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The impact of climate change on Mango production of small-scale farmers and their adaptation strategies in Ghana

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled the impact of climate change on Mango production of small-scale farmers and their adaptation strategies in Ghana. independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

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Abstract

In Ghana, a significant number of individuals engaged in agriculture are small-scale farmers residing in underdeveloped regions, using basic farming techniques. Climate change poses a challenge to these farmers as it impacts their income, the stability of food security, and their health status.This study investigates the impact of climate change on small-scale mango farmers and their adaptation strategies in the Eastern region of Ghana. Data was gathered from a survey conducted among 150 small-scale farmers

The Probit regression model was used to determine characteristics influencing use of adaptation strategies. Results revealed that more experienced farmers are more likely to practice soil management techniques compared to people with less than five years of experience. Similarly, farmers living in semi-urban areas are less likely to practice these soil management techniques than people in rural areas. However people with higher income were less likely to use these practices compared to lower income earners. The sources of information about the climate change were all statistically insignificant (except personal observation). In the case of construction of reservoirs and dams, experience played a major role since people with higher experience adapted these strategies to improve on their mango production compared to people with less than five years experience. Results revealed that higher income earners were less likely to adapt compared to lower income earners.

To help small-scale farmers adapt to climate changes and reduce the risks, the government, district governments, and non-profit organizations should work together to make climate information more available and provide mitigating strategies. Small-scale farmers should also get more education and information through programs that are not part of regular school, like workshops and farmer training.

Key words: smallholders, adaptation strategies, sustainable agricultural practices, Mango farming

Table of Contents

List of figures

List of tables

List of abbreviations

CSA……………………………………Climate-Smart Agriculture

CSRI…………………………………...Council for Scientific and Industrial Research

FAO……………………………………Food Agriculture organization

GCF……………………………………Green Climate Fund

GDP……………………………………Gross Domestic Product

GSS……………………………………Ghana statistical services

ILO……………………………………International Labour Organization

IPCC…………………………………...Intergovernmental Panel on Climate Change

MoFA…………………………………..Ministry of food and agriculture

RCP…………………………………….Representative Concentration Pathway

TPB…………………………………….Theory of planned behavior

VIF……………………………………Variance inflation factor

VSS……………………………………Voluntary sustainability standards

1. Introduction

Climate change is a global phenomenon that has profound implications for various sectors, and agriculture is no exception. In Ghana, the agricultural sector plays a crucial role in the national economy, providing livelihoods for a significant portion of the population. Mango production is a vital component of Ghana's agricultural landscape and contributes significantly to the country's export earnings. Small-scale farmers, who are the backbone of this industry, are particularly susceptible to the adverse effects of climate change. They heavily rely on rain-fed agriculture and have limited resources to adapt to changing climatic conditions (Yidu 2015).

The agricultural sector in many African countries, particularly in Sub-Saharan Africa, is crucial for economic development and livelihoods, but it faces significant challenges exacerbated by climate change. With a population exceeding 1.17 billion, the need to transform agriculture to meet rising food demands is pressing (Asare-Nuamah & Botchway 2019). However, efforts to enhance productivity often result in increased greenhouse gas emissions. While governmental bodies and development partners have promoted various adaptation and mitigation measures, such as soil conservation and agroforestry, limited attention has been given to market innovations like voluntary sustainability standards (VSS). Compliance with VSS has the potential to reduce emissions by 51% in developing countries, yet its environmental implications remain largely unexplored.

In Sub-Saharan African countries like Ghana, where mango production holds promise as a key export commodity, sustainability standards have mainly targeted non-food cash crops. Despite interventions aimed at enhancing productivity and certification rates among mango farmers, adoption remains at 50%, and the impact on climate change adaptation practices is poorly documented (Ehiakpor et al. 2016).

Mango production in Ghana is concentrated in several regions, with active participation from small-scale farmers. However, the impacts of climate change, including shifts in temperature, rainfall patterns, and extreme weather events, pose a severe threat to mango production. This has far-reaching consequences for food security, rural livelihoods, and national economic growth.

This thesis seeks to investigate the influence of climate change on mango production among small-scale farmers in Ghana, with a specific focus on the Yilo Krobo Municipality in the Eastern Region. The research will delve into observed changes in climate parameters, such as rainfall, temperature, and extreme weather events, and their implications for mango cultivation (MOFA 2021). Furthermore, the study will examine the adaptation strategies employed by small-scale farmers in response to these climate-related challenges.

Understanding the impact of climate change on small-scale mango producers in Ghana and their adaptive measures is crucial for ensuring food security, rural development, and the sustainability of the mango industry. This research will provide valuable insights into the dynamics of climate change impacts and adaptation strategies at the local level. These insights will be of significance to policymakers, agricultural extension services, and development organizations aiming to support and strengthen the resilience of small-scale farmers facing climate change challenges. By shedding light on the experiences and strategies of these farmers, this study aims to provide a foundation for informed decision-making and the development of sustainable interventions in Ghana's mango-producing regions.

By exploring the influence of factors such as knowledge, resources, and institutional support on the use of adaptation strategies, this research aims to provide insights into how mango farmers in Ghana can better mitigate the impacts of climate change on their production (Nasser et al. 2020). Understanding the nexus between climate change adaptation, market interventions, and sustainable agricultural practices is vital for policymakers, development practitioners, and farmers alike, as they strive to ensure food security, poverty alleviation, and environmental sustainability in Sub-Saharan Africa's agricultural sector.

2. Literature Review

2.1. Agricultural production in Ghana

As noted by Brown (2019) and Green (2020), the agricultural sector employs approximately 60% of the workforce and contributes an average of 30% to Gross Domestic Product (GDP) in Africa. Ghana, much like many other Sub-Saharan African countries, relies significantly on agriculture as a key contributor to its economy. However, in recent times, there has been a noticeable decline in the agricultural sector's contribution to Ghana's GDP. According to the Ghana Statistical Service (GSS 2021), the Services sector now takes the lead, contributing 46.3% to the GDP, while Agriculture lags behind the Industrial sector with a contribution of 19.7%. The decline in the agricultural sector's GDP contribution can be attributed to various factors, with climatic stressors, including late-onset and early cessation of rainfall, increased temperatures, and prolonged periods of drought, playing a substantial role. Consequently, smallholder farmers in Ghana employ various adaptive and coping mechanisms to address these challenges (GSS 2021).

Employment in agriculture thrives through mango farming, a significant sector contributing to the country's economy. With vast mango orchards scattered across different regions, numerous job opportunities arise throughout the cultivation cycle. From planting and pruning to harvesting and post-harvest handling, a diverse workforce engages in various tasks, fostering employment for both skilled and unskilled laborers. Furthermore, the processing and marketing of mango products such as dried mango slices, juices, and jams further stimulate job creation, supporting livelihoods in rural communities. Mango farming in Ghana thus serves as a vital source of employment, bolstering the agricultural sector and enhancing socio-economic development (World Bank 2021a). Employment in agriculture (% of total employment) (modeled ILO estimate).

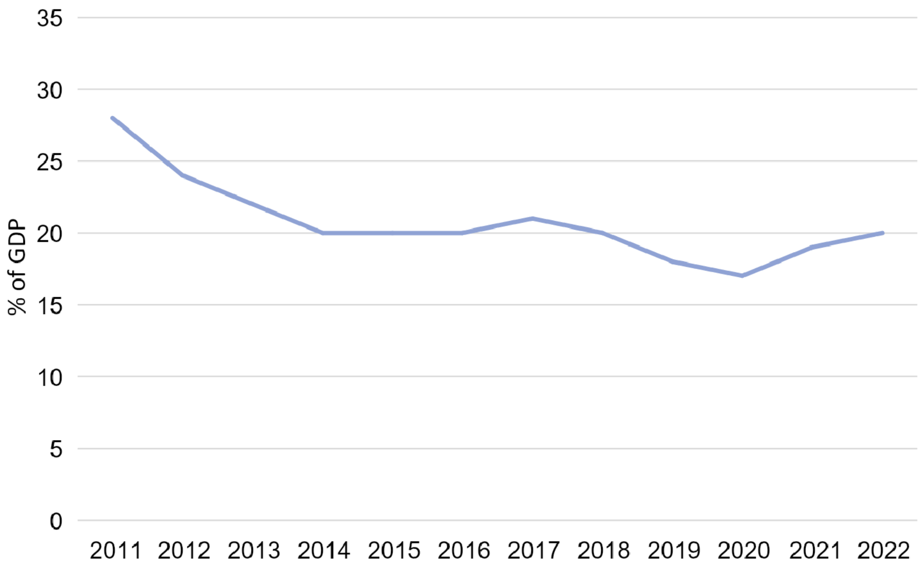

Figure 1: Agriculture as a share of GDP

Source: World Bank (2024)

2.1.1. Mango production

Mango production in Ghana is a significant contributor to the country's agricultural sector, renowned for its high-quality fruit. With favorable tropical climate conditions, Ghana boasts an optimal environment for mango cultivation. The cultivation process involves smallholder farmers as well as larger commercial enterprises, making it a vital source of income and livelihood for many communities. Improved farming practices and the adoption of modern technologies have led to increased yields and enhanced quality, fostering both domestic consumption and export opportunities, thereby bolstering Ghana's position in the global mango market.

Ghana has a great change when it comes to mango production because of the bimodal pattern of rainfall and affiliates with Yilo Krobo Municipality (MoFA 2013; Micah & Inkoom 2016). Research shows that mango production is one great potential economic booster after cocoa production (ADRA 2006). In realizing the great economic benefit posed by mango production, a lot of investments, both private and public, have been introduced to improve innovations and modern technologies and increase the productivity of farmers. Though all these appropriate measures prevail, results from previous research indicate that there is still a lower output of mango. However, the cause of low productivity in the area is affiliated with inefficiency in productivity (MoFA 2013). Addressing these challenges will require the usage of innovative strategies and modern technologies by most farmers in Sub-Saharan African countries to achieve higher production through the efficient and effective use of (Wambui 2005; Sentumbwe 2007; Farrell 1957). Farrell (1957) measures efficiency as (technical efficiency, economic efficiency, and allocative efficiency) which goes a long way in determining production growth.

Again, it has been noticed that farmers can increase their productivity without any technical change, if only they utilize the use of inputs and operate close to technology perimeters efficiently (Coelli et al. 2005). Normally, inefficiencies could be reduced and controlled by the farmers by using basic ideas in cultivation. Hence, the main reason for estimating efficiency is to indicate the growth rate of production units. The measurement of inefficiency helps to identify the efficiency differences in units of production (Wambui 2005; Sentumbwe 2007; Farrell 1957; Coelli et al. 2005). In view of the above-mentioned, economic efficiency is vital in being justified the benefit that can be derived in improving the productivity level in producing mango with the availability of inputs and existing technologies.

2.2. Climatic condition and climate change

2.2.1. Climatic conditions

Understanding the climatic conditions of Ghana necessitates an examination of crucial climatic variables that shape the nation's climate. These variables include temperature, rainfall, humidity, and wind patterns. Ghana experiences relatively high temperatures, with minimal variation throughout the year. The coastal regions benefit from a maritime influence, leading to milder temperatures. In contrast, the northern savannah regions are characterized by hotter temperatures. Average annual temperatures range from 24°C to 30°C (Asare-Nuamah & Botchway 2019).

