PAU
Institute for Water
and Energy Sciences
(incl. Climate Change)

PAN-AFRICAN UNIVERSITY

INSTITUTE FOR WATER AND ENERGY SCIENCES

(including CLIMATE CHANGE)

Master Dissertation

Submitted in partial fulfillment of the requirements for the Master's degree in

CLIMATE CHANGE ENGINEERING

Presented by

Henrietta ANDOH

TITLE:

ASSESSMENT AND PREDICTION OF CLIMATE CHANGE IMPACT ON CASSAVA PRODUCTION IN THE COASTAL SAVANNAH AGROECOLOGICAL ZONE OF GHANA

PAN-AFRICAN UNIVERSITY OF WATER & ENERGY SCIENCES (INCLUDING CLIMATE CHANGE)

ASSESSMENT AND PREDICTION OF CLIMATE CHANGE IMPACT ON CASSAVA PRODUCTION IN THE COASTAL SAVANNAH AGROECOLOGICAL ZONE OF GHANA

A thesis submitted to the Pan African University Institute of Water and Energy Sciences (Including Climate Change) in partial fulfilment of the requirements for the degree of Master of Science in Climate Change (Engineering option).

By

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PAUWES/2022/MCC02

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Tlemcen, Algeria

MARCH, 2024.

AUTHOR DECLARATION

I, Henrietta Andoh, hereby declare that this thesis titled "Assessment and Prediction of Climate Change Impact on cassava production in the Coastal Savannah Agroecological Zone of Ghana" represents my original work and has not been submitted to another institution for the award of a degree, diploma, or certificate. I also declare that all words and ideas from other works presented in this thesis have been duly cited and referenced under the academic rules and regulations.

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BIOGRAPHICAL SKETCH

Henrietta Andoh holds a Bachelor of Science degree in Natural Resources Management (Agroforestry option) from the Kwame Nkrumah University of Science and Technology (KNUST), Ghana. She has a strong passion for research in agroforestry, agriculture and climate change. She is interested in contributing to Sustainable Development Goals 2 (Zero Hunger) and 13 (Climate Change) through her research endeavours. Henrietta developed a heightened interest in climate change and modelling to make inferences on future implications of climate change particularly within the agricultural sector during her time at the Pan African University through her coursework.

Henrietta is due to graduate with an MSc in Climate Change (Engineering option) from the Pan African University. She has obtained adequate experience in the use of relevant software such as SDSM and ArcGIS to analyze data. With Henrietta's interest in research within the agricultural sector, she hopes to develop a career within this field, with the first step of pursuing a PhD in programmes related to agriculture, climate change and crop modelling. By this, she hopes to contribute to impactful research within the agricultural sector of Ghana and beyond. Henrietta is dynamic and blends well with teams of different cultural backgrounds and he is always open to learning.

ABSTRACT

Agriculture though an important livelihood venture and a contributor to food security is still a rain-dependent sector within Ghana and largely managed by smallholder farmers. As arable land diminishes and the impacts of climate change escalate, it becomes crucial to assess the future of cassava production and yield in the KEEA municipality located within the Coastal Savannah Agroecological Zone, a major cassava breadbasket of Ghana. This study utilized agroclimatology data from NASA Power and WorldClim to predict the near (2021-2040) and far (2081-2100) climate scenarios for KEEA municipality. In addition, a purposive sampling method was used to select 254 cassava farmers and semi-structured questionnaires were administered to assess the farmers' perception of climate change and its impact on cassava yield. The data was analysed using ArcGIS 10.8, SPSS 27, and XLSTAT 2024. The result showed that in the near future (2021-2040) maximum temperature (Tmax) is projected to decrease under SSP2 while under SSP5, a slight increase ranging from 0.1°C to 0.2°C is anticipated. In contrast, minimum temperatures (Tmin) are expected to rise under both SSP2 and SSP5. Additionally, a significant decrease in precipitation (rainfall) is anticipated under both scenarios, with SSP5 indicating a slight increase of 1mm. In contrast to the near future, the far future (2081-2100) is expected to witness a notable increase in temperatures under both the SSP2 and SSP5 scenarios. Maximum temperatures are projected to rise by approximately 1°C under SSP2 and by nearly 3°C under SSP5. Concurrently, minimum temperatures are anticipated to increase by approximately 1°C under SSP2 and by around 3.2°C under SSP5. However, the results for precipitation indicate a general decrease under both scenarios. In addition, the survey results showed that a majority (82.68%) of farmers within the KEEA municipality were conscious of climate change and acknowledged its potential consequences for their cassava productivity. Furthermore, a regression analysis revealed that climatic factors exerted little influence, accounting for 19.4% and 10.2% of the variations in cassava production and yields respectively. The findings of this study have implications for providing location-specific policies such as enhancing extension services within the municipality to bridge this information gap and introducing improved cassava varieties that are resilient and well-suited to the anticipated climate conditions.

ACKNOWLEDGEMENT

My sincerest and unfailing gratitude goes to God Almighty for the grace, strength and guidance in my academic achievements and towards the success of this study.

I wish to thank the staff of the Pan African University, Institute of Water and Energy Sciences (Including Climate Change) in Algeria, and the African Union for granting me this opportunity to undertake my studies under the African Union Scholarship Programme.

I would also like to express my deepest gratitude to my supervisors Dr. James S. Kaba and Professor Amos T. Kabo-bah for their time, dedication, advice, corrections, support, counselling and suggestions towards the completion and success of my project work.

Also, my heartfelt gratitude and thanks go to Mrs. Victoria Dansoa Abankwa, the director of the Agricultural Department at the KEEA Municipality for the opportunity to undertake my research internship and for her support during my data collection at the municipality.

To my wonderful parents and siblings, I say God richly bless you for your support financially, and spiritually and for your encouraging words throughout my academic journey to the completion of this study.

To my friends and colleagues especially Lawrence Blay, I say a big thank you for helping me with data collection throughout my study. To all and sundry who helped and contributed to the success of this study, I say God bless you all.

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
AR6	Sixth Assessment Report
CMIP6	Sixth phase of the Coupled Intercomparison Model Project
GCM	Global Circulation Model
GHG	Greenhouse Gases
IPCC	Intergovernmental Panel on Climate Change
KEEA	Komenda-Edina-Eguafo-Abrem
MoFA	Ministry of Food and Agriculture
MRI-ESM2.0	The Meteorological Research Institute Earth System Model Version 2.0
NASA	National Aeronautics and Space Administration
PRECIP	Precipitation
TMAX	Maximum Temperature
TMIN	Minimum Temperature
RH	Relative Humidity
SPSS	Statistical Package for the Social Sciences
SSP	Shared Socioeconomic Pathways
XLSTAT	Statistical Software for Excel

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CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Climate change is a global phenomenon experienced around the world that threatens the future of humans and ecosystems (Dervis, n.d.; Malhi *et al*., 2020; Abbass *et al*., 2022; Shivanna, 2022). Before the pre-industrial era, climate change was predominantly a natural event. However, in recent times, human activities mainly fossil fuel burning, have been the driving force of rapid changes in weather conditions and ultimately climate change due to the accumulation of Greenhouse gases (GHG) particularly CO_2 in the atmosphere (Kaba, 2015; Jakpa *et al*., 2019; Malhi *et al*., 2021; NOAA, 2021). Africa is one of the most vulnerable continents, climate change affects the livelihoods and economies of many countries, threatening the citizenry's survival. For instance, in Ghana, the common climate-related hazards are droughts, high temperatures, floods, and sea level rise, amongst other climate-related hazards (ThinkHazard, 2020; Atanga and Tankpa, 2021). Although climate change affects other sectors like energy and industry, the agricultural sector is the most climate-sensitive and vulnerable (Arndt *et al*., 2015; Jakpa *et al*., 2019; World Bank Group, 2021).

In Africa, agriculture is an important livelihood venture, especially for the majority who are smallholder farmers and a major contributor to the economies of most countries of which Ghana is no exception. In the case of Ghana, agriculture is considered the backbone of the economy as it supplies the majority (about 70%) of the country’s food demand and nutritional needs and is also a major source of inputs for the manufacturing industries (Choudhary *et al*., 2015; Kaba, 2015; Essegbey and MacCarthy, 2020; Ministry of Economy and Industry, 2020; Nyamekye *et al*., 2021; World Bank Group, 2021; AfDB, 2023). In addition, it is the second most important sector of Ghana’s economy (contributing about 20% to the country's GDP through the export of cocoa and other crops), remains a primary source of employment (about 45-56%) which is key to the household livelihood of rural Ghanaians (Sova *et al*., 2014; Arndt *et al*., 2015; Kaba, 2015; Ministry of Economy and Industry, 2020; Otoo *et al*., 2020; FAO, 2021; Nyamekye *et al*., 2021; World Bank Group, 2021; Kwakwa *et al*., 2022; Tetteh *et al*., 2022; AfDB, 2023). The agricultural sector in Ghana can be categorised into four subsectors namely: crop production (including tree crops), livestock rearing, forestry and fisheries, with the most dominant being crop production and these are spread across the five ecological zones: the Sudan Savannah, Guinea Savannah, Transition, Forest and Coastal zones (Ministry of Economy and Industry, 2020; Yamba *et al*., 2023).

Unfortunately, Ghana's agriculture is still largely rainfed and predominantly practised by smallholder farmers (about 75 - 80%) who are often within the rural areas and are often poor (Arndt *et al*., 2015; Choudhary *et al*., 2015; Naab *et al*., 2019; Ministry of Economy and Industry, 2020; Ritchie and Roser, 2020; EPA, 2022; Ritchie and Roser, 2022). Although new and advanced technologies (eg., irrigation) exist to help improve the agricultural sector and reduce its reliance on rainfall, such technologies are mostly inaccessible to farmers due to cost, availability and sometimes lack of technical skills for their operations restricting Ghanaian farmers to the old systems of farming (Pauw, 2018; International Labour Organization, 2020; AfDB, 2023).

The above challenges heighten the threat climate change poses to Ghana's rainfed agricultural sector particularly the production of crops such as cassava which happens to be among the most climate-sensitive crops of the subsectors (Chemura *et al*., 2020; World Bank Group, 2021; Trisos *et al*., 2022). As Ghana faces future predictions of increased temperatures and erratic rainfall (UNEP, 2017; USAID, 2017; Tuebner, 2023)., it has become imperative for comprehensive studies that assess the implications of climate change on the current and future food production as well as the impact on cassava farmers' livelihoods. In addition, outlines more sustainable means of cassava farming to reduce the increased risk of food insecurity and poverty within the rural areas of the country (UNEP, 2017; Adu-Boahen *et al*., 2019; Naab *et al*., 2019; Ritchie, 2021; Tetteh *et al*., 2022).

1.2 Problem Statement

The impact of climate change on Ghana's agricultural sector is a pressing concern, with increasing temperatures, droughts, floods, and erratic rainfall all contributing to reduced yields of staple food crops (The Climate Reality Project, 2023; Tuebner, 2023). Among these crops, cassava holds significant importance as an essential staple food, accounting for 22-30% of the Agricultural GDP and boasting a per capita consumption of 152.9 kg/year (Bayitse *et al*., 2017; Musah *et al*., 2020; Acheampong *et al*., 2021). As arable land diminishes and the impacts of climate change escalate, it becomes crucial to assess the future of cassava production and yield, focusing on the KEEA municipality as a case study (Afriyie *et al*., 2020; Kwapong *et al*., 2021; Dwamena *et al*., 2022; Sumbo *et al*., 2023). Despite existing studies on climate change and cassava production in the Semi-deciduous agroecological zone, there is a dearth of information specifically addressing the future climate and its repercussions on cassava cultivation within the Coastal Savannah agroecological zone (Mahama *et al*., 2021). This research gap underscores the necessity for further investigation and comprehension of the specific climatic dynamics in the KEEA municipality and their potential implications for cassava cultivation.

1.3 Justification

Cassava accounts for 22-30% of Ghana's Agricultural GDP and boasts a per capita consumption of 152.9 kg/year. Therefore, understanding the future of crop production will inform sustainable agricultural practices. In addition, information on the impact of climate change on farmers' livelihoods is necessary to develop effective adaptation strategies. Moreover, knowing the effectiveness of cassava farmers' climate change adaptation methods will help identify areas for improvement and provide better training on innovative strategies.

On policy, information obtained from this research will be beneficial to decision-making concerning the agriculture sector of the municipality. It will serve as a basis for implementing policies and measures to mitigate the impact of climate change on cassava production in the Komenda-Edina-Eguafo-Abrem (KEEA) Municipality.

1.4 Research Questions

- What are farmers' perceptions of climate change and its impact on cassava yield?
- What are the near (2021-2040) and far (2081-2100) climate scenarios for KEEA municipality?
- What is the influence of climate parameters on cassava production and yield?

1.5 Aim and specific objectives

This study aimed to assess farmers' perception of Climate Change, determine future climate, and quantify the impact of climate parameters on cassava production and yield in the Komenda-Edina-Eguafo-Abrem (KEEA) Municipality. The specific objectives were:

- To investigate farmers' perception of climate change and its impact on cassava yield in the Coastal Savannah Agroecological zone of Ghana.
- To determine the near (2021-2040) and far (2081-2100) future climate scenarios of the Coastal Savannah Agroecological zone of Ghana.
- To quantify the influence of climate parameters on cassava production and yield in the Coastal Savannah Agroecological zone of Ghana.

CHAPTER TWO

LITERATURE REVIEW

2.1 Climate change and its effect on agriculture

2.1.1 Overview of climate change and its drivers

The Earth's climate has undergone significant changes since the early industrial era, with increasing temperatures depicted in Figure 2.1 (Climate Change Knowledge Portal, 2021). These temperature anomalies are primarily a result of rising greenhouse gas (GHG) concentrations, which are the major drivers of climate change (OEHHA, 2018). Climate change, as defined by the World Bank's Climate Change Knowledge Portal (2021), refers to significant variations in average weather conditions over several decades or longer, leading to outcomes such as warmer, wetter, or drier conditions. Greenhouse gases (GHGs) are naturally occurring gases that regulate the Earth's temperature by trapping heat from the sun (US Global Change Research Program, 2017). However, human activities have intensified the normal concentrations of these gases, leading to increased global warming (Wilson and Primack, 2022; National Grid Group, 2023).

