducted by Dinh et al*.,* (2023) examined the benefits of organic farming practices on rice production, with preliminary findings from the context of the agricultural sector in Central Vietnam. The results shown that Organic cotton farming offers smallholder farmers a promising adaptation strategy amidst climate change challenges. Organic practices enhance soil fertility, water retention, and resilience to extreme weather events, thereby mitigating risks associated with climate variability. India is the largest producer of organic cotton in the world, accounting for 51 percent of the global organic cotton production in 2019 and 2022 (Textile Report 2021-2022) Farnworth (2015) observed that the annual global average surface air temperature in India has increased significantly in the past one hundred years ITC. (2011) which poses a negative impact on cotton growers this caused emergence of organic farming paradigm as a compelling alternative to conventional agriculture. This is because organic farming prioritizes soil health and delivers nutritious food without reliance on chemical fertilizers and pesticides which are very important aspects in promoting the environment (Hamad and Sawe 2022). Organic cotton production in India has been increasing in recent years as more farmers and consumers become aware of the benefits of organic farming in responding to climate change (Av and Batra 2023).

Climate change is a serious concern for cotton farmers in Africa, who are noticing droughts, flooding, pests and diseases, temperature increase, and shifts in rainfall season, in response to that Farmers are adopting organic cotton, which seems to be a long sustainable alternative, instead of conventional cotton which bought negative impact to the environment. Altenbuchner (2016) and threaten the livelihood of smallholder farmers who depend on rainfed cotton, Textile Exchange report (2020/2022) while organic farming emphasis mulching, cultivating in level curve, planting more trees, reducing clearing, and improving soil health,

biodiversity conservation and ecosystem function through crop rotation and compost application. All these contribute to crop resilience in this era of climate change (Sangeeta et al., 2024). Up to 1990s Organic cotton was produced by six countries in sub-Saharan Africa, three in Western Africa (Benin, Burkina Faso, and Mali) and three in Eastern Africa (Ethiopia, Tanzania, and Uganda). Textile Exchange Report (2021/2022). This expansion was driven by a rising demand for organic product from consumers in the global North and the EU Organic market which opened for imports of organic products. Merrigan et al., (2022) sub-Saharan countries occupied the second position in organic cotton production with production rising 44%, due to primarily growth in Tanzania in 2020/21, (Textile Exchange report 2020/2021). Organic agriculture is believed to be the most sustainable approach against climate change and ensuring Community resilience.

In East Africa organic cotton produced by only three countries these are; Tanzania, Uganda and Ethiopia besides Uganda grew an estimated 2,551 tonnes of organic cotton fiber on 7,940 hectares of certified organic land. Approximately 16,042 farmers were involved in this production. Ethiopia, Uganda and Tanzanian Smallholder farmers were mostly affected by climatic change impact hence. Farmers are increasingly integrating adaptation techniques into their production systems such as mulching, cultivating in level curve, planting more trees, reducing clearing, and improving soil health through crop rotation and compost application as well as increasing the adoption of Organic cotton Farming so as to adapt with climatic challenges (Yatundu et al., 2016). In Tanzania's cotton-growing areas are extremely vulnerable to external factors such as rainfall, drought, erosion, and pests. (Hamad and Sawe 2022) practicing organic farming were inevitable to adapt to the impact of climate change (Ackerl et al., 2023) organic cotton farming, seems to be the best adaptation strategy to climate change with increased cotton production and community resilience (Ume et al., 2023). Organic cotton farming in Tanzania started in 1994/1995 with the main areas of production being Singida, and Simiyu, (Textile Exchange Report 2019/2020) Tanzania grew an estimated 20,932 tonnes of organic cotton fiber on 235,992 hectares of certified organic land, involving around 33,378 farmers and accounted for an estimated 6.1% of global organic cotton production in 2020/2021, Compared to 2019/2020. However (Textile Exchange Report 2020&2021) stated that Tanzania is the leading fifth county in the World in the production of organic cotton delivered by organic cotton produced from Meatu District in Simiyu and Singida region.

Climate Change is real in Meatu District as a semi-arid area where unpredictable rainfall, temperature rise, temporal drought, increases in pests, and crop diseases have been noticed in the region. these affect the livelihood of smallholder farmers who depend on cotton production as a primary source of income (Taherdoost, 2016) in response to this fact organic cotton was initiated in Meatu, to minimize the negative impact caused by conventional cotton on the environment (Ume et al., 2023). To enable smallholder farmers to cope with the negative impact of climate change which conventional cotton fail to adopt. nevertheless. the application of pesticides and synthetic fertilizers leads to environmental pollution hence crop failure, and human health problems like skin irritation, yet most farmers are not aware of the negative side-effects of agrochemicals on human health and therefore do not use any protective gear during the application of pesticides (Ume et al., 2023).

In 1994 Organic cotton farming started in Meatu in one village with 45 farmers, founded by a private textile mill BioRe, with the support of the Swiss-based company Remei. Altenbuchner et al., (2016). The project began with twenty-five innovators. With time, the new cotton production system spread to Mwamishali village and then to other villages., Smallholder farmers have been gradually implementing it since its debut, Altenbuchner et al., (2016). Organic cotton in Meatu District is produced under COC principles with regards to IFOAM basic standards, which are in turn guided by the CAGs, Hamis (2014). This enables the crop to be certified as organic based on international minimum organic standards and hence qualify for organic premium price (OPP). Although some conventional farmers are unable to purchase synthetic pesticides and fertilizers, their crop is not regarded as organic due to a lack of certification tag and are therefore directed to CSC open market (Kaminski, 2011). Therefore, this study intends to assess the role of organic farming in climate change adaptation using smallholder farmers in Meatu district as a case study.

Therefore, cotton production is a major source of livelihood for the majority of smallholder farmers in Meatu District as about 89% of smallholder farmers in the district are engaged in organic

cotton production (Kaminski, 2011). But despite the importance of cotton production smallholder farmers are vulnerable to climate change because most of the smallholder farmers depend on rain-fed agriculture. With the current climate change changes, the district is facing significant adverse impacts of climate change which include unpredictable erratic rainfall patterns and increased temperature which poses significant threats to cotton crop production. The repercussions of climate change are becoming more pronounced, exposing smallholder farmers to heightened risks and uncertainties, changing precipitation patterns, increased pests and diseases have further compounded the challenges faced by smallholder farmers in Meatu District.

