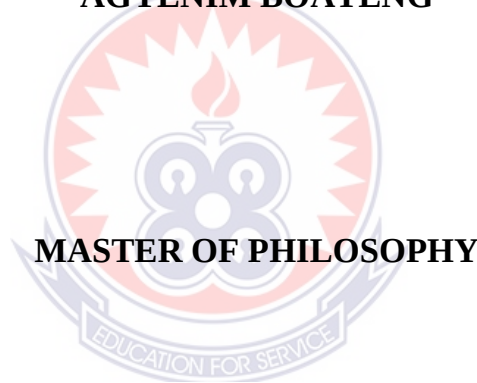


UNIVERSITY OF EDUCATION WINNEBA

**Spatial assessment of the effect of climate change on food inflation
evidence from the African economy**

AGYENIM BOATENG



MASTER OF PHILOSOPHY

2025

UNIVERSITY OF EDUCATION WINNEBA

**SPATIAL ASSESSMENT OF THE EFFECT OF CLIMATE CHANGE ON
FOOD INFLATION: EVIDENCE FROM THE AFRICAN ECONOMY**



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(8230220029)**

**A thesis in the Department of Geography Education,
Faculty of Social Science, submitted to the school of
Graduate Studies in partial fulfilment
of the requirement for the award of the degree of
Master of Philosophy
(Geography with Education)
in the University of Education, Winneba**

FEBRUARY, 2025

DECLARATION

Student's Declaration

I, Agyenim Boateng declare that this thesis, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature:

Date:

Supervisor's Declaration

We hereby declare that the preparation and presentation of this work were supervised in accordance with the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

Principal Supervisor: Dr. Yaw Asamoah

Signature:

Date:

Co-Supervisor: Dr. Matthew B. Kursah

Signature:

Date:

DEDICATION

I dedicate this work to my beloved parents, Mr George Appiah and Mrs Lydia Appiah.



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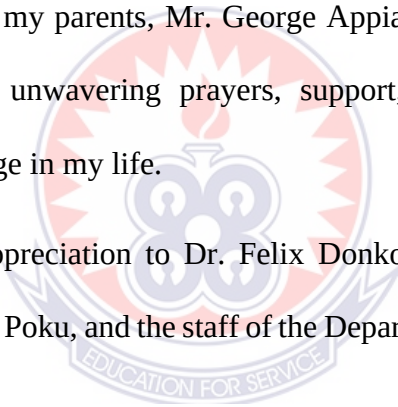


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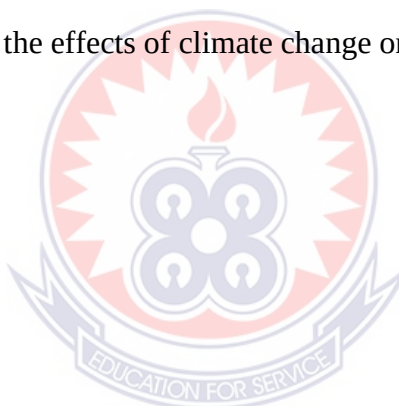
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LIST OF ABBREVIATION AND ACRONYMS

AfDB	African Development Bank
AU	Africa Union
CIAT	International Center for Tropical Agriculture
CO ₂	Carbon dioxide emissions
CPI	Consumer Price Index
CRED	Centre for Research on the Epidemiology of Disasters
EAC	East African Community
ECCAS	Economic Community of Central African States
ECOWAS	Economic Community of West African States
EPA	Environmental Protection Agency
FAD	Food Availability Decline
FAO	Food and Agriculture Organization
FED	Food Entitlement Decline
IEA	International Energy Agency
IFPRI	International Food Policy Research Institute
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
NASA	National Aeronautics and Space Administration
OECD	Organization for Economic Co-operation and Development
PPI	Producer Price Index
SADC	Southern African Development Community
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
UN	United Nation
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WB	World Bank
WMO	World Meteorological Organization
WFO	World Food Programme

ABSTRACT

The effect of climate change on agricultural productivity, food insecurity and food inflation are evidently witnessed across Africa. However, no empirical studies have been done to spatially ascertain the effect of climate change on food inflation in Africa. Hence this study sought to spatially assess the effect of climate change (temperature, carbon dioxide emission, and precipitation) on food inflation in Africa to identify specific countries at risk. The study utilized secondary data from the World Development Indicators, World Bank, and World Knowledge Climate Portal and applied exponential smooth forecast, forest-based classification and regression analysis to understand how climate change interacts with food inflation in all 54 African countries. This study's results showed that with the effect of climate change on food inflation in Africa, temperature is the most significant contributor, influencing food inflation rate by 47%, followed by precipitation at 32%, and carbon dioxide emissions at 21%. Notably, except for East and Southern Africa, countries in West Africa emerge as regions to experience the highest food inflation rate as a result of climate change. Furthermore, projections for the effect of climate change on food inflation indicated that precipitation will be the primary contributor, driving food inflation rate by 38% by 2037, while temperature and carbon dioxide emissions are expected to account for 33% and 29% respectively. By 2037 countries in West Africa are likely to experience the highest food inflation rates as a result of climate change's influence on food inflation than any other regions in Africa. The study concludes that immediate, targeted interventions are essential to mitigate climate impacts on food prices, particularly in vulnerable regions. Governments and development agencies such as the UN and FAO should promote the adoption of drought-tolerant crops, sustainable irrigation techniques, and investment in water harvesting and storage facilities to mitigate the adverse impacts of climate change on food price.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

In the 21st century, climate change has emerged as one of the most critical global challenges, characterized by significant alterations in average weather patterns (Davies & Smyth, 2018). Over the past decade the primary driver behind this phenomenon is the increased concentration of greenhouse gases (GHGs) in the atmosphere, which trap heat and contribute to rising global temperatures (Myers et al., 2017). Empirical studies attribute these emissions largely to human activities such as the burning of fossil fuels, deforestation, and various industrial processes (Bandara & Cai, 2019; Shahzad et al., 2021). This rise in greenhouse gases has resulted in a measurable increase in global surface temperature between 0.8 °C and 1.3 °C over recent decades. The consequences of this warming are multifaceted as climate change has contributed to widespread environmental degradation, reduced biodiversity and health-related challenges, resulting in significant loss of life and economic damage estimated at \$2.98 trillion worldwide from 2000 to 2019 (World Bank, 2022).

Beyond these general impacts, climate change poses a significant threat to agricultural systems and global food price. Studies have shown that rising temperatures, changes in precipitation patterns, and increased frequency of extreme weather events disrupt traditional farming practices, threatening crop yields and altering growing seasons in many regions. (Kumar et al., 2022). For instance, the United States Department of Agriculture (USDA, 2021) reported a 1% decline in crop production in 2020 directly linked to adverse climate-related weather conditions. Similarly, staple crops such as rice and maize in South America face projected yield reductions of up to 25% by 2050 if current climate trends continue (International Center for Tropical Agriculture [CIAT], 2019). These disruptions contribute to greater variability in food

supply and have been linked to fluctuating food prices globally, with significant socio-economic consequences (International Food Policy Research Institute [IFPRI], 2019).

In recent years, numerous studies globally have demonstrated that food inflation has been more persistently impacted by climate change, as evidenced by the study by Stewart et al. (2023), which showed that food prices in the United Kingdom increased by 10% in 2023 as a result of the ripple of extreme weather events on agricultural production. According to Stewart et al. (2023), El Niño, droughts, frost damage, cold snaps, and heatwaves have driven the United Kingdom household food bills up by an average of £605 (\$764). In addition, Barton, (2019) revealed that the drought and heatwaves that occurred in 2018 and 2019 also resulted in \$10 billion in losses and damages to agriculture, which raised food prices in the United States by 3.4% between 2018 and 2019. It is important to note, however, that while climate change is a critical driver of food price increases, other factors such as trade barriers, transportation costs, and market policies also play a significant role in shaping food price dynamics.

The African communities are witnessing the intertwining challenges of crop production and climate change, which have significant implications for food prices (Food and Agriculture Organization [FAO] 2021; Brenton et al., 2022). Across the continent, average temperatures have risen by 0.74 °C since the start of the 21st century compared to the 20th century and are projected to increase by 1.5–3 °C by 2050 (Marques et al., 2022). Studies show that this warming has already reduced crop yields across Africa and is exacerbating the dilemma of rising food prices. However, the impacts on agriculture and food pricing vary considerably between regions and countries. For instance, major growing areas in Eastern Africa, such as Ethiopia and Kenya, have experienced staple crop yields declining by 5–10% for each 1 °C rise in temperature, thereby reducing the availability of these crops and contributing to local food price increases (Davenport, 2018; Kassaye, 2022). In the Sahel region, countries

such as Niger, Mali, and Burkina Faso have experienced prolonged droughts and heat stress, leading to reductions in staple crop yields by 44%, 18%, and 45% respectively, which have contributed to sharp increases in food prices (Wudil et al., 2020; Baptista et al., 2024). These patterns show that climate change's influence on food prices in Africa is not uniform but shaped by distinct ecological, economic, and climatic conditions in each country and region.

Studies have pointed out that rising food prices as a result of climate change have drastically impacted economies, particularly affecting low-income populations who allocate a large portion of their income to food (Nelson et al., 2018; Miladinov, 2023). The United Nations (2022), revealed that the global food price index has increased by over 30% since 2021, hitting Africa particularly hard, where food expenditure constitutes a more substantial portion of household income. According to FAO (2021), rising food inflation has disproportionately impacted rural populations in Africa, where nearly 30% of households experience moderate to severe food insecurity, primarily due to inflated costs of basic foods like corn and wheat (FAO, 2021).

According to FAO (2021), rising food inflation has disproportionately impacted rural populations in Africa, where nearly 30% of households experience moderate to severe food insecurity, primarily due to inflated costs of basic foods like corn and wheat (FAO, 2021). Similarly, research shows that in sub-Saharan Africa, over 190 million people face malnutrition, a figure exacerbated by rising food costs that hinder access to adequate nutrition (Bell et al., 2024). Recently studies have suggested that climate change impacts on crop yields are beginning to emerge as a major driver of food prices in Africa (Nica et al., 2019; Yadav et al., 2021). Taking these into account it becomes imperative to take an empirical look at how climate change influences food inflation rates in Africa. This understanding can guide policy efforts and interventions aimed at climate adaptation and resilience within food systems in Africa.

1.2 Statement of the Problem

Poverty, hunger, and malnutrition are interconnected and significant challenges in Africa (WHO, 2022). According to FAO (2021), approximately 282 million Africans experienced hunger in 2022, while around 122 million people suffered from malnutrition. In addition, the WHO (2022) estimates that about 429 million Africans were living below the extreme poverty line of \$2.15 per day in 2022. These challenges have significant implications for the achievement of Sustainable Development Goals (SDGs) One, Two, and Three in Africa, which seek to eradicate extreme poverty, achieve zero hunger, and have access to affordable and nutritious food (Lohani et al., 2017). Because the foundation in which these goals are built is directly threatened by these challenges form of cycle deprivation. Furthermore, according to the African Development Bank (2022) the financial implications of these crises is that African economies lose between 5-15% of their GDP per capita growth alone as a result of hunger, poverty, and malnutrition alleviation efforts. Several studies and reports have identified rising food prices, food insecurity, and challenges in food production as major drivers of hunger, poverty, and malnutrition in Africa (Kogo et al., 2021; Habib et al., 2022).

And also, more recently, climate change has also been identified as the primary cause of rising food prices, food insecurity, and food production challenges that have these significant ramifications on Africa's economy (Kogo et al., 2021; Habib-ur-Rahman et al., 2022). However, most previous existing studies have focused on the relationship between climate change and agricultural production, food production, and food insecurity (Ayanlade et al., 2018; Adaawen, 2021; Zheng et al., 2022). No empirical studies have been conducted to assess the effect of climate change on food prices in Africa. Hence is imperative to understand the spatial effect of climate change on food inflation in Africa by pinpointing countries that are most at risk of experiencing

high food inflation rates. The call for a spatial approach aims to identify countries at risk of experiencing high food inflation rates as other analyses provide generic outcomes without pinpointing specific countries at risk. Again, based on the recent argument that rising food prices have largely been driven by climate change, the researcher argues that overlooking the role of climate change in influencing food prices could deprive policymakers of essential empirical evidence needed to develop actionable policies for achieving SDGs 1, 2, and 3 in Africa.

Furthermore, climate model analysts project a global increase in carbon dioxide emissions by 2050 with the largest increase expected to occur in Southern Africa (IEA, 2024). On the same note, studies in Africa observed a rising trend in temperature and erratic rainfall patterns causing extremely warming conditions in Sahara Desert and Sahel than expected (Odongo et al., 2022; Miladinov, 2023). For instance, the 2022 climate conferences in Egypt reveal that temperatures across the continent of Africa, especially the east of Africa, are rising faster than the global average, a trend that is likely to continue throughout the rest of the century (Molina et al., 2023). According to Friel (2019), the trend of rising average temperatures could expose up to 118 million extremely poor people in Africa to the compounded effects of food insecurity by 2030 through its influences on food prices. Despite these occurring trends and their effects in Africa, there has been limited research specifically focusing on how these climate change projections will influence future food prices. It is important that empirical study is undertaken to ascertain the future trends of climate change's effect on food inflation in Africa. This can help in targeting resources and intervention more effectively in specific countries that will be at risk of the effect posed by climate change on future food prices.

1.3 Purpose of the Study

The study aimed to spatially assess the effect of climate change on food inflation in Africa.

1.4 Research Objectives

The objectives of the study were to;

1. Explore the spatial trends of food inflation in Africa from the year 1992 to 2022.
2. Assess the spatial effects of climate change on food inflation in Africa from the year 1992 to 2022.
3. Spatially project the future trends of climate change's effect on food inflation in Africa by the year 2037.

1.5 Hypothesis

The study tested the following hypothesis using appropriate quantitative and statistical approaches. The following hypotheses were set to enable the study to achieve its specific objectives:

H₁: Food inflation is more persistent in the West Africa region than in any other region in Africa.

H₂: Climate change is more likely to increase food inflation in West Africa than any other region in Africa.

H₃: Climate change plus other confounding variables are more likely to increase food inflation in West African countries than any other countries in East, Central, North, and Southern Africa.

H₄: Climate change by 2037 is not likely to worsen food inflation in West Africa than in any region in Africa.

H₅: Climate change by 2037 plus other confounding variables are not likely to worsen food inflation in West African countries than any other countries in East Africa, Central, North and Southern Africa.

1.6 Significance of the Study

Climate changes are dynamic phenomena that manifest their impact on agricultural productivity through time and space as a result of increased greenhouse gas (GHG) concentrations in the atmosphere, which trap heat from the sun, leading to global warming (Kansanga et al., 2019). Therefore, understanding the effect of climate change on food inflation across various sub-regions in Africa will assist governments, international bodies (FAO, ECOWAS, UN, and AU), planners, and policymakers in coming out with good informed, and targeted policies to regulate it over time. The findings of this study, which identify countries at risk, will help governments and international organizations direct interventions to the areas that need them most. Additionally, by providing empirical evidence, these findings can strengthen the case for urgent climate policies and adaptive agricultural strategies.

The study aims to provide a comprehensive understanding of how future climate change will impact food inflation, guiding the development of targeted policies and interventions by governments, international bodies, planners, and policymakers. These efforts are crucial for ensuring food security in Africa. The study's findings on projected future effects will empower stakeholders to implement proactive measures, allowing at-risk countries in Africa to adapt, invest in resilient agriculture, and secure stable food supplies in the face of expected changing climate conditions.

Furthermore, understanding the trends and distribution of food inflation will contribute to a deeper understanding of the geographic disparities in food inflation in Africa, enabling the aforementioned policymakers and international organizations to design country- or region-specific interventions, ensuring that resources are allocated

effectively to areas most vulnerable to rising food prices. In addition, identifying areas where food inflation is most severe will help humanitarian organizations and development agencies in Africa and beyond, such as the World Food Programme, International Fund for Agricultural Development, and Action Against Hunger, to prioritize assistance programs, particularly in countries or regions facing extreme food insecurity.

1.7 Scope of the Study

The study is concentrated on the spatial assessment of the effect of climate change on food inflation in Africa. Using time series data from 1992 to 2022, thus a total of one thousand six hundred twenty (1620) observations, the study aims to spatially investigate the effect of climate change on food inflation in Africa via measurement. The year 1992 is significant as it marks the signing of the United Nations Framework Convention on Climate Change (UNFCCC) during the Earth Summit in Rio de Janeiro while 2022 was selected because of the readily available data for recent years. Geographically, the focus was on Africa which was narrowed to specific sub-regions such as West Africa, East Africa, Southern Africa, and North Africa.

The temporal scope encompasses both historical analysis and future projection in this study. The research uses a quantitative approach while mean center, incremental spatial autocorrelation, standard distance ellipsoid, getis Ord analysis, exponential smooth forecast, forest-based regression and classification, and pair test analysis were employed for the study. Climate change indicators including temperature, carbon dioxide emission precipitation, and other confounding variables were thoroughly examined to understand their ramification on food inflation across various sub-regions in Africa.

1.8 Organisation of the Study

The study is organised under five major chapters with each chapter linking the successive one. Chapter One comprises the introductory aspect of the study which outlines the background of the study, statement of the problem, objectives of the study, purpose of the study, research objectives, hypothesis, significance of the study, and scope of the study. Chapter Two provides a critical review of relevant literature. The section encapsulates a review of both empirical and theoretical studies. The third chapter presents the research method employed. It includes design, philosophy, the study's variables, the model definition, data sources, and data analysis.

Chapter Four provides a clear description and presentation of the results. It presents the core findings of the study derived upon analysis of all available data discusses the major findings of the study with references to existing knowledge, and relates them to the objectives and overall framework of the study. Finally, the fifth chapter presents the summary of key findings, conclusions, and recommendations.

This chapter also highlights limitation of the study and areas for further studies by researchers who are interested in climate change issues.

1.9 Summary of the Chapter

This chapter introduced the research topic by discussing the background information of the study. It continued with the discussion of the problem statement and provided the objectives, the hypotheses, and the significance of the study. The chapter also discussed the scope of the study and how the study was organized.

CHAPTER TWO

REVIEW OF RELEVANT LITERATURE

2.0 Introduction

This chapter focuses on a review of relevant literature about climate change and food inflation. The chapter deals with definitions and useful constructions for understanding the relationship between climate change and food inflation. In addition, it has a theoretical review and conceptual framework that provides the structure for understanding the relationship between climate change and food inflation.

2.1 Overview of Climate Change

Climate change, with far-reaching and multifaceted impacts, is one of the most pressing global environmental challenges facing humanity in the 21st century. Climate change, according to the Intergovernmental Panel On Climate Change (IPCC) (2023), is defined as an alteration in the state of the climate that can be identified by changes in the mean and/or the variability of its properties due to natural internal processes or external forces. Put differently, the United Nations Framework Convention on Climate Change [UNFCCC] (2022) also defines the phenomenon as a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere over comparable periods. The definition by the UNFCCC differs from that of IPCC in the sense UNFCCC defines it specifically as changes in climate directly or indirectly caused by human activities that alter the composition of the global atmosphere.

However, in contemporary discourse, according to Mikhaylov et al. (2020) the term is typically used to describe alterations that have been happening at an accelerated rate in recent decades. While causes of climate change can be divided into two categories, namely, natural and man-made causes (Kapsomenakis et al., 2023), there is

strong evidence that most of the observed warming (of 0.1 °C per decade) over the last 50 years has been attributed to human activities (Balaram, 2023; Balhane et al., 2022).

Over the past few decades, studies have provided substantial evidence supporting the idea that human activities, particularly the burning of fossil fuels, changes in land use, and deforestation, are the primary drivers of climate change (Handayani & Putra, 2019; Nica et al., 2019; Mikhaylov et al., 2020). These activities increase greenhouse gases (GHGs) compared to those naturally occurring in the atmosphere (Mulenga, 2023). According to the IPCC's Sixth Assessment Report, the atmospheric concentrations of GHG, i.e., carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O), have increased to unprecedented levels in the last century (IPCC, 2022). Research shows that an increase in GHG concentrations contributed to global warming, which in turn has affected global temperature, resulting in climate change (Mikhaylov et al., 2020). Between 2017 and 2021, the world recorded one of its highest average surface temperatures of 1.06 °C–1.26 °C (United Nations, 2021). Further, it is expected that by 2100 the globe will be 1.1–5.4 °C warmer than it is now (Bukari & Aluko, 2023).

Climate change is mostly caused by emissions from large developed or developing countries, such as the United States, the European Union, China, and India (Yoro & Daramola, 2020). All regions and countries worldwide regardless of size, developed or developing, have had to deal with and endure the negative consequences of their pollution. According to IPCC's report, agriculture is the sector most affected by climate change (IPCC, 2014). Yadav et al. (2021) confirm the report of IPCC that climate change, directly and indirectly, affects the production and yield of the agricultural sector, which can lead to serious socio-economic consequences such as shortages of food, and other basic commodities.

Climate change is of global concern due to its linkage with the occurrence of several extreme weather events and natural disasters. Available evidence (Stott et al., 2016; Kireyev, 2018) indicates that the severity and frequency of extreme weather events are due to climate change. These extreme weather events have had marked repercussions for global economic activities and have caused damage to properties as well as injuries and deaths of people. An estimate by the World Bank (2019), suggests that extreme weather events have caused about US\$3 trillion worth of damages globally over the last three decades and this is projected to increase in the future. A recent report by the Food and Agriculture Organization (FAO) (2021), also indicates that between 2008 and 2015, about 27 million people were displaced annually by natural hazards and climate-related disasters and this trend keeps rising.

Three major physical impacts of climate change have been identified and these are; temperature change, change in rainfall, and carbon dioxide emission (Serdeczny et al., 2017; Abiodun et al., 2017). The most significant climatic change that has occurred in Africa has been a long-term reduction in rainfall in the semi-arid regions of West Africa. For example, in the Sahel, there has been on average a 25% decrease in rainfall over the past 30 years characterised by a decrease in the number of rainfall events (Biasutti, 2019). This reduction has been much more moderate in regions other than the Sahel. Also, observational records show that Africa has been warming through the 20th century at the rate of about 0.05°C per decade with slightly larger warming in the June-November seasons than in December-May (Teshome -Game, 2015; Kew et al., 2021). In addition, recently Africa's emissions are growing faster than the global average percentage-wise, where top emitters in Africa were South Africa (largest by far), followed by Egypt, Algeria, Nigeria, and Morocco (Liu, 2023).