While natural drivers like volcanoes and solar irradiance contribute to climate change, their impact is limited compared to anthropogenic drivers (United Nations, n.d.; US Global Change Research Program, 2017; US EPA, 2023). Since the industrial era, the burning of fossil fuels by the energy sector has been the primary human-induced influence on climate change (United Nations, n.d.). The major human-induced GHGs contributing to global climate change, in order of increasing influence, include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (United Nations, n.d.; IPCC 2007; US EPA, 2023). Additionally, non-naturally occurring gases like fluorinated gases also contribute to climate change (US EPA, 2024). Figure 2.2 and Figure 2.3 illustrate that the energy sector is the largest contributor to climate change, accounting for the majority of CO2 emissions. Furthermore, Figure 2.2 shows the agriculture sector as the second highest contributor to climate change and is responsible for CH4 and N2O emissions, as depicted in Figure 2.4 and Figure 2.5 (Ritchie, 2020; Ritchie *et al*., 2024).

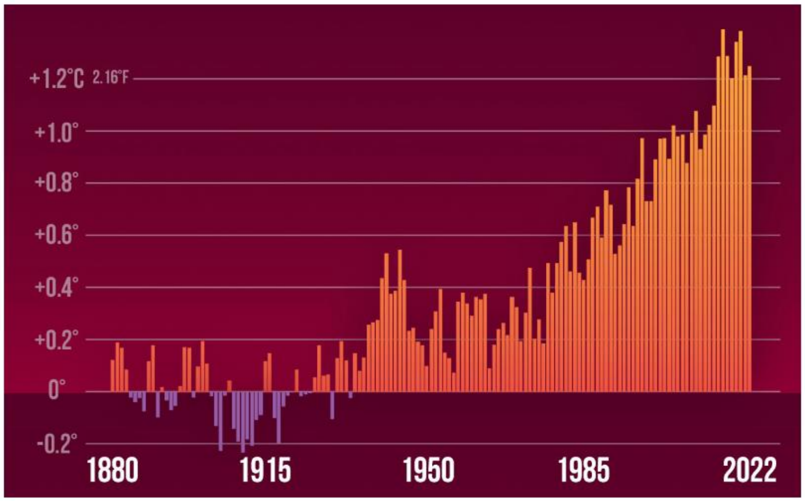
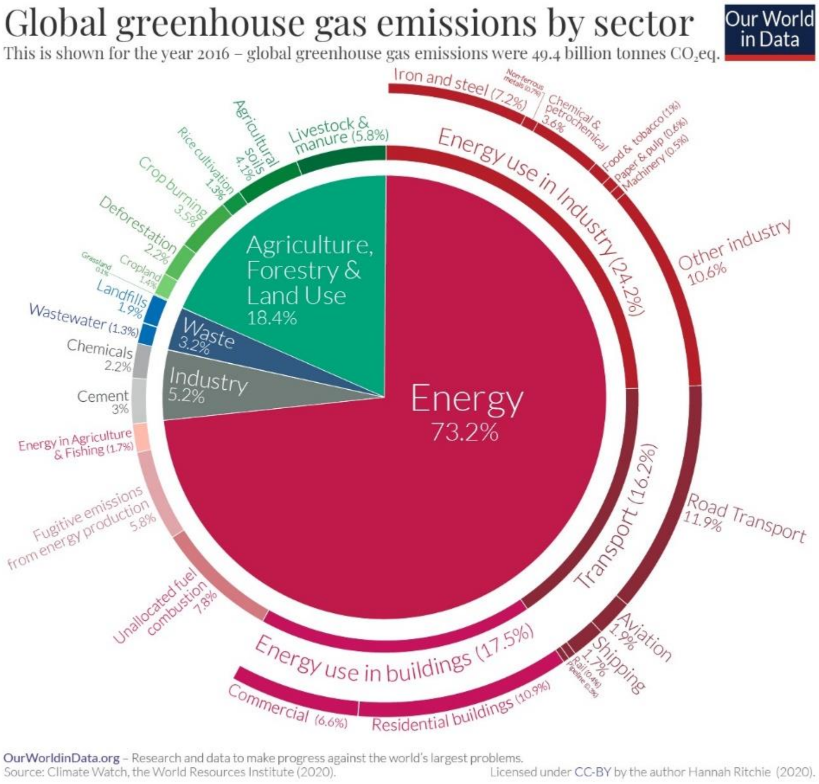


Figure 2. 1 Global Average Temperature Anomalies, departure from 1881-1910.

Source: Climate Change Knowledge Portal, 2021



OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).
Licensed under CC-BY by the author Hannah Ritchie (2020).

Figure 2. 2 Global climate emissions by sector in 2020

Source: Ritchie, 2020

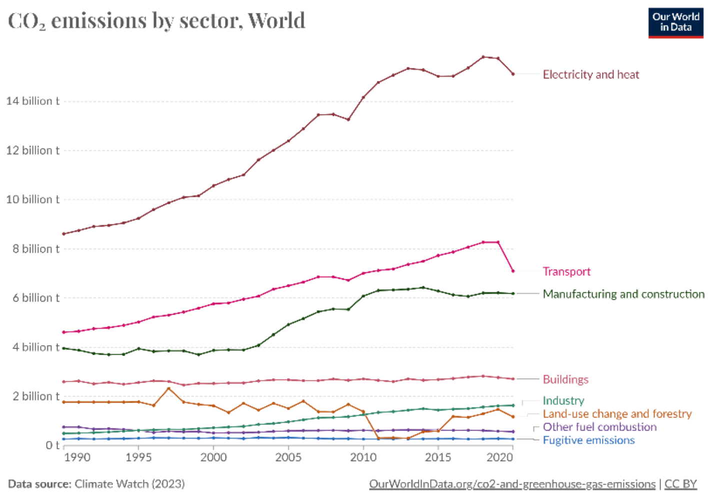
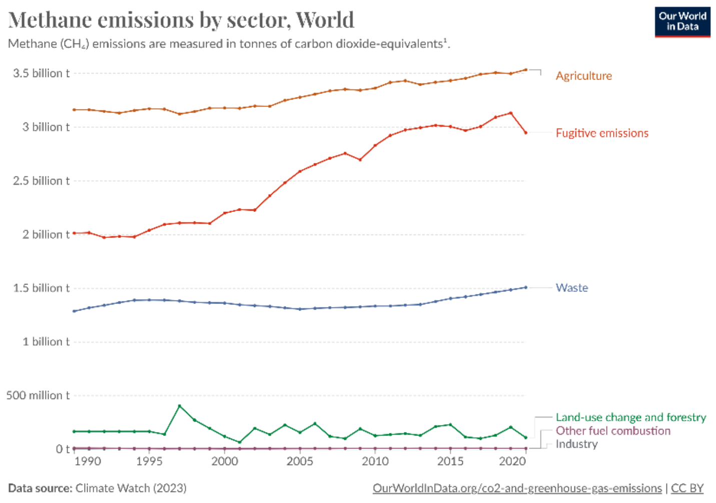


Figure 2. 3 World CO_2 emissions by sector from 1990 to 2020

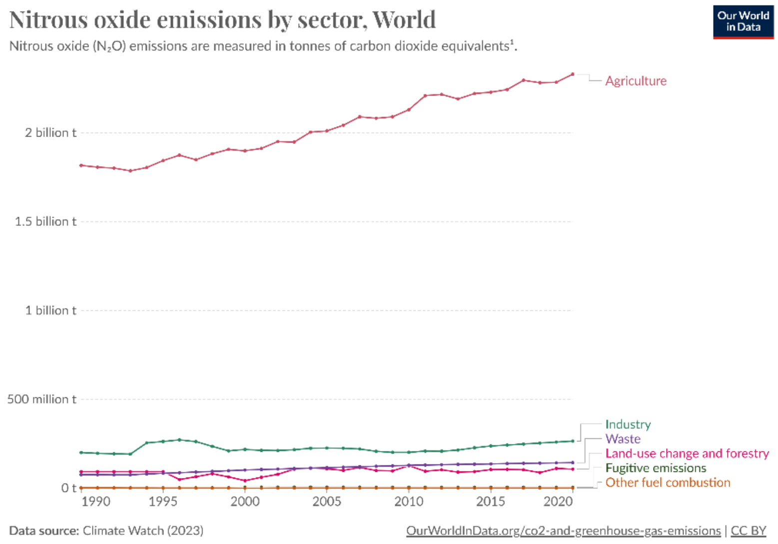
Source; Ritchie *et al*., 2024



1. **Carbon dioxide equivalents (CO_2eq):** Carbon dioxide is the most important greenhouse gas, but not the only one. To capture all greenhouse gas emissions, researchers express them in "carbon dioxide equivalents" (CO_2eq). This takes all greenhouse gases into account, not just CO_2. To express all greenhouse gases in carbon dioxide equivalents (CO_2eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO_2. CO_2 is given a GWP value of one. If a gas had a GWP of 10 then one kilogram of that gas would generate ten times the warming effect as one kilogram of CO_2. Carbon dioxide equivalents are calculated for each gas by multiplying the mass of emissions of a specific greenhouse gas by its GWP factor. This warming can be stated over different timescales. To calculate CO_2eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions – measured in CO_2eq – are then calculated by summing each gas' CO_2eq value.

Figure 2. 4 World methane emissions by sector from 1990 to 2020

Source: Ritchie *et al*., 2024



Nitrous oxide emissions by sector, World

Nitrous oxide (N_2O) emissions are measured in tonnes of carbon dioxide equivalents[1].

Data source: Climate Watch (2023) OurWorldInData.org/co2-and-greenhouse-gas-emissions | CC BY

1. **Carbon dioxide equivalents (CO_2eq)**: Carbon dioxide is the most important greenhouse gas, but not the only one. To capture all greenhouse gas emissions, researchers express them in "carbon dioxide equivalents" (CO_2eq). This takes all greenhouse gases into account, not just CO_2. To express all greenhouse gases in carbon dioxide equivalents (CO_2eq), each one is weighted by its global warming potential (GWP) value. GWP measures the amount of warming a gas creates compared to CO_2. CO_2 is given a GWP value of one. If a gas had a GWP of 10 then one kilogram of that gas would generate ten times the warming effect as one kilogram of CO_2. Carbon dioxide equivalents are calculated for each gas by multiplying the mass of emissions of a specific greenhouse gas by its GWP factor. This warming can be stated over different timescales. To calculate CO_2eq over 100 years, we'd multiply each gas by its GWP over a 100-year timescale (GWP100). Total greenhouse gas emissions – measured in CO_2eq – are then calculated by summing each gas' CO_2eq value.

Figure 2. 5 World nitrous oxide emissions by sector from 1990 to 2020

Source: Ritchie *et al*., 2024

2.1.2 Impacts of climate change on agricultural systems

Agriculture is a highly sensitive sector that is greatly influenced by weather and climate changes due to its reliance on land, water, and other natural resources (US EPA, 2023). Climate change has impacts on all subsectors of agriculture (Hatfield *et al*., 2020). Rising temperatures and irregular rainfall patterns can disrupt the growing seasons of crops, affecting crucial stages such as planting, flowering, and harvesting (Malhi *et al*., 2021; UK Research and Innovation, 2021). Furthermore, these climate changes can contribute to an increase in both flooding and drought events, which have adverse effects on crop production and yield (Ruane and Rosenzweig, 2019; McKinsey Global Institute, 2020; FAO, 2023). Drought conditions can lead to soil drying and compaction (Iowa State University, 2017; Qu *et al*., 2023). Meanwhile, flooding can result in the destruction of crops and a reduction in yield (UK Research and Innovation, 2021). Intense floods also have the potential to cause soil erosion, washing away essential plant nutrients (Union of Concerned Scientists, 2019; Hatfield *et al*., 2020).

Changes in temperature and rainfall patterns can also have implications for pests and diseases in agriculture. Such variations can influence the populations of pests and diseases, leading to the migration and emergence of new threats to crop production (UNFCCC, 2012; Union of Concerned Scientists, 2019; Malhi *et al*., 2021; FAO, 2023). For instance, the fall armyworm has emerged as a destructive pest affecting maize crops across Africa (Yan *et al*., 2022; Timilsena *et al*., 2022; AICCRA, 2023; Mlambo *et al*., 2024). Livestock production is also affected by climate change. Increasing temperatures can cause stress, disrupt reproductive cycles, and elevate mortality rates among livestock (Rojas-Downing *et al*., 2017; Hatfield *et al*., 2020; Cheng *et al*., 2022; Spiller *et al*., 2023). Additionally, climate change can heighten the occurrence of wildfires, particularly in drought conditions, which can reduce the availability of pasture and grazing lands, consequently impacting the food supply for livestock (UNFCCC, 2012; Cheng *et al*., 2022). It is important to note that the effects of climate change on agriculture will depend on the rate and severity of the changes, as well as the ability of farmers to adapt to these changes (Ruane and Rosenzweig, 2019; US EPA, 2023).

2.2 Cassava production and its importance

2.2.1 Introduction to cassava as a crop

Cassava (Manihot esculenta) is a cultivated crop known for its edible fleshy roots. It exhibits remarkable adaptability, as it can be grown throughout the year and withstands challenging conditions such as drought and low soil fertility, making it suitable for cultivation in marginal areas (FAO, n.d.; Waisundara, 2018; Kennedy *et al*., 2018). Optimal growth conditions for cassava include mean temperatures ranging from 25 to 35°C, with a soil temperature of around 30°C. Plant growth is significantly hindered when temperatures drop below 10°C (FAO, n.d.; Legesse, 2018). Cassava thrives in regions with an annual rainfall distribution of 1000-1500mm, with a minimum monthly rainfall of 50 mm. However, it can also tolerate semi-arid regions with an annual rainfall as low as 500mm (Hauser *et al*., 2014; FAO, n.d.). The crop demonstrates a remarkable ability to adapt to various soil types. Well-drained, light-textured, and deep soils with intermediate fertility are considered optimal for cassava growth. On the other hand, poorly drained, gravelly, saline, or hardpan soils are detrimental to their development (FAO, n.d.). The recommended soil pH range for cassava cultivation is 4.5-6.5 (FAO, n.d.).

Table 2. 1 Taxonomy of Cassava

SCIENTIFIC CLASSIFICATION OF CASSAVA	
Kingdom	Plantae
Phylum	Magnoliophyta
Class	Magnoliopside
Subclass	Rosidae
Order	Euphorbiales
Family	Euphorbiaceae
Genus	Manihot
Species	esculenta

Source: Invasive.Org, 2018

2.2.2 Significance of cassava

Cassava is a staple food crop grown extensively across Africa, Latin America, and Asia, as depicted in Figure 2.6 (World Population Review, 2024). Originally native to Latin America, its introduction to Africa and Asia was driven by the aim of enhancing food security and facilitating starch production (Chandrasekara and Kumar, 2016; Waisundara, 2018). Among the top 10 cassava-producing countries (Figure 2.7), five are located in Africa, with Nigeria being the largest producer (Waisundara, 2018; Statista, 2023). With its tolerance to severe climatic conditions, such as drought, and its ability to be cultivated throughout the year, cassava holds great potential in addressing food insecurity (Guira *et al*., 2017; Kennedy *et al*., 2018; Ouma and Ngala, 2021; Onyediako and Adiele, 2022; Adebayo, 2023; Akomolafe *et al*., 2023). Notably, it serves as an important source of carbohydrates, surpassing rice and maize by 40% and 25%, respectively (Waisundara, 2018; Gregory and Wojciechowski, 2020). Consequently, countries like South Africa have proposed increasing cassava production to combat food insecurity (Muimba-

Kankolongo, 2018; Amelework *et al*., 2021). Furthermore, the crop serves as a raw material for various industries offering economic opportunities for farmers in developing countries (Sanginga and Mbabu, 2015; Agricdemy, 2023;). Additionally, cassava can be utilized as a feedstock for bioenergy production, particularly in the production of bioethanol (Kennedy *et al*., 2018; Onyediako and Adiele, 2022; Agricdemy, 2023).