The rainfall is a pivotal climatic variable in Ghana, profoundly influencing the nation's agriculture and economy. The distribution of rainfall exhibits variations across the north-south gradient. Coastal regions receive higher rainfall, averaging between 1,000 mm and 2,000 mm annually, while northern regions receive considerably less, ranging from 800 mm to 1,100 mm (Adu-Boateng et al. 2017). Coastal regions, particularly the Western and Central Regions, experience high humidity levels due to their proximity to the Atlantic Ocean. Humidity decreases as one moves further inland and northward. These humidity levels have implications for human comfort, vegetation growth, and crop yields (Asare-Nuamah & Botchway 2019). Ghana is significantly influenced by the West African Monsoon, which brings moisture-laden air from the Atlantic Ocean. The Harmattan, a dry and dusty wind originating from the Sahara

Desert, affects the northern regions during the dry season. These wind patterns play a critical role in influencing rainfall distribution and have a substantial impact on agricultural planning (Adu-Boateng et al. 2017).

In agriculture, the timing and quantity of rainfall significantly influence crop production, and inconsistent rainfall patterns, along with temperature variations, can lead to crop failures, affecting food security (Asare-Nuamah & Botchway 2019). The availability of water for irrigation is also contingent on these climatic conditions. Ghana's energy supply relies heavily on the generation of hydroelectric power from rivers and dams. Climatic conditions, particularly rainfall, significantly influence water levels in these reservoirs, impacting energy generation capacity (Adu-Boateng et al. 2017). High humidity levels in coastal areas create a conducive environment for the spread of certain diseases, such as malaria. Understanding these conditions is essential for public health planning and disease control (Asare-Nuamah & Botchway 2019).

Ghana's diverse ecosystems, including rainforests, savannahs, and coastal wetlands, are highly dependent on climatic conditions. Changes in these conditions can disrupt biodiversity and conservation efforts (Adu-Boateng et al. 2017). Coastal regions, particularly the Greater Accra Region, are vulnerable to rising sea levels and flooding due to their low-lying nature. Urban planning and infrastructure development must account for these climatic challenges (Asare-Nuamah & Botchway 2019).

Ghana's climatic conditions are diverse and complex, shaped by geographical factors and the nation's proximity to the equator. The climatic variables, including temperature, rainfall, humidity, and wind patterns, play a fundamental role in various sectors, especially agriculture, energy generation, public health, and environmental conservation. As climate change continues to impact the global climate system, Ghana must adapt and mitigate its effects to ensure sustainable development and the well-being of its population. This understanding of Ghana's climatic conditions serves as a foundation for informed decision-making and policy development in response to the challenges and opportunities presented by its unique climate.

2.2.2. Climate Change

All reports issued by the Intergovernmental Panel on Climate Change (IPCC) consistently emphasize the global manifestations of climate change and its related extremes, including rising sea levels, high temperatures, erratic rainfall, snowmelt, recurrent floods, and persistent droughts. While these phenomena affect regions worldwide, they exhibit uneven intensity and frequency distribution, with developing economies experiencing a more significant rise in the occurrence of climate extremes. As a result, these climatic shifts elevate vulnerability in economically disadvantaged regions across the globe. Extensive studies conducted at the household level in agricultural communities throughout Africa provide substantial evidence of climate change's existence and its profound implications for agriculture, notably leading to significant reductions in both crop quantity and quality (Adeosun et al. 2021; Asare-Nuamah et al. 2021b; Chepkoech et al. 2018).

The scientific studies that have been carried out till date, underscore the significant impact resulting from climatic factor i.e. floods, too much rainfall, droughts, high temperatures to the growth and performance of crops. For instance, Vaughn et al. (2021), made use of the Representative Concentration Pathway (RCP) 8.5 scenario to conduct an experimental study on how different plants perform under different climatic conditions. The factors that were regulated in the Acadian Forest region of North America included temperature, level of carbon dioxide, and the amount of precipitation. The results of the study revealed both the negative and the positive impacts of climate change to the performance of the sampled plants. Some of the findings were during drought season, low or zero precipitation, the mortality rate of the prod spruce increased by 2%, while that of Balsam increased by 5%. On the other hand, the warm temperatures brought about growth of the spruce and balsam firm to significant heights; the increased carbon dioxide in the atmosphere enhance the performance of the plants.

The microclimate of crop growth can be subcategorized into temperature, light, water presence, leaf span, and budburst timing. Vitasse et al. (2021) conducted a study to determine the influence of these microclimatic factors to the performance and production of plants. After the analysis and interpretation of the results, it was found that, these microclimatic conditions have a substantial impact to the growth of the plants. Asante et al. (2017) conducted a study and found that any unfavorable condition has a negative impact on plant growth. They include: wilting, dying, pest and disease riddles, and stunted growth among cocoa plants. These negative impacts had a significant impact to the production of cocoa, and the farmer yield reduced which in turn decreased their income. These findings indicate that not every tropical tree is immune or in a position to adapt to the changing climatic conditions.

Vázquez-Ramírez and Venn (2021) carried out a series of surveys in high altitude and high latitude areas as to the effect of climate change on the germination of seeds and the growth of crops generally. In the study, it was found that for the germination of seeds, it required warm temperatures. Too high-temperature results in dormancy and lack of emergence of the planted crops. On the other hand, a reduction in the amount of rainfall has a negative impact to the growth of crops at all stages. Similarly, a rise in temperature causes snow melt; this positively affects the seedling's germination. A few years ago, a quantitative study was carried out in Ghana and Costa Rica to determine the level to which climate change impacts the production of Cocoa farming. The respondents revealed that there has been increase in seedlings mortality, drying of full-grown cocoa plant, low yields due to low rainfall. These factors significantly affected the production of cocoa because of climate change. The study concluded that despite the enormous efforts applied by the governments to plant over 50 million cocoa seedlings, there was no guarantee of their survival rate after they have been transplanted due to the adverse climatic conditions.

2.2.3. Climate Change Impacts on Agriculture in Ghana

Understanding the influence of climate change on Ghana's agriculture requires an examination of various climatic stressors, including changes in temperature, rainfall patterns, and the frequency of extreme weather events (IPCC 2014). Rising temperatures can lead to heat stress on crops and livestock, impacting agricultural productivity (Ciais et al. 2018). Altered rainfall patterns, characterized by late-onset and early cessation of rainfall, can disrupt planting and harvesting seasons, resulting in reduced crop yields (Doe 2019). Increased drought frequency and intensity pose additional challenges, particularly for rain fed farming systems (Lal 2014).

The ultimate impact of climate change on Ghana's agriculture is reflected in food security and livelihoods (Zhang et al. 2019). Climate-induced agricultural losses can lead to reduced food availability and increased food prices, affecting the nutritional well-being of vulnerable populations (FAO 2019). Livelihoods of smallholder farmers, particularly those heavily dependent on rain-fed agriculture, are at risk due to climate change impacts, necessitating a comprehensive approach to address these challenges (Kang et al. 2016).

2.2.4. Climate Change Impacts on Mango production

Whitmore (1988) found that the seasonal changes in the amount of down pour in the tropical regions has a serious negative impact to the growth, and yield of mangos. Further, as per an experimental sturdy conducted by Esmail and Olbermann (2011), it was confirmed that these climatic variables which ranges from the level of carbon dioxide in the air, the amount of precipitation, the state of soil fertility has a significant impact to the growth of tropical plants.

As such, the plants are affected by these factors from the nursery level to the maturity period, which might result in low yield. It is also important to note that the findings of the studies carried out in the tropical regions found that soil fertility and the level of carbon dioxide have the highest level of influence on crop growth.

2.3. Adaptation and coping strategies

Smallholder farmers in Ghana employ a range of adaptive and coping mechanisms to address the impacts of climate change (Fosu-Mensah et al. 2012). These strategies include the diversification of crops to spread risk (Salman & Fleischer 2018), the adoption of climate-resilient agricultural practices (Kouadio et al. 2017), and the utilization of traditional knowledge and indigenous practices (Teng et al. 2018). Additionally, the conceptual framework encompasses the role of government policies and international initiatives in supporting climate adaptation in agriculture, such as the Ghana Green Climate Fund (GCF) Readiness Programme (GCF 2020).

2.3.1. Adaptation strategies of mango farmers

There have been numerous inventions that have been created to reduce the impact of climate change on Mango seedlings and fruit production, this invention has been implemented in both nursery level of plant and in the farms. Some of these interventions specifically affect the seeds, and the seedlings, while others for the fully grown plant. Additionally, there has been implementation of interventions to the micro and macro environment of the plant survival. The technologies that have been created to combat these adverse effects of the climate change focus on enhancement of resilience of the plant from its germination to maturity. On the other hand, the macro and micro interventions are meant to improve other aspects including soil acidity, soil nutrients and the level of soil salinity as well as availability of the required water (Malik et al. 2021**).** As per recent published research by Vaughn et al. (2021), the amount of moisture present in the soil has a significant effect that combats the rising temperatures and drought on plants. Hutchins et al. (2015) has noted that there have been numerous other methods which are intended to combat the influence of climate; some of these methods have been implemented in Ghana and Costa Rica. They include irrigation, intercropping, crop rotation, moisture management, and mulching of the Mango plants.

By growing tree and edible plants together has known to effectively improve the soil erosion problem and thus conserve the nutrients, and water within the soil, which ultimately leads to improvement in performance of plants and crops (Akinyi et al. 2021), the idea agrees with the findings of a research carried out by Apuri et al. (2018). As per Apuri et al. (2018), the construction of fire belts within the crops plantations helps the farmer in controlling and mitigating any wildfires which might destroy the whole plantation. Further, for the plant, and crops in nurseries as seedlings, the provision of regular watering, shading, and fencing has been known to help the plants grow without undergoing the harsh climatic conditions (Apuri et al. 2018). One of the main issues with climate change is the extreme heat. Therefore, Asante et al. (2017) reported from his findings that when the seedlings are provided with shading, the amount of germination (density) per unit are increases abundantly.

As a method of coping with the changing climate, the small-scale farmers have resorted to adopting improved seedlings is another strategy documented in the literature. For instance, in the study carried out by Ehiakpor et al. (2016), it was found that the farmers involved in cocoa production in Ghana have decided to replace old cocoa trees with new and improved ones that can withstand the current hash climate as well as improvement in the general yield of the plants. The strategy aligns with the government efforts to combat the climatic effect on plant, hence their intervention of replacing the old breed of Cocoa tree within the country through the distributed of the newly crafted and improved seeds and seedlings to small scale farmer through COCOBOD.

As per the researcher Malik et al. (2021), the practice of prior treatment of seedling with bio stimulants can be essential for the plant to be able to adapt to the changing environment, as well as improving the quality of plant growth and thereby contribute to the general plant resilience under unfavourable climate. Further studies regarding the usage of bio stimulants to improve the resilience, improve growth period, and enhance flowering of the plant have been documented as observed from De Pascale et al. (2018) and Raphael et al. (2018) reports. Taylor et al. (2008) describe the use of biostimulants in seeds and seedlings as an improvement in farming technology; other practices categorized as technological enhancement in farming include seed priming, seedling, and seed conditioning treatment, and seed coating. Generally, these new practices help improve the survival rate of the seeds, seedlings, and the plants under the changing climate, and the harsh environment brought out by pollution.

3. Objectives and significance of study

3.1 Objectives

Main objective

To assess farmers´ perception of climate change and adaptation methods used by small-scale mango producers in the Yilo-Krobo Municipality of Ghana.

Specific objectives

1) To identify perception of small-scale farmers regarding rainfall patterns, rising temperatures, and increased instances of extreme weather events, influence mango production.
2) To identify the adaptation strategies employed by small-scale mango farmers in Ghana to cope with the challenges posed by climate change.
3) To determine the main sources of information about climate change used by farmers and its´effect on the use of adaptation strategies.