Meanwhile, climate change is largely driven by greenhouse gas emissions, and Africa contribution to global GHG emissions is little (Adzawla et al., 2019), reaching less than 5% annually (Azzarri & Signorelli, 2020). This suggests that the role of Africa in driving climate change may be inconsequential compared to other world regions. Despite this, the vulnerability of the region to climate change and its consequences is high. Of grave concern is that many countries in Africa are highly vulnerable to climate change (Codjoe & Atiglo, 2020; Affoh et al., 2022) due to the prevalence of poverty. Mulenga (2023) argue that the vulnerability to climate change tends to be higher among households facing higher multidimensional poverty. Poverty is generally considered a factor that increases the vulnerability of people and households to climate change (Castells-Quintana et al., 2021).

Unfortunately, virtually all Africa countries lack adequate capacity and resources to deal with these potential negative impacts. In an attempt to solve the problem of climate change, some African countries like United States, China, Brazil, India, the United Kingdom, Germany, France, Canada, Japan, Nigeria, and South Africa signed the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio de Janeiro's Earth Summit in June 1992, after the convention was adopted on 9 May 1992 (Chutab, 2023). Achieving this goal is controversial despite the broad international consensus behind the convention (Hounnou et al., 2023)

2.2 Food Inflation

Food inflation has become a major economic issue in recent years that has been studied extensively in literature. According to the World Bank (2019), food inflation refers to the increase in prices of food items over time, a phenomenon contributing to the general rise in prices for goods. On the other hand, the International Monetary Fund [IMF] also defined food inflation as a general rise in food prices (IMF, 2021). It is

typically measured by tracking the price changes of a basket of staple foods, such as grains, vegetables, meat, and dairy, through indices like the Consumer Price Index (CPI) (Ha et al., 2020). In the context of this study, food inflation is defined as the increase in prices of food items over time, leading to a general rise in overall costs for goods and services in the economy, as explained by the World Bank and the IMF.

Studies have revealed that several factors including climate change, rising production costs due to greater energy costs, supply chain disruptions, geopolitical events, and general inflation trends are the main causes of food inflation (Semenova, 2023; Sohag et al., 2023; Soliman et al., 2023; Cheng et al., 2023). Other scholars also support the view that supply and demand imbalances also often play a pivotal role in causing food inflation. By such opinion, Hunter et al. (2017) note that a sudden drop in agricultural yields due to adverse weather conditions leads to supply shortages, causing food prices to surge. On the demand side, Avtar et al. (2019) together with Boyacı-Gündüz et al. (2021) emphasise that the increasing global population and changing dietary habits have amplified the demand for food products. According to Li et al. (2023) supply-demand dynamics create fluctuations in food prices that can be exacerbated by external factors such as oil price hikes, which affect transportation and energy costs within the food supply chain.

To measure food inflation, economists use indices like the Consumer Price Index (CPI) and the Producer Price Index (Khan, et al., 2018). To Jongwanich et al. (2019), the CPI tracks changes in average prices paid by consumers for goods and services, including food items, while the PPI monitors changes in prices received by producers for their goods and services, including food products. Food inflation can have widespread effects on national economies, influencing key macroeconomic indicators such as GDP, inflation rates, and poverty levels. According to a report by the

International Monetary Fund (IMF, 2021), food inflation tends to elevate overall inflation, which can undermine economic stability. The impact of food inflation on food security and accessibility has been significant, with low-income earners being hit hardest by food inflation since they spend a high proportion of their income on food (Erokhin & Gao, 2020).

In advanced economies, a 10% increase in global food inflation raises domestic inflation by about 0.5 % point per year (Choi et al., 2018). However, the impact has declined over time and become less persistent (Ha et al.,2020; Headey & Ruel, 2023). The increase in food prices is likely to lead to higher poverty in sub-Saharan Africa, as the negative impact on net poor consumers outweighs the benefits to poor producers (Wodon & Zaman, 2010). Low-income earners are particularly affected by food inflation, making it difficult for them to plan current and future expenditures (Bergh & Rosenbaum, 2022).

2.3 Historical Trends in Food Inflation Rates

Globally, food inflation rates have shown significant volatility over the decades. In the early 2000s, research indicated food prices remained relatively stable, with inflation rates hovering around 1-2% in many developed economies (Ha et al.,2020). According to the World Bank (2021), food prices began to spike in the latter half of the decade, particularly in 2007-2008, when global food prices surged by over 40%. Data from multiple sources such as the FAO, IMF, and World Bank indicate that between 2014 and 2016, food prices experienced a relative decline, partly due to lower oil prices and a better global harvest. According to the FAO (2021), the global food price index fell by 3.5% in 2014, which brought some relief to import-dependent nations.

However, in the current context of 2023-2024, several studies reveal that global food inflation remains high, driven by several ongoing challenges, including the Russian invasion of Ukraine, which has disrupted grain supplies, and the continuing impacts of climate change on crop yields. The FAO (2023) reported that food prices have risen by 12.5% globally since the start of the conflict, with Ukraine being a key global exporter of wheat, maize, and sunflower oil.

In 2021, food inflation for low-income countries was 52.6%, 86% for middle-income countries, and 73.2% for high-income countries (World Bank, 2022). Regions that are mostly affected by the recent rising food prices are Africa, Asia, Europe, and North America respectively (World Bank, 2022). According to a report by Statista (2023), between 2019 and 2022, the average global food inflation rate was 6.5 % in Africa, 5.1 % in Asia, 3.9 % in Europe and 3.5 % in North America. In Africa, food inflation rates have been high in recent years, with staple food prices in sub-Saharan Africa surging by an average of 23.9 percent from 2020 to 2022 (World Bank, 2022), the most since the 2008 global financial crisis. Numerous empirical studies have found that food price inflation hit double digits in many African countries, with some countries experiencing food inflation rates as high as 50% (Okou et al. 2022; Woldemichael et al., 2022)

In East Africa, inflation has generally been moderate, but food prices have been relatively high. The World Food Programme [WFP] (2023) reported that food prices remain high across the region, with an average increase of 17.3%. According to the FAO (2023), countries like Burundi, Ethiopia, and Rwanda are experiencing double-digit food inflation. Specifically, Burundi (35.3%), Ethiopia (25.2%), and Rwanda (3.7%) have the highest rates, while Tanzania (3.7%) and Seychelles (4.1%) have the lowest rates. Studies have shown that factors such as droughts, floods, conflicts, reliance on food

imports, and the Russia-Ukraine war and disruptions in the global supply chain contribute significantly to food inflation in the region (Henry et al., 2020; Affoh et al., 2022; Kunawotor et al., 2022).

In West Africa, there has been a noticeable rise in general inflation rates, particularly in food prices across many countries. The World Food Programme [WFP] (2023) states that food inflation in West Africa stood at 24.3%, with Ghana and Nigeria recording the highest rates at 55% and 25.25%, respectively, while Senegal had a lower rate of 11.9%. A recent report from the World Bank (2023) indicates that Ghana ranked ninth (9th) globally in terms of Real Food Inflation, with a rate of 12%, and eighth (8th) in Nominal Food Inflation, at 54%. Furthermore, the WFP estimated over 30 million people in West Africa to face food insecurity in 2023, with projections suggesting this number will increase in the current year, 2024 (World Food Programme [WFP], (2023).

Over the past four years, North Africa has experienced a stable food inflation rate, remaining at around 3% according to FAO (2023). However, within the region, Egypt stands out with a significant increase in food prices, reaching an unprecedented 30% as highlighted by FAO (2023). Abdelhedi & Zouari (2022) identify several contributing factors to this surge, including disruptions in the supply chain, higher production costs, and adverse weather conditions affecting agriculture. Furthermore, the reports by FAO (2023) show that Morocco witnessed a 10.6% increase in food prices, ranking second after Egypt. Additionally, cross-sectional studies in Northern Africa, as noted by Le Mouël and Schmitt (2018) emphasize that while countries like Egypt, Algeria, and Morocco have historically maintained food subsidies to manage food inflation, reductions in fuel subsidies and currency devaluation have led to increased food costs.

In southern Africa, particularly in South Africa, Malawi, Madagascar, Mozambique, and Lesotho, food inflation rates continue to rise. As reported by FAO (2023), Malawi (31.7%) and Zimbabwe (368.8%) had the highest food inflation rates in 2022. The primary reasons behind the soaring food prices in Malawi and Zimbabwe are attributed to political and economic instability (Ellis & Manda, 2012; Mhlanga & Ndhlovu, 2020). Furthermore, a study by Ferrari et al. (2023) suggests that increased global commodity prices and elevated manufacturing costs, driven by higher expenses in fuel, transportation, and production, also contribute significantly to the escalating food prices in these countries.

In Central Africa, food inflation rates have generally been lower compared to other regions. However, there are still disparities between food prices and general inflation rates, as evidenced by research conducted by Bala and Chin (2018). Factors that have been identified to contribute to food inflation in central Africa include supply-side factors, yield variability, and international price arbitrage pressures (which together account for almost 60 percent of the total CPI basket) (Moraleja, 2019). Demand-side factors that are susceptible to monetary authority policy intervention have also been identified. According to FAO (2023), Burundi had the highest rate of food inflation in 2022 at 20.8%, while Equatorial Guinea had the lowest rate of food inflation at 5.8%. Duho et al. (2022) opine that Equatorial Guinea is an oil-producing nation with significantly higher per capita income, and this economic advantage helps insulate it from external shocks like the global food price rises experienced in 2022.

2.4 Factors Influencing Food Inflation

2.4.1 Population Growth

Population growth has been viewed by many scholars as the engine for recent rises in food prices. With the world's population growing rapidly, ensuring sufficient

and affordable food supplies remains a significant challenge (Calicioglu et al., 2019). According to a recent study by Fróna et al. (2019), the world's growing population has emerged as one of the major factors fueling the increasing demand for food, consequently leading to a significant rise in food prices. Numerous empirical studies have suggested that due to the basic economic principles of supply and demand, it is expected that food prices will continue to rise as the world's population follows its projected growth trajectory (Bijl et al., 2017; Gouel & Guimbard, 2019). For instance, a study project that real food inflation, mostly due to population expansion, could increase by 7–15% by 2030 and as high as 30% by 2050 (Wudil et al., 2022).

The total population of Africa has grown from 228.7 million in 1950 to 1.341 billion in 2020, 431 million in Eastern Africa; 404 million in Western Africa; 247.5 million in Northern Africa; 193.5 million in Middle Africa; and 64.5 million in Southern Africa showing an average annual growth rate exceeding 2.5% (Kaba, 2020). Dos Santos et al. (2017) and Kaba, (2020) added that the rapid population growth, along with increasing urbanization in recent decades, has driven significant growth in domestic food demand throughout the continent. However, studies have shown that domestic agricultural production in many African countries has not been able to meet these consumption needs due to low productivity and inadequate investment in agriculture (Bjornlund et al., 2020; Giller, 2020; Jayne & Sanchez, 2021).

With domestic production often lagging behind demand growth, scholars argue that rapid urbanization and population increases have exposed Africa's food prices to global food market inflationary shocks (Wudil et al., 2022). In Egypt, for instance, Abdalla et al. (2022) found that population growth accounted for over 20% of the increase in wheat prices and demand. According to Anaabah (2019), an increase in

population without any commensurate increase in agricultural production poses a serious threat to food prices in low-income economies.

2.4.2 Food Import

Food import recently has importantly cited as an important driver of domestic food prices (Tadesse et al.,2017; Bhattacharya&Sen-Gupta,2018), especially in developing economies where domestic agricultural production may not be sufficient to meet the demand needs. One of the primary ways food imports influence food inflations is through the dynamics of supply and demand. Studies have highlighted that when a country relies heavily on imported food, the price of these imports directly affects domestic food prices (Giordani et al.,2016; Kummu et al.,2020) According to Algieri et al. (2023), fluctuations in international food prices, driven by factors such as exchange rate variations, global supply chain disruptions, and changes in global demand, are often transmitted to domestic markets, leading to food pricing. For instance, during global food price volatility periods, such as the 2007-2008 food crisis, countries dependent on imports experienced sharp increases in domestic food prices (Tadasse et al.,2016). This is often exacerbated by the depreciation of local currency, which makes imports more expensive, further driving up food prices (FAO, 2021).

The effect of food imports on food inflation have also closely linked to exchange rate dynamics. For countries with depreciating currencies, the cost of imports increases can drive up domestic food prices (Meyer, 2020; Ganapati & Wong, 2023). This phenomenon is particularly relevant for developing countries with weak currencies, where food imports constitute a significant share of the total food supply. For instance, a study by Ogundiran, (2019) and Obiora (2024) found that exchange rate movements significantly influenced food prices in countries such as Kenya and Nigeria, where imported foods form a substantial part of the diet. Moreover, countries with volatile

exchange rates may experience significant fluctuations in food prices, even when global prices remain stable. This volatility can undermine food security and contribute to inflationary spirals, as seen in countries like Zimbabwe during periods of hyperinflation (Manda, 2017).

2.4.3 Exchange Rate

Apart from the food import, another notable factor influencing increases in food prices is the exchange rate. Despite Kusumawardani and Mubin, (2019) argument that exchange rate volatility and exchange rate misalignments do not affect international trade, the exchange rate is known to affect a lot of commodity prices. For instance, Santana-Gallego and Pérez-Rodríguez, (2019) argued that the exchange rate is the most essential factor influencing prices in every economy. This is because it affects all other prices, especially in low-income countries. It could be that a currency's value is fixed against another single currency or other currencies at an officially announced rate or it could be a common link to a commodity such as gold or other countries' currency pegged to the U.S. dollar. Studies have found that rapid depreciation of the currency against the US dollar inflated the local currency cost of major imported crops (Poku, 2017; Xue et al., 2021). For instance Magrini et al. (2019) also indicated that the depreciation of the U.S. dollar in the Sahara increased food prices by 20%, considering an elasticity value of 0.70%.

Exchange rate depreciation does not only inflate the costs of imported staple foods but according to Mbam et al. (2020) it inflates the cost of imported fertilizers and farm equipment. A panel study by Shokoohi and Saghaian, (2022) shows that over 2% of food inflation in exporting countries like Saudi Arabia, the United Arab Emirates, and Iran was attributable to the rising price of import fertilizers which occurred as a result of currency declination against the dollar rate. Beyond the rise of import food

prices, according to Iyer (2020), exchange rate volatility also hampers agricultural trade and investment, amplifying food inflation. Uncertainty over future currency values increases the risks for importers, distributors, and farmers in terms of pricing and profits (Peng & Pang, 2019). This may constrain long-term investments to raise productivity. In addition, traders may also limit imports when currencies fluctuate excessively. Such trade disruptions may further aggravate food shortages and food inflation according to (Peng & Pang, 2019).

2.4.4 Economic Growth (GDP)

Economic growth or GDP are commonly cited factors that influence food prices. Several studies have found that economic growth or an increasing GDP per capita tends to put upward pressure on food prices over time (Martin, 2019; Fukase & Martin, 2020). This is because rising incomes increase food demand and consumption, while limited agricultural productivity gains constrain supply response. Bai et al., (2021) stated that “a nation’s income growth may have influences on factors such as national food availability and food prices. Another researcher further indicated that an increase in income as a result of GDP growth will improve the quantity of food people purchase especially for people in low-income and middle-income economies (Tacoli, 2020). Studies have found a correlation between GDP growth and food price inflation in countries around the world. For instance, Fukase and Martin, (2020) found out that a 1% increase in per capita GDP was associated with a 0.75% increase in real food prices on average. They further added that per capita food demand growth is likely to be a more important driver of food demand to 2050 than population growth.

As a country's economy grows, people tend to have higher incomes and increased purchasing power, which can lead to an increase in demand for food. This increased demand can put upward pressure on prices. World Bank (2018) added that

GDP growth resulting from agriculture is about four times more effective and valuable for growing income for the poor than GDP growth from other sectors. Hence, continuous agricultural productivity growth will lead to a fight against hunger and, an increase in the quantity of food purchased. Reported by Anaabah (2019) confirmed that higher GDP will lead to more spending by consumers for goods and services. Higher GDP results in more spending, more income, and an improved amount of food purchased. According to the World Factbook (GDP) in 2018, there was about an 8% increase in food prices as a result of an increase in the income of people.

2.5 Effect of Climate Change on Food Inflation

Climate change has a significant impact on food inflation, primarily due to its effects on agricultural production (Chukwuone & Amaechina, 2021). Particularly in developing countries, climate change has increasingly been linked to rising and more volatile food prices as it has caused yield declines for most important crops (Tito et al., 2020; Anderson et al., 2020). Studies have shown that temperature, carbon dioxide emission, and precipitation which are very key determinants of climate change especially in Africa are important elements that affect the growth of most important plants and crops cultivated (Lemi & Hailu, 2019; Kogo et al., 2021). Thus, some level of relationship seems to exist between temperature, carbon dioxide emission, precipitation, and the yields obtained from the cultivation of crops and livestock production (Zhao et al., 2022; Liu et al., 2023) which ultimately affects food inflation.

2.5.1 Temperature Changes and Food Inflation

One of the primary mechanisms through which temperature influences food inflation is its impact on crop yields and overall food supply. Empirical studies consistently show that higher temperatures and extreme weather events linked to climate change can reduce agricultural productivity, creating supply shortages that push food

prices upward (Agnolucci et al., 2020; Gomez-Zavaglia et al., 2020). Research highlights that staple crops such as wheat, rice, and maize are particularly sensitive to heat stress (Eck et al., 2020; Zhao et al., 2022; Bhardwaj et al., 2023). For example, Chandio et al. (2023) found that every 1°C increase in global mean temperature is associated with a 6% decline in global wheat yields, which can translate into a 5–8% rise in wheat prices in import-dependent markets. Similarly, Zhao et al. (2017) estimated that global rice yields could drop by 3.2% per 1°C rise, contributing to price surges in rice-dependent economies. Yield losses driven by heat stress, water scarcity, and soil degradation reduce supply, creating upward pressure on food prices. McLachlan et al. (2020) analysed the 2013 European heat wave and found that wheat prices increased by 17% globally, contributing to higher food inflation in both exporting and importing countries. Such evidence underscores that temperature-induced yield declines directly transmit into market price volatility and inflationary pressure in the food sector.

In addition to direct impacts on crop yields, temperature variations have been linked to increases in pests and diseases, which literature identifies as a major driver of rising food prices (Campos & Ortiz, 2020). Warmer temperatures create favorable conditions for the spread of various plant diseases, including fungal pathogens, viruses, and bacteria (Chen & Yang, 2019; Shrestha, 2019). Tito et al. (2018) observed that larger pest populations and disease outbreaks lead to significant reductions in crop supply, which in turn causes notable increases in food prices. For instance, Liliane and Charles (2020) found that a 10% decline in maize output due to heat-induced pest attacks resulted in a 6% increase in maize prices in affected markets. The Food and Agriculture Organization (2020) reported that pest and disease infestations account for 20–40% of global crop losses annually, contributing to recurrent food shortages and price surges of up to 15–25% during peak scarcity periods. Furthermore, prolonged high temperatures

weaken plants' natural defense mechanisms, making them more vulnerable to pest infestations (Mera et al., 2018; Campos & Ortiz, 2020). Empirical evidence from East Africa by Waha et al. (2019) shows that a 1°C increase above the optimum growing temperature can elevate staple grain prices by 2–4%, largely due to supply constraints triggered by pest and disease pressure.

Furthermore, pesticides remain indispensable in agricultural production, as they help farmers control weeds, pests, and insects (Begum et al., 2021; Kole, 2021). Their significant role in protecting crops has historically contributed to stable food supplies and lower consumer prices (Sharma et al., 2022). However, rising temperatures often lead to more frequent and severe pest and disease outbreaks, increasing farmers' reliance on pesticides and other control measures (Sharifzadeh et al., 2023). This reliance raises production costs, which are frequently transferred to consumers in the form of higher food prices. For instance, Kansiime et al. (2019) found that in parts of sub-Saharan Africa, pest management costs can rise by 20–30% during hotter-than-average seasons, pushing staple crop prices up by 8–12%. Similarly, Lengai et al. (2021) reported that heat-related increases in pesticide use in East Africa contributed to maize prices rising by as much as 15% during severe pest seasons. The relationship is direct: higher costs of pest control increase the cost of food production, which in turn raises retail food prices, especially in markets with limited imports to offset domestic shortages.

Beyond agricultural production, higher temperatures can directly influence food prices by increasing the risk of spoilage and contamination, particularly during transportation and storage. Several studies have shown that post-harvest losses are a major driver of food inflation, as reduced shelf life leads to higher replacement and logistical costs (Hammond et al., 2015; Azad, 2019). The period that food remains

edible and nutritious depends heavily on temperature, which affects the growth rates of microorganisms responsible for spoilage. Perishable items such as fruits, vegetables, and dairy products are especially vulnerable to heat-induced quality deterioration (Mercier et al., 2020; Burek & Nutter, 2020). For example, Farandy (2020) found that in Indonesia, storage and transportation costs much of which are related to maintaining temperature control account for up to 30% of the retail price of food. Similarly, in West Africa, FAO (2021) estimated that heat-related post-harvest losses in fresh produce can reach 20–25% during peak temperature months, driving market prices up by 10–18%. Rising temperatures, alongside extreme weather events such as heat waves, droughts, and floods, can further disrupt transportation networks, damage storage facilities, and slow food distribution (Challinor et al., 2018). These supply chain interruptions often result in localized shortages, heightened price volatility, and elevated food inflation rates.

2.5.2 Precipitation and Food Inflation

Precipitation, specifically variations in rainfall patterns, as a crucial component of climate, has been recognized as a key factor influencing agricultural productivity and, consequently, affecting food prices (Mitra & Chattopadhyay, 2017; Moessner, 2022). According to Rojas et al (2019) and Chen et al. (2020), precipitation and crop production are directly related, with variations in precipitation affecting crop productivity. Wen et al. (2017) and Hussen (2018) emphasised that adequate and well-distributed precipitation is crucial for the growth of crops ensuring higher yields and a stable food supply, thus leading to lowering food prices and consequently lower inflation rates (Wijerathna-Yapa & Pathirana, 2022). For instance, the study of Maitah et al. (2021) demonstrates that a 10% increase in precipitation led to a 2% increase in crop yields and a 1% decrease in food prices in the Czech Republic. The study also

found that the positive impact of precipitation on crop yields and food prices was greater in countries with higher levels of population growth and urbanization.