While cassava is considered to have limited nutritional value, it does contain essential vitamins such as A, B, and C, as well as calcium, iron and zinc, which are crucial for growth and development (Sanginga and Mbabu, 2015; Muimba-Kankolongo, 2018). The versatility of cassava is noteworthy, as it can be prepared and consumed in various ways, including boiling, frying, mashing, or processing into flour, starch, and gari (Adebayo, 2023). This versatility allows for the creation of diverse and nutritious diets. Although cultivated for its roots, the leaves can also be eaten and in some cases used for medicinal purposes (Kennedy *et al*., 2018; Waisundara, 2018; Adebayo, 2023; Agricdemy, 2023).

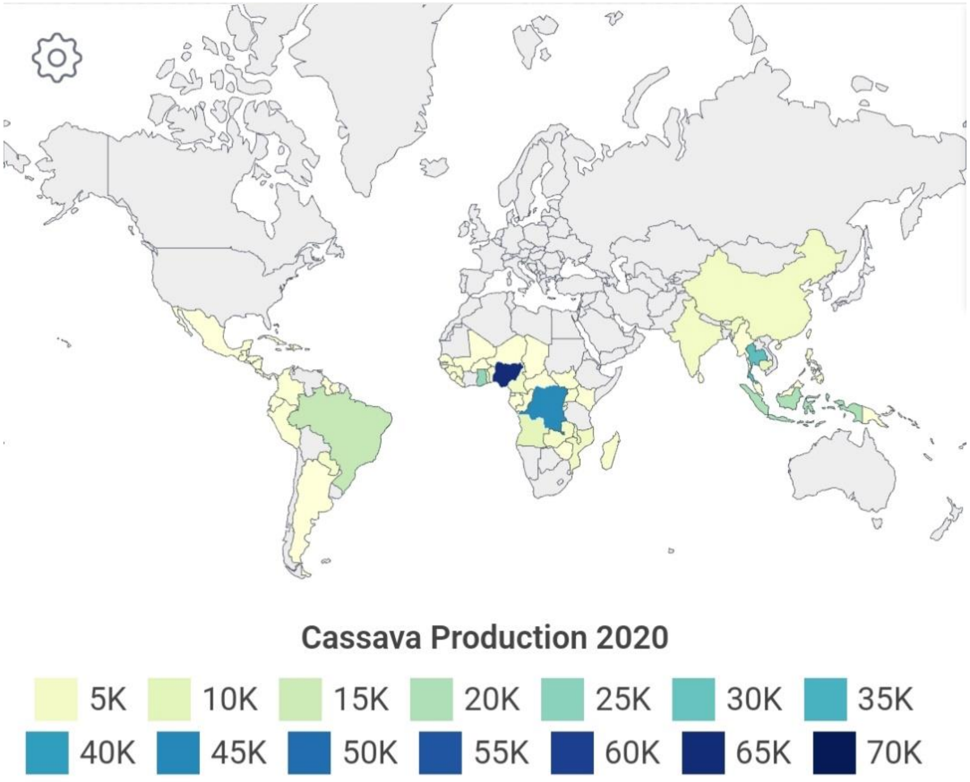


Figure 2. 6 World cassava production for 2020

Source: World Population Review, 2024

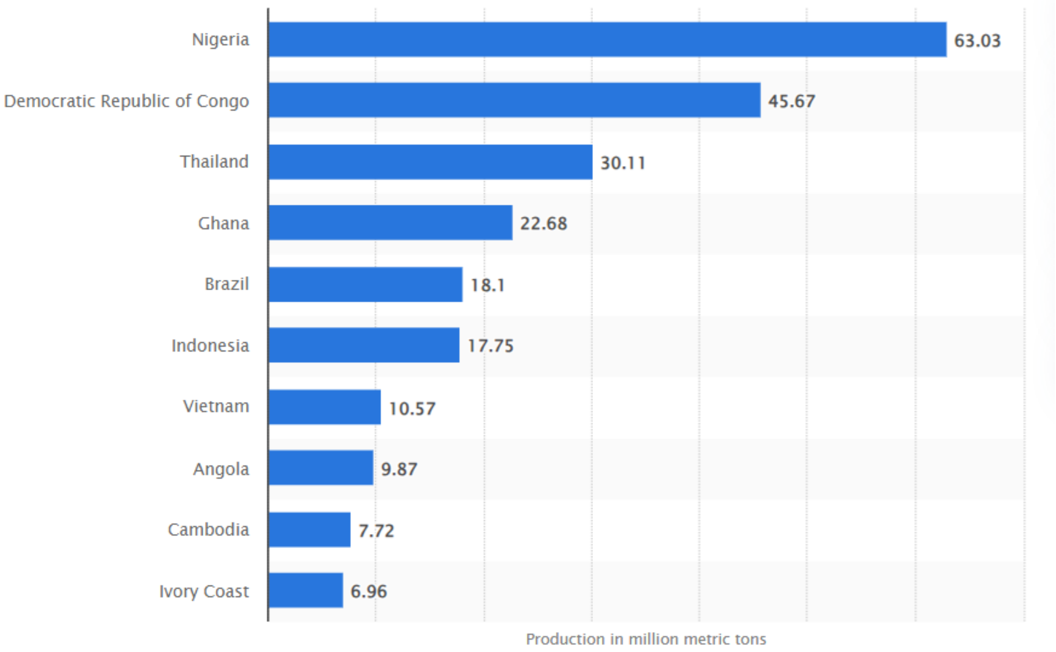


Figure 2. 7 Leading cassava producing countries worldwide in 2021 (in million metric tons)

Source: Statista, 2023

2.2.3 Key factors influencing cassava yield and productivity

Climate, environmental, and agricultural factors play critical roles in influencing the yield and productivity of cassava crops. High temperatures, irregular rainfall patterns, soil quality, pest and disease management, planting material, weed control, and crop harvesting are among the key factors that impact cassava production (Nyirakanani *et al*., 2021; Omoikhoje and Bigirimana, 2022; Adebayo, 2023; Zhu *et al*., 2023). In Sub-Saharan Africa (SSA), where the majority of global cassava production takes place, additional factors can influence cassava yield and productivity. These factors include farmers' health, education, farming experience, farm size, tenancy terms, access to credit, market opportunities, price fluctuations, inadequate infrastructure, and limited postharvest handling technologies (Aboajah *et al*., 2018; Legesse, 2018; Oyekola *et *al*., 2021; Charles, 2022; Omoikhoje and Bigirimana, 2022; Adebayo, 2023; Akomolafe *et al*., 2023; Manganyi *et al*., 2023).

2.2.4 Challenges and opportunities in cassava farming in Sub-Saharan Africa (SSA)

Cassava production in Sub-Saharan Africa (SSA) primarily occurs at the smallholder level and is predominantly focused on meeting local food demand, with a limited amount being exported and used in industries (Sanginga and Mbabu, 2015; Spencer and Ezedinma, 2017; Sahel Consulting, 2021; Adebayo, 2023; IITA, n.d.). Despite Nigeria being the largest cassava producer in terms of land area, approximately 90% of its total cassava output is consumed within the country (Ikuemonisan *et al*., 2020; Onyediako and Adiele, 2022). This indicates a significant untapped market opportunity for cassava exportation (Ikuemonisan *et al*., 2020). One of the key challenges faced by smallholder cassava farmers in SSA is the limited scale of their operations. Most farmers intercrop cassava on small land holdings, typically less than 2 hectares (Spencer and Ezedinma, 2017; Fan and Rue, 2020; Ikuemonisan *et al*., 2020; Szyniszewska, 2020; Kwapong *et al*., 2021). Additionally, they often rely on simple tools and traditional farming methods, which can result in lower productivity compared to their counterparts in other countries who have access to more advanced agricultural techniques and equipment (Bayitse *et al*., 2017; Spencer and Ezedinma, 2017; Sahel Consulting, 2021). Furthermore, many smallholder farmers in SSA inherit their farmland from previous generations, leading to a decline in soil quality over time (Jayne *et al*., 2016; Lu and Horlu, 2019; Fan and Rue, 2020). Continuous cassava cultivation without proper soil management practices can deplete soil nutrients and reduce overall productivity (Tully *et al*., 2015; Bilong *et al*., 2022). Additionally, there are issues with farmland tenure systems in the region, with some farmers lacking secure ownership rights to their land. This can hinder their ability to make long-term investments in soil conservation, improvement measures and mechanization (Jayne *et al*., 2016; Lu and Horlu, 2019; Ikuemonisan *et al*., 2020).

Smallholder farmers in SSA are particularly vulnerable to the impacts of climate change. They often lack the resources and capacity to adapt to changing environmental conditions with a small proportion having adaptation measures (Abdul-Razak and Kruse, 2017; Williams *et al*., 2018; Ogundeji, 2022). Rising temperatures, erratic rainfall patterns, and increased incidence of pests and diseases can have adverse effects on cassava yields (Abdul-Razak and Kruse, 2017; Spencer and Ezedinma, 2017; Szyniszewska, 2020). Technological capacity and access to finance are significant constraints for most smallholder cassava farmers (Owusu, 2017: Awotide *et al*., 2019; Yusuf *et al*., 2019; Fan and Rue, 2020; Balana and Oyeyemi, 2021; Adebayo, 2023). Limited access to modern farming technologies, such as improved varieties, mechanisation, and efficient irrigation systems, can restrict productivity gains (Adetarami *et al*., 2022; Sanusi *et al*., 2022). Moreover, inadequate access to finance prevents farmers from investing in essential inputs like high-quality planting materials, fertilizers, and pest management tools, ultimately limiting their production and yield potential (Bilong *et al*., 2022). Another factor that hinders cassava production in SSA is the underutilization of improved cassava varieties by farmers. This can be attributed to factors such as access to improved varieties, the perceived high cost of adopting new varieties, age, existing beliefs and preferences for traditional varieties, and limited awareness of the potential benefits of improved varieties (Afolami *et al*., 2015; Salum, 2016; Oryemo *et al*., 2021).

Opportunities for expanding the role of cassava beyond food security in the SSA region are supported by several studies (Spencer and Ezedinma, 2017; Amelework *et al*., 2021; Szyniszewska, 2020; Onyediako and Adiele, 2022). These opportunities include utilizing cassava as a cash crop for high-producing countries and smallholder farmers in SSA, which can contribute to economic development (Mbanjo *et al*., 2020; Acheampong *et al*., 2021; Amelework *et al*., 2021). By increasing cassava exports, countries with high cassava production can tap into the global market, potentially improving their GDP and increasing farmers' income (Dada, 2016; Bayitse *et al*., 2017; Adetunji, 2022). The international demand for cassava and its derived products, such as starch, flour, and chips, provides an opportunity for countries to generate foreign exchange and enhance their economic standing (Dada, 2016; Shittu *et al*., 2016; Dankwa and Peprah, 2019; Onyediako and Adiele, 2022). Furthermore, cassava holds promise as a valuable feed source for animals, addressing the growing demand for livestock products and contributing to the development of the livestock sector in SSA (Omede *et al*., 2018; Lubinga, 2022; Chisoro *et al*., 2023; Aroh *et al*., 2024).

Cassava also has potential as a biofuel feedstock, allowing for the production of bioethanol that can be blended with gasoline or used as a standalone fuel. This aligns with the global demand for renewable energy sources and the need to reduce greenhouse gas emissions (Bayitse *et al*., 2017; Pabon-Pereira *et al*., 2019; Mustafa *et al*., 2019; Fathima *et al*., 2023; Paredatu *et al*., 2023). Transitioning cassava production from subsistence farming to commercial cultivation in SSA can lead to improved incomes, job creation, and poverty reduction in rural communities (Mtunguja *et al*., 2019; Amelework *et al*., 2021). This transition can be facilitated by adopting improved farming practices, utilizing modern technologies, and accessing finance and markets (Sahel Consulting, 2021; Teye and Quarshie, 2021; Acheampong *et al*., 2022; Adetunji, 2022; Dadzie *et al*., 2022). Investing in research and development is crucial for enhancing cassava production and yield (Acheampong *et al*., 2021; Sahel Consulting, 2021). Scientific advancements, such as breeding high-yielding and disease-resistant cassava varieties, developing efficient agronomic practices, and improving post-harvest processing techniques, can unlock the full potential of cassava leading to increased productivity, better resilience against pests and diseases, and improve the quality of cassava-based products (Adjebeng-Danquah *et al*., 2020; Karim *et al*., 2020; Malik *et al*., 2020; Mbanjo *et al*., 2020; Kidasi *et al*., 2021; Mbinda and Mukami, 2022). Moreover, expanding cassava production provides raw materials for industrial development in SSA. Abundant cassava biomass can support industries such as starch processing, food processing, textile manufacturing, and pharmaceutical production, fostering economic diversification, value addition, and job creation (Bayitse *et al*., 2017; Dankwa and Peprah, 2019; Mtunguja *et al*., 2019; Jaenicke *et al*., 2020; Szyniszewska, 2020; Onyediako and Adiele, 2022).

2.3. Previous studies on climate change and cassava production

The impact of climate change on cassava production in Ghana has gained significant attention in recent years. Several studies have been conducted to understand the relationship between climate change and cassava cultivation, as well as to identify the challenges and potential mitigation strategies associated with it. These studies provide valuable insights into the dynamics of cassava production and its vulnerability to changing climatic conditions. According to Etwire *et al*. (2017), cassava tends to be cultivated in areas with relatively high precipitation. However, rising temperatures are associated with a gradual decline in the proportion of land devoted to cassava. Extreme levels of precipitation favour cassava cultivation due to its extensive root system, which protects it from drought and enables it to withstand high rainfall. Nevertheless, the study also revealed that at very high temperatures, farmers tend to substitute cassava with more heat-tolerant crops like millet, leading to a reduction in the probability of selecting cassava for cultivation.