    H0: there is no effect of source of information on the use of adaptation strategies

    HA: there is an effect of source of information on the use of adaptation strategies

3.2 Significance

Understanding the impacts of climate change on mango production is important for food security in Ghana. Small-scale mango farmers contribute to local food availability, and their ability to adapt to climate change directly affects the stability of food supplies in the country. Mango farming is a crucial source of income for many small-scale farmers in Ghana. By uncovering the economic repercussions of climate change on mango production, this research can guide policies that mitigate economic losses and protect the livelihoods of these farmers.

The study can contribute to the development and promotion of sustainable agricultural practices that are essential for the long-term sustainability of mango farming in Ghana, particularly in the face of climate change. The findings can have policy implications and potentially inform the design of more effective government programs and international collaborations to support small-scale mango farmers in adapting to climate change. The study's insights extend beyond Ghana and have broader relevance for regions facing similar climate challenges. By shedding light on climate-resilient strategies for mango production, the research can contribute to global discussions on climate-smart agriculture. Understanding the adaptation strategies employed by small-scale farmers can empower these communities to make informed decisions and build resilience against the adverse impacts of climate change, not only in mango farming but also in other agricultural sectors.

4.0 Methodology

4.1 Conceptual design

It's crucial to understand the psychological aspects involved in perceiving climate change. This encompasses attitudes, beliefs, and concerns regarding its occurrence (Fierros-González & Lopez-Feldman 2021). Perception, in this context, refers to how farmers comprehend the reality and causes of climate change, its consequences, and the factors influencing decisions to take appropriate measures (Van Valkengoed et al. 2021).

A multitude of factors shape farmers' perceptions. For example, Foguesatto and Machado (2021) found that factors like age, income, farm size, and access to weather information influence farmers' perceptions in Brazil. Similarly, Tesfahunegn & Gebru (2021) demonstrated that biophysical and institutional factors play a role in shaping farmers' perceptions of climate change. Personal experiences also significantly impact perception, potentially mitigating psychological barriers associated with climate change (Howe et al. 2019; Sambrook et al. 2021).

Farmers' perceptions are influenced by individual characteristics, life experiences, information sources, weather events, and socio-cultural contexts (Whitmarsh & Capstick 2018). Therefore, understanding farmers' climate perceptions and their adaptation processes necessitates grounding in perception theories. In this study, the theory of planned behavior (TPB) is employed to conceptualize farmers' perceptions and behavioral control concerning climate change and variability (Ajzen 1991; Hyland et al. 2016; Jethi et al. 2016; Morton 2007; Owusu et al. 2017; Rogers 2004; Teklewold et al. 2019; Wheeler et al. 2013).TPB is analyzed across three dimensions: attitudes toward behavior, subjective norms, perceived behavioral controls, farmers' cognition of climate change perceptions, and aspirations for adopting Climate-Smart Agriculture (CSA) practices. Aspiration serves as a reference point for farmers to improve agricultural production, aiming to enhance resilience against climate change risks (Duan et al. 2021).

Rogers's (2004) theory of diffusion highlights factors influencing farmers' aspirations and decisions regarding CSA adoption. These include innovators, early adopters, time conditions, skepticism, and socio-economic status. Farmers' adoption decisions are influenced by their willingness to change, information content, and access.

Previous studies have identified various factors affecting farmers' adoption of agricultural innovations, including social, economic, institutional, and environmental factors (Wheeler et al. 2013; Owusu et al. 2017; Jethi et al. 2016). Adaptation to climate change depends on farmers' perceptions, awareness, institutional support, and policy directions (Li et al. 2021; Mirzabaev 2018; Morton 2007).Understanding farmers' perceptions is crucial for designing and implementing effective agricultural interventions (Carlos et al. 2020). Effective implementation necessitates proper institutional arrangements and clear policy directions to enhance CSA adoption among rural farmers (Hellin et al. 2021).

This study focuses on farmers' knowledge and perception of climate change/variability and its impacts over the last three decades in Ghana. Farmers' responses to climate change are influenced by internal and external factors such as education, farming experience, household size, and access to resources. Examining farmers' perception of climate change and their adaptation intentions by integrating socioeconomic and biophysical factors would contribute to improved adaptation behavior. Adaptation constraints provide potential entry points for CSA adaptation policymaking and implementation. Figure 1 illustrates the conceptual framework of farmers' perception and adaptation behavior in this study, highlighting how their knowledge and perception of climate variability contribute to the adoption of suitable adaptation strategies to mitigate the negative impacts of climate change.

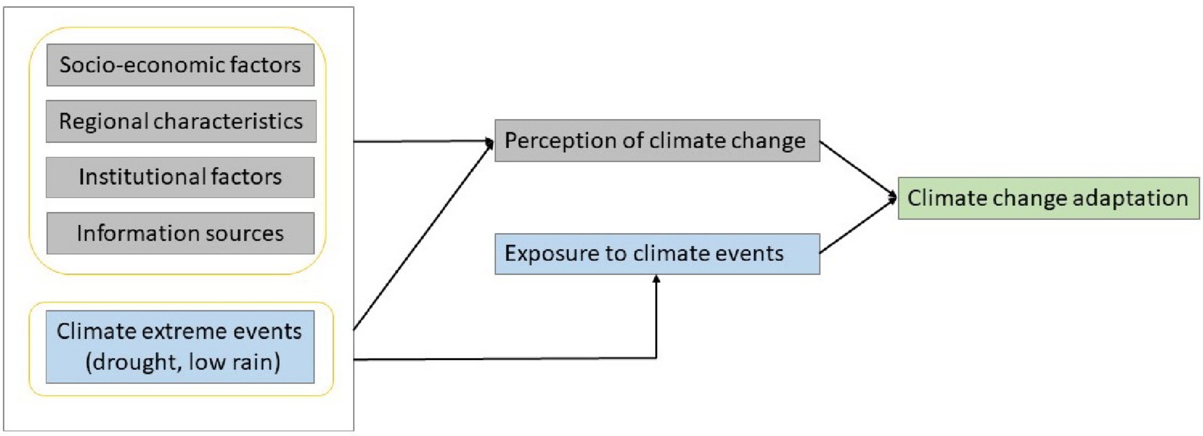

Figure 2: Conceptual framework design

4.3 Study Area

This study used a qualitative and quantitative design to understand the risks associated with climate change and adaptation in mango, as well as the adaptation strategies of gene producers in their environment (Creswell 2014; Creswell and Plano Clark 2018). As Yin (2004) said, the advantage of the research method is that it can collect interesting and detailed information from the real world. Many previous studies have also used case studies designed to improve our understanding of climate change and adaptation from smallholder farmers and ecological experiences (see Asare-Nuamah and Botchway 2019a).

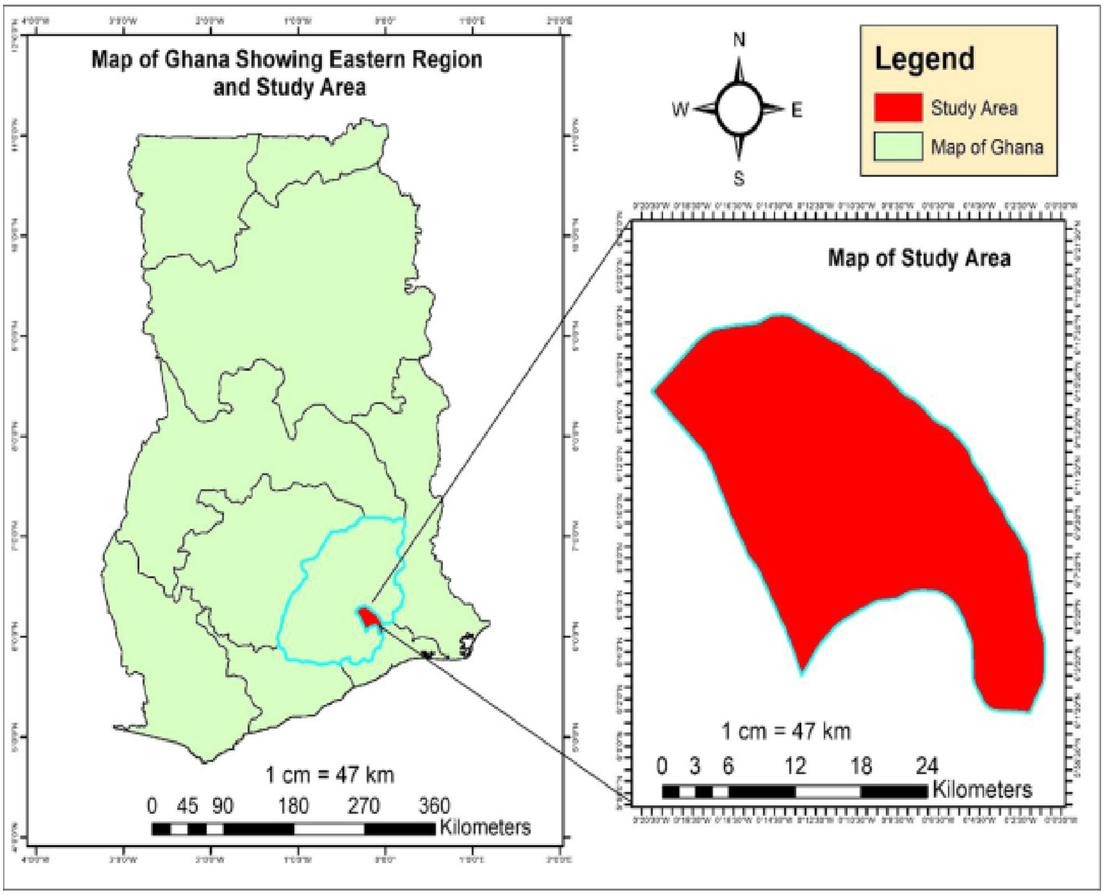

Figure 3: Map of Ghana showing the Eastern Region and the study area in the Yilo Krobo Municipality

Source: Asare-Nuamah et al. (2022)

Research was conducted in the Yilo Krobo area located within coordinates 06030N and 030100N in the Eastern part of the Republic of Ghana (**Figure 3**). According to the data we obtained from the Ghana Movement Archives of the Ghana Statistical Service (Census GSS 2014), Yilo Krobo consists mostly of rural areas, with approximately 87,847 residents (69%) living in rural areas. There is a bimodal rainfall pattern in the area, with annual rainfall ranging from 750 mm to 1600 mm and the temperature in the region ranging from 24.9 to 29.9 degrees (MOFA 2021b). The main economic activity in this rural area is agriculture and the primary source of welfare is agriculture, it is estimated that agriculture in this area produces up to 58% of income and employment compared to other economic activities (GSS 2014). Smallholder farmers mostly grow food crops such as cassava, maize, coconut, and yam. In addition, the area is notable for its mango production. Ghana's Ministry of Food and Agriculture noted in 2021 that climate change has had a substantial impact on the livelihoods of smallholder farmers, including mango producers. As such, the impact has a direct effect on their income, which is consistent with the conclusion of Waarts et al. (2021) that many tree growers in Africa who rely on agriculture to earn some income face a significant challenge from farmers.

4.4. Sampling method, data collection tools and procedure

Small-scale farmer quantitative questionnaire surveys, face-to-face qualitative interviews, and focus group discussions were used to compare qualitative data, whereas graphs, charts, the probit model, and Stata 18 were used to evaluate quantitative results and identify areas of overlap. For this study the climate data ranging from 1990 to 2020 were obtained from the Ghana Meteorological department.

4.4.1. Questionnaire survey

Data collection

Structured questionnaires were used to collect quantitative data on specific aspects of mango farming, such as crop yield, income, and adaptation practices. Careful design of questions, pre-testing, and piloting were essential to ensure that the data collected accurately reflected the intended variables. Data collection was carried out in October 2023 with the help of hired research associates who had initial data collection skills and lived within the study area, hence possessed prior knowledge as to the climatic conditions of the area of study. The data collection practice began by acquiring oral consent from the chosen respondents of the study ensuring that they were fully informed about the study's objectives and procedures. Each participant provided their consent willingly. Data collection involved gathering and recording qualitative and quantitative data through one-on-one interviews, with the choice of languages (English, Twi, and Krobo) as per the respondent's requirements. The data collection per session lasted approximately 30 minutes.