However, studies have also recognized that insufficient or excessive precipitation has also led to crop failures, reduced yields, and poor-quality produce affecting food prices which is consonance with what Begna, (2022) and Singh et al. (2021) said. In addition, Moges and Bhat (2021) added that a 10% decrease in rainfall variability led to a 3.5% decrease in agricultural yields in Ethiopia. The study also reveals that this decrease in yields had a significant impact on food prices, with a 10% decrease in rainfall variability leading to a 6.7% increase in food prices. Studies have shown that the impact of precipitation on crop yields can be attributed to various factors, including water stress, soil erosion, and changes in pest and disease dynamics (Affoh et al., 2022; Zheng et al., 2022). Drought conditions can limit crop growth and development, leading to reduced yields (Lesk et al., 2021). On the other hand, excessive rainfall can cause waterlogging, nutrient leaching, and increased susceptibility to pests and diseases, also resulting in yield losses (Kaur, et al., 2020)

On the other hand, food prices are influenced by precipitation in the area of flooding and waterlogging. Excessive rainfall can damage crops, delay harvesting, and disrupt the food supply chain, leading to significant price increases (Tumwesigye et al., 2019). Evidence from Ali et al. (2017) shows that heavy rainfall events can reduce crop yields by 15–30% in flood-prone areas, with corresponding food price hikes of 10–20% during the affected seasons. Urama et al. (2020) note that in Africa, both droughts and floods have measurable impacts on food price inflation, with extreme flood events sometimes pushing staple food prices up by over 25% in local markets. Changes in precipitation patterns also disrupt planting and harvesting calendars, and in some cases, increase pest and disease outbreaks, further reducing output and raising prices

(Grabrucker & Grimm, 2021). According to Ndlovu et al. (2020) and Habib-ur-Rahman et al. (2022), erratic rainfall makes it difficult for farmers to time planting accurately, while crops that are not aligned with optimal growing conditions often experience yield losses. The IPCC's uniform climate scenarios estimate that such rainfall irregularities could reduce African staple crop output by up to 12% by 2050, potentially increasing average food prices by 8–15% if adaptation measures are not implemented (Giordano et al., 2021).

Evidence suggests that excessive rainfall can lead to waterlogging, flooding, and destruction of crops, which in turn disrupts the food supply chain resulting in higher prices of food (Tumwesigye et al., 2019). Such extreme weather events such as heavy rainfall can have a significant impact on crop production, reducing yields and affecting the availability of food (Ali et al., 2017). For instance, Urama et al. (2020) opine that extreme weather events such as floods can affect food price inflation in Africa. They further added that the incidence of droughts and floods was found to have a bearing on food price inflation. In addition, changes in precipitation patterns also lead to changes in planting and harvesting calendars, as well as increased pest and disease invasion, further impacting food production (Grabrucker & Grimm, 2021). The IPCC uniform climate scenarios show that when farmers face challenges in determining the appropriate times for planting due to unpredictable weather specifically erratic rainfall (Ndlovu et al., 2020; Habib-ur-Rahman et al., 2022) and plants that are not aligned with optimal growing conditions can be adversely affected (Giordano et al., 2021).

Furthermore, the timing and distribution of precipitation throughout the growing season are crucial factors that can influence crop yields. Even if the total annual rainfall is adequate, an uneven distribution or untimely precipitation can adversely affect crop yields. Irregular or poorly timed precipitation can disrupt critical stages of crop

development, leading to yield losses (Dewianawati & Asyik, 2021). Ndlovu, et al. (2020) argued that uncertainties in farmers' production levels can lead to food shortages, driving down supply and increasing demand, subsequently raising food prices. Similarly, the study of Abegunde (2019) further revealed that disruption in agricultural schedules can create shortages in the market, reducing the overall supply of food. The forgoing studies give credence to the fact that as supply decreases due to these changes, food inflation can occur because of the increased demand for limited available resources, which drives prices higher in response to scarcity.

Moreover, extreme precipitation events, such as floods or severe storms, have been found them in literature to have disrupted transportation and distribution networks, impeding the movement of food from production areas to markets. The disruption in the food supply chain caused by excessive rainfall can result in higher input costs for non-farm enterprises in the food processing industry (Danso-Abbeam et al., 2022) as well as higher sales revenues for agriculture-related non-farm enterprises (Grabrucker & Grimm, 2021; Bogale & Erena, 2022) Jongwanich, et al. (2019) on determinants of producer price versus consumer price inflation in emerging Asia argue that increasing cost and higher revenues can contribute to food inflation by influencing the overall production costs, which are often passed on to consumers in the form of higher food prices. This food inflationary pressure occurs as businesses adjust their pricing strategies to cope with the changes in the supply chain dynamics caused by excessive rainfall.

2.5.3 Carbon Dioxide Emission and food inflation

The relationship between carbon dioxide (CO²) emissions and food inflation has become a topic of increasing concern and research in recent years. As global CO₂ levels continue to rise due to human activities, particularly the burning of fossil fuels, the

impacts on agricultural productivity and food prices have become more pronounced (Praveen & Sharma, 2022; Nunes et al., 2023). In the realm of agricultural production, one of the critical pathways through which carbon dioxide (CO_2) emissions influence food inflation is by directly affecting plant growth (Moessner, 2022; Somoye & Olowu, 2024). According to Appiah and Poku (2018), the direct effects of carbon dioxide (CO_2) emissions on plant growth are a crucial factor influencing agricultural production and, consequently, food prices.

Studies have shown that increased atmospheric CO_2 levels can stimulate photosynthesis, leading to enhanced plant growth and higher crop yields (Gamage et al., 2018; Nowicka et al., 2018). This phenomenon, known as CO_2 fertilization, has the potential to increase the availability of food and, theoretically, reduce food prices. Studies have shown that elevated CO_2 concentrations can improve the photosynthetic efficiency of plants, particularly C_3 crops such as rice, wheat, and soybeans, which constitute a significant portion of the global food supply. Gamage et al. (2018) made emphasized that enhanced photosynthesis can result in faster growth rates and increased yields. For instance, a study by Ainsworth and Long (2021) found that yields could increase by up to 20% under elevated CO_2 conditions. These increases in crop production can potentially stabilize or reduce food prices by boosting supply.

A notable example of the significant role of CO_2 in affecting food production and prices is observed in crop cultivation. Research by Ainsworth and Long (2021) demonstrated that while elevated CO_2 levels increased crop yields, the accompanying temperature rise negated these crops by reducing the crop quality and increasing the prevalence of pests and diseases. According to Ainsworth and Long (2021), this can result in increased production costs and higher rice prices, illustrating the intricate balance between CO_2 levels, plant growth, and food prices. Historical data and

experimental studies provide evidence of the direct effects of CO² on plant growth and subsequent impacts on food prices.

For instance, during the mid-20th century, the Green Revolution in Asia saw significant yield improvements partly due to the introduction of high-yielding varieties that thrived under increased CO² levels (Fahad et al., 2022). However, these high-yielding varieties were not uniformly distributed across all regions or crop types. In contrast, recent studies have shown that elevated CO² levels have not significantly improved yields in certain areas of Sub-Saharan Africa (Kim et al., 2021) where nutrient limitations and water scarcity prevail, highlighting the complex interplay of factors influencing agricultural productivity.

2.6 Theoretical framework

The study is underpinned by Food Availability Decline (FAD) and Food Entitlement Decline (FED) theories. Amartya Sen (1991) developed the Food Entitlement Decline (FED) and Food Availability Decline (FAD) theories to explain the underlying causes of food crises, which include hunger, famine, food insecurity, and raising food prices. The Food Availability Decline (FAD) theory is an early and influential framework for explaining famines, food insecurity, and price fluctuations. It posits that hunger, food scarcity, and elevated food prices primarily arise when the aggregate physical supply of food declines. According to Sen (1991), this decline in availability may result from environmental, economic, or political shocks. The Food Availability Decline (FAD) theory explains that food crises occur as the direct result of an insufficient supply of food. The theory assumes that the main trigger for famine, hunger, food insecurity and food price surges is a physical reduction in the amount of food available.

In the context of climate change, this framework is highly relevant as changes in temperature and precipitation, carbon dioxide emission patterns can directly reduce agricultural yields, disrupt supply chains, and shrink overall food supply, thereby exerting upward pressure on prices. The theory has its roots in agrarian economy frameworks stressing the importance of agriculture and food production for determining food prices. According to the agrarian economy, the key assumptions of FAD theory are that food supply and availability are foundational to an economy, especially in influencing food prices (Hymer & Resnick, 1999). In light of this study, the FAD theory suggests that a reduction in food supply cause by climate can lead to higher food prices and vice versa, in accordance with the basic economic principle of supply and demand.

The Food Entitlement Decline (FED) theory was also developed by Nobel laureate economist Amartya Sen in the 1980s as a critique of the dominant Food Availability Decline (FAD) explanation for the food crises. FED posits that hunger, food price surges, and famine do not necessarily result from an absolute shortage of food at the aggregate level, but rather from a failure of individuals or households to secure access to food through legally, socially, or economically recognized means, referred to as entitlements. This theory challenges the Food Availability Decline (FAD) theory by arguing that food crises are not necessarily caused by a shortage of food but rather by people's inability to access food due to economic and social factors. According to the agrarian economy this theory shifts the focus from total food supply to economic, social, and political factors that determine food prices (Hymer & Resnick, 1999).

According to the FED theory in relation to the agrarian economy, there will be an adequate food supply in the market however, economic and social factors are likely to have a greater impact on food prices than the availability of food supply. In light of this study, exchange rates, economic growth (GDP), population, and food imports are

the key social and economic factors likely to have a significant impact on food prices. Foundational to FAD and FED theories in this study is the causal link between food supply, socioeconomic factors, and food inflation. According to this view, the FAD theory suggests that food supply, which are significantly determined by climate change, can influence food prices, while the FED theory proposes that factors such as economic growth (GDP), exchange rates, population growth, and food imports function as market forces, and economic conditions can also influence food prices. Although both theories view food crises differently, whether food insecurity, raising food prices, or famine, the rational selection of both theories is a complementary role they play in helping us to understand the multidimensional nature of food price fluctuations, recognizing that they are not solely caused by the availability of food supply but are also significantly influenced by other important socio-economic factors.

2.7 Conceptual Framework

To guide the study a conceptual framework was developed from the two theories underpinning the study. The framework conceptualizes the implication of climate change on food inflation plus other control variables.

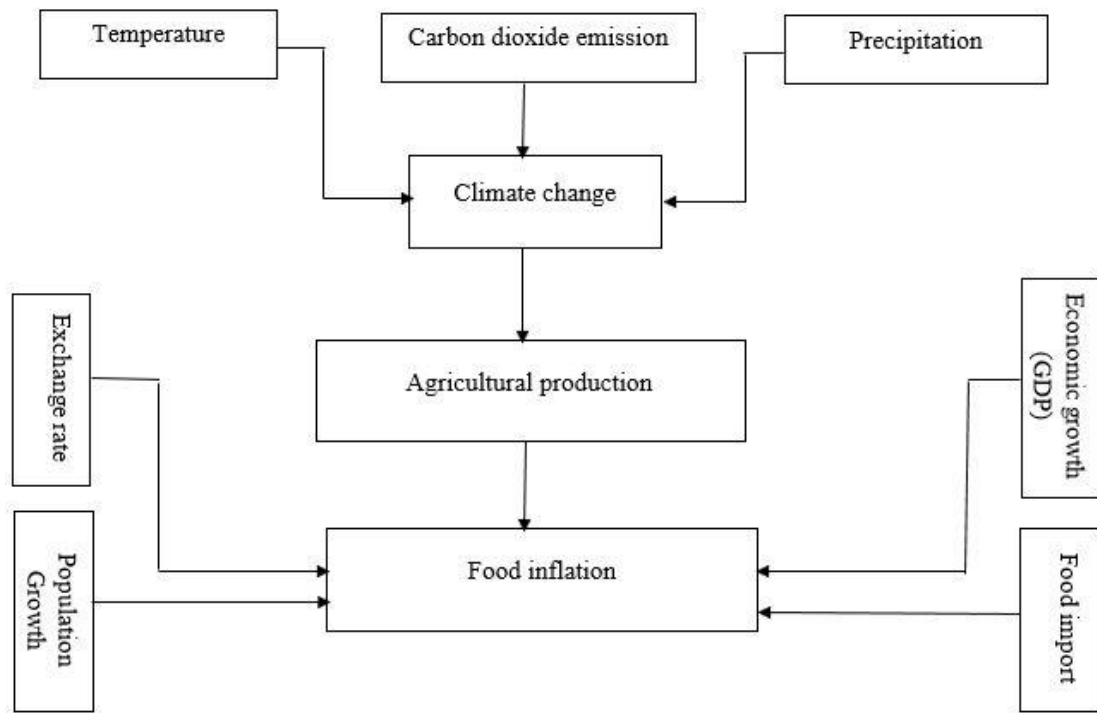


Figure 1: Conceptual Framework of the Study

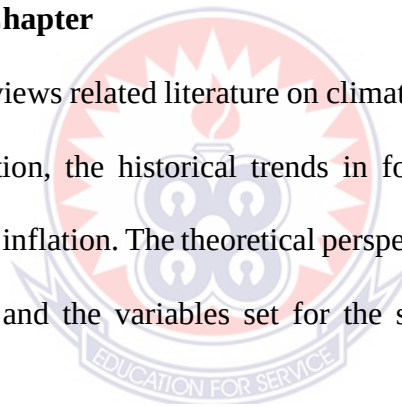
Source: Author's Construct, 2024

From Figure 1, climate change is presented as the central driver, manifesting through changes in temperature, carbon dioxide emission, and precipitation patterns. Increased temperatures can lead to higher evaporation rates and reduced humidity (Rajak 2021; Chandio et al., 2023), which can negatively impact agricultural production. Similarly, altered precipitation patterns, either in the form of droughts or flooding, can severely disrupt crop yields (Ndlovu et al., 2020; Urama et al., 2020). While higher CO₂ concentrations can stimulate photosynthesis and potentially increase crop yields under favorable conditions, the broader impacts are causing rising temperatures and changing precipitation patterns, which tend to affect agricultural systems negatively. These climatic factors directly impair agricultural production, which is the primary source of food supply. A decline in agricultural output can trigger food inflation, driving up food prices (Chukwuone & Ameachina, 2021). The confounding variables such as food production, exchange rate, economic growth,

population growth, and food import also have an impact on food price inflation (Bijl et al., 2017; Fukase & Martin, 2020; Xue et al., 2021; Wudil et al., 2022). Again, although in some studies all these socioeconomic factors can have influences on agricultural production, in the context of this study, these variables were treated as having different influences on food prices, as other studies have done. (Bijl et al., 2017; Xue et al., 2021; Wudil et al., 2022). The use of FAD and FED variables on influencing food inflation does not assume to have an equal influence because all countries in Africa do not uniformly experience the same climate condition and the same socioeconomic condition, so there will be instances where one single factor or condition will have a dominant influence on the other.

2.8 Summary of the Chapter

Chapter two reviews related literature on climate change, food inflation, factors influencing food inflation, the historical trends in food inflation, and the effect of climate change on food inflation. The theoretical perspective and conceptual framework linking the objectives and the variables set for the study were also covered in the chapter.



CHAPTER THREE

METHODOLOGY

3.0 Introduction

This chapter describes the methods which were used to elicit relevant data and information for the research. The chapter discussed the profile of the study area, research philosophy, research approach, research design, data sources, and data analysis techniques for this research. It also discusses the data employed and their sources, data processing techniques, and analysis.

3.1 Study area

The area considered for this study is Africa, with concentration on all the sub regions in Africa namely North Africa, Central Africa, East Africa, Southern Africa, and West Africa.

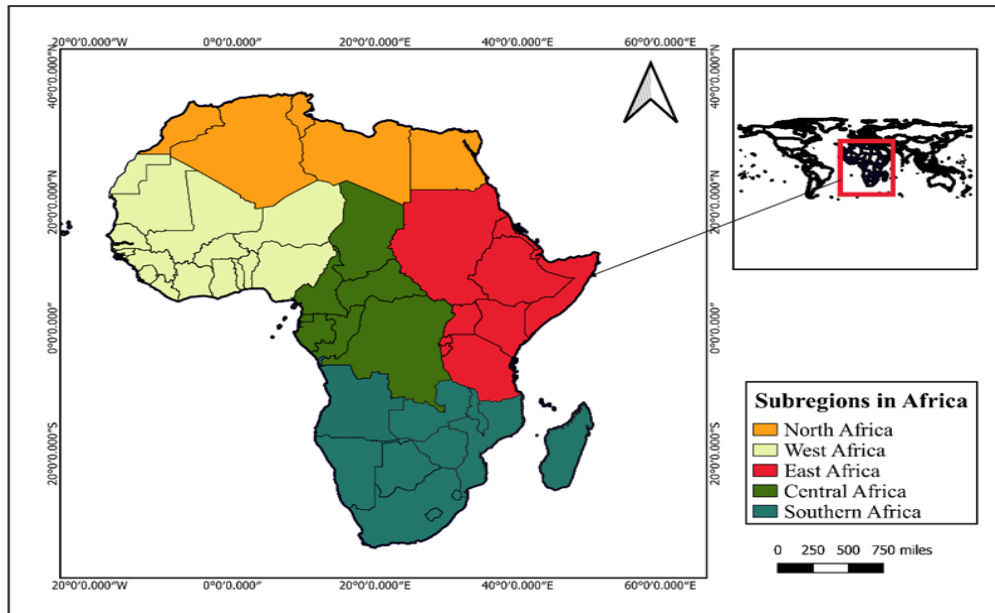


Figure 2: Map of Africa

Source: Author's construct, 2024

Africa is the world's second-largest and second-most-populous continent after Asia (World Population Review, 2023; Elwakil et al., 2023; Olubiyo, 2023). According to Elwakil et al. (2023), Africa cover about 30.3 million km² (11.7 million square miles) including adjacent islands and it covers 20% of Earth's land area and 6% of its total surface area. It is bounded by the Mediterranean Sea to the north, the Isthmus of Suez and the Red Sea to the northeast, the Indian Ocean to the southeast, and the Atlantic Ocean to the west (Yasuhara et al., 2022). Africa straddles the equator and is situated mainly in the eastern hemisphere, stretching from 37°N to 35°S latitude and 17°W to 52°E longitude (Ngwenya, 2019). With 1.4 billion people (World Population Prospects, 2022) as of 2021, Africa accounts for about 18% of the world's human population (Abramova, 2022).

The continent encompasses numerous regional environments with wide variations in geography, ecology, climate, anthropology, and levels of socioeconomic development (Blok et al., 2018). It contains the world's largest hot desert, the Sahara, as well as huge tropical rainforests around the Congo River Basin (Dezfuli, 2017). The diverse terrain also includes savannah grasslands, rugged mountain ranges like the Atlas Mountains and the East African Highlands, and thousands of miles of coastline along the Atlantic and Indian Oceans (Marchant, 2022). Africa consists of 54 fully recognized sovereign states and 9 territories, with Morocco, Algeria, Egypt, Nigeria, and South Africa being among the largest countries by land area and population (United Nations, 2022).

Africa's climate is heavily influenced by the continent's vastness, position across the equator, diverse topography, and proximity to oceans. The major climatic regions include equatorial, tropical, Mediterranean, desert/arid, and temperate (Mountjoy & Hilling, 2023). The equatorial region along the equator experiences a hot and humid

tropical rainforest climate characterized by heavy rainfall year-round. This climate dominates the Congo Basin and parts of West Africa (Dezfuli, 2017). The tropical climate, with distinct dry and rainy seasons, covers much of East Africa and regions north and south of the equator. Areas like coastal West Africa have a wet and dry cycle but with higher humidity than semi-arid interior zones (Ongoma et al., 2018).

Along the coast of the Mediterranean, the climate is characterized by mild, wet winters and dry summers. This climate extends into northern parts of Algeria, Tunisia, and Libya (Noureddine et al., 2018). The Sahara Desert across North Africa exemplifies the hot desert/arid climate with little rainfall, high temperatures, and scorching daytime conditions contrasted by cold nights (Eckardt et al., 2022). Southern Africa exhibits greater climatic diversity, with the Kalahari Desert's arid climate transitioning into semi-arid regions like Namibia and Botswana before reaching more temperate conditions along coastal South Africa and Lesotho (Howard, 2019). The East African Highlands experience an alpine climate due to high elevations over 1500m (NASA, 2023). Atmospheric circulation patterns like the Intertropical Convergence Zone, air masses, and El Niño contribute to yearly climate variability across Africa (Nicholson, 2018).

Agriculture is a crucial sector in Africa, employing over 60% of the continent's population (WHO, 2020). The region produces a wide variety of crops, including staples like maize, cassava, and rice, as well as cash crops such as cocoa, coffee, and tea. However, agricultural productivity in Africa remains low compared to other regions due to factors such as limited access to modern farming techniques, inadequate infrastructure, and climate change impacts. Africa remains a net food importer. According to the Food and Agriculture Organization (FAO) (2021), the value of Africa's food imports was estimated at \$43 billion in 2019. Crop yields in Africa are

significantly lower than global averages for instances, cereal yields in Sub-Saharan Africa are about 1.5 tons per hectare, compared to the global average of 3.9 tons per hectare (Mahofa, 2022).

3.2 Research Philosophy

A research philosophy encompasses a set of guiding principles that direct the research in its entirety. The research philosophy primarily explains a system of beliefs and assumptions about the development of knowledge and highlights how data is collected, estimated, and analyzed (Creswell, 2014). The study considered positivism because the research sought to measure a wide range of concepts (climate change and food inflation) over some time. Again, the study considered this philosophy because the main assumption of positivism is the reality and interpretation of nature independent of an observer's intuition. Thus, reality exists objectively and scientific methods are employed in gathering knowledge. This is mainly applicable to quantitative design where the researcher remains neutral to the object of the study. Therefore, examining the effects of climate change on food inflation in Africa is anchored on the positivism paradigm or positive epistemology to address the problem statement.