Rainfall variability has been identified as a crucial factor affecting cassava production in specific regions of Ghana. Kyei-Mensah *et a*l. (2019) conducted a study in the Worobong Ecological Area (WAA) of the Fanteakwa District and found a decreasing trend in rainfall for the major season and an increasing trend for the minor season from 1985 to 2014. The study also highlighted a negative correlation between rainfall and cassava production, indicating that increasing rainfall reduced cassava yields. Farmers' perceptions of climate change and its impact on cassava production have also been investigated. Adjebeng-Danquah *et al*. (2020) examined farmers' perceptions of drought constraints and mitigation strategies in cassava cultivation in northern Ghana. The study revealed that drought was the major climatic constraint associated with cassava production. Additionally, other factors such as pests, diseases, weed infestation, and floods were identified, with their significance varying across districts. The study emphasized the importance of considering farmers' preferences for improved cassava varieties in developing suitable mitigation measures.

Chemura *et al*. (2020) examined the impacts of climate change on the suitability of major food crops, including cassava, in Ghana. The study highlighted the significance of rainfall factors in determining the potential suitability of cassava, with rainfall explaining up to 60% of the current variability in cassava production. Future projections indicated an increase in rainfall for the cropping period, sowing month, and growing season. However, optimal suitable areas for cassava production were projected to decrease under different representative concentration pathways (RCP), emphasizing the need for proactive measures to address the potential challenges. The effect of climatic variables on cassava yield has been explored in the Ashanti region of Ghana. Dwamena *et al*. (2022) found that increases in maximum and minimum temperatures harmed cassava yields, with maximum temperature having a stronger correlation. On the other hand, relative humidity exhibited a significant positive correlation with cassava yields, while rainfall had a weak positive correlation. These findings underscore the complex relationship between climatic variables and cassava yield.

Farmers' perceptions of climate change and the corresponding effects on cassava production have also been investigated. Mahama *et al*. (2021) assessed farmers' perceptions in the Awutu Senya District of the Central Region. The study revealed that farmers had adequate knowledge of climate variations and highlighted the adverse effects of climate variability on cassava production, including yield decreases and frequent crop losses. These effects were attributed to delayed rains, high temperatures, and erratic rainfall patterns. Although not explicitly focused on cassava, a study by Tetteh *et al*. (2022) explored the effects of climate change on food production in Ghana. The study identified temperature as a defining factor for food production in the country. Increasing temperatures were found to exacerbate the already hot climate, reduce soil moisture, prolong crop growth cycles, and increase pests and parasites, ultimately reducing crop yields. These studies collectively demonstrate the dedication of Ghana towards improving cassava production and understanding the impacts of climate change on this vital crop. While there are similarities in the effects of climate change on cassava production, the studies also highlight the location-specific nature of these impacts. This underscores the need for further research and investments to investigate the dynamics of the relationship between climate change and cassava production, as well as to develop location-specific policies and recommendations to support farmers. Moreover, considering farmers' perceptions and preferences for adopting improved cassava varieties can provide a holistic approach to addressing the challenges associated with climate change and enhancing cassava production in Ghana.

CHAPTER THREE

MATERIALS & METHOD

3.1 Study Area

The Komenda-Edina-Eguafo-Abrem (KEEA) Municipality is located within the Coastal Savannah Agroecological zone in the Central Region of Ghana (Figure 3.1). It lies within longitude 1^0 20’ West and 1^0 40’ West and latitude 5^0 05’ North 15^0 North and occupies a land area of 372.45 square km. It is bounded on the South by the Atlantic Ocean (Gulf of Guinea), on the East by the Cape Coast Metropolis, the North by the Twifo-Hemang-Lower Denkyira District and on the West by the Mpohor–Wassa East District (Municipal Planning Co-Ordinating Unit, 2016). The population as of 2010 is 144,705 with 48.1% males and 51.9% females (Ghana Statistical Service, 2014). The municipality is characterized by high temperatures (Figure 3.2) and variable rainfall patterns with coastal areas receiving less rainfall compared to inland areas making climate and vegetation variation to be influenced more by rainfall than by temperature (KEEA Municipal Assembly, n.d). With two maximum values, annual rainfall in coastal areas ranges from 750 to 1,000 mm, while downstream inland areas range from 1,200 to 1,500 mm (Figure 3.3). The municipality is generally humid with morning relative humidity between 85%-99% and afternoon between 50-85%. The main agricultural activities include crop farming and fishing with the major crops being maize, cassava sweet potato, pineapple, watermelon and vegetables (okro, tomato, pepper, cabbage and garden eggs). The agricultural sector of the municipality employs about 85% of the farmers with 54.5% engaged in crop farming and 10.9% in fishing (KEEA Municipal Assembly, n.d).

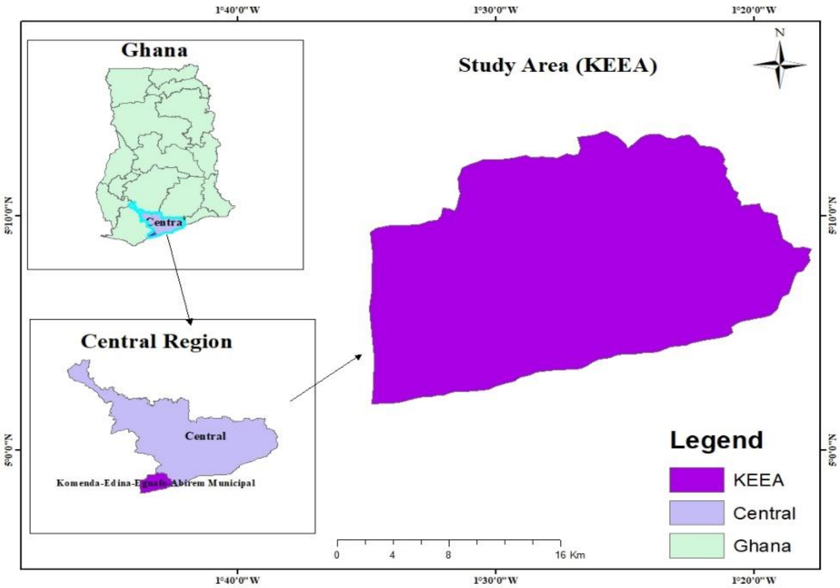


Figure 3. 1 Map of Ghana showing the study area

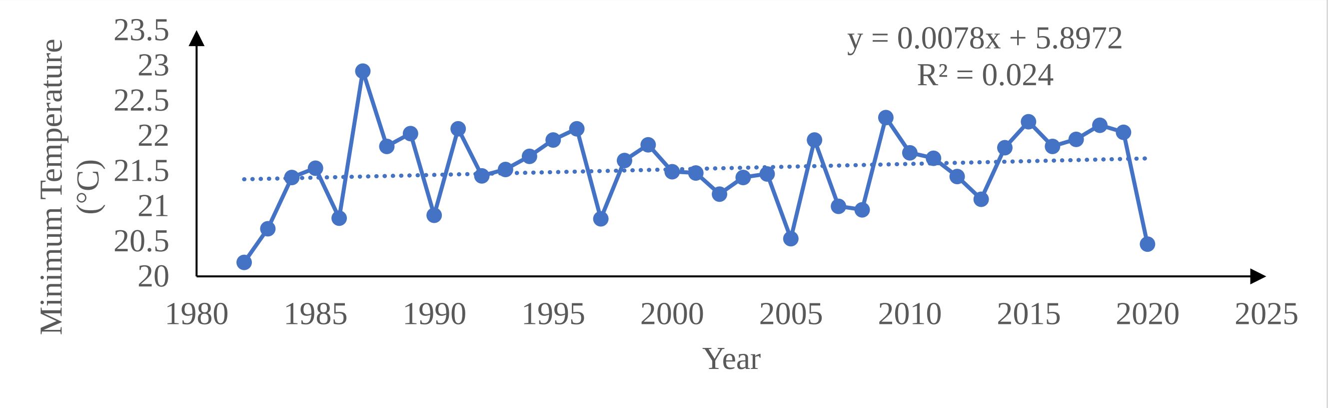


Figure 3. 2 Annual Minimum Temperature for KEEA Municipality

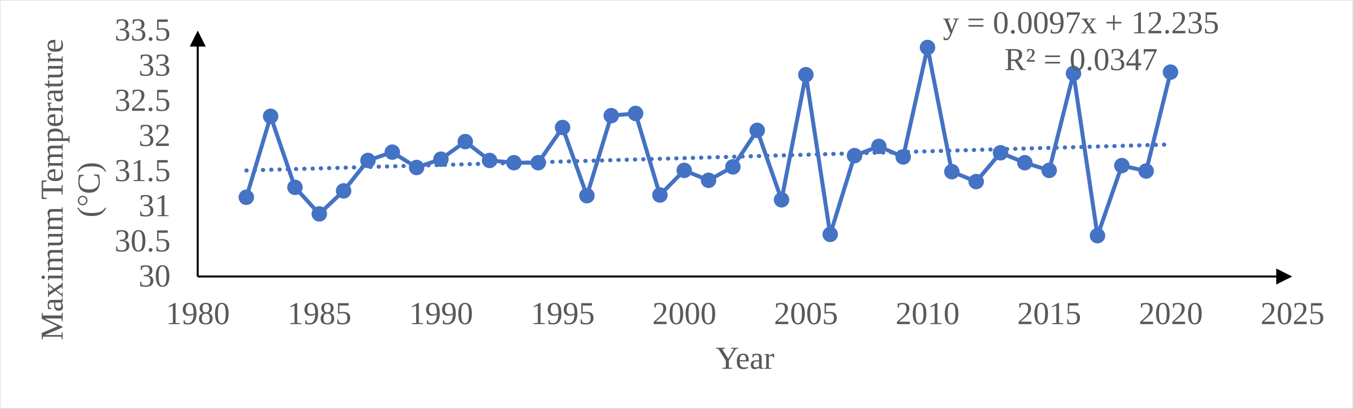


Figure 3. 3 Annual Maximum Temperature for KEEA Municipality

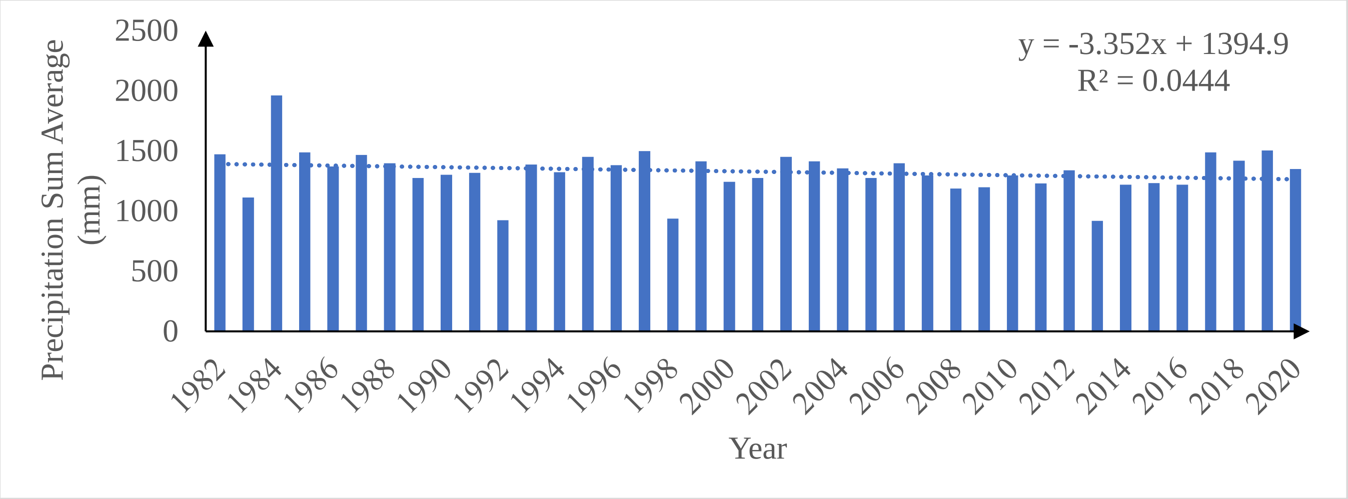


Figure 3. 4 Annual Precipitation Sum Average for KEEA Municipality

3.2 Methods

3.2.1 Data Collection

3.2.1.1 Secondary data

Temperature and precipitation data for the period 1982-2020 were downloaded from the NASA Power website https://power.larc.nasa.gov/data-access-viewer/. NASA Power generates reliable data and can help fill gaps associated with the primary data collected (Marzouk, 2021; Gunaratne *et al*., 2022; Mansour, 2022). These data were compared with observed data from the Ghana Meteorological Centre for the municipality. Also, downscaled and bias-corrected future climate data were downloaded from WorldClim at worldclim.org for the near (2021-2040) and far (2081-2100) future. WorldClim is a database of high spatial resolution global weather and climate data that can be used for mapping and spatial modelling. Crop data for the period 1982-2020 was obtained from the Department of Agriculture within the municipality.

3.2.1.2 Primary data

The study area has 28 communities; however, eight (8) communities were purposively selected for this study based on their major involvement in cassava production in the municipality. The sample size was determined using the Slovin formula:

Slovin formula $n = \frac{N}{(1+Ne^2)}$

Where:

n is the sample size, N is the population and e is the error margin; using an error margin of 0.05 (a 95% confidence level). Thus, a total of 254 respondents were selected from the eight (8) communities (which fall in at least one traditional zone) within the municipality to ensure a fair representation of results. The Slovin's formula is a useful tool in sample size determination which enables researchers to obtain sample sizes based on their desired degree of accuracy and has been employed in some agricultural studies (Rono, 2018; Tupamahu and Ivakdalam, 2020; Maryanti *et al*, 2022).

To obtain the specific sample size per community, the formula $\frac{P}{N}(n)$ was used where P is the population per community, N is the total population and n is the total sample size. A simple random sampling was employed in the selection of respondents from each community. The population and number of respondents per community are shown in Table 3.1.

Table 3. 1 Number of respondents sampled from each community in the KEEA Municipality

Community	Population of Cassava Farmers	Respondents
Abee	27	10
Agona	137	50
Dominase	107	39
Dutch Komenda	55	20
Kissi	77	28
Kokoado	52	19
Komenda	41	15
Simiw	200	73
Total	**696**	**254**

A semi-structured questionnaire was used to obtain responses from respondents. These questions were categorised into three main headings; personal and household characteristics, farm characteristics and perception of climate change. Personal and household characteristics centred mainly on their sex, age, education and household size. Farmers interviewed were aged 35 and above to accurately obtain their perception of climate change. Farm characteristics centred on the farm size, ownership status, farm labour, the quantity of cassava harvested yearly, the number of years of farming, etc. Furthermore, their perception of climate involved questions about their awareness, if they had received any information, its source and their perceived impact on yield as well as adaptation measures present. The responses to these questions were coded into SPSS 27. For example, regarding the sex of farmers, males were coded as 1 with females being 2.