Sampling method

The study employed a multi-stage sampling technique. In the first stage, we used a purpose selection of the Yilo Krobo metropolitan district. Additionally, because the author is familiar with the city, the convenience sampling technique was employed to facilitate the process of collecting data. Second, the chain-referral sampling strategy, sometimes known as the snowball sampling technique was used.

To gather comprehensive data, 150 mango seedling growers were selected from the Somanya suburbs, including Trom, Old Somanya, and New Somanya. The research was conducted through a series of techniques to ensure that the entire population is represented hence accurate results. First, three small scale mango producers were identified from the previous data that had been collected in the same region by previous scholars. These three participants were selected purposively for the study due to their expertise in mango seedling production. Subsequently, these initial participants recommended other seedling producers, which initiated the snowball sampling approach.

Questionnaire

Both open-ended and closed-ended were used in questionnaire (Creswell 2014). The design of the closed-ended questions for collecting quantitative data was carried out following the previously documented literature. The questionnaires were composed of closed ended questions which included personal information of the respondents (gender, age, how long they had been doing mango farming, annual income associated with mango production, and size of their household), their views on climate change, their ratings on impact of climate change to their annual income and most common adaptation strategies used by them. Questions regarding the views of the respondents on climate change and the reasons of climate change were extracted from previous studies, such as Asare-Nuamah and Botchway (2019a) and Baffour-Ata et al. (2021). The results and observations from previously documented research by Asante et al. (2017) and Vaughn et al. (2021) were added to our research questionnaires to study the impacts of climate change on mango-growing small-scale farmers and the strategies to adapt to these changes. Further, the question also contained open ended questions which was intended to extract in-depth understanding to the impact they have had because of climate change.

4.4.2. Interviews

Key informant interviews with farmers, agricultural extension officers, and local experts were done in Old Somanya and Trom. These people have been on the field for several years, so they had a lot of information which was helpful for the thesis. The author spent enough time interviewing them with open-ended questions, and in-depth conversations with these experts provided rich insights into the experiences and challenges faced by mango farmers. To ensure transparency and consent, the interviews were audio-recorded. Field notes and non-participant observations served as supplementary methods for data collection.

4.4.3. Focus group discussions

Focus group discussions have been made to brainstorm with the farmers on small scale farming, production of seedlings, growing of plants, the sale of the produced fruits, and recognizes the pivotal role played by mango seedling production in their living standards as well as ability to have food security.

Focus group discussions facilitated the exploration of adaptation strategies used by these small-scale farmers. It encouraged participants to share their perspectives, experiences, and solutions, which served as a valuable source of qualitative data for this thesis. In total three focus groups were realized in Trom, old Somanya, and new Somanya all surbubs of Yilo Krobo Municipality in October 2023. Challenges faced during prolong drought, higher temperatures, climate variability among others were discussed With five focused groups involving 8 people each we met in all these areas we were able to brainstorm with them in identifying some problems faced by them and came out with some common adaptation strategies that could be used in addition to what they already practiced.

4.5 Ethical considerations

Conducting this research required careful ethical considerations to ensure that the study is conducted with sensitivity, respect for participants, and adherence to ethical principles. This chapter describe the ethical considerations involved in research on the impact of climate change on mango production by small-scale farmers in Ghana.

In Ghana, where a multitude of languages and cultures exist, obtaining informed consent necessitates clear communication and language accessibility. It was vital to translate consent forms into local languages and provide them in written and oral formats to ensure comprehension.

Engaging with the local communities where the research was conducted was crucial since we established a respectful and mutually beneficial relationship with the communities to gain trust and facilitate the research process. Community leaders, farmers' associations, and local authorities helped ensure that the research was culturally sensitive and respects local customs and traditions.

We guaranteed the privacy and confidentiality of participants, especially when discussing topics related to income, family, and livelihood. Data collected was anonymized and stored securely to protect the identity and information of the participants.

We were cautious not to exacerbate the distress the participants by reporting solely on negative findings. Instead, we seek to provide recommendations and support for adaptation strategies that may ameliorate current challenges.

It was ethically important to communicate research findings in a way that promotes positive actions and outcomes for the participants and their communities.

4.6 Data analysis

Following a satisfactory face-to-face questionnaire administration process, 150 responses were obtained from participants in the Yilo Krobo metropolitan area. Data was manually entered into Microsoft Excel for data cleansing, as well as for the creation of charts and descriptive statistical analysis. Additionally, the Probit regression model, and descriptive statistics were performed using IBM SPSS software and Stata 18. Descriptive statistics like tables, frequencies, and percentages were used to accomplish the results of the thesis.
To analyse characteristics influencing adoption of sustainable agricultural practices, a two binary probit models in the following form was used:

$$\Pr(y = 1, x) = \Phi(x\beta)$$

Where y is a dependent binary variable – use of (1) soil management practices and (2) water management practices[1], taking a value of 1 if respondent used this type of practice and value 0 if not; x represents a set of explanatory variables and $\Phi(x\beta)$ is the cumulative distribution function.

In this research, socio-economic variables such as farm experience, source of information about climate change, perception of climate change, household income and access to subsidies were utilized as predictor variables used. List of variables is included in Table 1. The selection of dependent and independent variables was based on previous findings of Asare-

[1] Binary probit model was run for all types of adaptation strategies (e.g. improved seeds, wind-storm management, use of drip and sprinkler irrigation), but the explanatory power of model was insignificant meaning that the variables used (and available in the questionnaire) did not explain dependent variable well.

Nuamah et al. (2022), Bamweyana et al. (2020), Borrelli et al. (2007), Carmen et al. (2017), Evans et al. (2020), Hamidi et al. (2018), Peters (2018), Srivastav et al. (2021); Zhao et al. (2020); Zhang et al. (2023).

The regression model was tested for multicollinearity by calculating a variance inflation factor (VIF). All tested explanatory variables have VIF values within the range of 1.07 – 1.84. The mean VIF was 1.31 , which is below the threshold value of 10, as suggested by Kleinbaum et al. (2013). The results revealed that there was no statistically significant multicollinearity among the explanatory and dependent variables in the model.

Table 1: Definition and description of variables

Variable	Description	Data coding	Frequency
Dependent variables			
Soil management practices	Mulching. composting, crop rotation	Yes =1, No =0	65%
Water management practices	Construction of dam, irrigation methods, reservoirs	Yes =1, No =0	63%
Independent variables			
Working experience	Experience with mango production in years	< 5= 0 5-10 = 1 11-15 =2 16-20= 3 > 20= 4	29% 21% 2% 12% 17%
Locality	Location of farm	0= Rural 1= Urban 2= Semi-Urban	73% 11% 16%
Household income	Yearly household income	$5000 = 0 $8000 = 1 $11000 =2 $13000 =3 $15000 =4	31% 39% 29%
Source of information regarding climate change			
Personal observation	Climate knowledge obtained	Yes =1, No =0	93%
Radio	Climate knowledge obtained	Yes =1, No =0	8%
Television	Climate knowledge obtained	Yes =1, No =0	87%
Farmer to farmer extension	Climate knowledge obtained	Yes =1, No =0	8%
Farm seed-based association	Climate knowledge obtained	Yes =1, No =0	67%
Governmental subsidies	Climate knowledge obtained	Yes =1, No =0	49%
Percenption of farmers			
Drought perception	Climate knowledge obtained	Yes =1, No =0	48%
Low rain perception	Climate knowledge obtained	Yes =1, No =0	50%

5. Results

5.1 Farmer's profile

During the survey, 15% of respondents were females, while 85% were male, indicating that more males were interested in mango farming compared to females. Though they all shared their experiences and thoughts, but more information was gathered from the male respondents. About 17% of surveyed farmers had more than 20 years of experience in farming, 12% and 2% had 16-20 and 11-15 years of experience. About 21% had between 5-10 years of experience and 29% less than 5 years. An annual household income threshold of $ 5000 was used to help understand if the income had an impact on their annual yields. About 31% of respondents earned $5000, 39% earned $8000 and 29% earned $11000 annually.

The mean yield of mango was 68.19 crates in a year, whereas the minimum yield from our data was 35 crates and the maximum was 100 crates. This data informed us about how each of the respondents are able to increase their farm yields within a given year.About 49% of respondents indicated that they get any subsidies from the government. Most of the respondents complained of higher prices of fertilizers and other tools and equipment which could have helped them in these farming activities. Some respondents even complained of extension officers smuggling some of these materials, which are supposed to be given free to them.

5.2 Observed influence on climate change

About 90% of the respondents agreed that for the past 10 years, they have observed that the climate has changed, and it was affecting general farming practices. About 80% of the people interviewed about the rain pointed out that there was a decrease in both the amount and 93% spoke about rain duration, with the rain starting late 73% represented it and 27% of the farmers indicated the rain starting early, and 67% of the participants reported increased flooding. Regarding temperature, about 65% of participants mentioned daily high temperatures. Additionally, 53% stated that there was an increase in storms, while 47% of them pointed out that there was a decrease in storms (see Figure 4).

Even though temperature in the region increase during the summer seasons temperatures in the region increase to an average of 28°C in the dry season. The predictions of the numbers also show that temperatures will continue to rise in the future. While the main monsoon season, which is important for agriculture, in terms of rainfall, has decreased, the minor monsoon season has seen a different course and will gradually go up. Decreased rainfall during the main season is a concern because this is the period when small farmers engage inextensive farming, labor and harvesting. Therefore, low rainfall can cause agricultural yields to decrease, affecting family health, food security and national development.

Qualitative interviews provide additional insight into participants' perceptions of climate change based on their experiences. In terms of precipitation, most participants stated that 2012, 2014 and 2019 were rainy years with very little rainfall. For example, one of the interviewees explained:

"In 2012, 2014 and 2019, we experienced severe and prolonged droughts due to long delays and heavy rainfall. Rainy season."(P16, man)

Participants noted that rainfall decreased after a long drought. In contrast, 2020 and 2021 are identified as years withabundant rainfall for the study community. One participant said:

"We experienced a lot of rain in 2020 and 2021, both in terms of time, frequency and intensity."(P20, man)

This observation was also supported by a man who participated from New Somanya

"Heavy rains and monsoons,even the dry season (December), cause floods in our community." (P7, man)

Safety is an event that occurs on foot in a safe area, a low-risk area, or a nursery. All participants reported that the temperature in their neighbourhood had increased in¨the last five years. A male participant in Old Somanya said the following to draw attention to the increase in temperature:

"We now experience high temperatures every dayfrom morning to afternoon, this was not the case 20 years ago. It is only in the afternoon. But nowadays, high temperatures happensevery day, and our rooms are hot even at night due to that". (P76, man)

Tornadoes off the coast of Ida are well known, but participants are voicing concerns about hurricanes in the scientific community. For example, respondent from New Somanya said:

"We saw a lot of storms in 2019." (P112, man)