3.3 Research Approach

According to Creswell (2014), the research approach refers to strategies and processes for research that bridge the steps from broad assumptions to comprehensive data collection, analysis, and interpretation methods. The study follows the quantitative strategy, collects numerical data, and employs the deductive approach to do the logical analysis. This study, therefore, employed a quantitative approach to research. The quantitative aspect of the study was to collect and analyse numeric data from the World Climate Knowledge Portal, World Development Index, and World Bank to test correlation and causal relationships between climate change and food inflation in

Africa, and then make predictions. The quantitative approach was adopted because of the objective of the study which is to explain the causal relationship between climate change and food inflation.

3.4 Research Design

Research design is a strategy that helps the researcher in answering the research questions using empirical data. Thus, a research design is a blueprint that seeks to answer research questions and arrive at research objectives (Kothari, 2004). The study employed explanatory research design. The choice of an explanatory research design for this study is guided by its central assumption that research should not only describe phenomena but also identify and test cause-and-effect relationships between variables. In the context of a spatial assessment of the effect of climate change on food inflation in Africa, this design is particularly appropriate because the study seeks to establish how and to what extent climate and socio-economic factors influence variations in food prices across different geographic areas. Explanatory research is grounded on the assumption that phenomena do not occur randomly but are influenced by identifiable, measurable factors whose interactions can be systematically analysed (Ishtiaq, 2019). This aligns with the study's aim of moving beyond mere description of trends to uncovering the mechanisms through which temperature changes, precipitation variability, and extreme weather events influence food price dynamics.

3.5 Data Collection and Processing

The study collected data on climate change (temperature, carbon dioxide emission and precipitation), food inflation and other confounding variables (food production, food import, economic growth [GDP per growth], population growth, and exchange rate).

Table 1: Dataset and sources

Variables	Explanation	Sources	Year
Climate Change	Precipitation	World Climate Knowledge Portal	1992-2022
	Temperature	World Climate Knowledge Portal	
	Carbon dioxide emission	World Development Indicators	
Food Inflation	Food price inflation	World Development Indicators	1992-2022
Confounding Variables	Population growth	World Bank	1992-2022
	Economic growth	World Bank	
	Food import	World Bank	
	Food production	World Bank	
	Exchange rate	World Bank	

Source: Author's construct, 2024



Table 2: Dataset Description

	Metadata Definition
Temperature	Average annual temperature measured in degrees Celsius recorded on land, sea as well as some satellite measurements.
Precipitation	Water released from clouds in the form of rain, measured in millimetres (mm). It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth
Carbon dioxide emission	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring, measured in metric tons per capita
Food inflation	The general price level of food products over a specific period, usually measured annually.
Economic growth	Real gross domestic product per capita
Population growth	Population growth (annual %)
Food production	Food production index: Edible food crops that contain nutrients, excluding coffee and tea (2004–2006 = 100).
Food import	Food imports are the percentage of merchandise imports that consist of food products. These food products include commodities categorized under Standard International Trade Classification (SITC) sections, SITC sections 0 (food and live animals).

Source: Author's construct, 2024

Additionally, the Representative Concentration Pathway (RCP) website at <https://climateknowledgeportal.worldbank.org> was used to obtain the temperature and precipitation data. The World Development Indicators database (<https://databank.worldbank.org/source/world-development-indicators>) was also used to obtain food inflation and carbon dioxide emission data from 1992 to 2022. Additionally, data on food import, exchange rate, population, food production, and economic growth (GDP per growth) were obtained from the World Bank website, <https://databank.worldbank.org/source/world-development-indicators>.

The databases for these datasets were selected due to their comprehensiveness, as they contain data on more than 90% of the countries in the world, and for that matter, data for almost all the countries in Africa, and the year 1992 selected is significant as it marks the forming of the United Nations Framework Convention on Climate Change

(UNFCCC) during the Earth Summit in Rio de Janeiro, while 2022 was selected because of the readily available data for current years. Also, the projected year 2037 was selected due to the fifteen-year prognosis. The data was secured from various sources such as the World Bank, World Climate Knowledge Portal, and World Development Indicators because they adhere to the following data quality criteria: data relevance, applicability, adequacy, timeliness, quality, and coverage.

However, the data had limitations because there were no records for some countries. Nevertheless, the spatial autofill method of the K-nearest-neighbour (KNN) function was used to resolve this. K-nearest-neighbour is computed using the mean value of K, which is the number of nearest neighbours (Arnesson & Lewenhagen, 2018). Since K in this study had a value of four, the values of the four neighbouring countries were utilized to calculate the values of the zero-value countries. Tobler's first law of geography, which asserts that things closer together are more related in space and time and, therefore, more likely to have similar values, serves as the theoretical foundation for KNN (Osman et al., 2022). Because of the KNN's scalability, simplicity, speed, and dependability, it was selected (Arnesson & Lewenhagen, 2018).

The primary datasets (data on confounding variables, food inflation, and climate change) were also processed and filtered using Microsoft Excel. The variables and year gap for the study were considered for sorting. The globe shapefile was then joined with the datasets using ArcGIS PRO 2.8.2 software. Next, using ArcGIS Pro 2.8.2, the layers of the world country were projected to the WGS 1984 World Mercator projected coordinate system. Nevertheless, the shapefile for the global country's layers was obtained via the ICPAC GEOPORTAL website, which may be accessed at <https://bit.ly/3E1R33S>.

3.6. Data Analysis

In looking for a model that best explains the dependent variable within the dataset of this study, an exploratory regression was run to evaluate all possible combinations and the best fit of the input variables. For models with at least a minimal number of explanatory factors, the exploratory regression performs OLS on all possible combinations of the candidate explanatory variables. Temperature, precipitation, carbon dioxide emission, food production, population growth, food import, exchange rate, and economic growth were among the variables that were chosen. Afterward, a spatial autocorrelation method called Global Moran's I was used to evaluate the models' independence (Majeed et al., 2021). A VIF below 3.5 is a good measure of ensuring independent variables are not related to one another (Prather & Kaspari, 2019). All the predicting variables (food production, temperature, precipitation, carbon dioxide emission, food import, exchange rate, economic growth, and population growth) used in the study met the 3.5 VIF (Appendix 1).

The study employed both descriptive and spatial analysis techniques. Charts such as graphs and tables were employed to aid in the descriptive analysis. The spatial analysis techniques adopted for this study were mean center and trend analysis, incremental autocorrelation, standard distance ellipsoid, getis-Ord hotspot analysis, exponential smoothing forecast, and random forest-based classification and regression.

To achieve objective one and H₁ mean center analysis was used to determine the average x-y coordinates of the food inflation of the various regions in Africa. The mean center's function is given as (Equation 1)

$$\bar{X} = \frac{\sum_{i=1}^n x_i}{n} \text{ and } \bar{Y} = \frac{\sum_{i=1}^n y_i}{n} \dots\dots\dots \text{(Equation 1)}$$

where:

x_i and y_i as the coordinates for the features i and n as the number of features.

Also, incremental spatial autocorrelation was used to test for the presence of spatial autocorrelation at a range of band distances (Esen & Bayrak, 2017). It was used to identify the farthest distance at which food inflation have a significant impact on each region in Africa. For each distance increment, the method produces Global Moran's I , Expected I , variance, a z -score, and a p -value (Majeed et al., 2021). The z -score peaks reflect distances at which a clustering process seems to be occurring. The higher the z -score, the stronger the clustering process at that distance (Loayza et al., 2012). The incremental spatial autocorrelation function is given as (Equation 2)

$$LISA = (Z_i - \bar{Z}) / (1 - \bar{Z}) \dots \dots \dots (\text{Equation 2})$$

Where:

$LISA$ is the incremental spatial autocorrelation value for a given location i .

Z_i is the observed variable value at location i .

$\bar{Z}$ is the mean variable value for all locations (Anselin, 1995).

Likewise, utilizing the standard deviational ellipse, the trend of food inflation and was evaluated in order to determine whether the distribution was elongated and had a certain orientation. Standard deviational ellipse (Equation 3) has the following function.

$$C = \frac{\sum_{i=1}^n \bar{x}_i^2 \sum_{i=1}^n \bar{x}_i \bar{y}_i}{\sum_{i=1}^n \bar{x}_i \bar{y}_i \sum_{i=1}^n \bar{y}_i^2} \dots \dots \dots (\text{Equation 3})$$

where x and y as coordinates of the features (i) $\bar{X}$ and $\bar{Y}$ as coordinates of the features.

Furthermore, the getis-Ord hotspot analysis tool in ArcGIS Pro 2.8.2 software was used to identify emerging hotspot zones in food inflation in the African continent. The emerging hotspot analysis tool used each variable in the dataset to identify emerging hotspot trends and patterns. The tool detected, cold spot with 99% confidence, a cold spot with 95% confidence, a hotspot with 90% confidence, a hotspot with 95% confidence, and a hotspot with 99% confidence within datasets. It takes a space-time Net-CDF cube to conceptualize spatial relationship value to calculate Getis-Ord G_i^* statistics (Iizuka, 2020).

To achieve objectives two and three, spatial prediction model with the help of a space-time cube was employed. Space-time bins were generated for food inflation, climate change, and confounding variables with an interval of one year each. In each bin defined a set of observations over a year. A trend analysis for the bins across time was measured using the Mann-Kendall Statistics (Iizuka, 2020).

A random forest-based classification and regression was used to assess the factors influencing food inflation. In the analysis, entropy served as the foundation for examining the relationship between two or more variables. Entropy-based calculations search for relationships that are structural rather than just linear, including exponential, quadratic, sinusoidal, and complicated relationships (Osman et al., 2022). The random forest-based classification and regression were used to find out if climate change will affect food inflation or climate change plus the other confounding variables will also affect food inflation.

Again, after using exponential smoothing forecast to predict the future of the trend of the variables, random forest-based classification and regression were used to

find out if climate change will influence food inflation by 2037 and, plus the confounding variables influence how climate change will influence food inflation by 2037. This was done using ArcGIS Pro 2.8.2. A prediction model was produced by the tool using an ensemble of decision trees, which produced hundreds of trees (Soergel et al., 2021). A randomly generated portion of the original data is used to form each decision tree (Cuaresma et al., 2017). A random forest is a classifier consisting of a collection of tree structured classifiers (Osman et al., 2022). Cuaresma et al. (2017) gave the function of Leo Braiman Random forest-based regression (Equation 4) as follows

$$\{h(x, \Theta_k), k=1, \dots\} \dots\dots\dots \text{(Equation 4)}$$

Where:

$\{\Theta_k\}$ are independent identically distributed random vectors and each tree casts a unit vote for the most popular class at input x .

X is an input vector

N is the number of decision trees by using K regression of $h(x, \Theta_k)$ as the predictive results.

The software Stata version 17.0 was then used to further analysis the outcomes of the random forest-based classification and regression. Using one-way ANOVA analysis, the mean of the statistical data produced by random forest-based classification and regression was compared across the sub-regions in Africa (H_2 , H_3 , H_4 & H_5).

3.7 Summary of the Chapter

The methodology section outlined, discussed, and explained the vivid techniques used to address the objectives and hypothesis set for the study. It started by

giving a clear description of the study area. It further described the research paradigm, design, approach, data collection and processing, and analytical techniques employed for the study.



CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter focuses on the analysis of the results. The chapter is organised into the following sections: Descriptive statistics of discrete and continuous variables. The chapter is then followed by the discussion of the results based on the objectives and hypothesis underpinning this study, the spatial trends of food inflation in Africa, effect of climate change on food inflation, and the future trends of climate change's effect on food inflation in Africa by the year 2037.

4.1 Descriptive Statistics

This section provides a summary of descriptive statistics for nine variables across fifty-four (54) African countries over the period from 1992 to 2022. The table indicates the central tendency and measure of variability. The mean values represent the average of the variables used in the overall model, while the standard deviation reflects how the data is distributed around the mean. It also illustrates the degree to which the data points are clustered around the average over the specified period. Additionally, the spread of the data is represented by the range, which is determined by the maximum and minimum values of the variables. The range serves as an indicator of the degree of variation in the variables; larger range values suggest greater variability in a given variable.

Table 3: Descriptive statistics

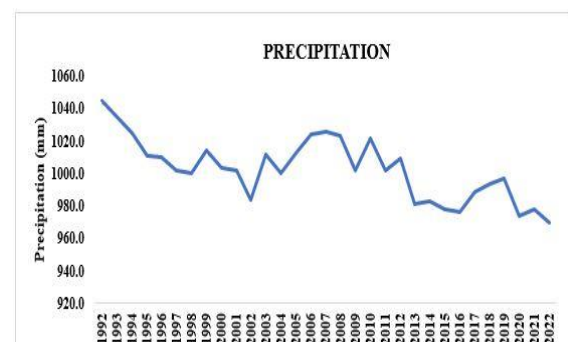
Variables	Obs	Mean	Std Dev.	Min	Max
Food inflation	1620	53.36	10.56	11.62	72.17
Temperature	1620	24.54	3.374	15.53	29.84
Precipitation	1620	1005.35	694.96	974.22	1596.82
Carbon dioxide emission	1620	358.84	149.46	94.63	436.45
Exchange rate	1620	67.84	25.34	41.32	118.44
Economic growth	1620	2.03	9.21	-19.01	35.92
Food import	1620	23.42	5.76	6.15	94.65
Population growth	1620	2.74	1.015	-5.28	10.20
Food production	1620	41.49	17.51	27.41	158.09

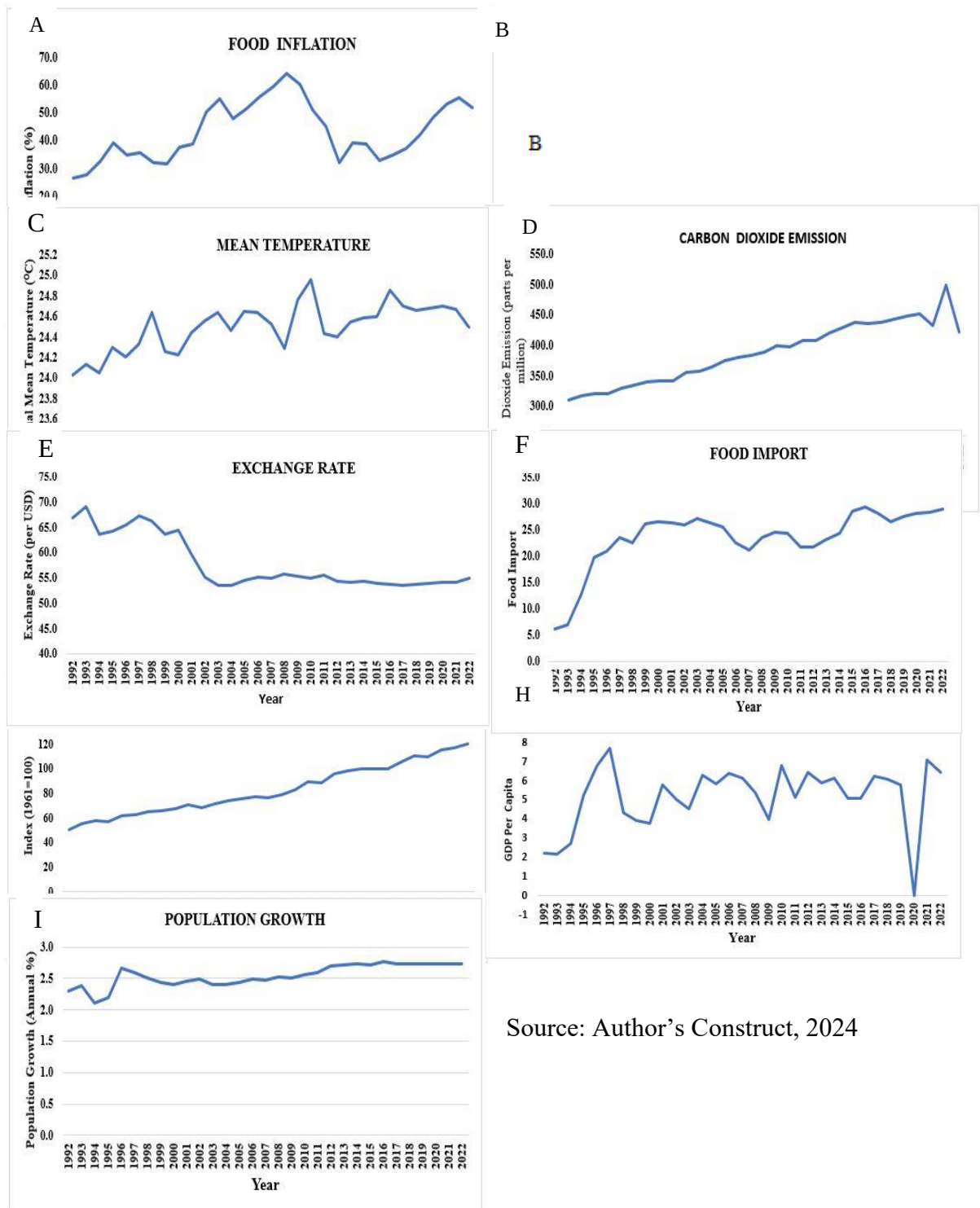
Source: Estimated from World Bank, World Development Indicators, and World Climate Knowledge Portal data using Stata version 17. Note: Std. Dev. represents Standard Deviation, Obs represents observation, min in represents minimum and max represents maximum.

From Table 3, the total number of observations used was 1620. It can be observed that all the variables in the table have positive average values (means). The study results indicate that the average food inflation rate for all countries in Africa during the period is 53.36%, with values ranging from a minimum of 11.62% to a maximum of 72.17%. The standard deviation is 10.56. A relatively high standard deviation suggests that food inflation rates in these countries differ considerably from one another. On the independent variables side, the average temperature across the sample period is 24.54°C, with the minimum and maximum temperatures recorded at 15.53°C and 29.84°C, respectively. For precipitation, the mean value is 1005.35 mm, with a standard deviation of 694.96 mm. The precipitation ranges from 974.22 mm to 1596.82 mm across Africa during the period from 1992 to 2022. Also, the average carbon dioxide emission value is 358.84 parts per million (ppm), with a standard deviation 149.46. The minimum and maximum values of carbon dioxide emissions are 94.63 ppm and 436.45 ppm, respectively.

Regarding the exchange rate, the study reveals an average value of 67.84, with a standard deviation of 25.34. The minimum value is 41.32, and the maximum value is 118.44. For food imports, the mean is 23.42, with the minimum and maximum values recorded at 6.15 and 94.65, respectively. The variation from the mean is 5.76. The average value for food production is 41.493, with a standard deviation of 17.51, and minimum and maximum values of 27.41 and 158.09, respectively. The mean value of population growth is 2.74, with minimum and maximum values of -5.28 and 10.20, respectively. The standard deviation is 1.01, which is lower than the mean, indicating minimal variability in population growth across Africa. Finally, the study shows an average economic growth rate of 2.03, with minimum and maximum values ranging from -19.01% to 35.92%. This suggests that economic growth in Africa was relatively high from 1992 to 2022.

As a starting point for the analysis, the study presents the trends of both the dependent variable (food inflation) and the independent variables (temperature, precipitation, carbon dioxide emissions, population growth, economic growth, exchange rate, food imports, and food production) in Figure 3.





Source: Author's Construct, 2024

Based on the data from Figure 3, the trends displayed in diagrams A, C, D, F, H and I exhibit a generally upward trend with minimal fluctuations throughout the period from 1992 to 2022. These trends indicate a steady increase over time, with slight

variations observed within some time frame. In contrast, the trends shown in diagrams B and E demonstrate a predominantly downward movement, although there are occasional upward and downward fluctuations within the same period. This suggests a decline over time, with some brief periods of increase or stabilization before continuing the downward trend.

4.2 Spatial Trends Analysis of Food Inflation

At this section various spatial techniques used to explore historical trends of food inflation were employed. The techniques include mean centre, incremental spatial autocorrelation, standard distance ellipsoid, and gets-Ord hotspot analysis.

4.2.1 Mean centre

A mean center analysis was performed to pinpoint the geographic areas where food inflation was most concentrated in each year from 1992 to 2022. Additionally, comparing food inflation rates across sub-regions further highlights regions more prone

Table 4: Mean center value for food inflation by years and sub-regions in Africa to high or low food inflation rates. This analysis provides valuable insights into the regions with the highest levels of food inflation rates, helping to understand where inflation is most concentrated over the past 30 years (1992-2022). On the Africa scale, the spatial mean center analysis from 1992 to 2022 revealed that the highest concentration of food inflation rate occurred in 2008, reaching a rate of 64.11, while the lowest concentration was recorded in 1992 at a rate of 26.42 (Table 4). In 2008, the highest concentration of food inflation rate (highest central mean value) was observed in Zimbabwe, while in 1992, the lowest concentration of food inflation rate (lowest central mean value) was found in Democratic Republic of the Congo.

Source: Boateng, 2024

This study's result indicated that between 1992 and 2022, the Democratic

Year	Mean Value	Latitude (Y)	Longitude (X)	Country
1992	26.42	-2.04	21.94	Democratic Republic of the Congo
1993	27.77	-4.52	22.60	Democratic Republic of the Congo
1994	32.59	-3.30	14.29	Cameroun
1995	39.26	-0.25	16.84	Republic of the Congo
1996	34.62	-1.72	18.62	Democratic Republic of the Congo
1997	35.66	-1.87	19.75	Democratic Republic of the Congo
1998	31.99	-2.18	15.62	Republic of the Congo
1999	31.54	-7.79	21.79	Democratic Republic of the Congo
2000	37.48	-8.07	25.93	Democratic Republic of the Congo
2001	38.94	-2.14	16.85	Democratic Republic of the Congo
2002	50.48	-9.30	21.13	Angola
2003	55.27	-10.69	24.55	Democratic Republic of the Congo
2004	47.83	-10.95	24.81	Democratic Republic of the Congo
2005	51.65	-5.83	20.58	Democratic Republic of the Congo
2006	55.86	-14.12	26.44	Zambia
2007	59.51	-18.07	29.21	Zimbabwe
2008	64.11	-17.05	28.82	Zimbabwe
2009	60.35	-0.80	22.46	Democratic Republic of the Congo
2010	51.14	3.20	14.47	Democratic Republic of the Congo
2011	45.26	2.11	17.76	Republic of the Congo
2012	31.94	1.78	18.39	Democratic Republic of the Congo
2013	29.07	0.42	18.20	Republic of the Congo
2014	28.85	0.62	17.67	Cameroon
2015	32.94	2.18	17.38	Republic of the Congo
2016	34.84	0.57	19.69	Democratic Republic of the Congo
2017	37.29	4.60	20.10	Central Africa Republic
2018	41.91	1.31	14.46	Republic of the Congo
2019	48.13	-0.91	38.13	Democratic Republic of the Congo
2020	53.23	-11.21	27.01	Democratic Republic of the Congo
2021	55.40	3.82	22.62	Republic of the Congo
2022	51.94	1.74	18.33	Democratic Republic of the Congo
Subregions				
West Africa	48.37	-18.720764	29.968936	Burkina Faso
East Africa	50.91	-4.574698	10.504195	South Sudan
Southern Africa	40.33	-7.874678	33.111905	Zimbabwe
Central Africa	20.15	1.205842	16.279398	Republic of the Congo
North Africa	31.80	1.294649	15.152384	Egypt

Republic of the Congo and the Republic of the Congo consistently emerged as the country with the highest concentration of food inflation rate (highest counts of central mean values) with almost seventeen and seven-year counts, respectively (Table 4). On

the other hand, Central Africa Republic, Zambia, Angola, and Cameroun all had one central mean value count, while Zimbabwe and Cameroun had two (Table 4).