In response to the impact of climate change, the majority of smallholder farmers have been engaged in organic cotton farming as an adaptation strategy to climate change. However, despite of adoption of organic farming by the majority of the smallholder farmers' information about the extent to which organic cotton production has contributed to smallholder farmers' adaptation to climate change is inadequate. Therefore there is a need informing policy makers on the extent of organic cotton contributions and practical interventions as to improve farmers' livelihoods. Therefore, based on this literatures there is limited information on to what extent organic cotton farming enhances resilience to smallholder farmers upon climate change impacts. Therefore, this gap will be covered by this study.

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in Meatu district between March and April 2024, in Shinyanga Region, located in the Lake zone of Tanzania. The study area consists of three (3) villages with different population namely, Mwamishali 210, Nkoma, 200 and Ng'hoboko 230. According to URT (2016) Meatu district spans a total area of 8,835 km^2, with nearly half dedicated to reserved areas (4,253 km^2) and the remaining portion of the district, totalling 4,582 km^2, is designated for agricultural land and pastures.

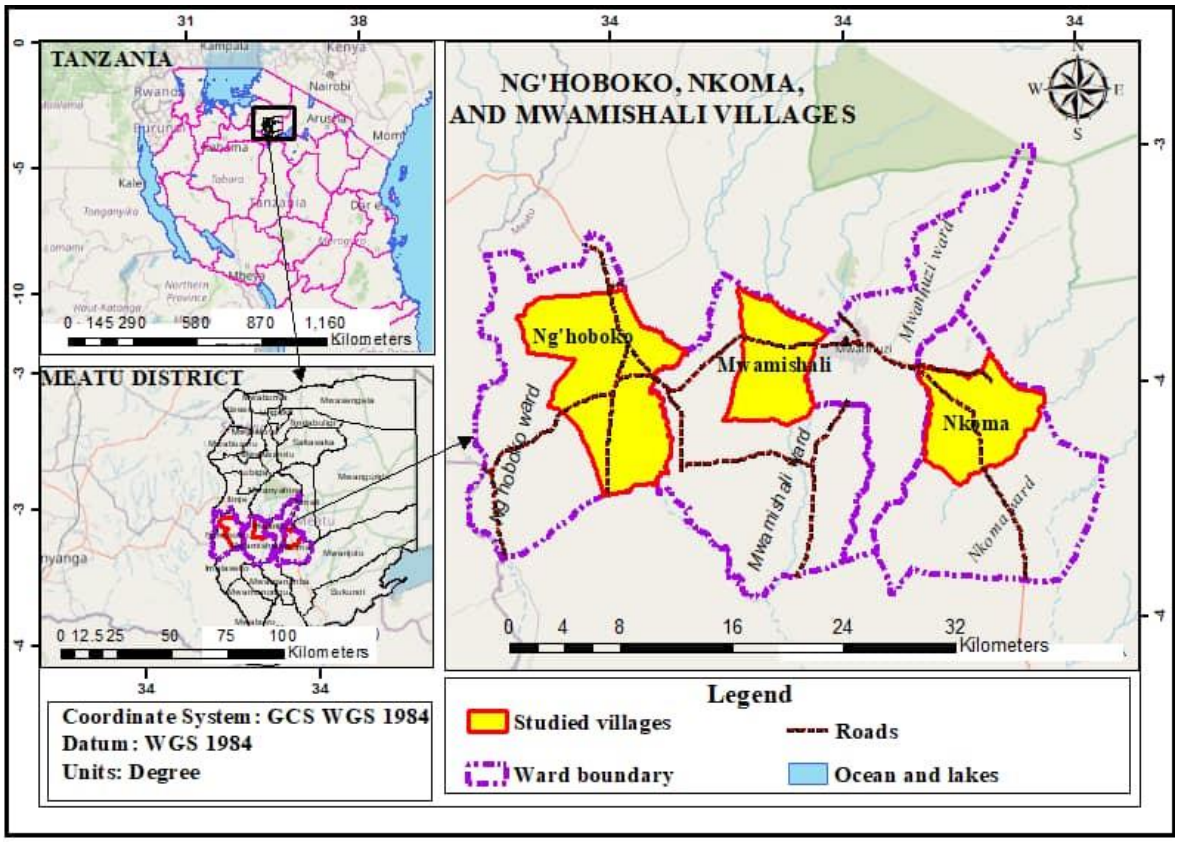

Fig. 1. Location of the study area
Source: NBS (2024)

Justification for the choice of Meatu District as the study area is because of its heavy reliance on organic cotton farming as a primary source of livelihood for most smallholder farmers, as 94% of smallholder farmers engage in organic cotton farming merely because conventional cotton, which was practiced before 1994, brought serious environmental problems due to the application of synthetic fertilizers and insecticides. Also, Meatu is a semi-arid area where smallholder farmers depend on rain-fed cultivation hence, conventional cotton that was practicing before 1994/1995 fails to align with the impact of climate change, especially prolonged dry seasons, which led to crop failures. This increases the level of poverty in Meatu District since the majority depend on cotton production to earn their livelihood (Ume et al., 2023), with the introduction of organic cotton in Meatu District small holder farmers have become more resilient, to climate change impact. The study villages Nkoma, Mwamishali, and Ng'hoboko villages were selected because all farmers are organically certified and the companies operating the project are located between them; therefore, on this basis, smallholder farmers from these villages had relevant information and experience with organic cotton farming. Hence, the study zones seem to be reliable and offer multiple opportunities for data collection.

2.2 Study Approaches and Design

The study employed an explanatory research design, under a mixed method approach where quantitative and qualitative research approaches were used. This approach is particularly important when deeper and broader understanding of a phenomenon is sought, which can't be captured by either qualitative or quantitative methods (Harvey et al., 2018). Data were collected once from 246 households to examine how organic cotton farming increases resilience among smallhoder farmers. Mixed methods are well known for their objectivity, generalizability, accommodation ability to participants' voice and potentiality to meaningful interpretation (Sangeeta et al., 2024). Under the mixed methods approach, the data collection tool complements each other so that, when some data were missed by one tool, they would be collected by the other tool (Harvey et al., 2018). Such descriptive and exploratory techniques have potential not only to describe events and phenomenon, but also narrate the causal and effect relationships. Therefore, the use of mixed methods in this study to increase the novelty of the findings.