3.2.2 Data Analysis

Data collected were analysed using ArcGIS 10.8 to map future scenarios of agro-climatology datasets (temperature and precipitation) for the study area. Data from questionnaires was analysed using the Statistical Package for the Social Sciences (SPSS) version 27. Data obtained from the questionnaire were categorised into various classes for easy analysis and presentation of results.

SPSS has been employed in several studies due to its simplicity in analysing data and providing an accurate representation of results (Kaba *et al.*, 2020; Mutombo and Musarandega, 2023; Tom-Dery *et al*., 2023). A multiple linear regression analysis was used to determine relationships between agro-climatology datasets (temperature, precipitation and relative humidity) and cassava yield using XLSTAT 2024. The results obtained were presented in tables and figures.

3.2.3 Future Climate Scenarios

To develop future climate scenarios, the MRI-ESM2.0 GCM 30-second resolution downscaled and bias-corrected data was downloaded from WorldClim. These data under the Shared Socioeconomic Pathways (SSP) were employed in ArcGIS 10.8. The shapefile for the study area was used to map out the future projections from the Global Circulation Model (GCM) by employing the clip function under Raster processing found within the ArcToolbox. This was done for all the agro-climatological datasets (precipitation, minimum and maximum temperatures) to obtain the possible trends in climatic conditions under SSP 2 (4.5 – Middle of the road) and SSP 5 (8.5 – Fossil-fuel development) for the near (2021-2040) and far (2080-2100) futures. The SSPs were developed by the IPCC in their Sixth Assessment Report (AR6) for the Sixth phase of the Coupled Intercomparison Model Project (CMIP6) which incorporates socioeconomic characteristics in the prediction of future climate scenarios and these have been adopted by various researchers in their studies (Mensah *et al*., 2022; Siabi *et al*., 2023).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Personal and Household Characteristics

4.1.1 Sex and Age distribution of farmers in KEEA Municipality

A comprehensive questionnaire was administered to a total of 254 cassava farmers, from which key insights were derived. The distribution of respondents revealed that 169 individuals, constituting 66.54% of the sample, were identified as female, while 85 individuals, accounting for 33.46%, were male (Table 4.1). This gender imbalance can be attributed to the demographic composition of the municipality, as reported in the 2010 Population and Housing Census (PHC) by the Ghana Statistical Service, which indicated a higher population of females compared to males (Ghana Statistical Service, 2014).

In addition, the age distribution of farmers was segmented into 10-year intervals (Table 4.1). Out of the 254 respondents, it was observed that 29.1% fell within the age range of 35-45. Similarly, proportions of 26.0% were identified for both the 46-55 and 56-65 age brackets. Furthermore, 10.2% of respondents were situated within the 66-75 age range, while 8.3% fell between 76-85. Notably, the 86+ age group constituted the smallest proportion, accounting only 0.4% of the total respondents (Table 4.1). These findings mirror the trends observed in the 2010 PHC for the KEEA Municipality, where the number of individuals decreases as the age brackets advance (Ghana Statistical Service, 2014).

Table 4. 1 Sex distribution and Age range of farmers in KEEA Municipality

Sex	Number of Respondents	Percentage (%)
Male	85	33.46
Female	169	66.54
Age range of farmers		
35-45	74	29.1
46-55	66	26.0
56-65	66	26.0

66-75	26	10.2
76-85	21	8.3
86+	1	0.4

4.1.2 The educational level of farmers in KEEA Municipality

Four categories were employed to ascertain the educational levels of farmers. Among the 254 respondents, 116 individuals were uneducated, whereas 138 had received some level of formal education. Notably, the majority of farmers possessing formal education had completed primary and Junior High School education (40.6%). Subsequently, farmers with secondary education accounted for 9.8% of the respondents, while those with tertiary-level education constituted the smallest proportion, amounting to 3.9% (Table 4.2). Education holds significant importance in Ghanaian society. The Central Region of Ghana, where the KEEA Municipality is situated, hosts some of the nation’s most esteemed educational institutions (Births and Deaths Registry, n.d.; Ghana Statistical Service, 2013). Undoubtedly, this influential educational landscape contributes to the higher prevalence of education observed among the respondents. These findings align with the results of the 2010 PHC, which similarly indicated a greater proportion of educated individuals in the municipality compared to those uneducated (Ghana Statistical Service, 2014).

Table 4. 2 The educational level of farmers

Educational level of farmers	Number of Respondents	Percentage (%)
Uneducated	116	45.7
Primary & JHS	103	40.6
Secondary	25	9.8
Tertiary	10	3.9

4.1.3 Household size and Migration status of farmers in KEEA Municipality

Table 4. 3 Household size and Migration status of farmers

Household size	Number of Respondents	Percentage (%)
1-5	133	52.4
6-10	108	42.5
11-15	11	4.3
16-20	2	0.8
Migration status of farmers		
Native	247	97.2
Migrant	7	2.8

Among the surveyed farmers, a significant majority of 52.4% reported having a household size ranging from 1 to 5 individuals. This was followed by 42.5% of farmers who reported a household size between 6 and 10. Conversely, the smallest proportion of farmers, representing only 0.8%, reported a household size of 16 to 20 individuals. Furthermore, out of the total respondents, it was observed that 247 (97.2%) farmers were native residents of their respective communities. In contrast, a smaller number of 7 (2.8%) farmers identified themselves as migrants, implying that they had relocated to the municipality from other areas. These findings are presented in Table 4.3. In the municipality, the average household size recorded in the 2010 population and housing census was approximately 3.9 individuals. However, the average household size observed in this study was notably higher at 5.77 individuals. This disparity can be attributed to the projected population increase outlined in the report by Ghana's Ministry of Finance in 2021 (Ministry of Finance, 2021). The projected population growth likely contributed to larger household sizes, reflecting changes in demographic trends and dynamics within the municipality. Also, the fact that 97.2% of farmers are natives speaks to the importance of cassava production to them.

4.2 Farm Characteristics

4.2.1 Years of Farming and Farm ownership status of farmers in KEEA Municipality

Table 4. 4 Years of Farming and Farm ownership status of farmers

Years of farming	Number of Respondents	Percentage (%)
0-10	110	43.3
11-20	68	26.8
21-30	38	14.9
31-40	31	12.2
41-50	7	2.8
Farm Ownership status		
Owner	250	98.43
Otherwise (lease land)	4	1.57

A 10-year interval was used to categorize the number of years of farming. Out of the total 254 participants, 110 (43.3%) farmers reported having between 0 and 10 years of farming experience. Similarly, 68 (26.8%) farmers fell within the 11–20-year range, while 38 (14.9%) farmers reported having 21-30 years of farming experience. Additionally, 31 (12.2%) farmers indicated 31-40 years of experience, and a smaller group of 7 (2.8%) farmers reported having 41-50 years of farming experience (Table 4.4).

Regarding farm ownership status, Table 4. 4 revealed that the majority of farmers, accounting for 98.4% of the respondents, owned their farms. Only 16% of the farmers reported cultivating their land on lease agreements, indicating a relatively smaller proportion of farmers operating on leased land.

The number of years of farming experience contributes to the climate awareness of farmers (Anuga *et al*., 2019; Mahama *et al*., 2021). The fact that the majority of residents in the municipality are natives (Table 4.3), with a significant portion of 144 farmers having more than 10 years of farming experience (Table 4.4), positions them well to discern changes in the climate. Their prolonged agricultural activities enable them to develop a keen sense of the local climate patterns and identify any shifts or deviations from the norm. Furthermore, the majority of farmers owning their farmlands may be an added advantage to obtaining accurate and comprehensive information about observed changes. As landowners, they have a direct and intimate connection to their farms, allowing them to closely monitor and document any climate-related transformations affecting their farms. Their ownership status provides them with greater access and involvement in land management practices, enabling them to gather valuable insights and provide reliable information about climate variations and their potential implications for agricultural activities in the municipality (Mahama *et al*., 2021; Mehmood *et al*., 2022; Temba and Said, 2023).

4.2.2 Farm size of farmers in KEEA Municipality

Table 4. 5 Farm size of farmers

Farm size (acres)	Number of Respondents	Percentage
1-2	114	44.9
3-4	74	29.1
5-6	40	15.8
7-8	17	6.7
9-10	9	3.5

Table 4.5 presents the distribution of land sizes cultivated by the farmers. The highest proportion, accounting for 44.9% of the respondents, reported cultivating 1-2 acres of land. On the other hand, the lowest proportion, representing 3.5%, reported cultivating 9-10 acres of land. Among the respondents, 29.1% reported cultivating 3-4 acres, while 15.7% and 6.7% cultivated 5-6 acres and 7-8 acres, respectively. Per the findings of Kwapong *et al*. (2021), the average land size for small-holder farmers in Ghana is reported to be approximately 1.6 hectares, which is equivalent to around 4 acres. Remarkably, the results of this study align with those findings, as the average farm size recorded for the municipality is 3.39 acres. This similarity in average farm sizes suggests a consistency between the study's findings and the broader context of small-holder farming in Ghana. This observation emphasizes the significance of farm size in influencing farmers'

understanding of climate-related changes. The relatively smaller land sizes within this range likely facilitate more intimate and hands-on engagement with their farms, enabling farmers to closely observe and interpret climate variations and their impact on agricultural practices (Uddin *et al*., 2017).

4.2.3 Source of labour in KEEA Municipality

Table 4. 6 Source of labour on farms

Source of labour on farms	Number of Respondents	Percentage (%)
Household	141	55.5
Hired	60	23.6
Household & Hired	52	20.5
Communal Assistance	1	0.4

The findings reveal that the majority of farmers, accounting for 55.5% of the respondents, reported working on their farms primarily through household labour. Additionally, 23.6% of the farmers indicated the use of hired labour on their farms. A notable proportion of 20.5% reported utilizing both household and hired labour. Lastly, a small percentage of 0.4% mentioned relying on communal assistance or labour for their farming operations.

The prevalence of household labour is a key indicator that further confirms the small-holder status of farmers in the study areas as farmers prefer utilizing family members rather than hiring external workers. This preference is usually driven by the cost considerations associated with hiring external labour. Furthermore, the inclination towards utilizing household labour may be influenced by the fact that farmers tend to have larger family sizes (the average household size of the municipality is 6). The presence of a larger pool of family members provides farmers with a readily available workforce to allocate to various farming tasks, without the need for additional expenditure on external labour (Rapsomanikis, 2015; Kwapong *et al*., 2021). Moreover, a research study conducted in Pakistan revealed a positive association between the employment of household labour and higher agricultural yields (Ayaz and Mughal, 2022). This finding suggests that family labour plays a crucial role in understanding the relationship between farm size and productivity.

The involvement of family members in the farming process may contribute to increased efficiency, as they possess a vested interest in the success of the farm and are often more committed and dedicated to its operations (Ayaz and Mughal, 2022).

4.2.4 Annual quantity (kg) of cassava harvested by farmers in KEEA Municipality

Table 4. 7 Annual quantity (kg) of cassava harvested by farmers in KEEA Municipality

Cassava harvested yearly (kg)	Number of Respondents	Percentage (%)
1-1000	189	74.4
1001-2000	35	13.8
2001-3000	16	6.3
3001-4000	8	3.1
4001-5000	4	1.6
5001-6000	1	0.4
6001-7000	1	0.4

Table 4. 8 Effects of Sex, Years of farming, Farm size, Source of labour and Agricultural practices on Cassava harvested yearly

		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.708	0.351		4.863	<0.001
	Sex	-0.573	0.127	-0.278	-4.530	<0.001
	Years of farming	0.152	0.049	0.181	3.071	0.002
	Farm size	0.071	0.052	0.079	1.355	0.177
	Source of labour	0.215	0.073	0.179	2.959	0.003
	Agricultural practices	-0.024	0.017	-0.080	-1.415	0.158

The quantity of cassava harvested exhibited significant variation among the farmers surveyed. The majority of farmers, accounting for 74.4% of the respondents, reported harvesting between 1 and

1,000 kg of cassava per year. Following this, 13.8% of farmers indicated harvesting a quantity ranging from 1,001 to 2,000 kg, while 6.3% reported a harvest in the range of 2,001 to 3,000 kg (Table 4.7). In contrast, a minority of farmers, comprising 0.8% of the respondents, reported higher yields, specifically between 5,001 and 6,000 kg, and between 6,001 and 7,000 kg of cassava per year (Table 4.7).

The observed variations in annual cassava yields among farmers can be attributed to several factors, including sex, years of farming experience, and source of labour (Table 4.8). Sex plays an important role in cassava production and yields (Table 4.8). Cassava is termed in some places as a female-dominant crop although a significant number of males are equally involved in its production (Nwaobiala *et al*., 2019). Moreover, studies conducted by Teeken *et al*. (2018) and Apata (2019) revealed that females were highly in cassava processing into other products than men which may equally be a possible influence of more females engaged in cassava production with a vested interest in higher yields. Furthermore, the number of years of farming experience can influence cassava yields as constant cultivation on one piece of land can lead to depletion of soil nutrients which can reduce cassava yields (Kintché *et al*., 2017; Kaluba *et al*., 2021). The source of labour employed by farmers is another important factor influencing cassava yields. Farmers who rely on household labour, as opposed to hiring external labour, may have different levels of availability and commitment from family members, which can impact the efficiency and productivity of farming operations (Legesse, 2018; Ayaz and Mughal, 2022; Daemo *et al*., 2023).

4.2.5 Agricultural practices of farmers in KEEA Municipality

Table 4. 9 Agricultural practices of farmers

Agricultural practices of farmers	Number of Respondents	Percentage
Weeding	33	13.0
Weeding & Row planting	121	47.6
Weeding & Others	13	5.1
Weeding, Row planting & Others	20	7.9
Weeding, Row planting & Intercropping/Mixed cropping	28	11.0
Weeding, Row planting & Ploughing	25	9.8

Weeding, Ploughing & Intercropping/Mixed cropping	4	1.6
Weeding & Intercropping/Mixed cropping	4	1.6
Weeding, Row planting, Ploughing & Intercropping/Mixed cropping	3	1.2
Row planting, Ploughing & Intercropping/Mixed cropping	1	0.4
Weeding, Row planting, Ploughing & Others	1	0.4
Weeding, Row planting, Ploughing, Intercropping/Mixed cropping & Others	1	0.4

Table 4.9 presents the results of a multiple-choice response survey administered to farmers within the KEEA Municipality. Farmers were allowed to select multiple choices that applied to their farming practices. The survey focused on different agricultural practices adopted by farmers within the municipality. The majority of respondents (47.6%) indicated that weeding and row planting were the most common practices implemented on their farms. Furthermore, 13.0% of respondents reported sole weeding as their primary agricultural practice. Additionally, 11.0% of respondents reported employing a combination of weeding, row planting, and intercropping/mixed cropping, while 9.8% reported utilizing weeding, row planting, and ploughing as their primary practices. It is worth noting that a small proportion of farmers, representing 1.6% of respondents, reported employing more than three agricultural practices on their farms.