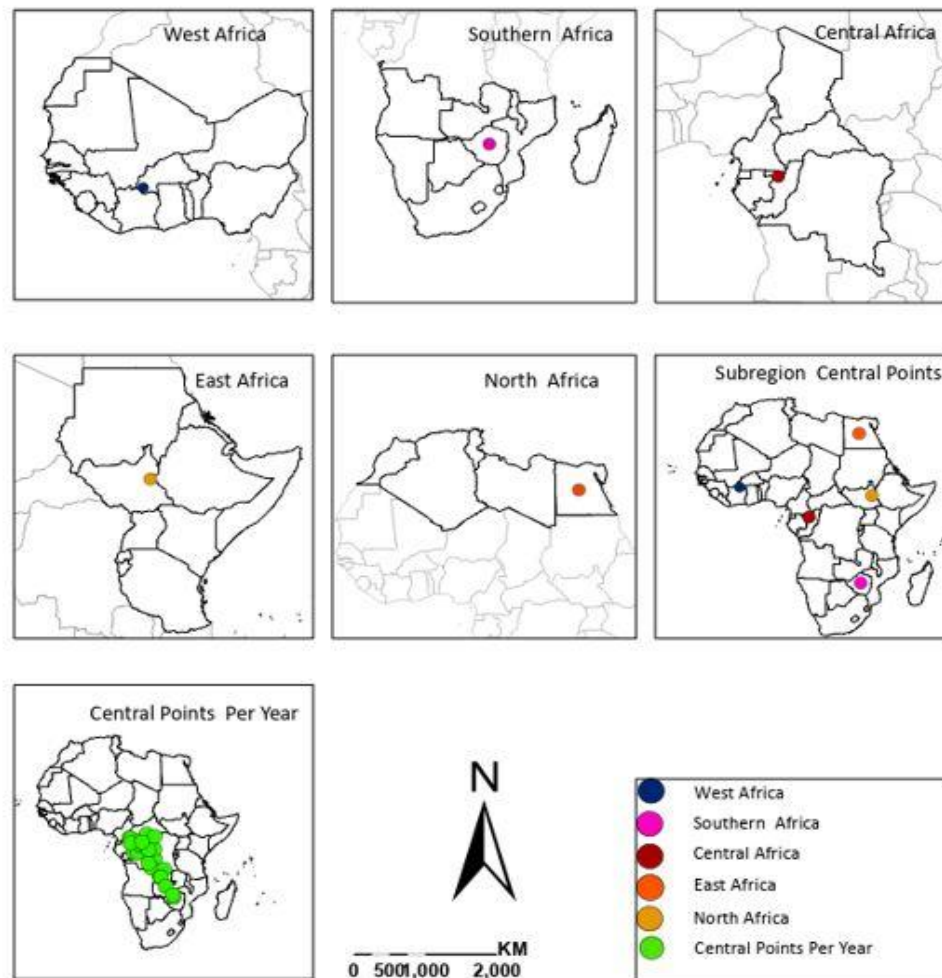


Figure 4: Mean center value for food inflation rate by years and sub regions

Source: Boateng, 2024

Regarding the regional distribution of food inflation, Table 4 and Figure 4 unequivocally demonstrate that, between period under study, the mean value distribution of food inflation was mostly concentrated in Central Africa, with only two mean values found in Southern Africa (Zambia and Zimbabwe), and no mean values was found in West, North, or East Africa (Figure 4; Table 4). With a mean value of 50.91, the results indicate East Africa had the highest incidence of that food inflation rate, whereas West Africa had the second greatest incidence of food inflation rate, with

a mean value of 48.37 (Table 4). Table 4 shows that, Central Africa had the least incidence of food inflation rate, with a mean value of 20.15. As illustrated in Figure 4, using different coloured points, the mean center country for North Africa was Egypt; for West Africa, it was Burkina Faso; for East Africa, it was South Sudan; for Central Africa, it was the Republic of the Congo; and for Southern Africa, it was Zimbabwe (Figure 4; Table 4).

4.2.2 Incremental Spatial Autocorrelation

An incremental spatial autocorrelation analysis was conducted to examine the geographic distribution of food inflation and to determine whether areas with high or low food inflation values tend to cluster at various distance intervals. The number of peaks reflects the number of distinct food inflation hotspots or regions of significant spatial correlation within a given year or subregion. As shown in Table 5, from 1992 to 2022, food inflation rate had an average of one peak at most and an average of two peaks at the lowest. This observation that food inflation has one or two peaks most of the time suggests that inflation tends to be geographically concentrated within specific regions or at certain distances, explaining that the phenomenon does not appear to be uniformly distributed across the entire continent, but rather tends to cluster in certain locations.

With food inflation rate per specific year, the results revealed that the average number of peaks at which food inflation rates cluster most was one (Table 5). The consistent presence of one peak at most over a majority of the years (Table 5), indicates that food inflation in Africa has tended to be geographically localized concentrated, with inflation pressures affecting specific countries at a given time. In contrast, the presence of two peaks during certain years (Table 5) signals periods where food inflation patterns were more complex and regionally diverse. Multiple peaks suggest

that food inflation was not only concentrated in one country but was also observed in distinct geographical areas across different distances. This might have been due to cross-border trade impacts, global food price shocks, or regional market fluctuations, which caused food inflation to occur simultaneously in multiple regions.

Also, with food inflation rate per specific year, it was observed that 2008 had the most incremental distance of 5.34 km with a peaking distance of 1171.23km while 1993 had the least distance of 1.42 km with a peaking distance of 921.30 (Table 5). The significantly larger incremental distance in 2008 indicates that food inflation was more spatially clustered that year, suggesting that food inflation was felt across larger geographical areas, possibly due to global factors such as the food price crisis of that year.



Table 5: Incremental spatial autocorrelation for food inflation by years and sub regions in Africa

Years	Number of Peaks	Distance Increment (Km)	Peak Distance (Km)	Moran's I	Expected Index	Z score	P value
1992	1	1.56	973.27	0.09	-0.02	3.97	0.02
1993	1	1.42	921.30	0.07	-0.02	3.86	0.01
1994	1	1.67	954.46	0.09	-0.02	2.92	0.01
1995	1	2.43	943.34	0.09	-0.02	2.50	0.01
1996	2	2.54	932.34	0.07	-0.02	2.52	0.00
1997	1	2.55	901.32	0.07	-0.02	2.54	0.00
1998	1	2.63	949.41	0.02	-0.02	3.92	0.01
1999	-	-	-	-	-	-	-
2000	1	2.74	942.16	0.02	-0.02	3.84	0.02
2001	-	-	-	-	-	-	-
2002	1	3.23	1204.38	0.07	-0.02	2.63	0.01
2003	1	3.45	1206.48	0.05	-0.02	1.49	0.01
2004	2	3.62	1294.31	0.07	-0.02	1.85	0.01
2005	1	3.92	1297.62	0.04	-0.02	1.01	0.01
2006	2	4.71	1340.23	0.07	-0.02	1.87	0.01
2007	1	4.93	1202.84	0.05	-0.02	1.21	0.01
2008	2	5.34	1171.23	0.09	-0.02	1.75	0.00
2009	2	5.12	975.27	0.02	-0.02	2.49	0.00
2010	-	-	-	-	-	-	-
2011	-	-	-	-	-	-	-
2012	2	4.23	1213.09	0.07	-0.02	1.46	0.02
2013	1	4.31	1303.92	0.07	-0.02	1.84	0.02
2014	1	4.45	1042.45	0.04	-0.02	1.9	0.02
2015	1	4.53	1073.84	0.07	-0.02	1.83	0.02
2016	-	-	-	-	-	-	-
2017	-	-	-	-	-	-	-
2018	2	4.72	952.40	0.07	-0.02	1.30	0.00
2019	2	4.93	1091.42	0.07	-0.02	1.87	0.00
2020	2	5.03	1209.84	0.02	-0.02	2.71	0.00
2021	2	5.09	1342.37	0.02	-0.02	7.94	0.01
2022	2	5.11	1591.27	0.07	-0.02	2.78	0.00
Subregions							
Southern	1	1.34	843.91	0.04	-0.02	2.94	0.00
West	2	8.94	602.65	0.04	-0.02	15.63	0.00
Central	1	1.04	489.72	0.09	-0.02	14.34	0.00
East	2	4.28	794.32	0.02	-0.02	10.03	0.00
North	1	1.26	647.82	0.09	-0.02	13.82	0.00

Source: Boateng, 2024

At the sub regional scale, West Africa recorded the highest peak distance for food inflation at 8.94 km (Moran's $I = 0.04$, Z-score = 15.63, $p = 0.00$), whereas Central Africa exhibited the lowest peak distance at 1.04 km (Table 5). The recorded incremental distance of 8.94 km in West Africa, along with a significant Moran's I value (0.04) and an exceptionally high Z-score (15.63), indicates a strong positive spatial autocorrelation in food inflation. This means that food inflation in West Africa is not only widespread but also influenced by common regional factors. The p -value of 0.00 indicates that these results are statistically significant, confirming that inflation patterns in this region are correlated over distances greater than what would be expected by chance (Table 5).

4.2.3 Standard distance ellipsoid

Based on the standard deviation ellipsoid analysis, the study identified the directional trends and spread of food inflation rate in different parts of Africa within each ellipsoid. This type of spatial pattern analysis is crucial for understanding how food inflation spreads and the geographical areas most affected by inflationary pressures. The standard distance ellipsoid analysis of food inflation across the entire African continent from 1992 to 2022 exhibited a rotation ranging from 115.57 to 171.20 degrees (Table 6). Among these years (1992-2022), 2021 recorded the highest rotation at 171.20 degrees, affecting 27 countries, while 2010 had the lowest rotation at 115.57 degrees, affecting 14 countries (Table 6). The high rotation value signifies a notable shift in the directionality of food inflation, with 27 countries experiencing this high rotation, implying that food inflation was not only widespread but also likely driven by common external factors, such as global food prices affecting multiple countries simultaneously.

**Table 6: Standard distance ellipsoid on food inflation by years and sub-regions
in Africa**

Source: Boateng, 2024

Year	Rotation	X Standard Deviation (Km)	Y Standard Deviation (Km)
1992	134.83	27.27	16.78
1993	130.84	28.40	11.85
1994	126.53	28.44	12.17
1995	127.16	31.68	11.56
1996	130.09	31.62	11.76
1997	125.31	28.14	12.99
1998	124.19	32.17	11.44
1999	122.95	31.32	12.85
2000	138.73	24.51	12.37
2001	131.41	30.28	11.41
2002	134.00	29.45	11.36
2003	130.97	25.30	12.09
2004	130.59	26.54	10.15
2005	128.76	29.61	10.89
2006	131.24	20.95	9.04
2007	131.74	10.14	4.21
2008	137.60	12.91	6.11
2009	120.90	26.90	14.00
2010	122.93	30.45	16.20
2011	115.57	31.12	15.66
2012	123.88	29.25	15.85
2013	124.57	30.39	16.39
2014	127.46	31.15	16.79
2015	120.94	30.68	16.70
2016	122.64	31.90	16.85
2017	133.72	26.86	19.92
2018	146.77	32.22	17.11
2019	158.72	26.94	18.84
2020	157.13	21.42	12.79
2021	171.20	25.56	14.34
2022	166.68	23.53	17.23
Sub regions			
West	96.02	12.63	5.01
Southern	91.29	6.21	3.51
Central	93.51	9.47	6.97
East	160.99	13.10	6.11
North	55.19	24.66	55.19

Throughout the study period, most years displayed a diagonal direction toward the northwest, while the remaining years exhibited a vertical north-south direction

(Table 6; Figure 5). Regionally, East Africa had the highest rotation at 160.99 degrees (Table 6). A rotation angle of 160.99° and higher dispersion (13.10 km X and 6.11 km Y) implies a northeast trend with a broader spread of food inflation. In terms of the regional direction of food inflation, the West Africa, North Africa, and Southern Africa showed a horizontal direction toward the east and west, whereas Central and East Africa displayed directional trends toward the southwest and a vertical north-south direction respectively (Figure 5).

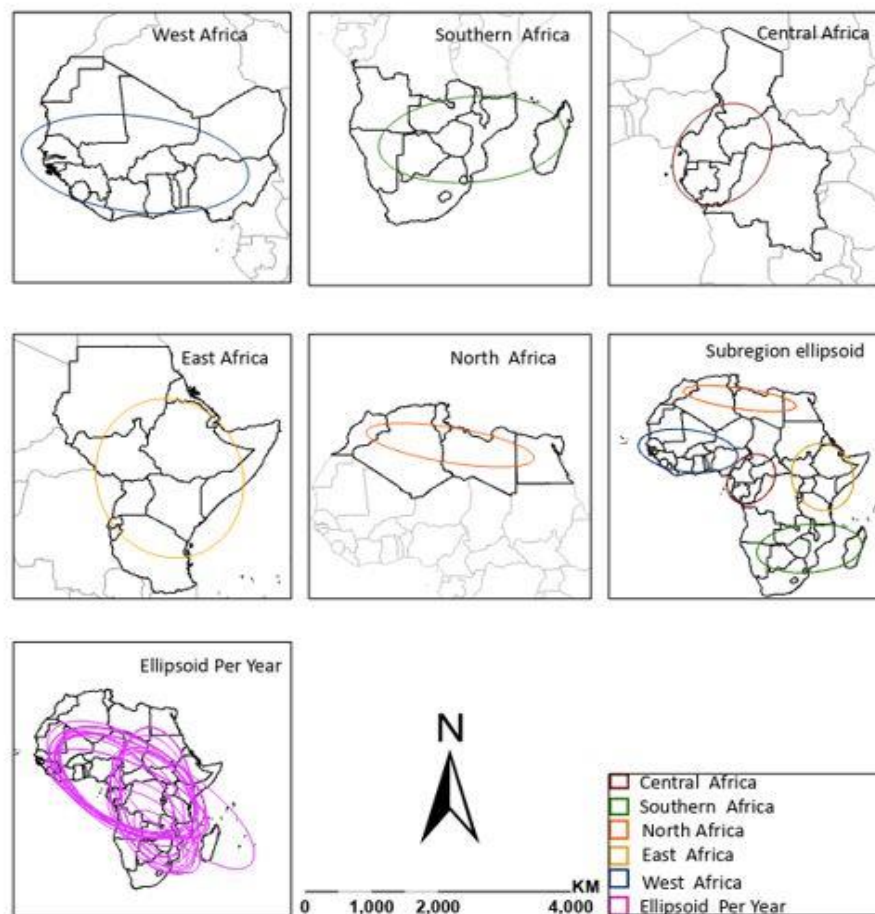


Figure 5: Standard distance ellipsoid on food inflation by years and sub-regions in Africa

Source: Boateng, 2024

4.2.4 Getis-Ord hotspot analysis

The primary function of the Getis-Ord analysis is to identify areas with statistically significant spatial clusters (hot spots and cold spots) of food inflation rates. Hot spots indicate areas with usually high food inflation rates, whereas cold spots indicate areas with usually low rates. The Getis-Ord hotspot analysis of food inflation showed that, of the 54 countries, 40 were classified as non-significant hotspot zones (neither hot spots nor cold spots) and the remaining 14 as significant hotspot zones (either hot spots or cold spots) (Table 7 and Figure 6). Among the countries identified as significant hotspot zones, half (7) were located in East Africa (Table 7 and Figure 6).

Table 7: Getis-Ord hotspot analysis on food inflation by regions from 1992-2022

Sub-regions	Countries	POH	Z-score	Z-p value
West	Mali	Hot Spot	1.68	0.09
	Niger	Hot Spot	1.70	0.08
Southern	Botswana	Cold Spot	-2.01	0.04
	South Africa	Cold Spot	-2.25	0.24
	Lesotho	Cold Spot	-2.17	0.03
Central	Chad	Hot Spot	2.12	0.03
	Republic of the Congo	Cold Spot	-2.37	0.01
North	-	-	-	-
	Sudan	Hot Spot	1.80	0.04
	Ethiopia	Hot Spot	1.91	0.05
	Eritrea	Hot Spot	2.13	0.03
	Tanzania	Cold Spot	-2.61	0.01
	Uganda	Cold Spot	-2.38	0.02
	Rwanda	Cold Spot	-2.05	0.04
East	Burundi	Cold Spot	-2.05	0.04

Source: Boateng, 2024

Countries that do not qualify as significant zones have Z-scores close to zero. This indicates that their food inflation rates are neither significantly high nor low compared to the overall trend in the dataset. These countries may experience average food inflation rates that do not deviate enough from the norm to warrant classification as extreme cases. From Table 7 the results indicated that five persistent hotspots across

Africa thus a cold spot with 99% confidence, a cold spot with 95% confidence, a hotspot with 90% confidence, a hotspot with 95% confidence, and a hotspot with 99% confidence. Out of the five persistent hotspots in Africa, cold spots with 95% confidence were the most prevalent, occurring in seven different countries (Table 7 and Figure 6).

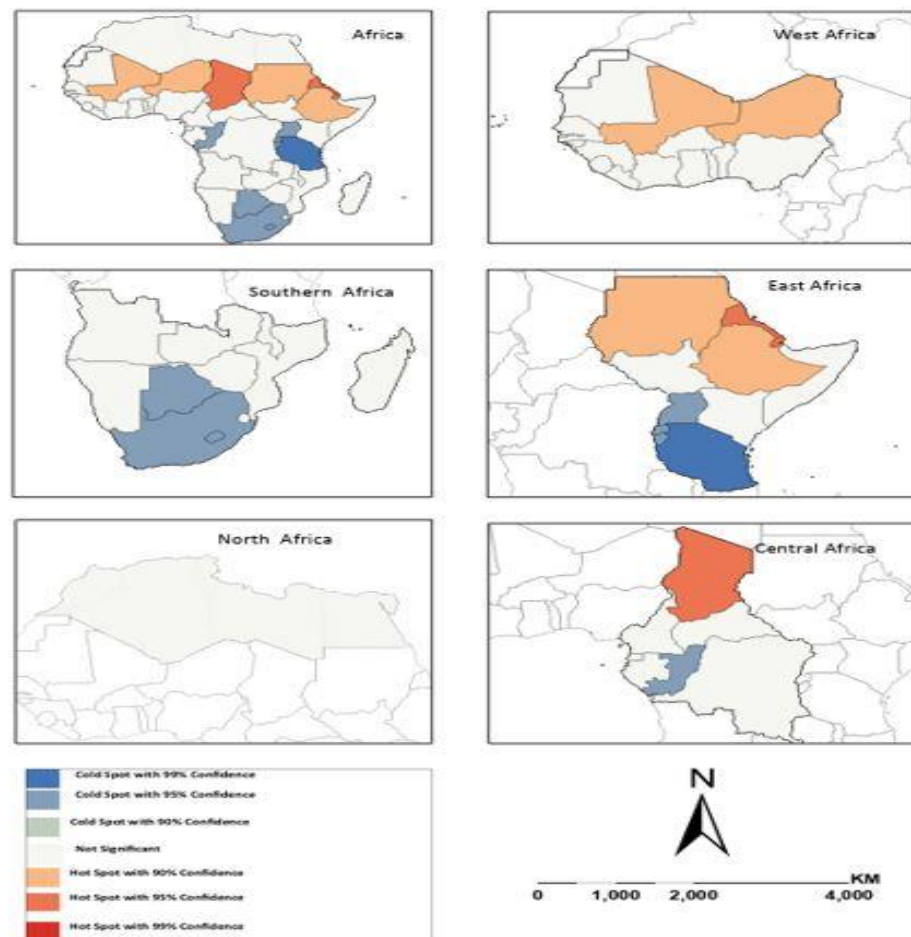


Figure 6: Getis-Ord hotspot analysis on food inflation by regions from 1992-2022

Source: Boateng, 2024

At the sub-regional levels, East Africa was found to have more significant hot spot zones than any other region in Africa thus Ethiopia [$Z=1.91$, $p=0.05$], Eritrea [$Z=2.13$, $p=0.03$], and Sudan [$Z=1.80$, $p=0.07$] were found to be hot spots with 95% and 95% confidence all suggesting rising inflation trends. On the other hand, Tanzania,

Uganda [$Z=-2.61$, $p=0.02$], Rwanda [$Z=-2.05$, $p=0.04$], and Burundi [$Z=-2.05$, $p=0.04$] in East Africa are cold spots, all showing significant low food inflation (95-99% significance). In West Africa, only Mali [$Z=1.68$, $p=0.09$], and Niger [$Z=1.70$, $p=0.08$], emerged as notable hotspots, indicating persistent inflation pressures in these countries. Conversely, Southern Africa exhibited a concerning trend of cold spots, with South Africa [$Z=-2.25$, $p=0.24$], Botswana [$Z=-2.01$, $p=0.04$], and Lesotho [$Z=-2.17$, $p=0.03$] indicating statistically significant low food inflation trend (99% significance). No countries were found to be hotspot zones in North Africa (Table 7; Figure 6).

4.3 Effects of Climate Change on Food Inflation Rate

The study sought to assess the effect of climate change on food inflation rate through three different scenarios. The first one was food inflation scenario one (FIS1) which looked at the effect of climate change (temperature, precipitation, and carbon dioxide emission) on food inflation. Also, food inflation scenario two (FIS2) dealt with the effect of only confounding variables (food production, exchange rate, economic growth, food import, and population growth) on food inflation. The food inflation scenario three (FIS3) focused on the effects of climate change plus the confounding variables on food inflation. The study further compared the statistical differences between the food inflation scenarios among the five main regions in Africa.