2.3 Sampling Procedures and Sample Size

Based on the sampling criterion three villages were selected purposely for the household survey method which was Nkoma, Nghoboko, and Mwamishali. The study employed a combination of simple random and purposive sampling. Simple Random Sampling used to obtain the 246 households. This technique was applicable to obtain respondents from the selected villages simply because it allows every individual to be involved within the sample without bias especially choosing heads of households who practiced organic cotton farming. Purposive Sampling was used to select five key informants that participated in the interviews, three from each village stand as extensional officers, while two from organic cotton companies stand as ICS managers, this technique is best simply because the interviewees were few and possess unique status on better understanding about climatic conditions in Meatu, the rate of adoption of organic cotton farming and the contribution of organic cotton as an adaptation to climate change.

The study used a sample of 246 to collect data each of whom represented one household and were believed to be more familiar with the study theme. This was because they were involved in organic cotton farming. Yamane formular (1967) at a confidence level of 95% was used to calculate the sample size from a targeted population and it has been indicated below.

$$n = \frac{\mathrm{N}}{1+\mathrm{N}e^2} \qquad \text{Consider } nh\left(\frac{\mathrm{Nh}}{\mathrm{N}}\right)n$$

nh = 200/640 x 246 = 77 households from Nkoma
nh = 230/640 x 246 = 88 households from Nghoboko
nh = 210/640 x 246 = 81 households from Mwamishali

Therefore, the total sample size was 246 households with different distribution per village.

2.4 Data Types and Data Collection Methods

The study used both primary and secondary data sources. Secondary data was collected from reading different published and unpublished

literatures, obtained from different sources of information from reputable journals, books, and unpublished documents from local government offices. The information gathered encompassed climate change trends from 1994 to 2023 from Tanzania Meteorological Authority (TMA). Primary data was collected from the respondents using a household survey through a questionnaire and In-depth interview, field observation and data were collected on the practice of organic cotton farming, climatic conditions, the rate of adoption, factor influencing the adoption of organic cotton farming, the impact of climate change, and the contribution of organic cotton farming as an adaptation strategy.

2.5 Data Analysis Techniques

Quantitative data collected from the household survey was coded and analyzed using the Statistical Package for Social Sciences (SPSS) version 20, widely recognized software for statistical analysis. Again, the analysis primarily employed descriptive statistics, including frequency, mean, and standard deviation. These statistical measures were crucial in summarizing the central tendencies, variations, and trends in participants' responses. Furthermore, factor analysis and was employed to uncover underlying relationships between multiple variables and identify common themes or dimensions within the data. Results for quantitative data were presented by using tables. Qualitative data for this study were obtained from interviews**,** and analysed through content analysis however data presented through descriptive statements and direct quotations.

3. RESULTS AND DISCUSSION

In this section the study present results in four major analytical themes that depict the pace of recovery that entails the role of livelihood assets, self-organization and capacity to learn in building resilience of a SES to climate shocks and hazards. These themes depicts the;

1. Trend and patterns of climate Change in the study villages
2. The impacts of Climate Change on Smallholder Farmers cotton growers,
3. Influencing factors on adoption of Organic Cotton Farming in the study villages
4. Pontentials of Organic Cotton Farming to Smallholder Farmers as Adaptation to Climate Change in the study villages.

3.1 Farmers' Perception of Climate Change Trends and Patterns

Assessing awareness levels is essential for developing targeted education and outreach initiatives, as well as informing policy decisions aimed at addressing climate change at local, national, and global levels. The findings reveal a high level of awareness of climate change among respondents in the Meatu district, with 91.5% indicating familiarity with the concept. This suggests a significant recognition of the agricultural challenges posed by climate change within the local community. The high level of awareness of climate change among respondents in the Meatu district underscores the importance of local communities' understanding of environmental challenges. The findings of the study align with previous research conducted in similar agricultural contexts like Studies by Kotir (2011) in Sub-Saharan Africa and Hamad and Sawe (2022) in Zanzibar also underscored the significance of climate change awareness among rural populations. Like the findings in the Meatu district, these studies revealed high levels of awareness among respondents, indicating a widespread recognition of the challenges posed by climate change to agricultural livelihoods.

Perceptions of rainfall patterns involve individuals' subjective understanding and observations of changes in precipitation over time. These perceptions provide valuable awareness of how residents interpret and experience shifts in rainfall frequency and intensity with 61.0% indicating a perception of a decrease. This perception aligns with broader concerns about changing precipitation patterns in the region, which can have significant implications for agricultural activities and water resource management. Also, 30.9% of respondents perceive fluctuations in rainfall, reflecting the variability and unpredictability of precipitation patterns experienced in Meatu. Furthermore, during interviews with Agricultural officers mostly they mentioned that;

> *"Indeed, over the past three decades, we've observed a discernible decline in rainfall patterns within the Meatu district. This trend is quite noticeable and raises concerns about the long-term implications for our community's agricultural practices and water resource management."*

Except, one Agricultural officer mentioned that;

> *"Regarding the rainfall patterns in the Meatu district over the past three decades, it's evident that there's been a notable fluctuation. This variability in precipitation poses challenges for our community, particularly in terms of planning for agricultural activities and ensuring water availability for various needs."*

Moreover, the study involved secondary data from the Tanzania Meteorological Agency (TMA) concerning precipitations of rainfall patterns for the last 30 years (from 1994 – 2023). Fig. 2 shows the summary of rainfall patterns.

The data shows fluctuations in average rainfall levels across different five-year periods within the specified timeframe. From 1994 to 1998, the average rainfall was recorded at 1360.24 mm, followed by a decrease to 1107.16 mm from 1999 to 2003. Subsequently, there was an increase in rainfall to 1236.78 mm from 2004 to 2008, followed by relatively stable levels around 1200 mm from 2009 to 2018. Notably, there was a minor increase in average rainfall to 1363.88 mm from 2019 to 2023. The analysis was done using a simple regression model. The results indicate a significant increase in the trend of rainfall as shown by y = y=4.8543x + 1226.9mm. The increase in the trend is explained by 2.02% of the variance observed in the Meatu district (R^2 = 0.0202).

This variability in rainfall patterns reflects the dynamic nature of the climate in the Meatu district over the past three decades, with periods of both abundance and scarcity. Fluctuations in average rainfall across different five-year periods highlight the dynamic nature of climate in the region, characterized by periods of both abundance and scarcity. The recorded decrease in rainfall from 1999 to 2003 followed by an increase in subsequent years, along with relatively stable levels during certain periods, demonstrates the complexity of climate patterns and the challenges they pose for agricultural planning and resource management. Therefore, the convergence of findings from various sources underscores the complexity of climate change and its implications for agricultural planning and resilience building in Meatu district and similar regions. While exploring community perceptions of temperature patterns about 51.2% of respondents, perceive fluctuations in temperature, while 34.1% of respondents perceived an increase in temperature, and 14.6% perceive a decrease. These findings suggest an understanding of temperature dynamics among residents, with implications for the agriculture sector.