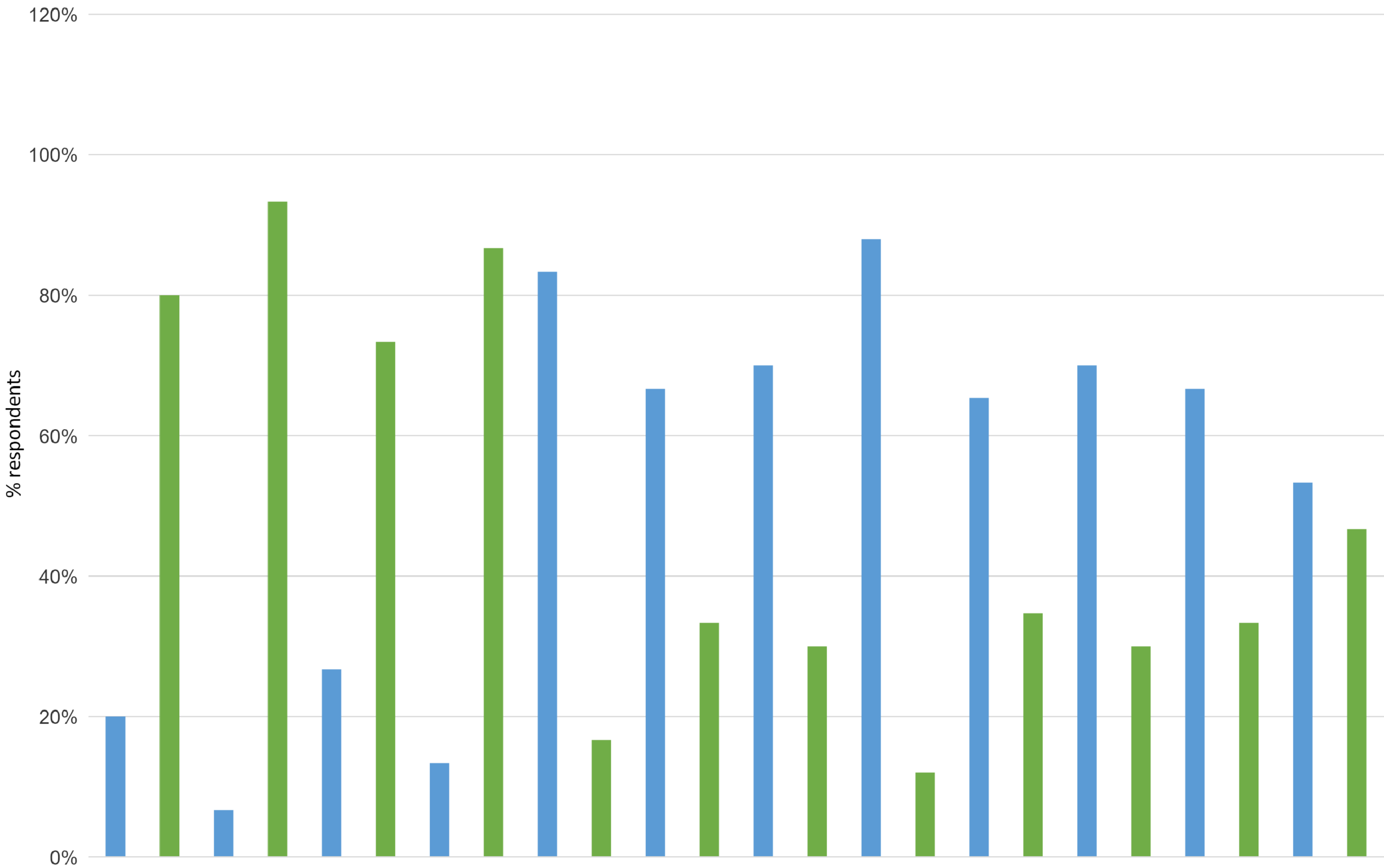

Figure 4: Perceived climate variability and change

5.3 Causes of climate change in Ghana

Figure 5 describes the perceived causes of climate change and the changes reported by participants. According to the respondents, the most common is deforestation, followed by poor farming practices, gas emissions from industry and transportation, use of agricultural chemicals, and agriculture. Expansion and poor agriculture played also important role. Other impacts include mention of *"the wrath of the gods"*, superstitious belief, overgrazing and livestock activities, population growth, change in cities lifestyles, and construction.

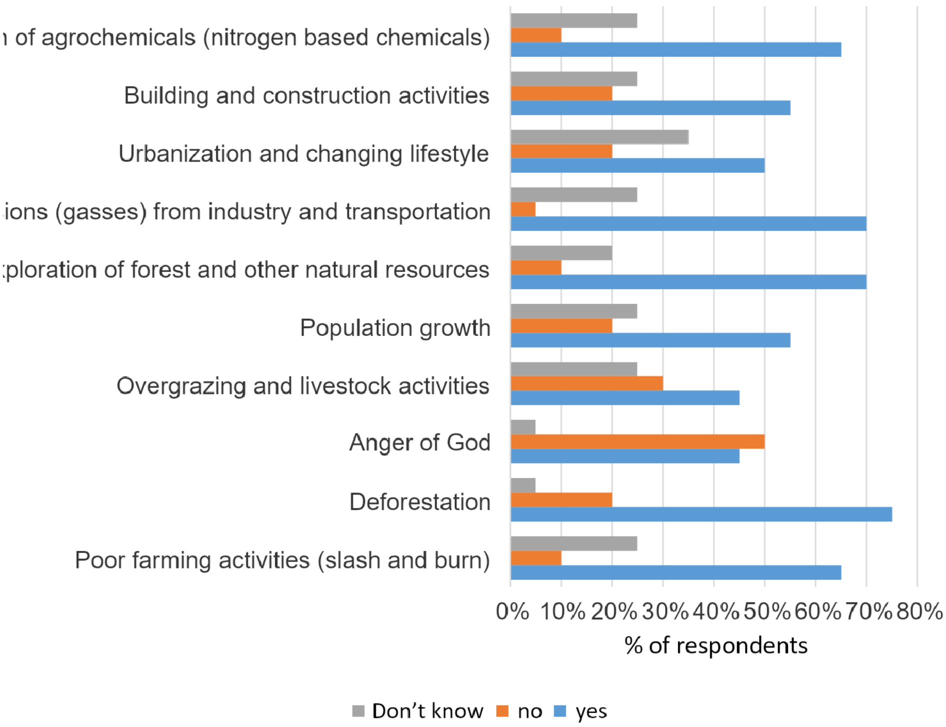

Figure 5: Causes of climate change

About 75% of respondents perceive *deforestation* as a driver of climate change. This high percentage indicates a strong awareness among farmers regarding the link between deforestation and climate change. 70% of respondents believe that *overexploitation of natural resources* contributes to climate change. This high percentage underscores the understanding of how resource depletion impacts the environment.70% of respondents attribute climate change to *emissions from industry and transportation*. This indicates a strong recognition of the impact of industrial and transportation-related emissions on climate change. 65% of respondents believe that the *application of agrochemicals*, particularly nitrogen-based chemicals, plays a role in climate change. This underscores the recognition of the environmental consequences of certain agrochemicals. About 65% of respondents believe that poor farming practices, such as *slash and burn*, contribute to climate change. This suggests that a significant portion of farmers recognizes the environmental impact of certain agricultural practices 55% of respondents consider *population growth* as a driver of climate change. This suggests an awareness of the link between population growth and increased resource consumption. About 55% of respondents perceive *building and construction activities* as contributing to climate change. This indicates an awareness of the environmental impact of construction practices. However 50% of respondents link *urbanization and changing lifestyles* to climate change. This reflects an acknowledgment that urbanization and lifestyle changes can lead to increased resource consumption and emissions. Again, 45% of respondents attribute climate change to the *"anger of God," superstacious belief* while 50% do not attribute it to this factor. This perception reflects a combination of cultural beliefs and recognition of environmental factors as drivers of climate change. A total of 45% of respondents associate climate change with *overgrazing and livestock activities.* This highlights the acknowledgment of the role of agricultural and livestock practices in climate change.

The data reflects a diverse range of perceptions among mango farmers in Ghana regarding the drivers of climate change. While some factors, such as deforestation, overexploitation of natural resources, and emissions from industry and transportation, are widely recognized as contributing to climate change, others, like the "*anger of God*," have more variable levels of attribution.

The interviews confirmed many conclusions; many interviewees identified human activities as the main drivers of climate change and adaptation. For example, one of the interviewees explained:

"Almost all the forests have been destroyed due to thedevelopment project. Trees play an important role in climate control but because we have cut down most of the trees in the country. The world is made of wood, resulting in the climatechange we are currently experiencing." (P133, male)

Participants also reported that business, transportation, and carbon emissions impact climate change, but they were unable to clearly identify responsibility for this impact. Regarding population growth and development, a male participant from old Somanya noted:

"Population and development activities also create environmental problems, including climate change. For example, when the population increases, people must eat, build, and build their own communities. These activities require the development of natural resources. Inequality in

development also pushes people into urban areas, putting pressure on natural resources and production". (P15, male)

Some participants attributed climate change to the actions of God or divine wrath and expressed the belief that only gods can influence the weather and cause climate change. Some participants also said climate change was linked to divine punishment, with some gods able to withhold rain to retaliate against worshiping communities. Also, participants agreed that the expansion of agriculture such as slash-and-burn agriculture and the use of agricultural chemicals lead to climate change because these, activities change and affect the environment. Addressing this issue, one respondent said:

"Like cars and industries, the explosion and combustion emissions of agriculture mix with the atmosphere, causing climate change." (P1, male)

5.4 Origin of climate change information

Respondents derived their knowledge about climate change from a variety of sources, as shown in Figure 6. All respondents cited personal observation as the primary source of their knowledge about climate change. More than 87% of respondents mentioned radio and television as another important source of information, 80% of respondents mentioned acquiring knowledge through additional services among farmers. About 67% of respondents cited farm-based organizations as an important source of information. About 50% of respondents mentioned the internets as the primary sources of their knowledge about climate change.

For example, one respondent commented: *"Extension services have increased my knowledge about water requirements for seedlings at different stages."* (P25, male)

However, interviews revealed that access to extension services was limited for those engaged in seedling production, especially for micro, small and medium seedling producers. One interviewee specifically pointed out:

"Extension service providers mainly focus on farmers and not on seedling producers, even though we contribute significantly to agricultural activities because farmers must use quality seedlings to improve yields and minimize the effects of climate change." (P45, male)

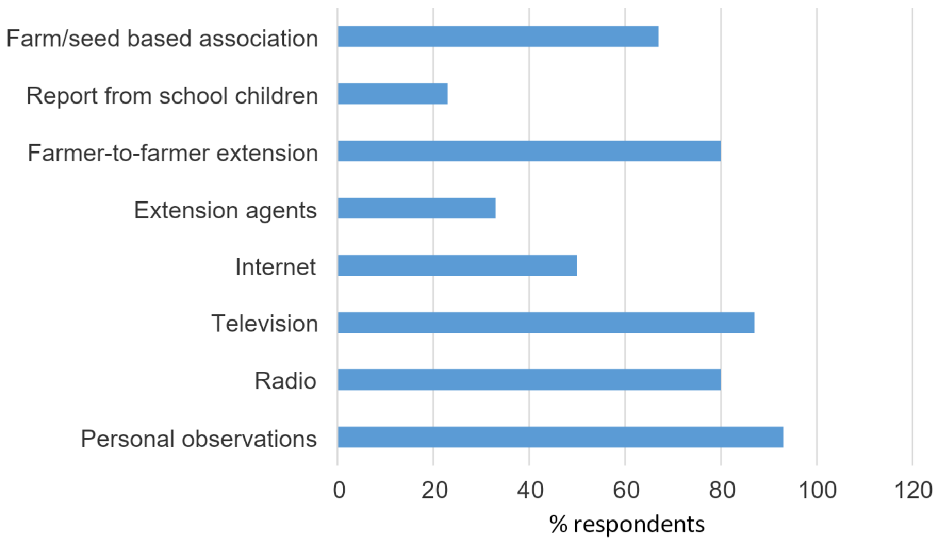

Figure 6: Source of climate change knowledge

About 78% farmers that were interviewed indicated that pest and diseases are the issue to the overall production of mangos in the region. About 80% of the respondents cited wilting and mortality rate of young mango plants because of droughts, and low precipitation levels. Whiles 76% reported impacts to mango farming due to climate change were stunted growth of the plants, poor germination of the planted mango seeds, and limited water saw 77% respondents voting for these causes, while 60% said the increase in soil dryness causes it. On the other hand, 63% of the farmers admitted that the mango production has improved because of climate change.