Table 8: Effect of climate change on food inflation rate

% Importance	Model 1	Model 2	Model 3
	(FIS1)	(FIS2)	(FIS3)
Temperature	45%		15%
Precipitation	33%		11%

Carbon Dioxide Emission	22%		7%
Food production		27%	18%
Exchange rate		10%	6%
Economic growth		13%	4%
Food import		33%	26%
Population growth		17%	13%
Number of Trees	100	100	100
MSE	8.24	8.93	9.01
Training			
R-Squared	0.91	0.79	0.82
P -value	0.00	0.00	0.00
Standard Value	0.04	0.05	0.01
Validation			
R-Squared	0.53	0.49	0.52
P-value	0.00	0.05	0.02
Standard Value	0.11	0.16	0.13

Source: Boateng, 2024

4.3.2 Food inflation scenario one (FIS1): Effects of climate change on food

inflation

A random forest-based regression and classification was used to assess the effects of climate change (temperature, precipitation, and carbon dioxide emission) on food inflation rate in Africa. The result generated the training R^2 of 0.91 with a p-value of 0.00 and a validation R^2 of 0.53 for food inflation rates (Table 8). The study model result indicated that climate change had a 100% influence on food inflation rate. The influence/importance of climate change on food inflation rate in Africa ranged from 22% to 45% (Table 8). The model statistics on the effect of climate change on food inflation (FIS1) revealed that temperature had the highest influence on food inflation rate in Africa by 45% (Table 8).

Moreover, precipitation had the second highest influence on food inflation rate in Africa by 33%. In addition, the model results further revealed that carbon dioxide emission also had the least influence on food inflation rate in Africa by 22% (Table

8). From FIS1, countries experiencing the highest food inflation rate (as represented by 57.96 to 70.57 on the map) as a result of climate change in Africa were Kenya (65.15), Somalia (59.44%) and Eritrea (59.05%) (Figure 7; Appendix 2).

4.3.3 Food inflation scenario two (ES2): Effects of confounding variables on food inflation

The forest-based classification and regression analysis on food inflation by confounding variables influences (food production, exchange rate, economic growth, food export, and population growth) revealed that food inflation rate had training R^2 of 0.79 with a $p=0.00$ and a validation R^2 of 0.49 with a $p=0.05$ (Table 8). The model statistics on the level of influences/importance from confounding variables revealed that food inflation rate in Africa had the highest influences from food import (33%) (Table 8).

Also, food production, population growth, and economic growth had the next highest-level influences of 27%, 17%, and 13% respectively on food inflation rate in Africa (Table 8). In addition, the model statistics found that the exchange rate had the least influence on food inflation rate in Africa by 10% (Table 8). From the model, as a result of confounding variables influence, countries like Zimbabwe (62.26%) and Eswatini (52.55%) were experiencing the highest percentage increase in food inflation rate as represented by 52.09 to 62.67 on the map (Figure 7; Appendix 3).

4.3.5 Food inflation scenario three (FIS3): Effects of climate change plus the confounding variables on food inflation.

With regards to assessing the effect of climate change plus confounding variables influences, the forest-based classification and regression result showed various levels of importance/influence on food inflation rate. The model statistics on

FIS3 revealed that cumulatively in Africa, confounding variables had the highest influence of 64% on food inflation rate, while climate change had the least influence of 36% (Table 8). The results from FIS3 model statistics (Table 8) indicated that food import had the highest influence on food inflation rate by 26% followed by food production (18%) (Table 8). Also, temperature recorded the third highest influence on food inflation rate with 15% (Table 8).

In addition, population growth, precipitation, and carbon dioxide emission had the next highest influence on food inflation rate by 13%, 11%, and 7% respectively. Moreover, the exchange rate had 6% influence on food inflation rate while economic growth had the least (4%) influence (Table 8). Beside the model statistics, FIS3 produced a training R^2 of 0.82 ($p=0.00$, $e=0.01$) and a validation R^2 of 0.52 ($p=0.02$, $e=0.13$) (Table 8). From Figure 7, as a result of climate change plus confounding variables' influences countries like Zimbabwe (53.59%), Namibia (52.97%), Eswatini (52.64%), Botswana (47.77%), and Rwanda (46.15%) were revealed to experience the highest percentage increase in food inflation rate in Africa as represented by 46.85 to 55.92% on the map (Appendix 4).

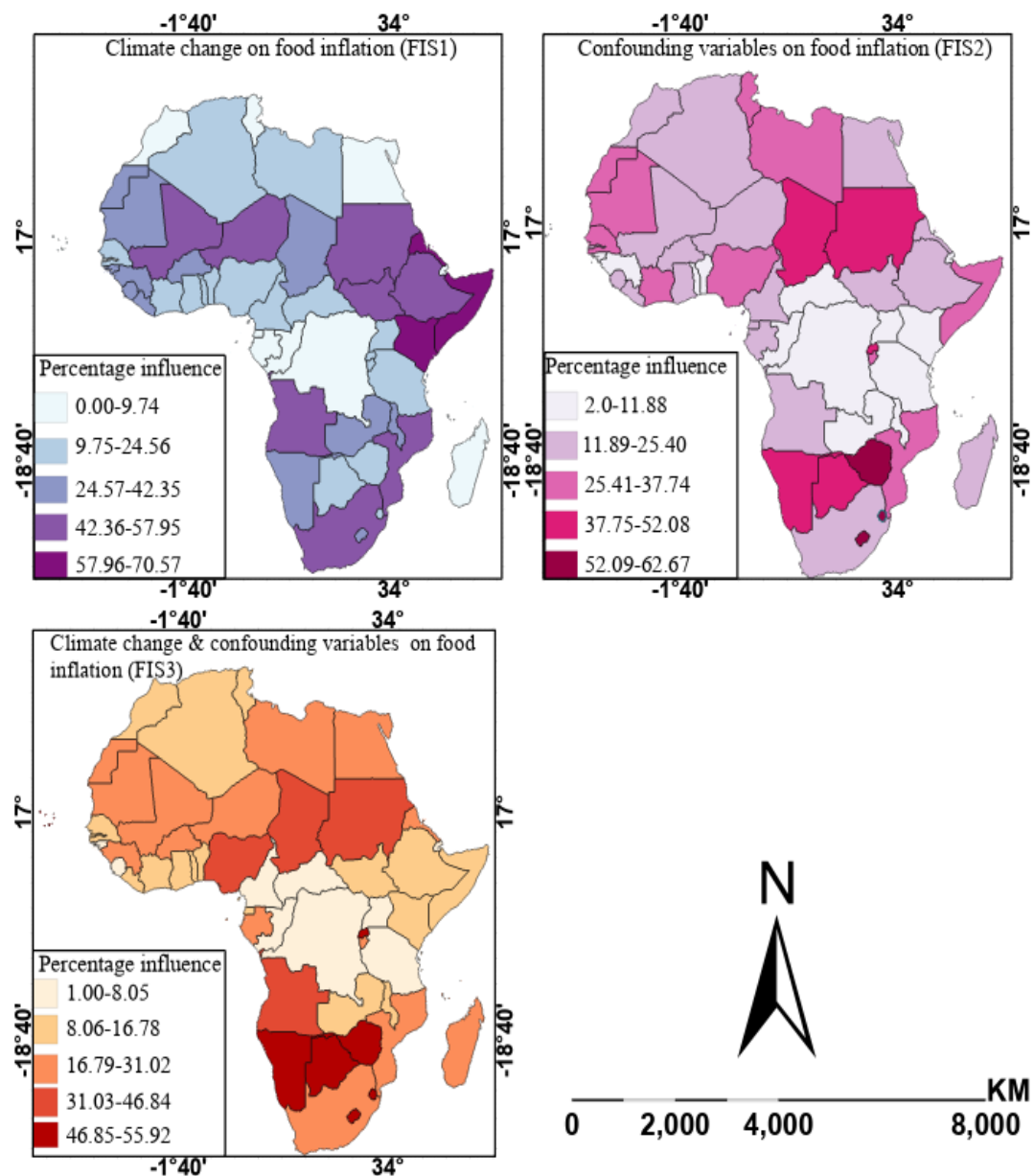


Figure 7: Differences between the effects of climate change on food inflation in Africa.

Source: Boateng, 2024

4.3.6 Differences between the food inflation scenarios

Regarding the spatial assessment of the effects of climate change on food inflation, the study further sought to find out whether there is a statistical difference among the five main regions in Africa for each of the three food inflation scenarios (FIS1, FIS2, and FIS3). For FIS1, using one-way ANOVA analysis, the Games-Howell

post hoc result found statistically significant differences between West Africa and Southern Africa (MD=-6.06, $p=0.04$), with a similar statistically significant relationship established between West Africa and East Africa (MD=-3.59, $p=0.03$) (Appendix 8). In contrast, the Games-Howell post hoc result found no statistically significant differences between West Africa and North Africa (MD=19.01, $p=1.04$) on FIS1 (Appendix 8). Also, there was no statistically significant relationship between West Africa and Central Africa (MD=16.01, $p=0.07$) with a similar relationship established between West Africa and North Africa (MD=19.01, $p=0.10$) on FIS1 (Appendix 8).

Based on the effect of climate change on food inflation in Africa (FIS1) the one-way ANOVA analysis result found food inflation rate in East Africa ($m=25.21$) to be statistically higher than West Africa ($m=21.62$) (Table 9). From Figure 7 countries experiencing the highest food inflation rate in East Africa as a result of climate change were Somalia, Kenya, and Eritrea. In the same vein, one-way ANOVA result also revealed food inflation rate in Southern Africa ($m=27.68$) to be statistically significantly higher than West Africa ($m=21.62$) in terms of the climate change effect of food inflation (Table 9). From Figure 7 in Southern Africa, countries experiencing the highest percentage increase in food inflation rate as a result of climate change's effect on food inflation were Angola and South Africa.

Regarding the effects of climate change plus the confounding variables on food inflation (FIS3), using one-way ANOVA analysis the Games-Howell post hoc analysis result found statistically significant differences existed between West Africa and South Africa, West Africa and Central Africa (Appendix 10). The Games-Howell post hoc analysis result showed that for FIS3, there was statistically significant differences existed between West Africa and Southern Africa (MD=-7.16, $p=0.04$) (Appendix 10). Similarly, there was a statistically significant relationship between

West Africa and Central Africa (MD=8.82, $p=0.01$) on FIS3. However, there is no statistical difference between West Africa and North Africa (MD=-4.57, $p=0.14$), West Africa and East Africa (MD=2.26, $p=0.07$) on FIS3, as shown in Appendix 10.

Moreover, the result for FIS3 found Central Africa ($m=17.59$) food inflation rate to be statistically lower than West Africa ($m=30.40$) (Table 9). In addition, contrary to the above finding the one-way ANOVA analysis results also found the Southern Africa ($m=33.57$) food inflation rate to be statistically significantly higher than West Africa ($m=30.40$) for FIS3 (Table 9). Per country levels from Figure 7 and Appendix 4 countries experiencing the highest food inflation rate in Southern Africa as a result of FIS3 were Uganda, Tanzania, Mozambique, and Madagascar.

Table 9: One-way ANOVA analysis on regional differences on food inflation

Regions	Mean	Std. Deviation	Std. Error	95% Lower	CI Upper	CI
FIS1						
Central Africa	9.60	9.08	3.21	3.31	15.89	
East Africa	25.21	11.38	3.43	18.49	31.93	
North Africa	6.61	10.95	4.90	-2.99	16.21	
Southern Africa	27.68	12.18	3.38	21.04	34.31	
West Africa	21.62	7.63	1.85	17.99	25.25	
FIS 2						
Central Africa	16.47	15.88	5.62	5.47	27.47	
East Africa	22.38	11.78	3.40	15.72	29.04	
North Africa	28.54	5.28	2.36	23.91	33.17	
Southern Africa	30.88	11.23	3.24	24.53	37.23	
West Africa	24.42	12.41	3.01	18.52	30.32	
FIS 2						
Central Africa	17.59	17.61	6.23	5.37	29.81	
East Africa	24.14	13.07	3.77	16.76	31.52	
North Africa	21.97	5.85	2.62	16.83	27.11	
Southern Africa	33.57	12.47	3.60	26.50	40.63	
West Africa	30.40	13.76	3.34	23.85	36.95	

Source: Boateng, 2024

FIS1 = Food inflation scenario one, FIS2 = Food inflation scenario two, FIS3 = Food inflation scenario three

4.4 Future Trends of Climate Change Effect on Food Inflation Rate in Africa by 2037.

By using three different scenarios, the study sought to assess how climate change will affect food inflation rate by the year 2037. But first, the forecast trends were presented in Appendix 8 to 16. Additionally, food inflation scenario one (FIS1) dealt with the effects of climate change (temperature, precipitation, and carbon dioxide emission) on food inflation by the year 2037. Food inflation scenario two (FIS2) looked at the effects of only confounding variables (food production, exchange rate, economic growth, food import, and population growth) on food inflation by the year 2037. The food inflation scenario three (FIS3) focused on the effects of climate change plus the confounding variables on food inflation by the year 2037. The study further compares statistical differences between the food inflation scenarios among the five main regions in Africa.

4.4.1 Forecast Trends from 2023 to 2037

An exponential smoothing forecast analysis was performed to predict climate change (temperature, precipitation, and carbon dioxide emission), confounding variables (food production, exchange, economic growth, food import, and population growth), and food inflation trends from the year 2023 to 2037 (Appendix 14 to Appendix 22). With regard to food inflation trends specifically, the results indicated that the rising food inflation rate was likely to occur from 2023 to 2037 (Appendix 14).

Concerning climate change from 2023 to 2037, specifically temperature and precipitation (Appendix 15 & 16), we expect both increasing and decreasing trends, as indicated by the average values. Similarly, concerning carbon dioxide emissions (Appendix 17), we anticipate a consistent increasing trend. Additionally, for other

confounding variables such as population growth, exchange rate, food production, food imports, and economic growth from 2023 to 2037, we expect fluctuating trends, including both increases and decreases, as indicated in the average values (Appendix 18 to 22).

Table 10: Future trends of climate change effect on food inflation rate in Africa by 2037

%Importance	Model 1	Model 2	Model 3
	(FIS1)	(FIS2)	(FIS3)
Temperature	32%		13%
Precipitation	40%		17%
Carbon Dioxide Emission	28%		7%
Food production		18%	11%
Exchange rate		13%	5%
Economic growth		11%	4%
Food import		25%	15%
Population growth		32%	28%
Number of Trees	100	100	100
MSE	6.79	8.14	8.99
Training			
R-Squared	0.90	0.85	0.75
P -value	0.00	0.00	0.00
Standard Value	0.04	0.01	0.06
Validation			
R -Squared	0.54	0.46	0.52
P value	0.00	0.05	0.02
Standard Value	0.09	0.11	0.14

Source: Boateng, 2024

4.4.2 Food inflation scenario one (FIS1): Effect of climate change on food inflation by the year 2037

The random forest-based regression and classification was used to assess the future trends of climate change (temperature, precipitation, and carbon dioxide emission) effect on food inflation rate in Africa by 2037. The result from the forest-based classification and regression analysis on future trends of climate change effect on food inflation in Africa by 2037 showed various levels of influence. The predicted level influences of climate change on food inflation rate in Africa by 2037 ranged from 40% to 28% (Table 10). The model statistics result indicated precipitation to have the highest (40%) influence on food inflation rate in Africa followed by temperature (32%) and carbon dioxide emission at 28%.

Food inflation scenario one produced a training R^2 of 0.90 with a p-value of 0.00 and a validation R^2 of 0.54 with a p-value of 0.00 (Table 10). From FIS1, countries likely to experience the highest percentage increase in food inflation rate by the year 2037 as a result of climate change were Mauritania (23.08%), Mali (21.40%), Kenya (21.31%), Chad (20.23%), Niger (18.62%), Somalia (19.21%), and Liberia (17.53%) as represented by 16.46 to 24.09 on the map (Figure 8; Appendix 5).

4.4.3 Food inflation scenario two (FIS2): Effects of confounding variables on food inflation by the year 2037

The forest-based classification and regression analysis on confounding variables (food production, exchange rate, economic growth, food import, and population growth) had a training R^2 of 0.85 and a p-value of 0.00 with validation R^2 of 0.46 (Table 9). Regarding the effect of confounding variables on food inflation rate by the year 2037, the forest-based classification and regression result indicated that

population growth (32%) is predicted to have the highest influence in Africa (Table 10).

This was followed by food import at 25%, food production at 18%, exchange rate at 13%, and economic growth with the least prediction at 11% (Table 10). From FIS2, Togo (-6.09%), Benin (-0.29%), Tanzania (2.70%), Algeria (3.37%), Egypt (4.96%), and Western Sahara (7.74%) were countries likely to experience the least percentage increase in food inflation rate as a result of confounding variable influences as represented by -7 to 7.80 on the map (Figure 8; Appendix 6).

4.4.4 Food inflation scenario three (FIS3): Effect of climate change plus confounding variables on food inflation by the year 2037

With regards to assessing the effect of climate change plus confounding variables on food inflation rate by the year 2037, the result indicated a significant change in the level of influence on food inflation rate in Africa. The model statistics on FIS3 indicated that cumulatively confounding variables are expected to have the highest influence of 61% on food inflation rate, while climate change is also expected to have least (39%) influence. The expected influence ranged from 5% to 28% with population growth predicted to have the highest (28%) influence on food inflation rate followed by precipitation (17%) (Table 10). In addition, food import, temperature and food production were also predicted to have next highest influence on food inflation rate by 15%, 13% and 11% respectively.

Furthermore, carbon dioxide emission (7%) is expected to have the next corresponding highest influence on food inflation rate while economic growth (5%) is predicted to have the least influence (Table 10). The model statistics produced a training R^2 value of 0.75 with a p-value of 0.00, and a validation R^2 value of 0.52 with a p-value

of 0.02 (Table 10). By the year 2037 based on FIS3, countries likely to be affected by a high percentage increase in food inflation rate in Africa were Ethiopia (51.77%), Somalia (47.44%), Nigeria (42.65%), Burkina Faso (39.34%) and Kenya (39.28%) as represented by 33.05 to 59.62 on the map (Figure 8; Appendix 7).

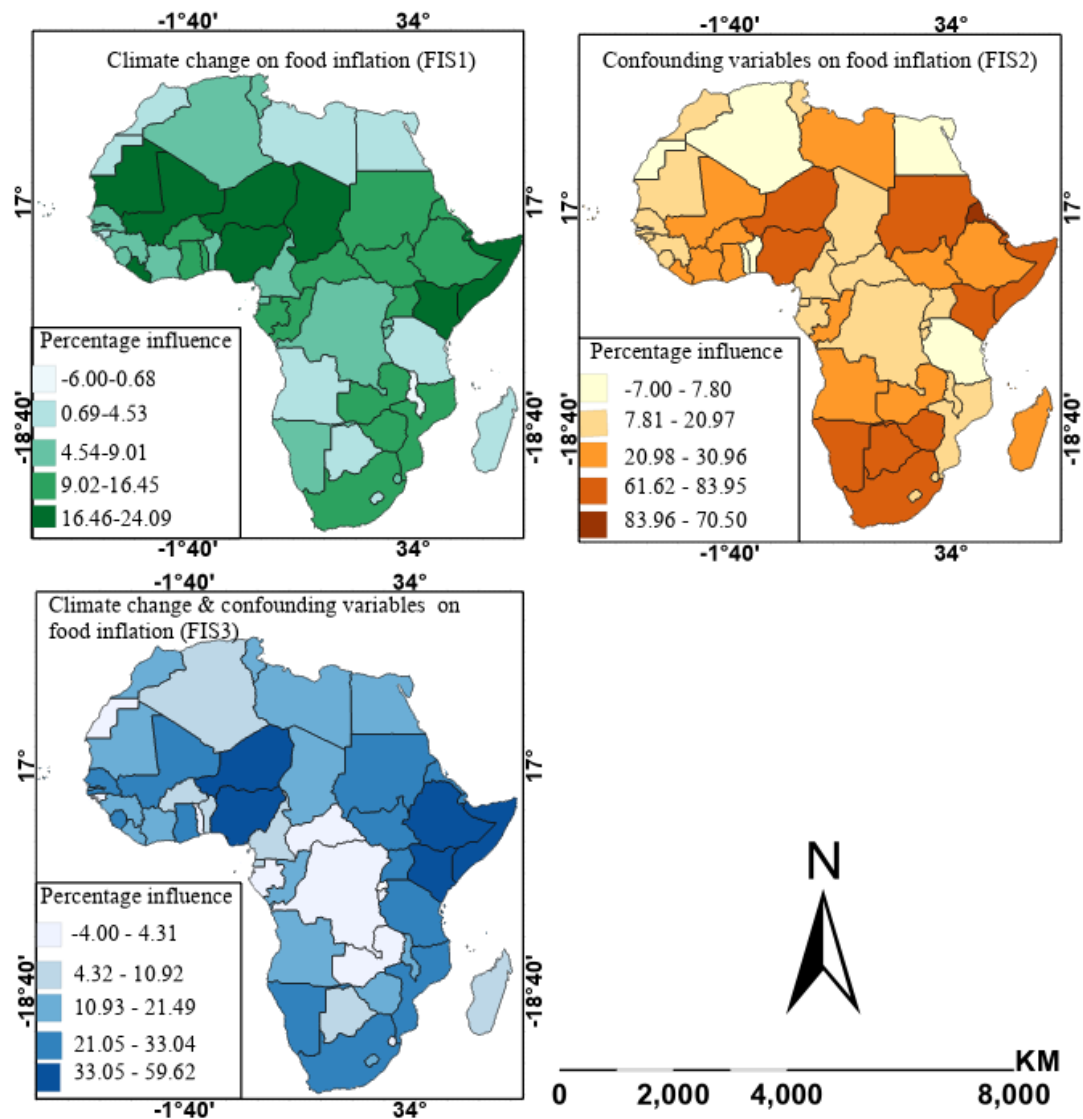


Figure 8: Differences between the effects of climate change on food inflation in Africa by 2037

Source: Boateng, 2024

4.4.6 Differences between the food inflation rate scenarios by the year 2037

Regarding the assessment of future trends of climate change's effect on food inflation by the year 2037, the study further sought to find out whether there is a statistical difference among the five main regions in Africa to each of the three food inflation scenarios (FIS1, FIS2, and FIS3) (Table 11). Based on the effect of climate change on food inflation (FIS1) by 2037, using one-way ANOVA analysis the Games-Howell post hoc result found statistically significant differences (MD=12.93, $p=0.03$) between West Africa and Southern Africa (Appendix 11). Following a similar pattern there were statistically significant differences (MD=8.26, $p=0.02$) established between West Africa and Central Africa with the same differences (MD=13.47, $p=0.01$) established between West Africa and North Africa (Appendix 11). The one-way ANOVA analysis result found West Africa [$m=19.23$] to have a statistically higher food inflation rate for FIS1 than Southern Africa [$M=6.32$]

The result also found a higher food inflation rate for West Africa ($m=19.23$) than Central Africa ($m=11.00$) for FIS1 (Table 11). All the one-way ANOVA analysis in which Games-Howell post hoc found to be statistically significant on FIS1 revealed food inflation rate in West Africa to be statistically higher than all the regions in Africa. In West Africa countries likely to experience the highest percentage increase in food inflation rate by 2037 as a result of climate change were Mauritania, Mali, Niger, Liberia, and Nigeria (Figure 8; Appendix 5).