Weed control, row planting, and intercropping/mixed cropping are widely recognized as common practices in cassava cultivation. These practices, when combined with other factors, exert significant influences on cassava production and yield. Intercropping of cassava, when implemented under recommended spatial and temporal conditions, serves a dual purpose; it helps control weeds and can contribute to increased yields (Taah *et al*., 2017; Kreye *et al*., 2020; Taah and Adu, 2021; Amoako *et al*., 2022). Furthermore, studies conducted by Kintché *et al*. (2017), Weerarathne *et al*. (2017), Zaknayiba *et al*. (2019), and Acheampong et al. (2021) highlight the significance of weeding and subsequent weed control practices in cassava production. Weeds compete with cassava plants for nutrients, water, and sunlight, negatively impacting their growth and development. Effective weeding techniques, such as manual or mechanical weeding, herbicide application, or a combination of these methods, play a vital role in minimizing weed interference and optimizing cassava yields. In addition, row planting facilitates efficient plant management, including ease of access for weeding, and pest and disease monitoring. Proper spacing and alignment, characteristic of row planting, promote optimal cassava plant growth, maximize land utilization, and contribute to higher yields (Hauser *et al*., 2014).

4.2.6 Alternative livelihood types of farmers in KEEA Municipality

Table 4. 10 Alternative livelihood types of farmers

Alternative livelihood types	Number of Respondents	Percentage (%)
Cereals & legumes farming	66	26.0
Cereals & legumes farming and Others	79	31.1
Others (trading, operating provision shops, etc)	23	9.1
Vegetable and Cereals & legumes farming	26	10.2
Vegetable farming, Cereals & legumes farming and Others	17	6.7
Fruit and Cereals & legumes farming	14	5.5
Fruit farming and Others	13	5.1
Fruit farming, Cereals & legumes farming and Others	5	1.9
Fruit, Vegetable and Cereals & legumes farming	4	1.6
Fruit farming, Vegetable farming and Others	3	1.2
Fruit farming	1	0.4
Fruit, Cereals & legumes and Herbs farming	1	0.4
Fishing and Cereals & legumes farming	1	0.4
Vegetable farming and Others	1	0.4

The results in Table 4.10 indicate that all farmers in the Municipality had alternative livelihoods (aside from cassava farming). For instance, the majority of farmers opted for alternative livelihoods within the agricultural sector, with only 9.1% exclusively engaged in non-agricultural activities such as trading, operating provision shops, or working as seamstresses. Among the farmers who pursued alternative livelihoods within the agricultural sector, a significant proportion, representing 31.1%, were involved in cereals and legumes farming (particularly maize, and groundnuts). Following closely were farmers engaged solely in cereals and legume farming, accounting for 26.0% of the respondents.

Cassava cultivation in tropical regions, including Ghana, commonly involves intercropping practices, particularly with crops like maize and legumes. This approach aims to enhance yields, control weeds, diversify farm income, optimize land utilization, and improve overall agricultural system productivity (Silva *et al*., 2016; Kuyper and Adejeh-Nsiah, 2017; Jones and Issaka, 2017; Fening *et al*., 2020; Amoako *et al*., 2022; Wahab *et al*., 2022). Therefore, the outcomes observed in this study are indicative of the prevailing cassava production practices in the country. Given the ease of engagement and substantial market demand for agricultural and agricultural-related livelihoods (as food consumption is a daily necessity), it is common for smallholder farmers to pursue alternative livelihoods within and associated with the agricultural sector. They often perceive these ventures as less risky compared to non-agricultural alternative livelihoods, which may require specific skills and educational qualifications (Wahab *et al*., 2022)

4.3 Perception of climate change

4.3.1 Climate Change (CC) awareness status of farmers within the KEEA Municipality

During the interviews conducted with farmers, their awareness of climate change was assessed. Out of the 254 respondents, a significant majority of 210 farmers (82.68%) demonstrated an awareness of climate change, as indicated by their affirmative responses. On the other hand, a smaller proportion of 44 farmers (17.32%) expressed unawareness or lack of knowledge regarding climate change, as they provided negative responses. The high level of awareness among farmers regarding climate change in this study can be largely attributed to their age and years of farming experience. As indicated in Table 4.2, a significant proportion of farmers, approximately 70.87%, were above the age of 45. Additionally, Table 4.5 reveals that 56.69% of farmers had more than 10 years of experience in farming. Previous studies as confirmed by Asante *et al*. (2021), Mahama *et al*. (2021) and Ricart *et al*. (2023) showed that the age of the farmer and the number of years spent in farming are likely to have a positive effect on farmers' understanding and level of awareness of climate change. For example, in a study conducted by Asante *et al*. (2021), they found that farmers who were between the ages of 41-61+ years developed a deeper understanding of climate change and were therefore able to assess risks to implement appropriate adaptive strategies. Also, Ricart *et al*. (2023) in their studies observed that farmers with 10 years of farming had a better understanding and awareness of climate change as they would be exposed to temperature and rainfall changes.

4.3.2 Climate Change (CC) information status of farmers within the KEEA Municipality

In a follow-up question targeting farmers who demonstrated awareness of climate change, they were asked whether they had received any information related to climate change. Out of the 210 respondents who were aware of climate change, approximately 59.52% (125 farmers) responded affirmatively, indicating that they had received information on this subject. Conversely, 40.48% (85 farmers) responded negatively, indicating that they had not received any information specifically related to climate change. It is possible that the minority of farmers who received no information on climate change lacked access to extension officers (The extension officer to farmer ratio in Ghana is 1:1500 farmers compared to the FAO standard of 1:500) and the media outlets as these formed the majority of sources such information as seen in Table 4.11 (MoFA, n.d.; Farm Radio International, 2022; Mumuni *et al*., 2023).

Table 4. 11 Source of Climate Change (CC) information

Source of CC information	Number of Respondents	Percentage (%)
Extension Officers	63	50.8
Media	37	29.8
Extension Officers and Media	19	15.3
Others	4	3.2
Extension Officers, Media and Others	1	0.8

For instance, the majority of information farmers received was either from the Extension Officers (50.8%) or the media (29.8) or both (15.3%). A minority of farmers received their climate information from other sources (particularly family, friends and other farmers), and one person received climate information from all sources representing 2.4% and 0.8% respectively (Table 4.11). The findings of this study suggest extension officers and media as important sources of climate information as reported by Busungu *et al*., (2019) and Adu-Boahen (2023).

Table 4. 12 Type of climate change (CC) information received

Type of CC information received	Number of Respondents	Percentage (%)
Changes in rainfall patterns	15	12.1
Changes in rainfall patterns & temperature	73	58.9
Others (farm health)	26	21.0
Changes in rainfall patterns & Adaptive measures	4	3.2
Changes in rainfall patterns & Others	3	2.4
Changes in temperature & Others	1	0.8
Changes in rainfall patterns & temperature and Others	1	0.8
Changes in rainfall patterns & temperature, Adaptive measures and Others	1	0.8

The results presented in Table 4.12 reflect the outcomes of a follow-up question posed to farmers who had reported receiving information on climate change. The objective of this enquiry was to ascertain the specific types of climate change information that farmers had been exposed to. It is important to note that farmers were allowed to select more than one applicable response. The findings reveal that a majority of farmers, comprising 58.9% of the respondents, reported receiving information that covered both changes in rainfall patterns and temperature. Furthermore, 21.0% of the farmers reported receiving information related to other topics (farm health). In addition, 12.1% of the farmers stated that they had received information solely regarding changes in rainfall patterns and a small percentage of farmers (8%) reported receiving information that covered a combination of changes in rainfall patterns, temperature, adaptive measures, and other related topics. The emphasis on changes in both rainfall patterns and temperature reflects the recognition of these factors as important influences on agriculture (Chemura *et al.*, 2020; Etwire, 2020; Keutgen, 2023).

4.4 Farmers perceived reasons for the impact of Climate Change on cassava yield and their adaptation measures in the KEEA Municipality of Ghana

4.4.1 Cassava Farmers’ perception of Climate Change (CC) on yield

Among the farmers who responded positively to the climate change awareness question, a subsequent enquiry was made to ascertain whether climate change had influenced their yields. Out of the total 210 respondents, a significant majority of 187 (89%) farmers acknowledged that climate change had indeed impacted their yields. Among the key reasons were the flooding on their farms, stunted growth of cassava and the high incidence of pest and diseases (Table 4.13). For example, Out of the 187 respondents who reported an impact, 33.7% identified the flooding of farms as the primary factor affecting their yields. This was closely followed by 16.6% of farmers who cited stunted growth of tubers as a significant impact. Additionally, 16.0% of respondents stated that other factors, such as rotten tubers and early and late harvesting, contributed to the impact on their yields. Climate change has been identified as a significant driver of various adverse effects on agricultural systems, including increased flooding, the migration and spread of pests and disease vectors, and stunted crop growth due to rising temperatures. These factors collectively contribute to a negative impact on crop yields (Magado and Ssekyewa, 2018; Atanga and Tankpa, 2021; Skendžić *et al*., 2021; Anyaegbu *et al*., 2022; Omodara *et al*., 2023).

Table 4. 13 Reason for the impact of CC on yield

Reason for the impact of CC on yield	Number of Respondents	Percentage (%)
Flooding of farms	63	33.7
Stunted growth of tubers	31	16.6
Pest & disease infestations	11	5.9
Others	30	16.0
Flooding of farms and Others	14	7.5
Pest & disease infestations and Stunted growth of tubers	10	5.3
Flooding of farms and Stunted growth of tubers	8	4.3
Stunted growth of tubers and Others	7	3.7

Flooding of farms, Pest & disease infestations and Stunted growth of tubers	3	1.6
Flooding of farms, Stunted growth of tubers and Others	3	1.6
Pest & disease infestations, Stunted growth of tubers and Others	3	1.6
Flooding of farms and Pest & disease infestations	2	1.1
Pest & disease infestations and Others	1	0.5
Flooding of farms, Pest & disease infestations and Others	1	0.5

Conversely, 23 farmers representing 11% of reported no such impact. They attributed it to the good agronomic practices and other adaptative measures such as the use of improved varieties, as the reasons for the lack of impact (Table 4.14). It is worth highlighting that the use of GAPs and improved varieties have been reported to help farmers adapt to changing climate as well as increase their crop yields (Acheampong *et al*., 2021; Acheampong *et al*., 2022; AICCRA, 2023).

Table 4. 14 Reason for no impact of CC on yield

Reason for no impact of CC on yield	Number of Respondents	Percentage (%)
Good agronomic practices {GAPs)	12	52.2
Good agronomic practices and Adaptive measures	6	26.1
Adaptive measures	5	21.7

4.4.2 Cassava Farmers' Adaptive Measure Status

In response to a follow-up question aimed at understanding whether farmers who reported an impact of climate change on their yields had any adaptation measures, 73 (39.0%) out of the 187 respondents answered affirmatively, while 114 (61%) respondents indicated that they had none. Adaptation measures are farmers' responses to the impact of climate change on their production and yield. Farmers' adoption of adaptation measures may be influenced by farmers' perception and preferences, anxiety, access to information, and finance, (Belay *et al*., 2017; Mairura *et al*., 2021; Tangonyire and Akuriba, 2021; Abunyewah *et al*., 2023).

4.4.3 Type of Adaptive Measure of Cassava Farmers

Table 4. 15 Types of adaptive measures of farmers

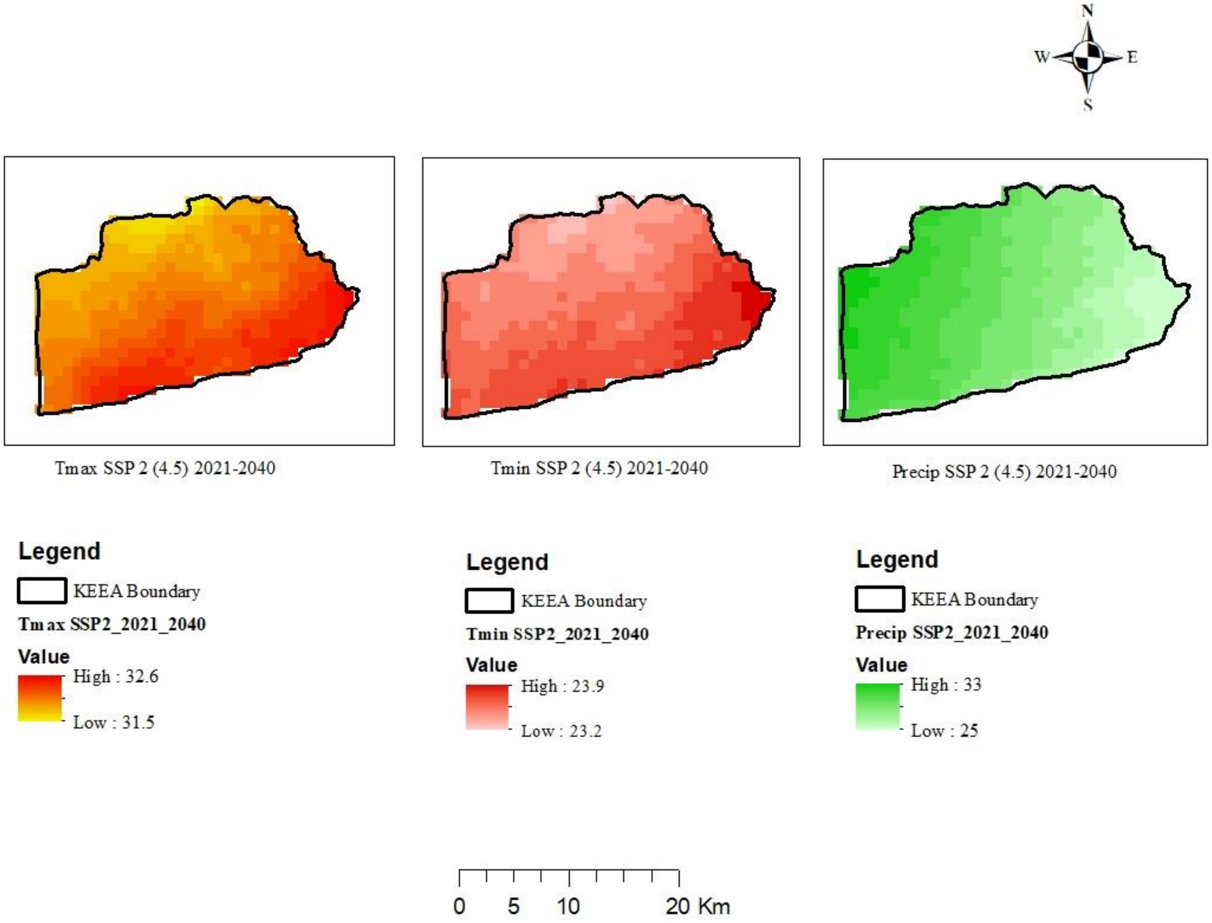
Types of Adaptive Measures	Number of Respondents	Percentage (%)
Early planting	19	26.0
Early harvesting	2	2.7
Others	13	17.8
Use of pesticides	7	9.6
Use of crop varieties	1	1.4
Early planting & Early harvesting	8	11.0
Early planting & Others	8	11.0
Early planting & Use of pesticides	3	4.1
Early harvesting & Use of pesticides	1	1.4
Early planting, Early harvesting & Use of pesticides	3	4.1
Early planting, Early harvesting & Others	3	4.1
Use of pesticides & Others	2	2.7
Early planting & Use of crop varieties	1	1.4
Early planting, Use of pesticides & Others	1	1.4
Use of crop varieties, Use of pesticides & Others	1	1.4