The interviews of the participants highlighted key factors that needs to be discussed regarding the impact of climate change on the overall mango farming among small scale farmer in Eastern Ghana. Some of these highlighted points were droughts, flooding, increase in temperatures, and the new diseases and pest. The participants reported that excessive rains lead to flooding which leads to waterlogged farms, rise in pest and diseases, as well as stunted growth of the mango plants. For instance, a participant from Trom explained that flooding is very harmful to mango farming; he said:

"When the farms are flooded for seven to 14 days, you stand a chance of losing half of the plants due to wilting resulting from excess acid in the soil". (P115, man)

In new Somanya (P71, man) also added that, with waterlogged farms, there is high chance that diseases and pest will affect the plants.

Drought and rise in temperatures were also identified as one of the impacts resulting from climate change. Participant (P120, male) reported that persistent lack of water for the mango trees will result in stunted growth, and poor yield for the mature plants. Discoloration of plant leaves results from lack of water due to droughts, as such the process of food manufacture of plants (photosynthesis) is affected hence poor development of young plant and poor yield of the mature plants.

As per one of the participants of the study *"Prolonged drought increases the chance of soil acidity, which in turn affect soil fertility".* (P8, woman)

Lack of water for the plants especially during the flowering season has emerged to be a significant impact on the performance of the mango plants. Additionally, prolonged droughts have led to many wildfires which race down the mango farms destroying the plants. Generally, these factors have led to a reduction in selling prices of the output due to low quality yield hence a reduction in annual income for the farmers.

5.5. Rainfall Patterns

Most farmers (85%) reported a *decrease in rainfall* amount, indicating that a significant portion of respondents perceives a reduction in overall precipitation. This can have adverse effects on mango farming, as adequate water is essential for healthy tree growth and fruit production. Regarding *rainfall duration*, 75% of farmers reported a decrease. A shorter rainy season could impact mango flowering and fruit setting, potentially reducing yields. Farmers reported both early and late onset and retreat of rainfall. The split between early and late onset suggests variability in the start of the rainy season. Late rainfall onset can disrupt the flowering and fruit development stages in mango farming, potentially leading to lower yields. The data indicates a 70% perception of early *rainfall retreat*, which could have implications for post-harvest practices and fruit quality.

Most farmers (80%) reported *an increase in flood intensity*, which is concerning as flooding can damage mango trees and fruits. Adequate drainage and flood management strategies may be needed. Regarding *flood frequency*, 65% of farmers reported an increase, which indicates that flooding events are occurring more frequently. This can lead to crop loss and damage to orchards.An increase in both *drought intensity* (55%) and *frequency* (55%) were reported by an equal proportion of farmers. Drought conditions can stress mango trees, reduce fruit quality, and, in severe cases, lead to crop failure.

The majority (70%) reported *high daily temperatures*, which can affect mango flowering and fruit set. High temperatures may also contribute to heat stress on the trees. In terms of *temperature duration*, 75% of farmers perceived an increase, indicating longer periods of high temperatures. Extended periods of heat can be detrimental to mango trees and fruit development.

A higher percentage of (60%) farmers reported an increase in *windstorm intensity*, suggesting that these events are more damaging to mango orchards. *Windstorm frequency* data shows that 55% of farmers reported an increase. Frequent windstorms can lead to physical damage to trees and fruit.

The data paints a picture of climate-related challenges faced by mango farmers in Ghana. Decreasing rainfall, increased flood and drought events, higher temperatures, and more frequent and intense windstorms are all concerns. These perceptions have direct implications for mango production, affecting fruit quality, yield, and overall orchard health. Climate change is impacting mango farming in Ghana, and farmers are responding to these perceived changes.

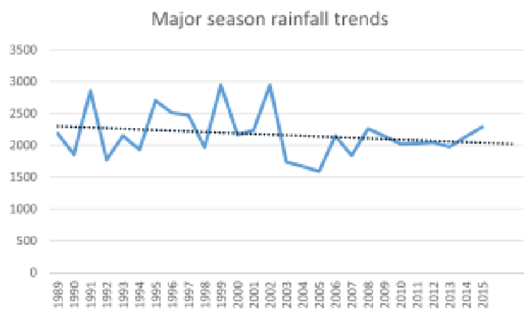

Figure 3a. Rainfall trend for the major raining season

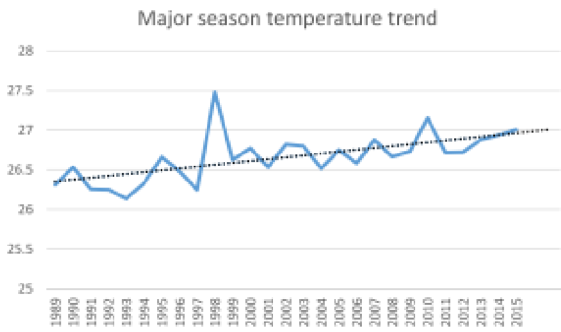

Figure 3b. Temperature trend for the major raining season

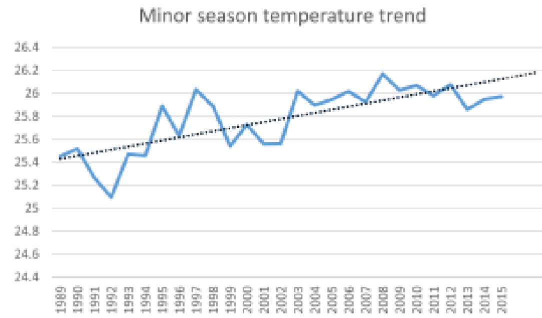

Figure 3c. Temperature trend for the minor raining season

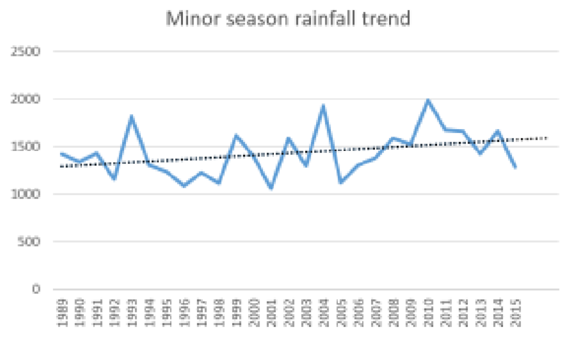

Figure 3d. Rainfall trend for the minor raining season

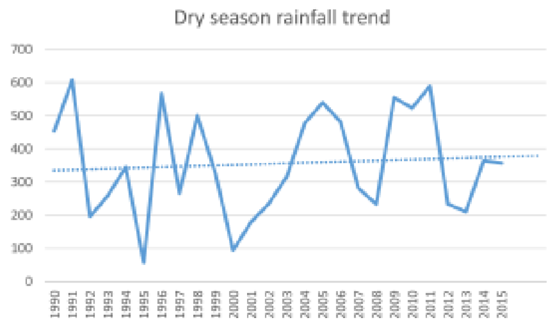

Figure 3f. Rainfall trend for the dry season

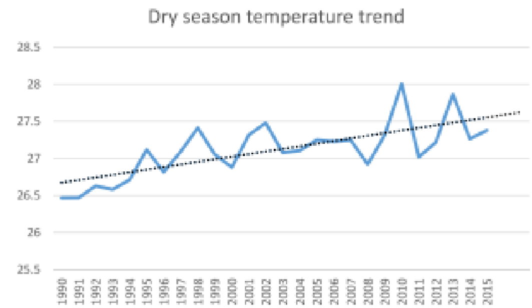

Figure 3e. Temperature trend for the dry season

5.6. Adaptation strategies

Flood management

For flood management, participants build canals and water pipes on their farms to help the flow of water during floods. Some people use sawdust and mulch to help absorb moisture, reduce flooding and erosion, and thus maintain soil fertility. Emergency Management Partners are solving the heat problem by planting trees around nurseries simply to provide shade for plants and reduce direct sunlight. This practice is common in all childcare facilities. Some participants also cover nurseries with palm leaves and branches to protect seedlings from solar energy, especially during the dry season. These machines are used only by micro and small seed producers. Participants emphasized the importance of removing shade when plants reach a certain stage where they need more air and water. Conversely, during grafting, seeds benefit from additional heat, so rubber mulch is used in nurseries to increase heat.

Tools and equipment used

Farmers utilize a range of tools and equipment specifically designed for mango cultivation. These tools include irrigation equipment such as drip systems or water-efficient sprinklers, enabling precise water application and promoting efficient water usage in orchards, also mobile phones are used in tracking the weather conditions.

Pest Control

Farmers employ various soil management practices to maintain soil fertility and health. Techniques such as mulching, composting, and crop rotation enhance soil structure, moisture retention, and nutrient levels, creating favorable conditions for mango cultivation. *"Despite the use of chemicals, pests and diseases can occur in nurseries." When my nursery got infected, I stopped using the medicine and did nothing. Diseases have been eliminated."* (P3, male)

Respondent P3(male) added that overuse of chemicals can help pests thrive, which explains why the same pests appear again and again even after chemical treatment. Some participants said that placing netting on and around nurseries can reduce pest infestation.

Fire Fighting

Participants expressed their concern that fires during the dry season create problems for farmers. To prevent this problem, farmers who have nurseries near dry and dense areas have built fire barriers to prevent fire from entering their facilities and damaging the plants.

One participant explained: *"During the dry season, we often start fires because there are a lot of plants and dry leaves, and they can easily catch fire. So, we lit a fire around the nursery to protect them."* (P15, male)

Water management techniques

Given the unpredictable rainfall patterns and increased risk of drought, mango farmers adopt water management strategies to ensure adequate irrigation and conservation. These strategies include constructing water storage facilities such as dams or reservoirs and implementing efficient irrigation methods to optimize water usage and minimize wastage.

Soil Management practices

Interviews revealed that seed producers use soil management to reduce the effects of climate change. While normal soil can be used in the nursery, respondents prefer soil management in the nursery. Black clay enhances the growth of seeds and overall productivity, Black clay has the dual benefits of increasing soil fertility and water retention. However, the mango production area in Yilokrobo City isin the Savannah AgroEcological Zone and access to black clay soil is limited. Therefore, farmers often mix the soil with other materials such as ash or potassium fertilizer to increase the fertility of the soil. Farmers employ various soil to maintain soil fertility and health. Techniques such as mulching, composting, and crop rotation enhance soil structure, moisture retention, and nutrient levels, creating favourable conditions for mango cultivation.

Improved Seed Varieties

The respondents of the study also indicated that, with the changing climate, the new nurseries for mango trees require the improved seed qualities that can be able to withstand the adverse climatic conditions. The Kent and Keit mango seed variety seem to be the most preferred by the respondents. For instance, one participant said that:

"I have been purchasing Kent and Keit seeds for some time now, they have high germination density, and ability to withstand the present climatic conditions, further the seed variety produces plants that are highly marketable". (P12, male)

On the other hand, respondent (P3, male) indicated that although the Kent and Keith seed variety are excellent, they are costly to acquire, nonetheless; through grafting a farmer can create multiple varieties with one single seedling. Grafting also create a mongo tree with multiple branches producing different varieties of the fruit. Additionally, application of fertilizers to the plants is done to accelerate the growth and ensure that the plant is healthy enough to withstand any adverse climatic condition that might occur soon. Farmers actively select, and plant seedlings known for their resistance to drought conditions. This adaptation strategy aims to ensure continued growth and productivity of mango trees, even during periods of reduced water availability.