On the other hand, with regards to the effect of climate change plus confounding variables on food inflation (FIS3) by 2037, using one-way ANOVA analysis the Games-Howell post hoc result indicated a statistically significant difference (MD=2.21, $p=0.03$) between Southern Africa and West Africa (Appendix 11). In line with this,

from Appendix 11 statistically significant differences ($MD=13.93$, $p=0.04$) were also found between West Africa and Central Africa, with a similar relationship ($MD=-10.82$, $p=0.02$) also established between West Africa and East Africa. In addition, for FIS3, food inflation rate in East Africa ($m=30.84$) was found to be statistically higher than in West Africa ($m=20.02$). Countries which will be affected most in East Africa by the effect of climate change plus confounding variables on food inflation by 2037 were Kenya and Somalia (Figure 8; Appendix 7).

Furthermore, in contrast to the aforementioned results it was therefore expected that, for FIS3, West Africa's ($m=20.02$). food inflation rate was found to be statistically higher than Southern Africa's ($m=17.81$) (Table 11). By the year 2037, the result also found a lower food inflation rate for Central Africa ($m=6.09$) than West Africa ($m=20.02$) for FIS3 (Table 11). The above findings from one-way ANOVA analysis results clearly show that only East Africa by 2037 is expected to have a higher food inflation rate than West Africa as result of the combined effect of climate change and confounding variables on food inflation.

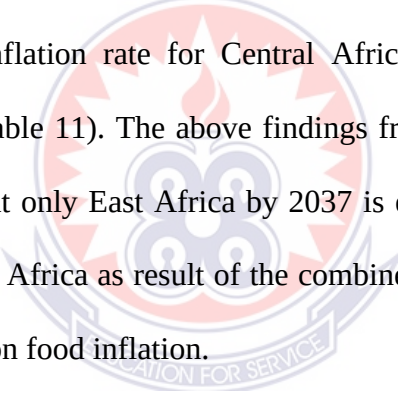


Table 11: One-way ANOVA analysis on regional differences on food inflation

Regions	Mean	Std. Deviation	Std. Error	95%CI Lower	95%CI Upper
FIS1					
Central Africa	11.00	2.59	0.91	9.21	12.79
East Africa	10.95	4.30	1.30	8.41	13.49
North Africa	5.78	1.62	0.73	4.36	7.22
Southern Africa	6.32	4.22	1.17	4.03	8.61
West Africa	19.23	4.08	0.99	17.32	21.20
FIS 2					
Central Africa	16.80	4.06	1.44	13.99	19.61
East Africa	27.66	9.86	2.97	21.83	33.49
North Africa	15.49	6.98	3.12	9.37	21.61
Southern Africa	29.25	8.41	2.33	24.67	33.83
West Africa	21.46	9.09	2.20	17.14	25.78
FIS 3					
Central Africa	6.088	6.59	2.33	1.52	10.66
East Africa	30.84	9.17	2.77	25.41	36.27
North Africa	16.00	2.77	1.24	13.57	18.43
Southern Africa	17.81	7.35	2.04	13.81	21.81
West Africa	20.02	9.57	2.32	15.47	24.57

Source: Boateng, 2024

FIS1 = Food inflation scenario one, FIS2 = Food inflation scenario two, FIS3 = Food inflation scenario three, CI =Confidence Interval, =Std =Standard Deviation

4.5 Discussion of Results

4.5.1 Spatial trends of food inflation

The spatial mean center analysis from 1992 to 2022 reveals significant fluctuations in food inflation rates, with the highest concentration recorded in 2008 at 64.11 and the lowest in 1992 at 26.42. The high food inflation rate in 2008 can be attributed to several global and local factors. According to Ha et al. (2020), the 2007-2008 global food crisis driven by rising oil prices, increased demand for biofuels, climate-related crop failures, and export restrictions in major food-producing countries were among the factors. Research has shown that these dynamics led to a global surge in food prices in 2007–2008 (Semenova, 2023; Sohag et al., 2023), which is probably

one of the main causes of the high rate of food inflation in Africa in 2008. Conversely, the low level of food inflation in 1992 can be attributed to more stable global food production and market conditions. Boyacı-Gündüz et al. (2021) argue that declining oil prices, improved agricultural yields, and the relaxation of export bans contributed to reduced global food prices between 1990 and 1995.

Over the past 30 years, this study's results revealed that food inflation rate has shown a diagonal northwest direction in the majority of the years, indicating a persistent upward trend marked by periodic fluctuations. According to the IMF (2021), this trend implies that food prices in Africa have generally increased over time, possibly due to several interrelated factors, and it is a major concern for Africa. These dynamics highlight the multifaceted nature of food prices in Africa, and studies have emphasized the need for comprehensive policy interventions focused on enhancing agricultural resilience, improving infrastructure, and stabilizing political environments to curb inflation sustainably (Okou et al.2022; Woldemichael et al.,2022). Numerous studies contend that in the absence of such actions, the rate of food inflation might keep rising, exacerbating the continent's economic problems (Okou et al.2022; Cheng et al., 2023).

In addition, the consistent presence of one peak at most over a majority of the years, indicates that food inflation in Africa has tended to be geographically localized concentrated, with inflation pressures affecting specific countries at a given time. This suggests that, for the most part, inflation in food prices has not been a widespread, diffuse phenomenon but rather more localized or clustered within certain areas. Also, this study's results identify East Africa as a significant hotspot for food inflation in Africa, indicating that this region is facing a particularly severe and persistent challenge in terms of rising food prices. Research has shown that the causes of this elevated food

inflation are multifaceted, with both local and global factors contributing to the worsening economic conditions (Kunawotor et al., 2022).

The first hypothesis (H_1) of the study sought to assess the persistence and disparities of food inflation in Africa from 1992 to 2022. The study showed that food inflation was prevalent in East Africa, with South Sudan emerging as the mean center country with a mean value of 50.91. These findings confirm a report by the World Food Programme [WFP] (2023), which indicated that between 2000 and 2018, East Africa recorded the highest average food inflation rate among African subregions, at around 20.3%. However, Saifaddin-Galal's (2023) research published in Statista (2023) showed that from 2000-2020 the highest food inflation rates were recorded in East and West Africa, at 24.3% and 21.7% respectively. This agrees with this study's finding that food inflation is most prevalent within East Africa.

Several studies have identified the most potential drivers of high food prices in the East African region. Hunter et al. (2017), Semenova (2023) and Sohag et al. (2023) argue that disruptions in food production and distribution in East African countries have resulted in increased food prices. These disruptions are attributed to factors such as rapid population growth, poor agricultural infrastructure, conflict and insecurity, and climate change. This holds true for the food availability theory by Sen (1981), which pointed out that food production and supply availability are foundational to every economy, especially in determining food prices.

In addition, East Africa's high dependence on food imports, coupled with global commodity price fluctuations as cited by Hunter et al. (2017), has made the region vulnerable to imported inflation, contributing to the overall high food inflation rates. This goes back to confirm food entitlement decline theory developed as a critique

of the dominant food availability decline theory by Sen (1981), which later argued that more important than food supply is whether people have adequate income and purchasing power to access available food and determine food prices (Sen, 1981). Sen highlighted that, despite a decline in food production during many food crises, these declines were insufficient to explain the significant increases in food prices. He argued entitlements and the ability to acquire food played a bigger role. Exchange rate, economic growth (GDP), population, and food export shape entitlements. Concerning South Sudan identified as the mean center country of high food inflation in East Africa is not surprising. Given its position as a landlocked country in the Horn of Africa, some studies have highlighted that the country is particularly vulnerable to the effects of desertification, erratic rainfall, and prolonged droughts, which negatively impact agricultural productivity (Bazame et al., 2022; Igbatayo et al., 2022).

4.5.2 Effect of climate change on food inflation

Climate change is increasingly recognized as a critical factor influencing food security, with its impacts manifesting through various socio-economic channels, including food inflation (Agnolucci et al., 2020; Gomez-Zavaglia et al., 2020). This issue is common in Africa, where the agricultural sector is among the key determinants of food price. These research findings confirm this study's result that climate change influences food inflation rate in Africa. Regarding the level of influence of climate change, the study findings revealed that temperature (47%) has the highest influence on food inflation rate in Africa, while precipitation (32%) and carbon dioxide emission (21%) had the least influence on food inflation rate.

This finding is in line with Chen et al's. (2019) study which found that among temperature, carbon dioxide emission and precipitation, temperature was indicated to

be most significantly associated with lower crop yields and higher food prices in South Asia. Chen et al's. (2019) study indicated that temperature was negatively significant at 5% to crop production, which led to a 36% increase in food prices supporting this study's finding that temperature has higher a significant influence on food inflation rate in Africa. Other studies have well established that higher temperatures adversely affect crop yields, reduce agricultural productivity, and disrupt food supply chains, which ultimately can lead to higher food prices. (Eck et al., 2020; Zhao et al., 2017).

This study's result that precipitation had the least influence on food inflation in Africa as compared to temperature seems to contradict some existing studies. Several studies have highlighted the significant impact of precipitation patterns among climate change variables on food production and food prices (Mitra & Chattopadhyay, 2017; Moessner, 2022). According to Maitah et al. (2021), climate change impact resulting in monsoon failures in India (especially in key agricultural regions like Maharashtra and Uttar Pradesh) were associated with an increase of 10-12% in food inflation rates. Thus, the failure of the monsoon rains directly decreases rice and wheat yields, and with this consequent increase in food inflation. Nonetheless, the finding that precipitation had the least impact on food inflation may be explained by the fact that many African countries have installed irrigation systems and raised crop varieties resistant to drought to adjust to erratic rainfall patterns (Wijerathna-Yapa & Pathirana, 2022).

In addition, this study's result that carbon dioxide emission had the least influence on food inflation in Africa as compared to temperature and precipitation can be attributed to these reasons. Africa's contribution to global carbon emissions is minimal compared to other continents, which studies have indicated that it may reduce

the direct influence of CO₂ on agricultural productivity (Griggs & Reguero, 2021; Teske et al., 2021). According to the International Energy Agency (IEA, 2020), Africa is responsible for only about 4% of global CO₂ emissions, while other regions, particularly North America, Europe, and Asia, contribute significantly more. As a result, the global CO₂ concentration increase, which has some impact on crop yields through enhanced photosynthesis (the CO₂ fertilization effect), is less pronounced in Africa (Griggs & Reguero, 2021). Also, Teske et al. (2021) emphasize that for many African countries, agriculture is highly dependent on the timing and amount of rainfall, which is far more susceptible to changes in rainfall patterns and rising temperature than to increases in atmospheric CO₂.

Comparing the differences in food inflation rate on a regional basis given the first food scenarios, the paired t-test analysis indicated that with the effect of climate change on food inflation, West Africa experienced the least food inflation rate compared to East and Southern Africa. This finding can be attributed to the compounded effects of prolonged droughts and extreme temperatures that East and Southern Africa have been facing in recent years. For instance, the Intergovernmental Panel on Climate Change (IPCC) reports that countries in the Horn of Africa, including Kenya, Somalia, Djibouti, Eritrea, South Sudan are increasingly experiencing severe droughts, which have drastically reduced agricultural yields and heightened food insecurity (IPCC, 2022). Similarly, Southern Africa has witnessed severe climate-related challenges, such as the El Niño-induced drought of 2015-2016, which had a devastating impact on food security, leading to a food crisis throughout the region.

It is worth noting that climate change's impact on food inflation is often compounded by other factors, such as population growth, economic growth, food

import, exchange rate, and food production (Martin, 2019; Fukase & Martin, 2020) which also play significant roles in influencing food price. By assessing the influences of climate change plus confounding variables on food inflation, this study's finding revealed that cumulatively, confounding variables had the highest influence (69%) on food inflation rate in Africa, while climate change had just 31%. This suggests that while climate change is a critical factor, the broader economic and structural conditions play a more dominant role in shaping food prices in Africa. This finding aligns with a growing body of studies that emphasizes the dominant role of economic and demographic factors in shaping food price dynamics, particularly in regions with rapidly expanding populations and economies (Hunter et al., 2017; Avtar et al., 2019). The result goes back to confirm the food entitlement decline theory by Sen (1981), who explains that the social, economic, and political dynamics are often more important than food supply in influencing food prices.

This study's also finds that, among all variables considered, food imports exert the most substantial influence on food inflation rate across the African continent. This finding is critical, as it highlights the role of global trade dynamics in shaping domestic food prices in Africa. Available studies show that Africa's dependence on food imports makes it particularly vulnerable to global market fluctuations, currency devaluations, and supply chain disruptions, all of which can exacerbate the impact of climate change on food prices. According to Tadesse et al. (2017) and Algieri et al. (2023), food import dependence not only increases the vulnerability of countries to global price shocks but also limits their ability to implement effective domestic policies to stabilize food prices. In this context, other factors act as a multiplier, intensifying the effects of global market volatility on local food inflation, particularly in import-dependent countries.

On the other hand, the relatively smaller influence of climate change, accounting for only 31% of the impact on food inflation rate, suggests that while climate change is a significant factor, its effects are often mediated through other variables. This is not to diminish the role of climate change, rather, it reflects the multifaceted nature of food inflation where environmental factors interplay with socio-economic conditions. In Kummu's (2020) view, while climate change affects agricultural productivity and food supply stability, its influence on food prices is often mediated by economic variables such as trade policies, market access, and infrastructural capacities.

Moreover, comparing the statistical difference among the five main regions in Africa, the pair test results study indicated that with the effect of climate change plus confounding variables influence on food inflation, West Africa experiences the lowest food inflation rate than Southern Africa. This finding is somewhat unexpected, as the studies often emphasize West Africa's susceptibility to food price surges due to rapid population growth, urbanization, and food import dependency (Nhemachena et al. 2020; Ndoye, et al. 2022). In addition, this studies also found that West Africa, despite experiencing a lower food inflation rate compared to Southern Africa, still experiences a higher food inflation rate than Central and East Africa. This suggests that while Southern Africa's situation is dire, West Africa's susceptibility to higher food prices remains pronounced. This finding contradicts the UN Office for the Coordination of Humanitarian Affairs (2022) report, which notes that the Horn of Africa is experiencing severe food price increases due to its longest drought in 40 years, compounded by political instability and ongoing conflicts, resulting in 36.4 million people suffering from hunger and 21.7 million needing food assistance.

4.5.3 Future trends of climate change effect on food inflation by the year 2037

Many countries have been projected to be at risk of experiencing extremely rising temperatures, erratic rainfall patterns, and rising carbon dioxide emissions (Maidment et al., 2015; Chen et al. 2023). Therefore, it's crucial to understand how these projections will affect food prices in the future. In accordance with this study's findings regarding the future trends of climate change's effect on food inflation by 2037, forecast result predicted precipitation (38%) to be the most significant factor to influence food inflation rate in Africa by the said period, compared to temperature (33%) and carbon dioxide emissions (29%). These findings align with other studies that emphasized the critical role of rainfall variability in agricultural productivity and food prices (Wen et al. 2017; Hussien, 2018).

Others have argued that irregular rainfall patterns have disrupted planting and harvesting cycles, leading to reduced yields and increased food prices (Ndlovu et al., 2020; Moges & Bhat 2021). For instance, Ndlovu, et al. (2021) demonstrated that uncertainties in farmers' production levels as a result of irregular rainfall patterns can lead to food shortages, driving down supply and increasing demand, subsequently raising food prices. This study finding holds true for the food availability theory by Sen (1981), who pointed out that food production and supply availability are foundational to every economy, especially in determining food prices.

Although rising temperatures and increased carbon dioxide emission levels can also affect agriculture productivity and influence food prices, the forecast results (temperature [32%], carbon dioxide emission [28%]) showed that impact is often less immediate compared to precipitation changes. With this, the Food and Agriculture Organization [FAO], (2021) noted that while temperature increases and emission level

can reduce yields, the direct effects of precipitation on growing seasons, water availability, and crop growth are more immediate to affect agriculture productivity which is a key factor in determining food price in mostly developing countries. This thus explains the reasons behind why most developing and developing countries have invest in irrigation infrastructure, climate-resilient agriculture, water management systems, early warning systems, flood and drought management infrastructure to mitigate the effects of irregular rainfall patterns.

Moreover, comparing the differences in food inflation rate on a regional basis given the first food inflation scenarios, the one-way ANOVA analysis indicated that with the effect of climate change on food inflation by 2037, West Africa is expected to experience the highest food inflation rate by 2037 compared to Central and Southern Africa. This projection is indicative of the region's acute vulnerability to climate change effects. The study by Odongo et al. (2022) supports this finding by highlighting that the Sahel region, found in the northern part of West Africa, frequently experiences prolonged droughts and erratic rainfall patterns, which adversely affect staple crop production and contribute to rising food prices. Similarly, the IPCC AR6 projects that by 2050, the Sahel region could experience a 20-30% increase in the frequency of extreme droughts, and this could cause spikes in food prices by 1–29% in affected areas (IPCC, 2022). Mauritania, Mali, Niger, Liberia, and Nigeria are likely to experience the highest percentage increase in food inflation rate by 2037 as a result of climate change. These projected findings are corroborated by various studies highlighting the specific vulnerabilities of these countries. For instance, Biasutti et al. (2019), together with Kew et al. (2021), established that as long as the Sahel continues to expand its territory, Mali and Niger will face frequent droughts with erratic rainfall, which will significantly affect crop yields due to their dependence on agriculture production.

Regarding the future trends of climate change plus confounding variable effect on food inflation by the year 2037, the model results further indicate that cumulatively, confounding variables, including exchange rate, economic growth (GDP), population growth, and food import, are expected to exert the highest influence on food inflation rate, accounting for 64% of the level of influence, while climate change is projected to have a 36% influence on food inflation rate. This finding is also consistent with other studies which have emphasized the multifactorial nature of food price dynamics. For instance, Taghizadeh-Hesary et al. (2019) points out that food prices in the eight Asian countries (Bangladesh, Indonesia, India, Japan, Sri Lanka, Thailand, and Vietnam) are influenced by a range of factors, including market policies, global trade, and macroeconomic stability.

Also, the relatively lower influence of climate change (36%) on food inflation as indicated by the model results suggests that while climate change is a critical factor, other variables such as exchange rate, economic growth (GDP), population, and food import play a more dominant role in driving food prices. This result reinforces the study's conceptual framework, which demonstrated that climate change, mediated through temperature, precipitation, and carbon dioxide emissions, influences agricultural production and can be a key factor in determining food prices. However, other factors, such as food imports, exchange rates, population growth, economic growth, and food production, which are indicated as control variables in the framework, can also influence food prices. This thus explains the reasons why both climate change and confounding variables were revealed to influence food prices in Africa in this study.

Specifically, assessing the effect of climate change plus confounding variables on food inflation by 2037 among variables used for the study the result showed that population growth by 2037 is predicted to have the highest influence on food inflation rate in Africa. This prediction aligns with the studies that underscore the role of demographic trends in driving food demand and prices. According to Dos Santos et al. (2017) and Kaba (2020) rapid population growth in developing regions, particularly in Africa, is a primary factor contributing to increased food demand, exerting upward pressure on prices. Additionally, Wudil et al. (2022) argue that the interplay between population growth and limited agricultural productivity in many African countries will exacerbate food security challenges, leading to higher food inflation rates. However, it is important to note that the relatively lower percentage attributed to climate change variable does not diminish its importance, as its effects may be more acute in certain regions or for specific crops.

Again, when comparing the differences in food inflation rate on a regional basis among the five main regions, the one-way ANOVA analysis revealed that except only East Africa, West Africa is expected to experience the highest food inflation rates by 2037 than those in Central and Southern. This study's findings can be attributed to factors like the expected projected higher population growth rate in the sub-Sahara (Kaba, 2020) and the susceptibility of the Sahel region agriculture experiencing prolonged droughts and erratic rainfall patterns (Giller, 2020). In addition, the Food and Agriculture Organization (FAO) noted that population growth, coupled with urbanization in major growing cities in West Africa, can significantly increase food demand, thereby affecting food prices (FAO, 2021).

Also, on the flip side, this study's results showing that East Africa is the only region expected to experience a higher food inflation rate than West Africa can be attributed to several reasons. Algieri et al. (2023) found that, in Africa, fluctuating currencies can increase the cost of imported agricultural inputs, while sluggish economic growth limits local investment in food production, which significantly exacerbates supply shortages. Hence the giants of East African economies, which studies have indicated to be experiencing persistently unstable exchange rates and weak economic growth (Mbam et al., 2020; Xue et al., 2021), in addition to frequent droughts and unpredictable rainfall patterns, can cause East Africa region to be expected to experience a higher incidence of food prices.



CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This is the concluding chapter of this study which places emphasis on four major sections. First, the entire study is summarised here with a greater focus on what the key findings of the study were. Secondly, based on the findings, conclusions were drawn, and the last section gave recommendations aimed at addressing the adverse effects associated with climate influences on food inflation in Africa. It also includes areas for further studies.

5.1 Summary

The relationship between climate change and agriculture production, food production, and food insecurity, in both developing and developed economies has been the subject of several theoretical and empirical research. However, no empirical studies have been conducted to spatially assess the effect of climate change on food inflation in Africa. The study therefore spatially assessed the effect of climate change on food inflation among 54 countries in Africa. The study specifically explored the spatial trends of food inflation in Africa from 1992 to 2022; assess the spatial effects of climate change on food inflation in Africa from 1992 to 2022; spatial projection of the future trends of climate change's effect on food inflation in Africa by 2037. The study was underpinned by food availability decline and food entitlement decline theory by Amartya Sen. The theories provided a useful theoretical foundation for the study.