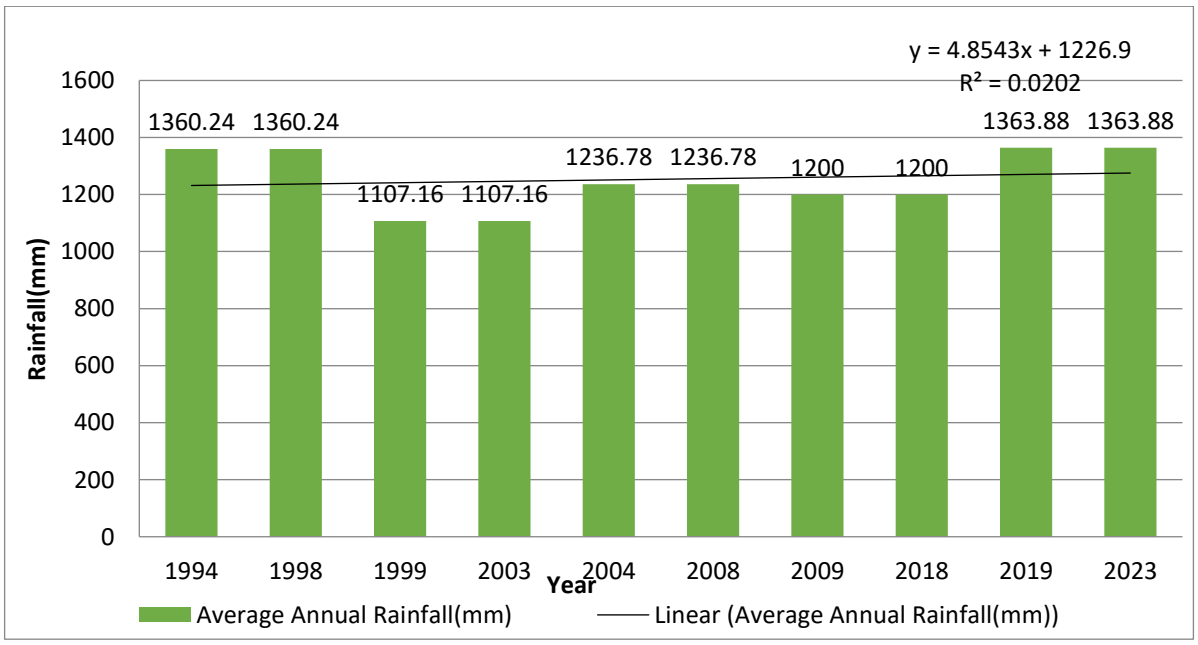

Fig. 2. Precipitations of Rainfall Patterns in Meatu District From 1994-2023
Source: Tanzania Meteorology Agency, 2024

Furthermore, the interview responses from all Agricultural officers mentioned that the temperature patterns in the Meatu district have been increasing. The consistent response from all agricultural officers, indicating an increase in temperature in the Meatu district over the last 30 years, underscores a clear trend in climate change impacts. This alignment between community perceptions and expert observations highlights the need for tailored adaptation strategies that address the multifaceted challenges posed by temperature change, ensuring resilience and sustainability in Meatu district's agricultural sector.

Moreover, the study involved secondary data from the Tanzania Meteorological Agency (TMA) concerning temperature patterns for the last 30 years (from 1994 – 2023). From 1994 to 1998, the average temperature was recorded at 22.98°C, followed by a slight increase to 23.00°C from 1999 to 2003. Subsequently, there was a further increase in average temperature to 23.22°C from 2004 to 2008, with relatively stable levels around 23.120°C from 2009 to 2018. Notably, there was a slight rise in average temperature to 23.46°C from 2014 to 2018, followed by a slight decrease to 23.20°C from 2019 to 2023. The annual mean temperature showed an increase (y = 0.013x -2.946) for the whole period of 30 years with the observed variance of 45% (R3 = 0.45). These fluctuations in temperature reflect the dynamic nature of the climate in the Meatu district over the past three decades, with periods of both slight increases and decreases.

Studies such as those by (Sangeeta et al., 2024) in India, similarly Kotir (2011) in Sub-Saharan Africa, and Mikova and Msafiri (2019) in Tanzania have highlighted the dynamic nature of temperature changes over time, characterized by both slight increases and decreases within certain periods. The overall trend of relatively stable temperature regimes with fluctuations observed in the district aligns with findings from scientific research on climate change impacts. Exploring primary sources provides awareness of the accessibility, credibility, and diversity of climate change information available to different demographics. By understanding where people obtain their information, the study revealed that mass media emerges as the most common source, with 35.0% of respondents indicating reliance on platforms such as television, radio, and newspapers. Social media also plays a significant role, with 26.4% of respondents obtaining climate change information through digital platforms. Also, local experiences (25.2%) and village meetings (9.3%) are cited as important sources, highlighting the importance of community-based knowledge sharing and traditional forms of communication. However, it's notable that only a small proportion of respondents cite religious meetings (0.4%) and traditional ways (3.7%) as primary sources. These findings underscore the importance of leveraging diverse communication channels to effectively disseminate climate change information and engage local communities in climate action initiatives tailored to their needs and preferences.