Windstorm Management

As indicated before, one of the main hazards that results in the destruction of mango trees in eastern Ghana is the windstorm. Therefore, planting of big trees within the farm compounds prevents the destruction. The measure acts as a wind breaker which reduce the speed and the strength of the wind. However, during strong windstorms, the fence trees can fall resulting in a lot of damages to the mango trees. They implement these measures to protect their crops from wind damage. Establishing windbreaks, such as planting trees or erecting barriers, is essential to shield mango orchards from the destructive effects of strong winds.

Adapting social media for marketing mango seedlings

Several participants mentioned their use of social media as a marketing tool to find suitable markets for their mango produce. For example, participant P3 (a male from Trom) stated, "Climate change is impacting mango yields, so to counter this, I post high-quality mango produce on my Facebook and Instagram accounts to attract better markets." He also noted that his brother utilizes Twitter and Instagram to generate demand for his produce, resulting in increased overall income. Notably, this technological approach to marketing through social media was more prevalent among younger respondents in the study.

5.7. Characteristics influencing adoption of sustainable agricultural practices

Farmers employ various soil management practices to maintain soil fertility and health. Techniques such as mulching, composting, and crop rotation enhance soil structure, moisture retention, and nutrient levels, creating favorable conditions for mango cultivation. The chi^2 results of both probit models show that likelihood ratio statistics are highly significant suggesting that the models have a strong explanatory power.

Table 2: Characteristics influencing adaption of soil management techniques in mango production

	Coefficient	Std. error	p-value	Marginal effects
Experience (less than 5 years = reference)				
5-10 years	-0.242	0.355	0.496	-0.096
11-15 years	1.103	0.357	0.002	0.358
16-20 years	1.020	0.431	0.018	0.340
More than 20 years	0.950	0.366	0.009	0.323
Locality (rural = reference)				
urban	0.770	0.464	0.097	0.201
semi-urban	-0.748	0.357	0.036	-0.288
Household annual income ($5000 = reference)				
$8000	-0.876	0.333	0.009	-0.270
$11000	-1.014	0.339	0.003	-0.324
Source of information about climate change				
Personal observation	-1.107	0.581	0.051	-0.391
Radio	-0.458	0.317	0.149	-0.162
Television	0.010	0.362	0.978	0.003
Farmer to farmer extension	0.030	0.307	0.923	0.010
Farm seed based association	0.068	0.251	0.786	0.024
Subsidy from government	0.206	0.260	0.429	0.073
Farmer perception				
Drought	-0.153	0.246	0.533	-0.054
Low rain	0.052	0.245	0.833	0.018
Constant	1.976	0.831	0.017	
LR chi2	41.08		0.0005	
Pseudo R2	0.211			

Based on our findings, more experienced farmers are more likely to practice soil management techniques compared to people with less than 5 years experience. Similarly, farmers living in semi-urban areas are less likely to practice this soil management techniques compared to people in rural areas. However people with higher income were less likely to use these practices compared to lower income earners. The sources of information about the climate change were all statistically insignificant (except personal observation). Farmers who personally observed climate change were less likely using soil management techniques compared to those who did not. The rest of variables was not statistically significant (see Table 2).

Given the unpredictable rainfall patterns and increased risk of drought, mango farmers adopt water management strategies to ensure adequate irrigation and conservation. These strategies include constructing water storage facilities such as dams or reservoirs and implementing efficient irrigation methods to optimize water usage and minimize wastage.

Table 3: Characteristics influencing adaption of water management in mango production

	Coefficient	Std. error	p-value	Marginal effects
Experience (less than 5 years = reference)				
5-10 years	0.304	0.353	0.389	0.121
11-15 years	0.555	0.337	0.100	0.216
16-20 years	1.239	0.461	0.007	0.419
More than 20 years	1.337	0.376	0.000	0.439
Locality (rural = reference)				
urban	-0.449	0.418	0.283	-0.175
semi-urban	0.407	0.351	0.246	0.135
Household annual income ($5000 = reference)				
$8000	0.031	0.313	0.920	0.010
$11000	-1.060	0.326	0.001	-0.397
Source of information about climate change				
Personal observation	-0.563	0.596	0.345	-0.206
Radio	-0.003	0.306	0.993	-0.001
Television	-0.290	0.378	0.443	-0.106
Farmer to farmer extension	-0.415	0.317	0.190	-0.152
Farm seed based association	0.068	0.250	0.787	0.025
Subsidy from government	-0.252	0.272	0.353	-0.092
Farmer perception				
Drought	0.342	0.251	0.172	0.125
Low rain	0.237	0.250	0.344	0.086
Constant	1.080	0.802	0.178	
LR chi2	43.93		0.0002	
Pseudo R2	0.222			

In the case of construction of reservoirs and dams, experience played a major role since people with higher experience adapted these strategies to improve on their mango production compared to people with less than five years experience. Results revealed that higher income earners were less likely to adapt compared to lower income earners. The sources of information about the climate change were all statistically insignificant (See Table 3).

6. Discussion

6.1. Observed influence on climate change

The findings of our study into the impacts of climate change to small scale mango farming in Ghana agrees with previous studies that have been conducted regarding effects of climate change to agricultural activities (AGRA 2014; Asare-Nuamah et al. 2021b). The results of the study expound on the vulnerability of small-scale mango farming to climate change. Some of the climatic conditions identified and studied were, uneven and erratic rainfall, droughts, floods, windstorms and the ever-rising temperatures. The IPCC have found that, the smaller the scale of farming in a particular region, the higher the chances that it will be affected by climatic condition changes (IPCC 2018). The cultivation of quality seedling, and high-quality plants is very essential to enhancement of the resilience, and resistance to the changing climatic conditions (Atlin et al. 2017; Ifie et al. 2022).

The study area as observed from the charts and graphs extracted from the Ghanaian ministry of environment has experienced a rise in temperature since the 1990s to date, unpredictable rainfall, and occasional droughts. The mango farmers that were interviewed attributed these climate changes to human activities; mainly they were induced by human factors, they include: deforestation, greenhouse gases emission from industries, and motor vehicle emissions, use of chemicals while farming, and usage of poor fertilizer; the finding where in agreement with that of existing literature in regard to the subject (IPCC 2012).

6.2. Causes of climate change in Ghana

Nonetheless, it important to point out that some of the respondents of the study attributed the changes to the climate to divine power, they said it was an act of God that there has been erratic rainfall, drought, and flooding. Generally, their feedback is agreement with the belief of the African culture and religion. These feedback however, can result in the hindrance of the efforts and strategies to mitigate the climate change issue and be able to save the agricultural sector from completely failing.

The small-scale mango farmer's perceptions and feedback regarding the causes of climate change has a great significance in finding ways and strategies to adapt to the current climatic conditions (Ehiakpor et al. 2016).

6.3. Origin of climate change information

As such it's important to improve the knowledge to all individual to reasons of climate change, negative impacts, and strategies to combat it through televisions, radios, and the social media. Through these efforts, we can be able to correct the misconceptions and the wrong information the public have on the causes of climate change. In a study that was carried out by Asare-Nuamah and Botchway, 2019a, it was found that farmer-based organizations which provide education to farmer through televisions and radios are very effective in ensuring that people have the correct information of the causes of climate change. The teachings provide accurate, timely and importantly very relevant information on climatic condition, how to prevent climate change and how to adapt to it. In order to fully implement the current adaptation strategies, and to ensure that people have accurate and relevant information about the climate, Antwi-Agyei, Dougill et al. (2021a) suggest that national, and the local governments should work together in prioritizing effective information of the weather to the most remote areas of the country.

6.4. Weather patterns

Climate change and its effects is very significant to food production and with extreme influence on survival of mango seedling, growth of the plant, and the general production of the fruits. The results obtained from this research has accurately indicated that climatic events occurring due to climate change (droughts, flood, erratic rainfall) leads to poor germination of planted mango seedling, stunted growth of the transplanted seedling, higher chances of being affected by diseases and pest as well as the overall low yields of the plants. Essentially, climate change does implicitly affect the quality of the germinated mango seedlings, growth of the plant, and the fruit production of the mature mango plant. As such, climate change by extension has affected food production hence affecting the annual income of the small-scale farmers, which increase poverty level and high food insecurity.

The result from my sturdy is consistent with other past studies on the impacts of climate change to cocoa production in Ghana (Asante et al. 2017). The previous studies on impact of climate change on cocoa concluded that drought, floods, high temperatures and other adverse climatic conditions has increase the mortality rate of the cocoa plant, wilting, increased chances of contracting diseases, and pest as well as a reduction in the overall yield of the cocoa plants.

On the other hand, Lee and Ibáñez (2021) found that in some cases the climate change can result in positive impacts to agriculture. The rise in temperature at times can improve the growth of the mango plant by increasing the required sunshine hence quality growth. During the flowering season of the mango trees, the warm climatic conditions are conducive and favourable to produce large fruits and improve faster maturity of the yields. Ifie et al. (2022) recommended that the vulnerable agricultural area should adopt the new and improve adaptation strategies to climate change. This is by planting high quality seedling (grafted and treated to fit the current conditions) and also usage of quality and proper fertilizers.

6.5. Adaptation strategies

Climate change adaptation strategies among the small-scale farmers has become vital to ensure income, and food security. This research has pointed out various adaptation strategies that needs to be fully implemented to be able to cope with the changing climatic conditions by the small-scale mango farmers in Ghana. Some of the suggested mitigation strategies are using firebreaks during drought season, irrigation, agrochemicals to prevent infestation of pest and diseases, soil mixing before planting of new mango trees, grafting, potash farming, soil management, wind shields (growing of tall trees to prevent strong winds from destroying the mango plantations). Consequently, it is important for the government to create, and implement interventional ways that will solve the climate change issues. One of the most important mitigation strategies, is replanting deforested areas to ensure regular rainfall annually, reduction of inappropriate chemical use in agriculture, adoption of low pollution motor vehicles countrywide.

These strategies discussed help the small-scale mango farmers navigate and be able to produce adequate produce even during hazardous climatic conditions while enhancing their income and ensuring that there is food security (Arend et al., 2016a, 2016b). For example, Apuri et al. (2018) discuss fencing of the farms with barbed wires prevent the destruction of the small mango trees by strong winds, animals, and other adverse conditions. Similar, irrigation of the mango farms from time to time during drought seasons help the small-scale farmers overcome wilting and mortality rates of the large and small mango trees (Vitasse et al. 2021).

Additionally, the usage of organic, and safe inorganic fertilizers, fungicides, and insecticides as a mitigation response to the issue of climate change and attack by diseases, and insects has been documented to produce positive results in that regard (Fernández et al. 2018; Parađiković et al. 2017). Asante et al. (2017) in his study on effect of climatic changes to cocoa plants, he concluded that the density of cocoa plantation has a significant effect to the overall yield. Therefore, a proper and calculated density applied to mango farming will see that the effects of change has been mitigated.

6.6. Characteristics influencing adoption of sustainable agricultural practices

7. Conclusion

This study aimed to investigate how mango seedling producers in the Yilo Krobo Municipality of Ghana adapt to climate variability and change. The findings revealed that these producers possess knowledge about climate changes, including rising temperatures, irregular rainfall patterns, windstorms, and the resulting climate extremes like floods and droughts. Their primary sources of climate change knowledge are their own observations and experiences, although media (radio, television, and the internet) and extension services also play significant roles in providing information about climate change. Despite their awareness of climate change and its causes, there is a potential for misconceptions among these producers, which may hinder effective responses.