Table 4.15 presents the results of farmers who reported having implemented adaptation measures. The purpose of the survey was to ascertain the specific types of adaptation measures employed by these farmers in response to climate change. Among the 73 respondents, the most commonly reported adaptive measure was early planting, adopted by 19 farmers (26.0%). Thirteen respondents (17.8%) stated utilizing other measures such as irrigation systems and farm diversification. Eight respondents (11.0%) implemented both early planting and early harvesting as their adaptive measures. Another eight respondents (11.0%) combined early planting with other

approaches. Seven respondents (9.6%) reported using pesticides as their chosen adaptive measure. Three respondents (4.1%) employed a combination of early planting and pesticide use, as well as a combination of early planting, early harvesting, and pesticide use. Finally, two respondents (2.7%) exclusively relied on early harvesting as their adaptive measure. Early planting, early harvesting, farm diversification, irrigation systems and the use of pesticides are critical adaptation measures adopted by farmers (Henri-Ukoha, 2019; Kalu and Mbanasor, 2020; Maruthi *et al*., 2020; Magesa *et al*., 2023; Osuji *et al*., 2023) to mitigate the impact of climate change on their crops production.

4.5 Climate projections for KEEA for the near (2021-2040) and far (2081-2100) future

4.5.1 Climate projections for KEEA for the near future (2021-2040)



Tmax SSP 2 (4.5) 2021-2040

Tmin SSP 2 (4.5) 2021-2040

Precip SSP 2 (4.5) 2021-2040

Figure 4. 1 Temperature (minimum and maximum) and Precipitation projections of KEEA for 2021-2040 under SSP 2

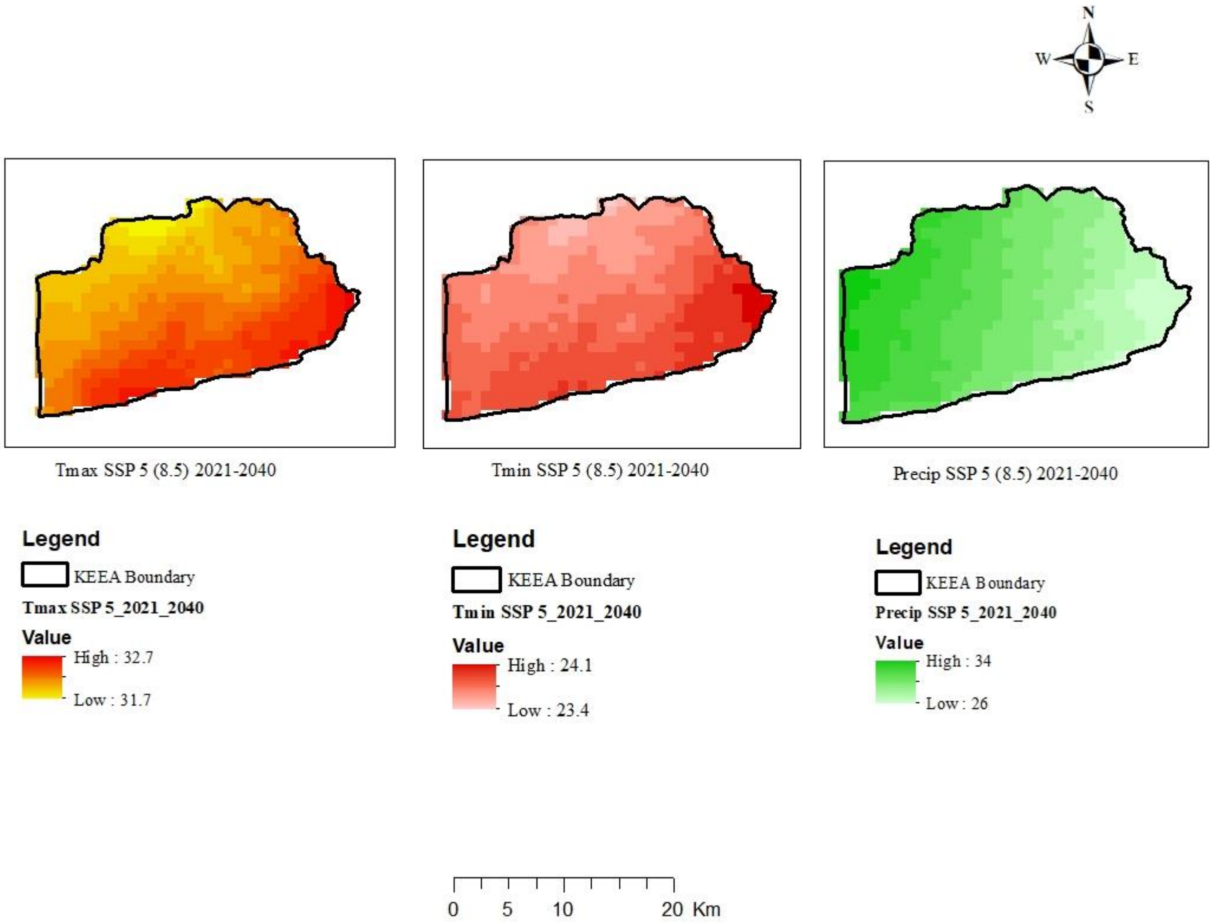


Figure 4. 2 Temperature (minimum and maximum) and Precipitation projections of KEEA for 2021-2040 under SSP 5

In the near future (2021-2040), both the SSP2 (Figure 4.1) and SSP5 (Figure 4.2) scenarios indicate higher temperatures in the southern part of the municipality compared to the northern region. Specifically, for maximum temperature (Tmax), a decrease (Figure 3.3 as reference) is projected under SSP2, while under SSP5, a slight increase ranging from 0.1°C to 0.2°C is anticipated. In contrast, minimum temperatures (Tmin) are expected to rise (Figure 3.2 serves as a reference) under both SSP2 and SSP5. Additionally, a significant decrease (Figure 3.4 provides a reference) in precipitation (rainfall) is anticipated under both scenarios, with SSP5 indicating a slight increase of 1mm. The temperature disparity between the north and south regions can be attributed to the relatively higher concentration of built-up areas in the south compared to the north, as well as the presence of trees in the northern region. Built environments tend to absorb and re-emit heat more than natural landscapes, resulting in increased temperatures—a phenomenon known as the Heat Island Effect (Druckenmiller, 2023; US EPA, 2024). Conversely, trees play a crucial role in reducing temperatures by providing shade and through evapotranspiration processes (Armson *et al*., 2012, Lenart, 2019; World Economic Forum, 2023). The projected increase in temperatures and decreased precipitation can potentially disrupt the timing of cassava cultivation, as cassava in Ghana is typically cultivated at the onset of rains. This delay in agricultural activities could lead to reduced productivity, affecting the availability of cassava and posing a threat to food security within the municipality (Bayitse *et al*., 2017; Climate Policy Watcher 2024).

4.5.2 Climate projections for KEEA for the far future (2081-2100)

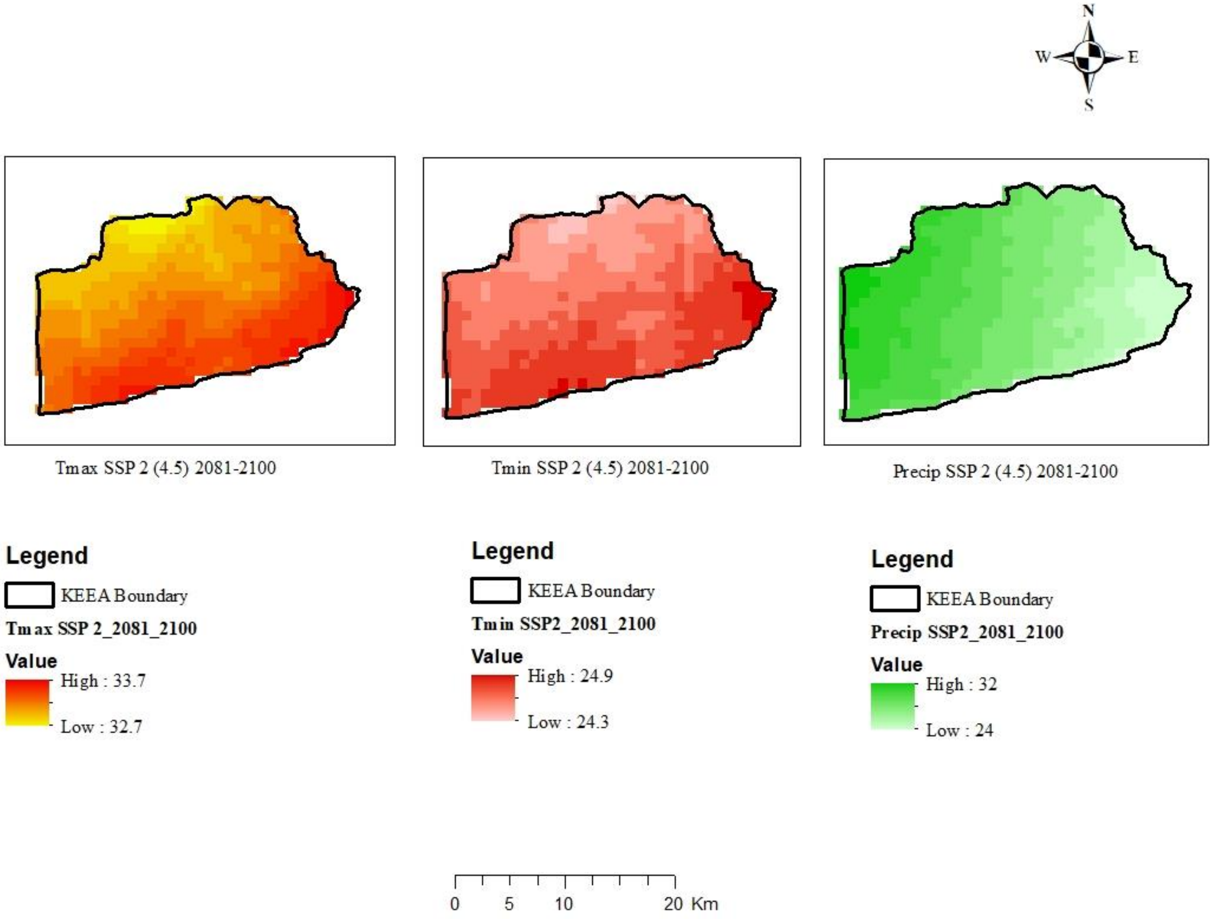


Figure 4. 3 Temperature (minimum and maximum) and Precipitation projections of KEEA for 2081-2100 under SSP 2

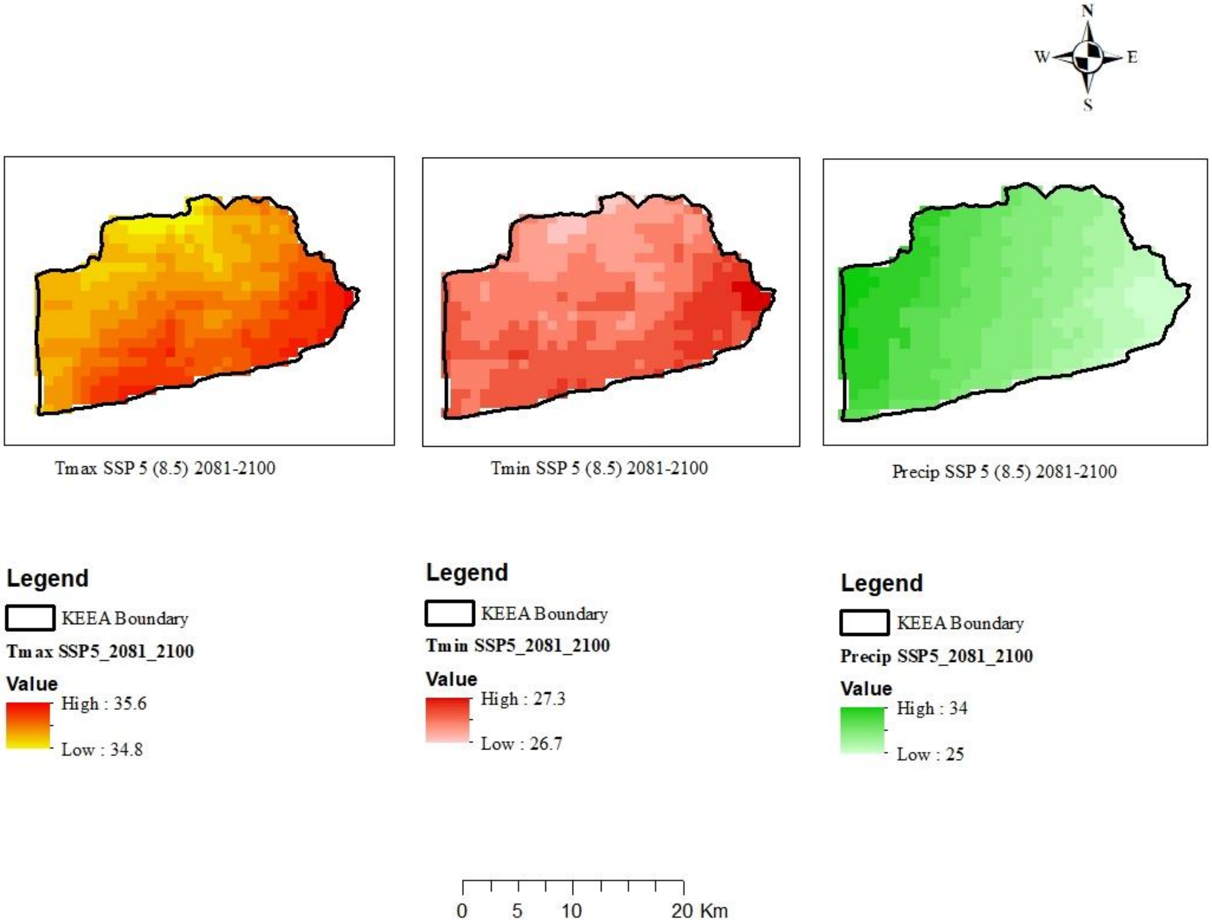


Figure 4. 4 Temperature (minimum and maximum) and Precipitation projections of KEEA for 2081-2100 under SSP 5