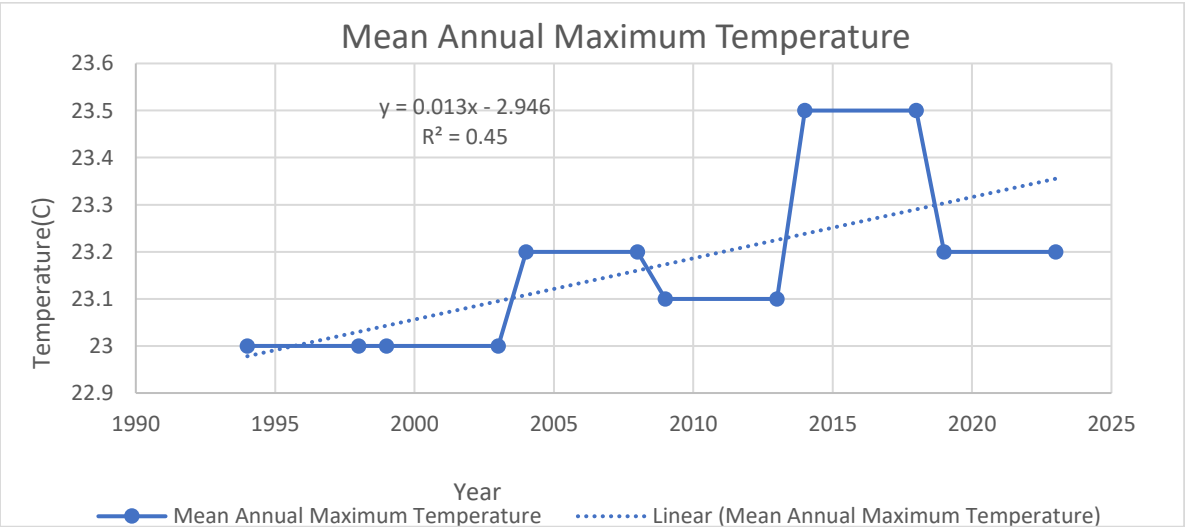

Fig. 3. Temperature trends In Meatu District From 1994-2023
Source: Tanzania Meteorology Agency, 2024

3.2 Impacts of Climate Change on Smallholder Farmers in Meatu District

Changes in temperature, rainfall patterns, and the frequency of extreme weather events are increasingly affecting agricultural productivity, water availability, and livelihood security. Smallholder farmers, who heavily rely on rain-fed agriculture, are particularly vulnerable to these impacts. In Table 1, the study presents the opinions or views regarding the impacts of climate change on smallholder farmers in the district using a Likert scale ranging from 1 to 5, where 1 represents "Strongly Disagree", 2 represents “Disagree”, 3 represents “Neutral”, 4 represents “Agree” and 5 represents "Strongly Agree." By analyzing responses on this scale, we can assess the perceived severity and significance of climate change impacts on smallholder farmers and facilitate a strong discussion on adaptation strategies and interventions.

The table further presents respondents' opinions or views regarding the impacts of climate change on smallholder farmers in Meatu district using a Likert scale ranging from 1 to 5. A majority of respondents agree or strongly agree with the identified impacts. Specifically, 93.5% of respondents agree or strongly agree that climate change has reduced crop yields, indicating widespread concern about agricultural productivity. Similarly, 56.1% of respondents agree or strongly agree that climate change has diminished water sources, highlighting the growing challenges associated with water scarcity and access to farming activities. Soil erosion is also recognized as a significant impact, with 76.5% of respondents agreeing or strongly agreeing with its occurrence. Moreover, 81.3% of respondents agree or strongly agree with an increase in pest and disease incidences, further exacerbating agricultural challenges. The drying of crops is perceived as a notable impact by 88.9% of respondents, indicating the severity of climate-related droughts. The high level of agreement among respondents is consistent with findings from other studies highlighting the significant challenges faced by agricultural communities due to climate change.

During an interview with one agriculture officer from Remei company quoted saying,

> *“Smallholder farmers in Meatu district are aware of the impact of climate change and to confirm that, I have observed them plant early and sometimes they plant drought-resistant crops such as cotton, sorghum, cassava etc etc.”*

The statement made by the agriculture officer from Remei company underscores the proactive adaptation strategies employed by smallholder farmers in the Meatu district in response to climate change impacts. During an interview with agriculture officers concerning the support and resources they provide to help farmers adapt to climate change they responded with different opinions.

> *“As agricultural officers, we provide various forms of support to help farmers adapt to climate change. One of the key resources we offer is training programs on climate-smart agricultural practices, where farmers learn about techniques like conservation agriculture, crop diversification, and water management strategies”.*

and,

> *"Farmers in Meatu district have access to a range of support and resources aimed at helping them adapt to climate change. We organize field demonstrations and extension services to introduce farmers to how to practice organic farming"*

The interview responses indicate that the agricultural officers in Meatu district emphasize the importance of providing diverse forms of support to help farmers adapt to climate change. While one officer focuses on training programs covering climate-smart agricultural practices like conservation agriculture and water management, the other officer highlights field demonstrations and extension services specifically aimed at promoting organic farming. These efforts reflect a comprehensive approach to building farmers' capacity and resilience to climate variability, addressing both technical knowledge and practical implementation strategies.

Opinions from all agriculture officers concerning the impact of climate change on smallholder farmers were alike as they responded as;

"I've observed shifts in rainfall patterns, more frequent extreme weather events, and unpredictable growing seasons, all of which directly impact agricultural productivity. Farmers are facing increased risks of crop failures, reduced yields, and heightened vulnerability to

pests and diseases. These challenges not only threaten their livelihoods but also undermine food security and economic stability in our community."

Concerning the existence of collaborations or partnerships between the agricultural sector and other stakeholders to address climate change impacts all agriculture officers responded that;

> All agricultural officers stated that "*currently, there are no existing collaborations or partnerships between the agricultural sector and other stakeholders specifically dedicated to addressing climate change impacts".*

Component 1 predominantly captures the direct impacts on agricultural productivity. This component includes "Reduced crop yields" (0.804), "Diminished water sources" (0.672), and "Soil erosion" (0.592). The high loadings on these variables suggest that the primary concerns for farmers are the direct and immediate effects on crop production. These findings indicate that farmers are highly aware of how climate change directly reduces their agricultural output and affects soil quality, which are crucial for sustaining their livelihoods. Component 2 highlights the adaptive and resource-related impacts. "Drying of crops" (0.664) and "Changes in traditional farming practices" (-0.712) load significantly on this component. This suggests a shift in farming practices and adaptations that farmers are making in response to changing climatic conditions. The negative loading on changes in traditional practices reflects the disruptive nature of these changes, indicating that farmers may be forced to abandon long-standing methods in favour of new, potentially less familiar practices that are more suited to current climatic conditions. Component 3 captures the health and resilience of the agricultural system, particularly about pest and disease pressures. "Increase in pest and disease incidences" (-0.708) relies heavily on this component, suggesting that climate change is exacerbating biotic stresses, which in turn affect crop health and resilience. The higher incidence of pests and diseases further challenges the farmers' ability to maintain productivity and protect their crops.