The observed climate changes have detrimental effects on the survival, growth, quality, and establishment of mango seedlings, impacting farmers involved in mango seedling production. Nonetheless, the study communities have implemented various adaptation strategies to mitigate climate change effects, including constructing gutters, using agrochemicals, grafting, adopting improved seed varieties, planting trees for shade, irrigation, and soil improvement techniques such as mulching.

Results from our Probit model analysis revealed that more experienced farmers are more likely to practice soil management techniques compared to people with less than 5 years experience because P value was less than 0.05 making it significant. Similarly, farmers living in semi-urban areas with P value of 0.04 which is less than 0.05 are less likely to practice this soil management techniques compared to people in rural areas. However people with higher income with P value of 0.009 and 0.003 respectively were less likely to use these practices compared to lower income earners. The sources of information about the climate change were all statistically insignificant (except personal observation with P value of 0.05). Farmers who personally observed climate change were less likely using soil management techniques compared to those who did not. The rest of variables was not statistically significant.

In the case of construction of reservoirs and dams, experience played a major role since people with higher experience adapted these strategies to improve on their mango production compared to people with less than five years experience. With P value of 0.007 and 0.000 which indicated statistically significant for farmers with higher experiences. Results revealed that higher income earners were less likely to adapt compared to lower income earners. The sources of information about the climate change were all statistically insignificant).

Based on these results, the study recommends that government, civil society organizations, and farm-based groups intensify climate change education and awareness efforts. This should involve using social and traditional media, extension services, and dedicated climate change platforms to enhance the knowledge of farmers and communities while reducing misconceptions. Micro/small-scale mango seedling producers are encouraged to join farm-based organizations to benefit from the educational and capacity-building opportunities they provide. The TCDA (presumably an organization) should prioritize the production and expansion of high-quality, climate-tolerant improved seed varieties through collaboration with the Council for Scientific and Industrial Research (CSRI) and other reputable seed producers. The government should demonstrate a strong commitment to enhancing communities' capacity to address climate change challenges by providing access to modern and mechanized farming tools, infrastructure, and irrigation facilities in cooperation with the private sector. Furthermore, there is a need to intensify extension and technical services for mango seedling producers to enhance their resilience and adaptive capabilities in the face of climate change.

7.1 Limitations to the research

While the research covers various regions in Ghana, it may not capture the full diversity of local conditions. Generalizing findings to all small-scale mango farmers in the country may have limitations. Local variations in climate, resources, and farmer practices can affect the applicability of results. Further, the study relies on the availability and quality of data, which may be limited in some regions and among certain small-scale farmers. This limitation could impact the comprehensiveness of the analysis and lead to potential data gaps. Mango farming has distinct seasonal variations, and the study's time frame may not capture the full spectrum of climate impacts throughout the year. Seasonal variations in mango production and climate patterns may not be fully represented.

External factors, such as economic changes, market fluctuations, and government policies, can also influence mango production. While the study aims to isolate climate change impacts, these external factors may have some overlapping effects that are challenging to separate. This research specifically focuses on small-scale mango farmers. While this group is vulnerable to climate change, the scope does not include larger commercial mango farms, which may face different challenges and employ different adaptation strategies.

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Appendices

List of appendices Appendix :

Annex 1 List of respondents from interviews

ID	Gender	Location	Age
1	man	Old Somanya	40
2	man	Old Somanya	45
3	man	Trom	47
4	man	Trom	49
5	man	Trom	50
6	woman	Trom	37
7	man	New Somanya	38
8	woman	Old Somanya	42
9	man	Trom	39
10	man	Trom	36
11	woman	Old Somanya	41
12	man	Trom	59
13	man	Old Somanya	56
14	man	Trom	63
15	man	New Somanya	48
16	man	Trom	44
17	man	Trom	46
18	man	Old Somanya	35
19	woman	Old Somanya	29
20	woman	Old Somanya	32
21	woman	Trom	37
22	man	Old Somanya	25
23	man	Old Somanya	41
24	man	Trom	42
25	man	Old Somanya	66
26	man	Old Somanya	56
27	man	Old Somanya	38
28	man	Old Somanya	39
29	woman	Old Somanya	47
30	man	Trom	45
31	woman	Old Somanya	31
32	woman	Trom	33
33	man	Trom	36
34	man	Trom	57
35	man	Old Somanya	59
36	man	Old Somanya	60
37	man	Trom	45
38	man	Old Somanya	38
39	man	Old Somanya	49
40	man	Old Somanya	55
41	woman	Old Somanya	36
42	man	Old Somanya	32
43	woman	Old Somanya	69
44	man	Trom	58
45	man	Old Somanya	55
46	man	Trom	46
47	man	Old Somanya	38
48	man	Old Somanya	27
49	woman	Old Somanya	48
50	man	Trom	56

51	man	Old Somanya	34
52	man	Old Somanya	69
53	man	Old Somanya	32
54	man	Trom	36
55	man	Trom	28
56	woman	Old Somanya	27
57	man	Old Somanya	34
58	man	Old Somanya	45
59	man	Old Somanya	42
60	man	Trom	44
61	man	Old Somanya	62
62	man	Trom	67
63	man	Old Somanya	45
64	woman	Old Somanya	54
65	man	Old Somanya	66
66	man	Old Somanya	33
67	man	New Somanya	25
68	man	Trom	28
69	man	Trom	31
70	man	Old Somanya	30
71	man	New Somanya	34
72	man	Old Somanya	44
73	man	Old Somanya	55
74	man	Old Somanya	67
75	man	Trom	68
76	man	New Somanya	64
77	man	Old Somanya	33
78	woman	Old Somanya	45
79	man	New Somanya	47
80	man	Old Somanya	49
81	man	Old Somanya	50
82	man	Old Somanya	29
83	man	New Somanya	60
84	man	Trom	48
85	woman	New Somanya	54
86	man	Old Somanya	42
87	man	New Somanya	65
88	man	Trom	43
89	man	New Somanya	44
90	woman	Old Somanya	38
91	man	New Somanya	42
92	man	New Somanya	32
93	man	New Somanya	38
94	man	Old Somanya	45
95	man	New Somanya	60
96	man	Old Somanya	68
97	man	Trom	54
98	man	New Somanya	43
99	man	Trom	26
100	man	New Somanya	47
101	man	Trom	32
102	man	New Somanya	27
103	woman	Old Somanya	33
104	man	New Somanya	58
105	woman	New Somanya	46
106	man	New Somanya	57
107	man	New Somanya	41
108	man	New Somanya	40

109	man	Trom	36
110	man	New Somanya	43
111	man	New Somanya	56
112	man	New Somanya	35
113	man	New Somanya	69
114	man	Old Somanya	33
115	man	New Somanya	26
116	man	New Somanya	31
117	man	New Somanya	45
118	woman	Old Somanya	52
119	man	New Somanya	66
120	man	Trom	65
121	man	New Somanya	47
122	man	New Somanya	36
123	man	Old Somanya	62
124	man	New Somanya	44
125	man	Trom	47
126	man	New Somanya	49
127	man	Trom	32
128	man	New Somanya	37
129	man	New Somanya	35
130	man	Trom	44
131	woman	New Somanya	50
132	woman	Old Somanya	56
133	man	New Somanya	53
134	man	New Somanya	59
135	woman	New Somanya	46
136	man	New Somanya	37
137	man	Old Somanya	44
138	man	Trom	63
139	man	Trom	42
140	man	Old Somanya	45
141	man	New Somanya	37
142	man	Trom	56
143	man	Trom	65
144	man	New Somanya	39
145	man	Old Somanya	48
146	man	Old Somanya	52
147	woman	New Somanya	38
148	woman	Trom	44
149	man	Old Somanya	58
150	man	Trom	50

Annex 2 Data collection in Ghana

Annex 3 Questionnaire

Questionnaire

The impact of climate change on Mango production of small-scale farmers and their adaptation strategies in Ghana

Personal information

Close ended questions

1. Name ………………………………………………………………………
2. Gender (mark the appropriate box)
   - □ Male
   - □ Female

3. Locality
   - □ Rural
   - □ Urban
   - □ Semi – urban

4. Years of experience in mango production
   Less than 5 years
   5-10 years
   11-15 years
   16-20 years
   Above 20 years

5. What is your household yearly income?
   - □ $10000-20000
   - □ $20000-30000
   - □ $30000-40000
   - □ $40000-50000
   - □ Above $50000

Closed-ended questions

Section B

Climate change perceptions

1. **Kindly respond to these questions regarding your perceptions and observations of climate change?**

Perceived climate variability and change			
Variable	Change indicators	Yes	No
Rainfall amount	Increasing		
	Decreasing		
Rainfall Duration	Increasing		
	Decreasing		
Rainfall onset	Early		
	Late		
Rainfall retreat	Early		
	Late		
Flood intensity	Increasing		
	Decreasing		
Flood frequency	Increasing		
	Decreasing		
Drought intensity	Increasing		
	Decreasing		
Drought frequency	Increasing		
	Decreasing		
Temperature (daily)	High		
	Low		
Temperature (duration)	Increasing		
	Decreasing		
Windstorm intensity	Increasing		
	Decreasing		

Windstorm frequency	Increasing		
	Decreasing		

Perceived drivers of climate change

2. **What do you think are the causes of climate change?**

(Give your opinion by marking one off the box for each variable Yes/No)

Perceived drivers of climate change	yes	No	Don't know
Poor farming activities (slash and burn)			
Deforestation			
Anger of God			
Overgrazing and livestock activities			
Population growth			
Over exploration of forest and other natural resources			
Emissions (gasses) from industry and transportation			
Urbanization and changing lifestyle			
Building and construction activities			
Application of agrochemicals (nitrogen-based chemicals)			

Section C

Sources of knowledge on climate change

3. **Respond to the questions on the sources of information that shape your knowledge on climate change?**

Source of climate change knowledge		
Variable	Yes	No
Personal observations		
Radio		
Television		
Internet		
Extension agents		
Farmer-to-farmer extension		
Report from school children		
Farm/seed-based association		

Section D

Climate change impacts on mango production

4. **Respond to the questions on the impact of climate change on mango production?**

(Give your opinion by marking one off the box for each variable Yes/No)

Variables	Yes	No
Mango seedlings wither		
Mango seedlings flourish		
Stented plant growth		
Low yield		
Increase soil acidity		
Increase attack by pest and diseases		
Poor produce quality		

Part E

1. Fill in the table with yes or no in if you experienced the following impacts due to climate change, also include the number of crates of mangos you harvested the previous year

ID	last year mango yield (Crates)	pest and disease	low rain	fire	drought	flooding	soil acidity

Open-ended questions

1. Have you observed any changes in the climate over the past 10 years?
2. If yes, what changes in climate (temperature, rainfall, windstorm, etc.) have you observed in this area over the past 10 years?
3. Which year(s) was/were these changes intense? Describe the situation.
4. What do you think contributed to these changes?
5. Were there any impacts of the changes on your mango production activities? If Yes, describe the impacts (Hint for probing: production of seedlings, sales/marketing, income generated etc.)
6. Have you adjusted your mango production activities due climate change and its impacts? Yes/No
7. If yes, what measures have you put in place to reduce the impacts of climate change on your farming activities? (Hint for probing: type/variety of seedlings and their resistance to drought, floods, poor rainfall, high temperature; tools and equipment used to reduce impact of floods, droughts, poor rainfall; windstorm management strategies; use of agrochemicals; soil management techniques; water management techniques; etc.)
8. What are the most common adaptation strategies been used by you?

9. How beneficial are the measures to mitigating climate change impact on your mango farming production?

10. Do you receive government support (e.g. extension services, trainings etc.) for your farming activities? If yes, what specific support do or have you received and how does the support help to minimize the impact of climate change?

Thank you for your participation.