In contrast to the near future (Figures 4.1 and 4.2), the far future (2081-2100) is expected to witness a notable increase in temperatures under both the SSP2 and SSP5 scenarios. Maximum temperatures are projected to rise by approximately 1°C (Figure 4.3) under SSP2 and by nearly 3°C (Figure 4.4) under SSP5. Concurrently, minimum temperatures are anticipated to increase by approximately 1°C under SSP2 and by around 3.2°C under SSP5. However, the results for precipitation indicate a general decrease under both scenarios. The persistence of rising temperatures and reduced precipitation patterns may contribute to prolonged drought conditions, which can adversely impact soil compactness, particularly affecting the harvesting of cassava. Such challenges in cassava production can lead to reduced yields, potentially compromising the income and food security of farmers who heavily rely on cassava as a staple crop within the municipality (Asante and Amuakwa-Mensah, 2014; Antwi *et al*., 2017; Bayitse *et al*., 2017; Kyei-Mensah *et al*., 2019; Frimpong *et al*., 2023). Furthermore, predictions made by the Environmental Protection Agency (EPA) have indicated a potential decline in cassava yields for Ghana by 53% in 2080 (Sagoe, 2006; Armah *et al*., 2011; Asante and Amuakwa-Mensah, 2014; Alhassan, 2021).

4.6 Regression results for climatic factors on cassava production and yield

Table 4. 16 Summary of the regression model analysis for production (MT)

Source	Coefficients	Standard error	t	Pr > |t|	R^2	Adjusted R^2	P-value
Intercept	-7273075.778	3559864.060	-2.043	0.053	-	-	0.053
TMAX	45849.794	39900.352	1.149	0.262	0.194	0.054	0.262
TMIN	22640.699	50309.489	0.450	0.657	0.194	0.054	0.657
PRECIP	-378.352	207.013	-1.828	0.081	0.194	0.054	0.081
RH	70695.837	33545.690	2.107	0.046	0.194	0.054	0.046

Equation of the model (Production (MT))

Production (MT) = -7273075.77810402+45849.7942068168*Tmax+22640.6990123734*Tmin-378.35221361394*Precip+70695.8370790336*RH

Table 4. 17 Summary of the regression model analysis for Yield (MT/HA)

Source	Coefficients	Standard error	t	Pr > |t|	R^2	Adjusted R^2	P-value
Intercept	-176.413	130.402	-1.353	0.189	-	-	0.189

TMAX	0.952	1.462	0.652	0.521	0.102	-0.054	0.521
TMIN	0.234	1.843	0.127	0.900	0.102	-0.054	0.900
PRECIP	-0.008	0.008	-1.016	0.320	0.102	-0.054	0.320
RH	1.957	1.229	1.593	0.125	0.102	-0.054	0.125

Equation of the model (Yield (MT/HA))

Yield (MT/HA) = -176.412981810878+0.952362931726102*Tmax+0.234216727436869*Tmin-7.70724775887303E-03*Precip+1.95715838938452*RH

Table 4.16 is the results of multiple regression analysis conducted to evaluate the influence of climatic factors, namely minimum (Tmin) and maximum (Tmax) temperatures, precipitation (Precip), and relative humidity (RH), on cassava production. The predicted annual cassava production according to the model is stated in the production equation. The intercept coefficient is negative (-7273075.778) and statistically significant (p = 0.053), indicating that when all climatic factors are zero, production is expected to decrease by 7273075.778. The slope of the line depicts varying impacts across all climatic factors with an annual increase of Tmax, Tmin and RH increasing cassava production whereas an annual increase in precip reduces annual cassava production. For Tmax, an increase of 1°C increases the annual cassava production by 45849.7942068168 metric tonnes, 22640.6990123734 for Tmin and 70695.8370790336 for RH. However, an increase in annual precip by 1mm reduces annual cassava production by 378.35221361394. The regression further shows that all climatic factors account for about 19.4% of the variations in the annual cassava production as indicated by the value of R^2 (Table 4.16).

The regression analysis in Table 4.17 indicates that at zero, all climatic factors result in a decrease in annual yield per hectare (intercept is -176.413) although not statistically significant (p= 0.189). The slope indicates similar results to the production where annual increases in Tmax, Tmin and RH increase annual cassava yields per hectare with an annual increase in precip decreasing annual yields as seen in the model equation for yield. Overall, the climatic factors account for 10.2% of variations in annual cassava yield per hectare.

The remaining 80.6% and 89.8% for cassava production and yield respectively, of the variability, can be attributed to other factors, such as agricultural practices, pest and disease management, and other unidentified variables. These findings suggest that climatic factors, as observed within the KEEA municipality, are important but contribute little to influencing cassava production and yield. These results are consistent with previous studies by Adejuwon and Ogundiminegha (2019), and Tajudeen *et al*. (2022), which also reported a negative association between cassava yield and precipitation. However, this study differs from the findings of Adejuwon and Ogundiminegha (2019) regarding the impact of temperature where they indicated only maximum temperatures had an impact on annual cassava yields which contradicts the findings of this study. Moreover, this study disagrees with Tajudeen *et al*. (2022) who indicated minimum temperatures had a stronger correlation to cassava yields than maximum temperatures. Furthermore, the results of Dwamena *et al*. (2022) agree with the positive influence of relative humidity while contradicting the results of rainfall (precipitation) impact on annual cassava yields. They reported a slight increase in cassava yield with higher rainfall, whereas this study observed a decrease in yield with increased rainfall. Additionally, the overall impact of climatic factors on cassava yields contradicts the findings of Dwamena *et al*. (2022) and Tajudeen *et al*. (2022) who indicated higher R^2 values (74.3% and 96.17% respectively) compared to that of this study. These disparities in findings may be attributed to differences in geographical location, local climatic factors, and variations in the dataset employed.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study was conducted to assess and predict the climate change impact on cassava production in the coastal savannah agroecological zone of Ghana using the KEEA Municipality as a case study. The aim of the study was guided by three objectives; 1) to investigate farmers' perception of climate change and its impact on cassava yield in the Coastal Savannah Agroecological zone of Ghana, 2) to determine the near (2021-2040) and far (2081-2100) future climate scenarios of the Coastal Savannah Agroecological zone of Ghana, 3) to quantify the influence of climate parameters on cassava prodution and yield in the Coastal Savannah Agroecological zone of Ghana. To achieve the objectives of this study, semi-structured questionnaires were used to obtain responses from 254 farmers' perceptions of climate change from 8 communities (Abee, Agona, Dominase, Dutch Komenda, Kissi, Kokoado, Komenda, and Simiw) within the KEEA Municipality and responses were analyzed using SPSS 27 software. Also, 30-second resolution MRI-ESM2.0 data from WorldClim for near (2021-2040) and far (2080-2100) future for Tmin, Tmax and Precip were employed in ArcGIS 10.8 to predict the near and far future climate for the municipality. Furthermore, data for Tmin, Tmax, Precip and RH from NASA Power as well as crop data from the Agricultural Department were employed in XLSTAT 2024 to obtain the percentage influence of climatic factors on cassava production and yield.

5.2 Conclusion

Climate projections for the KEEA municipality indicate a general increase in minimum temperatures, accompanied by slight increases in maximum temperatures, under both the SSP4.5 and SSP8.5 scenarios for both the near (2021-2040) and far futures (2080-2081). In terms of precipitation, it is projected to decline in the near future, followed by a relatively constant to slight increase in the far future, under both scenarios. Furthermore, it is worth noting that farmers within the municipality have demonstrated a certain level of awareness regarding climate change. They were able to provide valuable insights into their perceptions of climate change's impact on crop yields. The majority of farmers indicated that climate change has negatively affected their yields.

However, a few farmers have implemented adaptation measures such as early planting, early harvesting, and livelihood diversification to mitigate the adverse effects of climate change. Moreover, a multiple regression analysis conducted in the municipality revealed that climatic factors exert little influence of 19.4% and 10.2% on cassava production and yields respectively. Among the climatic factors analyzed, relative humidity was found to have the greatest influence on cassava production and yields.

5.3 Recommendations

Based on the findings of the study, these recommendations have been suggested to address the identified issues and improve cassava production agricultural outcomes in the KEEA municipality. Firstly, considering the projected climate conditions, Ghana's Ministry of Food and Agriculture (MoFA) department should prioritize research and policies aimed at enhancing farmers' productivity. This can be achieved by introducing improved cassava varieties that are resilient and well-suited to the anticipated climate conditions. Such varieties should be carefully selected and tested to ensure their acceptability, adaptability and sustainability within the projected climate. Secondly, while it is encouraging that a majority of farmers demonstrated awareness of climate change, it is concerning that a significant number of them had not received any climate information. It is crucial to enhance extension services within the municipality to bridge this information gap. Strengthening the capacity of extension officers and providing them with up-to-date climate information will enable them to effectively disseminate knowledge and practices related to climate change adaptation and mitigation to farmers. Additionally, organizing workshops and training programs focused on climate change education will foster greater awareness and understanding among farmers. Furthermore, it is recommended to explore supplementary information channels, such as media outlets, to augment the extension services. Leveraging media platforms, including radio, television, and online platforms, can help reach a wider audience and disseminate climate change information to farmers who may have limited access to extension services. Collaborations with media houses can facilitate the development and broadcasting of informative programs, interviews with experts, and dissemination of climate-related news and updates.

5.4 Contribution to Knowledge

This research provides a comprehensive understanding of the future climate projections for KEEA Municipality under SSPs 2 and 5. Additionally, it explores the perceptions of local farmers regarding climate change and its perceived impact on cassava yield, while also quantifying the percentage of influence that climatic factors (Tmin, Tmax, Precip and RH) have on cassava production through regression analysis. These findings enhance understanding of the potential climate risks faced by agricultural systems and provide valuable insights for developing climate change adaptation strategies suitable for the KEEA municipality.

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APPENDICES

Appendix 1 Regression Model Summary for Effects of Sex, Years of farming, Farm size, Source of labour and Agricultural practices on Cassava harvested yearly

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.472[a]	0.223	0.207	0.869

a. Predictors: (Constant), Agricultural practices, Source of labour, Farm size, Years of farming, Sex

Appendix 2 ANOVA[a] for Regression on Effects of Sex, Years of farming, Farm size, Source of labour and Agricultural practices on Cassava harvested yearly

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	53.736	5	10.747	14.219	<0.001[b]
	Residual	187.445	248	0.756		
	Total	241.181	253			

a. Dependent Variable: Cassava harvested yearly (kg)

b. Predictors: (Constant), Agricultural practices, Source of labour, Farm size, Years of farming, Sex

Appendix 3 ANOVA table for Regression Analysis of climatic factors on Cassava Production (MT)

Source	df	Sum of Squares	Mean squares	F	Pr>F
Model	4.000	73500370541.5875	18375092635.3969	1.382	0.271
Error	23.000	305790621016.597	13295244392.0259		
Corrected	27.000	379290991558.184			

Appendix 4 ANOVA table for Regression Analysis of climatic factors on Cassava Yield (MT/HA)

Source	df	Sum of Squares	Mean squares	F	Pr>F
Model	4.000	46.668	11.667	0.654	0.630
Error	23.000	410.324	17.840		
Corrected	27.000	456.992			

Appendix 5 Questionnaire for primary data collection

PAN AFRICAN UNIVERSITY OF WATER AND ENERGY SCIENCES (INCLUDING CLIMATE CHANGE) - PAUWES

TLEMCEN, ALGERIA.

This questionnaire will help to solicit information from **cassava farmers'** within the KEEA Municipality. This is part of an MSc. research work on Climate Change. ***The information collected is solely for academic work and respondents are assured of privacy and confidentiality of data.***

****Kindly Seek the farmer's consent to proceed.***

Questionnaire number (……………..) Date……………………………………

Name of Enumerator………………………………………………………………………

Community:

………………………………………………………………………………………..

Name of Respondent……………………..

Telephone number…………………………..

SECTION 1: Personal and Household Characteristics

1. What is your sex?

1. Male ( ) 2. Female ( )

2. What age range do you fall within?

1. 35-45 ( ) 2. 46-55 ( ) 3. 56-65 ( ) 4. 65-75 5. 76-85 ( ) 6. 85+ ( )

3. What is your level of education?

1. Uneducated ( ) 2. Primary & JHS ( ) 3. Secondary ( ) 4. Tertiary ( )

4. What is the size of your household? …………………………..……………………………………….

5. Are you a native or migrant in the community?

1. Native ( ) 2. Migrant ( )

SECTION 2: Farm Characteristics

6. How long have you been farming? …………………………………………………

7. What is the ownership status of the above-mentioned farm(s)?

1. Owner ( ) 2. Otherwise ( )

8. What is the size(s) farm?

…………………………………………………………

9. What is the main source of labour for your maize and cassava farm? (***Thick all that applies)***

1. Household ( ) 2. Hired ( ) 3. Community help (Enuoboa) ( ) 4. Others,……………………………

10. How many kg of cassava do you produce/ harvest in a year? ……………………………..

11. What are some of the agricultural practices you usually undertake?

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12. Apart from cassava farming, do you have any other alternative livelihoods?

If yes, what are they?

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SECTION 3: Perception of climate change.

13. Are you aware of climate change?

1. Yes ( ) 2. No ( )

14. If yes, have you received any information related to climate change and its impact?

1. Yes ( ) 2. No ( )

15. What is the source of your information?

1. Extension Officers (   ) 2. NGOs (   ) 3. Media (   ) 4. Others (   )……………………..

16. If yes, what are some of the information received?

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17. Do you think climate change has in any way affected your cassava yields?

1. Yes (   ) 2. No (   )

18. If no, why?

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19. If yes, how?

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20. Do you have any adaptation measures in place?

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THANK YOU