Table 1. Distribution of Respondents by Impacts of Climate Change on Smallholder Farmers in Meatu District (N=246)

Impacts	Responses				
	1	**2**	**3**	**4**	**5**
Reduced crop yields	5 (2.0%)	3 (1.2%)	8 (3.3%)	169 (68.7%)	61 (24.8%)
Diminished water sources	3 (1.2%)	14 (5.7%)	91 (37.0%)	112 (45.5%)	26 (10.6%)
Soil erosion	3 (1.2%)	8 (3.3%)	47 (19.1%)	134 (54.5%)	54 (22.0%)
Increase in pest and disease incidences	2 (0.8%)	5 (2.0%)	39 (15.9%)	82 (33.3%)	118 (48.0%)
Drying of crops	1 (0.4%)	3 (1.2%)	23 (9.3%)	126 (51.2%)	93 (37.8%)
Changes in traditional farming practices	2 (0.8%)	13 (5.3%)	77 (31.3%)	120 (48.8%)	34 (13.8%)

Source: Field Data, 2024

Table 2. Factor Analysis on the Impacts of Climate Change on Smallholder Farmers in Meatu District

Impacts	Components		
	1	2	3
Reduced the crop yields	.804	-.214	.061
Diminished water sources	.672	.168	-.227
Soil erosion	.592	-.238	.277
Increase in pest and disease incidences	.046	.293	-.708
Drying of crops	.299	.664	.148
Changes in traditional farming practices	-.033	-.712	.002

Source: Field Data, 2024

The analysis underscores the complex nature of climate change impacts on smallholder farmers, highlighting the need for comprehensive adaptation strategies. Component 1 suggests that interventions should focus on improving water management and soil conservation techniques to moderate direct productivity losses. Component 2 indicates a need for support systems that help farmers transition to new farming practices, providing them with the knowledge and resources necessary to adapt effectively. Finally, Component 3 emphasizes the importance of integrated pest management and resilient agricultural practices to combat the increased pressure from pests and diseases. Policymakers and agricultural extension services should thus adopt approaches, that address both the direct impacts on productivity and the broader adaptive strategies required to sustain farming in the face of climate change.

The factor analysis results presented in Table 2 align with the findings of Mbilinyi, and Kazi (2013) in Tanzania which have also identified similar components reflecting the direct impacts on agricultural productivity, adaptive responses, and challenges related to pest and disease pressures. The complex nature of climate change impacts, as highlighted by the factor analysis, underscores the multifaceted challenges faced by smallholder farmers and the need for holistic adaptation strategies.

3.3 Contribution of Organic Cotton Farming to Smallholder Farmers as Adaptation to Climate Change in Meatu District

Under this section, the study examines the adoption rate of organic cotton farming, factors influencing the adoption, and lastly the contribution of organic farming to climate change adaptation.

3.3.1 Adoption of organic cotton farming in Meatu District

Understanding the extent of the adoption of organic cotton farming in the Meatu district signifies a shift towards sustainable agricultural practices among smallholder farmers in the region. The findings reveal a high level of adoption of organic cotton farming among smallholder farmers in the Meatu district, with 98.4% of respondents adopting it. This indicates a significant shift towards sustainable agricultural practices in the region, reflecting growing awareness of the benefits associated with organic farming methods. The overwhelming majority of farmers embracing organic cotton cultivation underscores the potential of this approach to enhance production, ensure environmental sustainability, and respond to climate change.

However, the small percentage of respondents who have not adopted organic cotton farming suggests potential barriers to stance transitional period; these findings align with the study conducted by Mshana (2014) in Meatu District, about the constraints in the adoption of Organic Cotton. This upward trajectory in adoption underscores a promising trajectory towards more ecologically sound and socially responsible agricultural practices within the Meatu district farming community.

The high level of adoption of organic cotton farming among smallholder farmers in the district, as revealed by the findings, resonates with trends observed in previous empirical studies on the adoption of sustainable agricultural practices. Studies such as those conducted by Dinh et al. (2023) in Central Vietnam and Nyagumbo et al. (2021) in Ghana, likewise study conducted by Mshana (2014) in Meatu, as well as Altenbuchner (2014) Tanzania have also documented high rates of adoption of organic farming methods among smallholder farmers, driven by increasing awareness of the environmental and economic benefits associated with organic cultivation. There are various influencing factors for adoption of Organic Cotton Farming in the District Understanding the factors that influence the adoption of organic cotton farming in the Meatu district is essential for promoting sustainable agricultural practices among smallholder farmers. By exploring these factors, we can identify key drivers and barriers to adoption, inform targeted interventions, and support farmers in navigating the transition towards more environmentally friendly and socially responsible cotton production. Table 3 shows the distribution of respondents based on those factors.

Table 4 illustrates various factors influencing the adoption of organic cotton farming among smallholder farmers in Meatu district. Market demand emerges as the most significant factor, with 41.9% of respondents citing it as a key driver. This suggests that economic incentives and market opportunities play a crucial role in encouraging farmers to transition to organic

cotton cultivation. Moreover, factors such as low cost (27.6%) and influence of education (14.2%) also contribute to adoption, highlighting the importance of financial feasibility and awareness-building efforts in promoting sustainable farming practices. However, the relatively low percentages of respondents citing access to information (5.3%) and influence of family systems (11.0%) as influencing factors suggest potential gaps in knowledge dissemination and support systems that could be addressed through targeted capacity-building and outreach initiatives. Also, one officer from Remei company added that,

> *"Smallholder farmers are motivated to shift towards organic cotton farming due to the reasons that organic farming improves soil health and fertility"*

This recognition of the environmental advantages of organic agriculture reflects a broader shift towards sustainable practices and underscores the importance of promoting regenerative farming approaches to enhance soil resilience and agricultural sustainability in the Meatu district. By prioritizing soil health and adopting holistic management strategies, smallholder cotton farmers in Meatu can not only secure their livelihoods but also contribute to building a more sustainable and resilient agricultural landscape for future generations.

3.3.2 The benefits of organic cotton farming in smallholder farmers' adaptation to climate change

Organic cotton farming offers a range of advantages that can enhance farmers' resilience to climate change and cope with the impacts of environmental challenges. Recognizing the benefits of organic cotton farming in smallholder farmers' adaptation to climate change is crucial for fostering sustainable agricultural practices in the Meatu district.

In Table 4, the study presents the opinions or views regarding the benefits of organic cotton farming in smallholder farmers' adaptation to climate change using a Likert scale ranging from 1 to 5, where 1 represents "Strongly Disagree", 2 represents "Disagree", 3 represents "Neutral", 4 represents "Agree" and 5 represents "Strongly Agree." By analysing responses on this scale, we can evaluate the perceived effectiveness and significance of organic cotton farming as an adaptation strategy among smallholder farmers in the Meatu district.

Table 4 reveals that the majority of respondents agree or strongly agree with the identified benefits. Specifically, 93.1% of respondents agree or strongly agree that organic cotton farming improves soil health and fertility, underscoring the role of sustainable farming practices in enhancing soil resilience to climate change. This high level of agreement emphasizes the significance of prioritizing organic approaches within agricultural strategies, not only for enhancing productivity but also for building a more robust foundation to withstand environmental challenges in the Meatu district and beyond.

Also, 80.1% of respondents agree or strongly agree that organic cotton farming enhances crop yield, highlighting its potential to boost agricultural productivity amidst changing climate conditions. This statistic underscores the importance of organic farming practices in not only promoting sustainability but also in bolstering agricultural productivity, especially crucial in the face of unpredictable climate conditions. The finding is in line with the study conducted by Sangeeta et al. (2024) in Benin which discovered that "*organic practices could contribute to increasing yields through better soil fertility and pest management"* Similarly the study by Bwana (2019) in Meatu revealed the same results. Furthermore, 80.1% of respondents agree or strongly agree that organic cotton farming increases crop quality, indicating the importance of sustainable production methods in ensuring high-quality agricultural products. This emphasis on crop quality highlights the importance of adopting universal and eco-friendly approaches to farming, which not only benefit the environment but also ensure the delivery of superior agricultural products to the market, thus enhancing overall farm profitability and sustainability.

Water use efficiency is also recognized as a significant benefit, with 84.1% of respondents agreeing or strongly agreeing with its occurrence, addressing concerns about water scarcity and conservation in agriculture. This acknowledgment highlights the universal approach of organic farming, which not only focuses on environmental sustainability but also addresses critical issues such as water conservation, ensuring the long-term viability of agricultural systems in the face of evolving climatic conditions. The findings align with the study conducted by Sartaj (2013) in India, and Mshana Hamis (2014) in Meatu Tanzania which

revealed that organic cotton farming increased water retention or drainage response to droughts and floods decreased irrigation needs and avoided land degradation.

Moreover, organic cotton farming is perceived to improve income (84.6% agree or strongly agree) and increase market opportunities (81.5% agree or strongly agree), demonstrating its potential to enhance livelihoods and economic resilience among smallholder farmers. By tapping into premium markets for organic products and reducing dependency on costly inputs like synthetic fertilizers and pesticides, organic cotton farming offers smallholder farmers in the Meatu district a pathway to higher incomes and greater market access to improve their livelihood. These findings make straight with the study conducted by (Martins et al., 2018) in India which revealed that "*By its nature, organic farming is an adaptation strategy that can be targeted at improving the livelihoods of rural populations and those parts of societies that are especially vulnerable to the adverse effects of climate change"*. In addition, the findings align with the study of Bwana (2019) and Hamis (2014) in Meatu, Tanzania.

Biodiversity conservation is acknowledged as a benefit by 78.9% of respondents, highlighting the role of organic farming practices in promoting ecosystem health and resilience. This emphasis on biodiversity conservation reinforces the rounded nature of organic farming, which prioritizes the well-being of both the environment and agricultural communities it should be remembered that the communities that are involved in conventional cotton farming are exposed to health risks due to the use of pesticide and chemical fertilizers, against poor application methods. Ultimately organic cotton farming contributes to the long-term sustainability of farming systems in Meatu district and beyond.

Table 3. Distribution of Respondents by Factors Influencing Adoption of Organic Cotton Farming in Meatu District

Factors	Frequency	Percent
Low cost	68	27.6
Family influence	27	11.0
Access to information	13	5.3
Market demand	103	41.9
Influence of education	35	14.2
Total	246	100.0

Source: Field Data, 2024

Table 4. Respondents Distribution by Benefits of Organic Cotton Farming in Smallholder Farmers' Adaptation to Climate Change (N=246)

Benefits	Responses				
	1	2	3	4	5
Improved soil health and fertility	3 (1.2%)	4 (1.6%)	10 (4.1%)	175 (71.1%)	54 (22.0%)
Enhanced crop yield	3 (1.2%)	1 (0.4%)	45 (18.3%)	120 (48.8%)	77 (31.3%)
Increase crop quality	5 (2.0%)	6 (2.4%)	38 (15.4%)	162 (65.9%)	35 (14.2%)
Water use efficiency	4 (1.6%)	13 (5.3%)	138 (56.1%)	69 (28.0%)	22 (8.9%)
Improved income	3 (1.2%)	2 (0.8%)	33 (13.4%)	117 (47.6%)	91 (37.0%)
Increase market opportunities	4 (1.6%)	5 (2.0%)	36 (14.6%)	145 (58.9%)	56 (22.8%)
Biodiversity conservation	2 (0.8%)	12 (4.9%)	112 (45.5%)	87 (35.4%)	33 (13.4%)
Reduces cost of production	8 (3.3%)	8 (3.3%)	16 (6.5%)	107 (43.5%)	107 (43.5%)

Source: Field Data, 2024

Table 5. Factor Analysis on the Benefits of Organic Cotton Farming in Smallholder Farmers' Adaptation to Climate Change in Meatu District

Benefits	Components		
	1	2	3
Improved soil health and fertility	-.044	-.096	.749
Enhanced crop yield	.724	.173	.015
Increase crop quality	.531	.059	.381
Water use efficiency	-.215	.810	.291
Improved income	.843	.007	.074
Increase market opportunities	.349	.524	-.067
Biodiversity conservation	.188	.108	.584
Reduces cost of production	.405	.587	-.304

Source: Field Data, 2024

These findings align with the study of Sreejith (2010) in India which exposed that *the greater biodiversity of most organic systems increases their ability to adapt to climate change,* also a study conducted by Mshana (2014) revealed the same results agreed that organic cotton continues providing both economic and ecosystem benefits organic farming systems provide benefits to water quality, biodiversity, rural communities, and human health. Similarly, Sartaj (2013) conducted research in India about Organic farming as an adaptation and mitigation strategy and discovered the same results that organic cotton enhanced ecosystem balance, protection of vegetative cover and wildlife of wild biodiversity, and better corridors resistance to wind and heat waves.

Lastly, 87% of respondents agree or strongly agree that organic cotton farming reduces the cost of production, suggesting potential cost savings associated with reduced reliance on external inputs and improved resource management. These cost-saving benefits not only make organic cotton farming financially viable for smallholder farmers but also enhance their overall economic resilience. Thus, the recognition of reduced production costs highlights the practical advantages of transitioning to organic methods, aligning economic incentives with environmental sustainability in the agricultural landscape of the Meatu district. The result aligns with the study of Martins et al. (2018) revealed that organic cotton producers face lower opportunity costs than conventional producers. These findings underscore the multifaceted benefits of organic in enhancing smallholder farmers' adaptation to climate change in the Meatu district and emphasize the importance of promoting sustainable agricultural practices for building resilience and ensuring food security in the face of environmental challenges.

The factor analysis presented in Table 5 explores the underlying relationships among various benefits of organic cotton farming for smallholder farmers in Meatu District, identifying three primary components. This analysis helps to clean the diverse benefits into coherent themes, aiding in the understanding of how these benefits interrelate and contribute to climate change adaptation.

Component 1 primarily captures economic and productivity benefits. Benefits such as improved income (0.843), enhanced crop yield (0.724), and increased crop quality (0.531) load heavily on this component. This suggests that economic gains and productivity improvements are strongly linked and are central to the farmers' perception of the benefits of organic cotton farming. The high loading of improved income indicates that financial benefits are a key driver for the adoption of organic practices. Enhanced crop yield also contributes significantly, highlighting the importance of productivity in securing farmers' livelihoods.

Component 2 emphasizes resource efficiency and market opportunities. Water use efficiency (0.810) and reduces cost of production (0.587) load significantly on this component, along with increased market opportunities (0.524). This indicates that farmers perceive organic farming as a means to use resources more efficiently and reduce production costs, which is critical for smallholders operating with limited resources. The inclusion of market opportunities suggests that accessing new markets is also seen as an important benefit, likely tied to the perceived quality and sustainability of organic products.

Component 3 is centred on environmental and soil health benefits. Improved soil health and fertility (0.749) and biodiversity conservation (0.584) load strongly on this component, highlighting the environmental sustainability aspects of organic farming. This suggests that farmers recognize the long-term ecological benefits of organic practices, such as enhanced soil fertility and biodiversity, which are crucial for maintaining productive and resilient farming systems.

Therefore, factor analysis highlights that the benefits of organic cotton farming are multi-dimensional, encompassing economic, resource efficiency, and environmental sustainability aspects. For policymakers and agricultural extension services, this means that promoting organic farming can address various farmer needs simultaneously, from improving incomes and productivity to enhancing resource use and environmental health. By recognizing these distinct components, interventions can be more effectively tailored to emphasize the comprehensive benefits of organic farming. For example, training programs can focus on both the economic benefits and the environmental practices that underpin sustainable agriculture, thereby fostering universal approaches to climate change adaptation for smallholder farmers in Meatu District.

The factor analysis results resonate with the study by Dinh et al. (2023) and Nyagumbo et al. (2021). Whereby, Dinh et al. (2023) emphasize the economic advantages of organic farming, highlighting improved incomes and productivity as central themes, which align with the economic and productivity benefits captured in Component 1 of the factor analysis. Similarly, Nyagumbo et al. (2021) emphasize resource efficiency and market opportunities as critical drivers of organic farming adoption, echoing the themes of water use efficiency, reduced production costs, and increased market opportunities Mshana (2014), and Bwana (2019) both their study revealed the same results. identified in Component 2. Moreover, both studies underscore the environmental benefits of organic farming, such as improved soil health and biodiversity conservation, which resonate with Component 3 of the factor analysis. Concerning ways organic cotton farming contributes to maintaining or improving soil health, however, the findings supported by an agro-ecological theory that emphasizes the use of agro-ecological principles such as recycling, Input reduction, Soil health, Animal health, Biodiversity, and other aims to maximize environmental health, increase crop yield as well as water management. the interview responses added,

> *"Organic cotton farming plays a significant role in maintaining and improving soil health through various sustainable practices. Organic farmers promote beneficial soil microorganisms and preserve soil structure. Also, practices like crop rotation, cover cropping, and mulching help enhance soil fertility, water retention, and overall soil biodiversity, contributing to long-term soil health."*

Another agricultural officer added,

> *"Organic cotton farming prioritizes soil conservation and organic matter enrichment, which are fundamental to maintaining soil health. Through techniques such as composting and green manure application, organic farmers replenish soil nutrients naturally, fostering a balanced ecosystem within the soil. Furthermore, reduced tillage practices minimize soil disturbance, preventing erosion and preserving soil structure, thus promoting sustainable soil health management*."

On the economic benefits, agricultural officers responded as;

> "*Smallholder farmers in Meatu district are motivated to shift towards organic cotton farming primarily due to the economic incentives associated with it. The premium prices offered for organic cotton in the market, coupled with the reduced production costs through the elimination of chemical inputs, and incentivized farmers to adopt this sustainable farming approach*."

The transition to organic cotton farming among smallholder farmers in the Meatu district is largely driven by economic factors. Premium prices for organic cotton in the market, combined with the cost savings achieved by eliminating chemical inputs, serve as powerful incentives for farmers. This economic motivation underscores the practical benefits of organic farming, aligning financial incentives with environmental sustainability efforts in the agricultural landscape of Meatu District

4. CONCLUSION

The study concludes that climate change is real and majority of small holder farmers perceived climate change through observed decrease in rainfall with changes in rain seasons, increase in temperature and increase in incidences of droughts and dry spells. It argues that climate change is really a global challenge affecting smallholder farmers in Meatu district. Organic Cotton Farming has been one of the practical climate change adaptation strategies due to various potentials associated with it. Therefore, this farming system is still viable, appropriate and a game-changer in responding to climate change. These findings underscore the need for proactive adaptation strategies to enhance the resilience of local communities to climate change impacts. Moreover, organic cotton farming emerges as a promising adaptation strategy in the Meatu district, offering a range of benefits that enhance farmers' resilience to climate variability. The high adoption rate of organic farming reflects a growing recognition of the advantages associated with sustainable agricultural practices, including improved soil health, increased crop quality, and water use efficiency. Furthermore, organic farming contributes to biodiversity conservation and creates market opportunities for farmers, highlighting its potential to mitigate the impacts of climate change while promoting environmental sustainability. Therefore, it is recommended that the government should promote more Organic Cotton Farming because is still feasible and suitable in responding to climate change. Education should be provided to smallholder farmers on the usefulness of Organic Cotton Farming as a response to the impact of climate change, especially for those who neglected it. This should be accompanied with the establishment of more Organic Cotton Farming demonstration farms to give farmers hands-on experiences and the future scope to many organic cotton growers to join the practices, however the limitations on adoption of the practice is the continued environmental changes.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

CONSENT

As per international standards or university standards, respondents' written consent has been collected and preserved by the author(s).

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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