The study adopted a positivist research philosophy with a descriptive research design because it involves measuring a wide range of concepts or predicting and

analysing trends and patterns. The research was conducted using secondary data. The datasets that were employed to conduct the study were climate change (temperature, carbon dioxide emission, and precipitation), food inflation, and other confounding variables (food production, food import, economic growth (GDP per growth), population growth, and exchange rate) and were sourced from WorldClimate Knowledge Portal (<https://climateknowledgeportal.worldbank.org/>), World Bank (<https://datacatalog.worldbank.org/>), and World Development Indicators Data (<https://databank.worldbank.org/source/world-development-indicators>).

In achieving the objective and hypothesis one of the studies, the mean center, incremental autocorrelation, standard distance ellipsoid, and gets-Ord hotspot analysis were used. Additionally, random forest-based classification and regression was used to achieved objective two. Also, the exponential smooth forecast and the random forest-based classification and regression were used to achieved objective three. The paired t-test analysis was further used to analysed the results of the random classification and regression. The mean of the statistical data that was generated by random forest-based classification and regression were compared across the sub-regions in Africa to achieved hypotheses two, three, four, and five.

5.2 Key findings of the study

The main findings of the study are summarized as follows:

Objective one explored the spatial trends of food inflation in Africa from 1992 to 2022.

- The spatial mean center analysis from 1992 to 2022 revealed that the highest concentration of food inflation rate occurred in 2008, reaching a rate of

64.11, while the lowest concentration was recorded in 1992 at a rate of 26.42. In 2008, the highest concentration of food inflation rate was observed in Zimbabwe, while in 1992, the lowest concentration of food inflation rate was found in Democratic Republic of the Congo.

- The Getis-Ord hotspot analysis of food inflation showed that, of the 54 countries, 40 were classified as non-significant hotspot zones and the remaining 14 as significant hotspot zones. Among the countries identified as significant hotspot zones, half (7) were located in East Africa.

The first hypothesis was that food inflation is more persistent in West Africa than any other region in Africa. The following key findings were discovered in achieving this hypothesis:

- East Africa had the highest occurrence of food inflation rate (1992-2022) than any region in Africa with South Sudan being the mean center country.
- East Africa has more significant hotspots than any other sub-region, with Ethiopia [Sig HS=90, Z=1.91, p=0.05], Eritrea [Sig HS=90, Z=2.13, p=0.03], and Sudan [Sig HS=90, Z=1.80, p=0.04] showing consistently high food inflation trends.

The second objective found that, in terms of the effect of climate change on food inflation in Africa, temperature has the highest influence on the food inflation rate, compared to precipitation and carbon dioxide emissions.

- Kenya, Somalia, and Eritrea in Africa were countries identified to be experiencing higher food inflation rates as a result of climate change.
- With the combined effect of climate change and confounding variables on food inflation, food import was found to have the highest influence on food

inflation rate, while economic growth had the least influence on food inflation rate in Africa.

The second hypothesis was that: climate change is more likely to increase food inflation rate in West Africa than any other region in Africa. The study revealed the following:

- The effect of climate change on food inflation revealed that West Africa experiences a lower food inflation rate compared to East Africa and Southern Africa.
- No statistical relationship existed between West Africa and North Africa as well as West Africa and Central Africa.

The third hypothesis was that: the effect of climate change plus confounding variables is more likely to increase food inflation in West African countries than any other countries in East, Central, North, and Southern Africa. The study revealed the following:

- The combined effect of climate change and confounding variables on food inflation shows that countries in West Africa experience the lowest food inflation rates compared to those in Southern Africa.
- However, contrary to this finding, the study results further revealed that, despite the influence of climate change and confounding variables, countries in West Africa still have a higher food inflation rate than those in Central Africa.

The third objective sought to find out that, in terms of the future trends of climate change's effect on food inflation by 2037, precipitation is predicted to have the

highest influence on food inflation rate in Africa, surpassing temperature and carbon dioxide emissions.

- Mauritania, Mali, Niger, Chad, Liberia, Gabon, Somalia, and Kenya were countries in Africa likely to experience the highest percentage increase in food inflation rate by 2037 as a result of climate change.

The forecast results indicate that by 2037, with the combined effect of climate change and confounding variables on food inflation in Africa, population growth is expected to have the highest influence on food inflation rate, while economic growth is predicted to have the least influence on food inflation rate in Africa

The fourth hypothesis was to model and forecast that climate change by 2037 is not likely to worsen food inflation in West Africa than any region in Africa. The study revealed the following:

- The effect of climate change is expected to increase the food inflation rate in West Africa more than in Southern Africa and Central Africa by 2037 in Africa.
- Mauritania, Mali, Niger, Liberia, and Nigeria were countries in West Africa likely to experience a high percentage increase in food inflation rate by the year 2037 as a result of climate change.

The fifth hypothesis was to model and forecast that climate change plus confounding variables by 2037 is not likely to worsen food inflation in West African countries than any other countries in East Africa, Central, North, and Southern Africa. The study revealed the following:

- The combined effect of climate change and confounding variables is expected to increase food inflation rate in East African countries by 2037, surpassing that of West African countries.
- However, in contrast to this finding, the results further indicate that by 2037, West African countries will experience a higher food inflation rate than any other countries in Central and Southern Africa.

5.3 Conclusion

The study draws the following conclusions from the major findings.

- The spatial trend concludes that the highest concentration of food inflation rate occurred in 2008, while the lowest concentration was observed in 1992.
- Food inflation is more persistent in East African countries than but least persistent in Central African countries.
- Temperature is the most significant climate change variable influencing food inflation rate in Africa, exerting a stronger influence than both precipitation and carbon dioxide emissions.
- Climate change is more likely to increase food inflation rate in East and Southern Africa regions than West Africa, but less likely to reduce food inflation rate in Central African countries than West African countries.
- Climate change, plus confounding variables is more likely to increase food inflation rate in West African countries than only Central African countries but more likely to increase food inflation rate in Southern Africa than West African countries.
- There is a shift in the future trends of climate change's effect on food inflation in Africa, with precipitation predicted to have the greatest

influence on food inflation rate by 2037, surpassing temperature and carbon dioxide emissions

- Also, the study concludes that climate change by 2037 is more likely to increase food inflation in West Africa than Central and Southern Africa.
- The effect of climate change by 2037, plus confounding variables will further increase the food inflation rate in only East African countries than in West African countries, but West African countries by 2037 would still experience the highest food inflation rate as a result of climate change plus confounding variables influences than countries in Central Africa and Southern Africa.

5.4 Recommendation

Based on the major findings and the conclusion drawn from the study, the following recommendations made:

- FAO, EAC (East African Community), and SADC (Southern African Development Community) should promote climate-resilient agriculture through improved seeds, advanced irrigation, and sustainable land management to reduce the impact of climate change on food inflation in Africa, especially in East and Southern regions.
- Through the African Climate Policy Centre (ACPC), AU, ECOWAS, and FAO should enforce policy frameworks that encourage climate-smart agriculture and assist smallholder farmers in embracing these methods while fostering knowledge exchange in Africa specifically in West Africa which is expected to experience a higher percentage increase in food inflation rate as a result of climate change by 2037.

- Furthermore, finance and agriculture ministries in each “at-risk countries” (Zimbabwe, Namibia and Botswana) alongside the Green Climate Fund (GCF) and the International Fund for Agricultural Development (IFAD), should allocate technical support and financial resources to initiatives that advance sustainable agricultural practices, helping to mitigate the impact of climate change on food prices.
- National agricultural ministries, trade authorities, and the FAO should prioritise policies that strengthen local food production such as subsidies, better access to inputs, and support for smallholder farmers in order to reduce reliance on food imports and stabilize food prices.
- Regional bodies like ECOWAS, EAC, and SADC, together with the UN and AU, should strengthen family planning programs by providing funding, contraceptives, and sexuality education to manage population growth and reduce its projected impact on food inflation in Africa by 2037.

5.5 Limitations of Study

Some countries lacked records for certain variables, and in some cases, the data was not available. To address these data gaps, the researcher estimated scores for these countries using spatial interpolation and machine learning algorithms, methods that are statistically robust and widely accepted.

5.6 Areas for further studies

Obtaining data on extreme weather events (such as heatwaves, droughts, and floods) proved difficult, preventing the framework from assessing the impact of these events on food inflation. Future studies could explore this impact on food

inflation if data on extreme weather events becomes available. Further research could also model the effect of food inflation on food insecurity.



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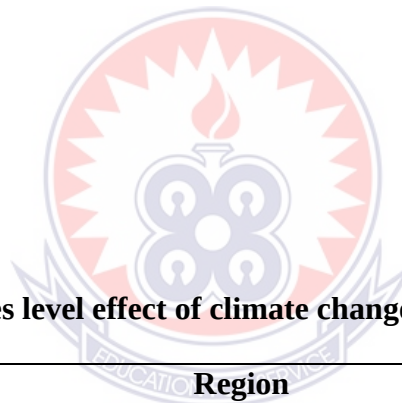


Appendix 1: **Results for Variance Inflation Factor (VIF) Test for**

Multicollinearity

Variable	VIF
Temperature	2.25
Carbon dioxide emission	2.03
Precipitation	1.40
Exchange rate	1.20
Food production	1.44
Food import	2.15
Economic growth	1.17
Population growth	1.43

Source: Boateng, 2024

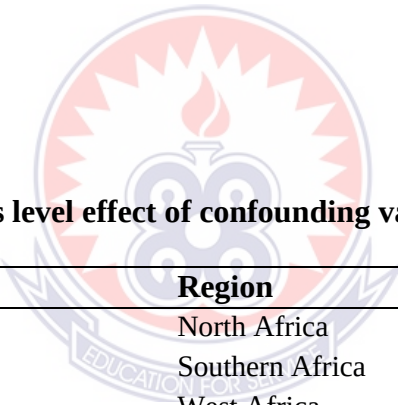


Appendix 2: Countries level effect of climate change on food inflation (FIS1)

Countries	Region	Percentage influence
Algeria	North Africa	20.21
Angola	Southern Africa	49.83
Benin	West Africa	13.33
Botswana	Southern Africa	22.04
Burkina Faso	West Africa	34.77
Burundi	East Africa	21.54
Cabo Verde	West Africa	16.52
Cameroon	Central Africa	12.79
Central African Republic	Central Africa	12.54
Chad	Central Africa	38.05
Comoros	Southern Africa	1.44
Côte d'Ivoire	West Africa	9.04
Democratic Republic of the Congo	Central Africa	1.80
Djibouti	East Africa	12.61
Egypt	North Africa	1.36
Equatorial Guinea	Central Africa	2.37
Eritrea	East Africa	59.05
Eswatini	Southern Africa	20.94

Ethiopia	East Africa	45.51
Gabon	Central Africa	2.47
Gambia	West Africa	10.32
Ghana	West Africa	12.44
Guinea	West Africa	24.95
Guinea-Bissau	West Africa	24.21
Kenya	East Africa	65.15
Lesotho	Southern Africa	24.77
Liberia	West Africa	25.04
Libya	North Africa	20.01
Madagascar	Southern Africa	6.93
Malawi	Southern Africa	30.67
Mali	West Africa	48.66
Mauritania	West Africa	26.39
Mauritius	Southern Africa	5.13
Morocco	North Africa	1.58
Mozambique	Southern Africa	48.23
Namibia	Southern Africa	41.58
Niger	West Africa	46.29
Nigeria	West Africa	14.21
Republic of the Congo	Central Africa	2.29
Rwanda	East Africa	21.33
Sao Tome and Principe	Central Africa	2.19
Senegal	West Africa	14.26
Seychelles	East Africa	7.49
Sierra Leone	West Africa	25.08
Somalia	East Africa	59.44
Southern Africa	Southern Africa	56.24
Southern Sudan	East Africa	46.24
Sudan	East Africa	44.49
Tanzania	East Africa	23.73
Togo	West Africa	10.09
Tunisia	North Africa	6.08
Uganda	East Africa	12.67
Western Sahara	West Africa	26.26
Zambia	Southern Africa	29.56
Zimbabwe	Southern Africa	20.54

Source: Boateng, 2024

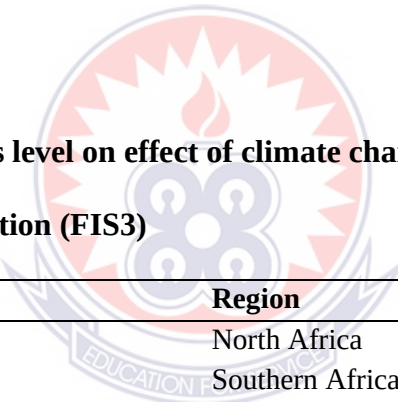
Appendix 3: Countries level effect of confounding variables on food inflation


Countries	Region	Percentage influence
Algeria	North Africa	22.56
Angola	Southern Africa	21.85
Benin	West Africa	6.62
Botswana	Southern Africa	45.13
Burkina Faso	West Africa	17.71
Burundi	East Africa	25.63
Cabo Verde	West Africa	95.16
Cameroon	Central Africa	8.40
Central African Republic	Central Africa	4.89
Chad	Central Africa	43.74
Comoros	Southern Africa	33.08
Côte d'Ivoire	West Africa	26.76
Democratic Republic of the Congo	Central Africa	2.03
Djibouti	East Africa	12.89
Egypt	North Africa	19.44
Equatorial Guinea	Central Africa	12.21
Eritrea	East Africa	19.60
Eswatini	Southern Africa	52.55
Ethiopia	East Africa	13.43
Gabon	Central Africa	24.83

Gambia	West Africa	15.20
Ghana	West Africa	18.83
Guinea	West Africa	10.68
Guinea-Bissau	West Africa	3.40
Kenya	East Africa	9.02
Lesotho	Southern Africa	10.68
Liberia	West Africa	55.40
Libya	North Africa	25.71
Madagascar	Southern Africa	24.47
Malawi	Southern Africa	11.67
Mali	West Africa	21.93
Mauritania	West Africa	28.38
Mauritius	Southern Africa	95.43
Morocco	North Africa	25.01
Mozambique	Southern Africa	28.59
Namibia	Southern Africa	44.79
Niger	West Africa	15.39
Nigeria	West Africa	27.41
Republic of the Congo	Central Africa	6.08
Rwanda	East Africa	51.22
Sao Tome and Principe	Central Africa	57.49
Senegal	West Africa	34.36
Seychelles	East Africa	29.64
Sierra Leone	West Africa	21.74
Somalia	East Africa	28.06
Southern Africa	Southern Africa	24.89
Southern Sudan	East Africa	24.18
Sudan	East Africa	51.63
Tanzania	East Africa	4.59
Togo	West Africa	6.09
Tunisia	North Africa	35.32
Uganda	East Africa	3.78
Western Sahara	West Africa	33.59
Zambia	Southern Africa	8.03
Zimbabwe	Southern Africa	62.26

Source: Boateng,2024

Appendix 4: Countries level on effect of climate change plus confounding influence on food inflation (FIS3)



Countries	Region	Percentage influence
Algeria	North Africa	14.63
Angola	Southern Africa	33.82
Benin	West Africa	13.18
Botswana	Southern Africa	47.77
Burkina Faso	West Africa	23.82
Burundi	East Africa	16.46
Cabo Verde	West Africa	50.30
Cameroon	Central Africa	8.41
Central African Republic	Central Africa	4.89
Chad	Central Africa	32.62
Comoros	Southern Africa	20.48
Côte d'Ivoire	West Africa	15.51
Democratic Republic of the Congo	Central Africa	6.68
Djibouti	East Africa	5.33
Egypt	North Africa	25.18
Equatorial Guinea	Central Africa	12.22
Eritrea	East Africa	30.13
Eswatini	Southern Africa	52.64
Ethiopia	East Africa	15.13
Gabon	Central Africa	24.84

Gambia	West Africa	10.23
Ghana	West Africa	13.34
Guinea	West Africa	18.57
Guinea-Bissau	West Africa	3.79
Kenya	East Africa	16.17
Lesotho	Southern Africa	55.67
Liberia	West Africa	12.90
Libya	North Africa	26.87
Madagascar	Southern Africa	26.83
Malawi	Southern Africa	8.63
Mali	West Africa	30.96
Mauritania	West Africa	27.42
Mauritius	Southern Africa	54.75
Morocco	North Africa	13.17
Mozambique	Southern Africa	27.38
Namibia	Southern Africa	52.97
Niger	West Africa	31.30
Nigeria	West Africa	32.34
Republic of the Congo	Central Africa	4.06
Rwanda	East Africa	46.15
Sao Tome and Principe	Central Africa	31.39
Senegal	West Africa	10.07
Seychelles	East Africa	21.53
Sierra Leone	West Africa	6.96
Somalia	East Africa	15.12
Southern Africa	Southern Africa	30.53
Southern Sudan	East Africa	10.92
Sudan	East Africa	36.59
Tanzania	East Africa	8.34
Togo	West Africa	14.49
Tunisia	North Africa	13.31
Uganda	East Africa	6.08
Western Sahara	West Africa	17.90
Zambia	Southern Africa	12.66
Zimbabwe	Southern Africa	53.59

Source: Boateng, 2024

Appendix 5: Countries level effect of climate change on food inflation by 2037**(FIS1)**

Countries	Regions	Percentage influence
Algeria	North Africa	7.35
Angola	Southern Africa	4.25
Benin	West Africa	5.02
Botswana	Southern Africa	1.55
Burkina Faso	West Africa	11.60
Burundi	East Africa	5.84
Cabo Verde	West Africa	2.82
Cameroon	Central Africa	7.82
Central African Republic	Central Africa	13.27
Chad	Central Africa	20.23
Comoros	Southern Africa	2.63
Côte d'Ivoire	West Africa	9.11
Democratic Republic of the Congo	Central Africa	8.41
Djibouti	East Africa	24.18
Egypt	North Africa	4.37
Equatorial Guinea	Central Africa	9.79
Eritrea	East Africa	10.65
Eswatini	Southern Africa	8.69
Ethiopia	East Africa	11.76
Gabon	Central Africa	10.23
Gambia	West Africa	8.59
Ghana	West Africa	10.93
Guinea	West Africa	6.17
Guinea-Bissau	West Africa	2.91
Kenya	East Africa	21.31
Lesotho	Southern Africa	2.17
Liberia	West Africa	17.53
Libya	North Africa	3.10
Madagascar	Southern Africa	1.30
Malawi	Southern Africa	-0.12
Mali	West Africa	21.40
Mauritania	West Africa	23.08
Mauritius	Southern Africa	4.58
Morocco	North Africa	3.20
Mozambique	Southern Africa	12.49
Namibia	Southern Africa	8.27
Niger	West Africa	18.62
Nigeria	West Africa	20.12
Republic of the Congo	Central Africa	10.70
Rwanda	East Africa	5.03
Sao Tome and Principe	Central Africa	6.18

Senegal	West Africa	7.01
Seychelles	East Africa	4.37
Sierra Leone	West Africa	9.04
Somalia	East Africa	19.21
South Africa	Southern Africa	11.82
South Sudan	East Africa	11.76
Sudan	East Africa	13.38
Tanzania	East Africa	0.94
Togo	West Africa	11.50
Tunisia	North Africa	8.09
Uganda	East Africa	12.47
Western Sahara	West Africa	4.39
Zambia	Southern Africa	10.62
Zimbabwe	Southern Africa	11.91

Source: Boateng,2024



Appendix 6: Countries level effect of confounding variables on food inflation by 2037

Countries	Regions	Percentage influence
Algeria	North Africa	3.37
Angola	Southern Africa	28.69
Benin	West Africa	-0.29
Botswana	Southern Africa	53.80
Burkina Faso	West Africa	29.34
Burundi	East Africa	18.08
Cabo Verde	West Africa	19.26
Cameroon	Central Africa	17.95
Central African Republic	Central Africa	14.74
Chad	Central Africa	17.69
Comoros	Southern Africa	31.46
Côte d'Ivoire	West Africa	30.61
Democratic Republic of the Congo	Central Africa	14.15
Djibouti	East Africa	38.07
Egypt	North Africa	4.96
Equatorial Guinea	Central Africa	13.14
Eritrea	East Africa	60.66
Eswatini	Southern Africa	12.39
Ethiopia	East Africa	30.76
Gabon	Central Africa	19.56
Gambia	West Africa	14.30
Ghana	West Africa	28.59
Guinea	West Africa	20.55
Guinea-Bissau	West Africa	20.44
Kenya	East Africa	39.55
Lesotho	Southern Africa	14.94
Liberia	West Africa	20.25
Libya	North Africa	26.22
Madagascar	Southern Africa	27.92
Malawi	Southern Africa	19.87
Mali	West Africa	28.10
Mauritania	West Africa	33.25
Mauritius	Southern Africa	20.12
Morocco	North Africa	19.62
Mozambique	Southern Africa	14.52
Namibia	Southern Africa	40.33
Niger	West Africa	39.72
Nigeria	West Africa	40.02
Republic of the Congo	Central Africa	27.84
Rwanda	East Africa	12.80
Sao Tome and Principe	Central Africa	5.16

Senegal	West Africa	12.39
Seychelles	East Africa	38.84
Sierra Leone	West Africa	14.14
Somalia	East Africa	40.61
South Africa	Southern Africa	40.42
South Sudan	East Africa	30.78
Sudan	East Africa	34.00
Tanzania	East Africa	2.70
Togo	West Africa	-6.09
Tunisia	North Africa	19.48
Uganda	East Africa	13.83
Western Sahara	West Africa	7.74
Zambia	Southern Africa	29.37
Zimbabwe	Southern Africa	33.83

Source: Boateng,2024



Appendix 7: Countries level on effect of climate change plus confounding influence on food inflation by 2037 (FIS3)

Countries	Regions	Percentage influence
Algeria	North Africa	9.28
Angola	Southern Africa	14.39
Benin	West Africa	9.27
Botswana	Southern Africa	10.85
Burkina Faso	West Africa	39.34
Burundi	East Africa	0.60
Cabo Verde	West Africa	13.95
Cameroon	Central Africa	7.68
Central African Republic	Central Africa	-1.69
Chad	Central Africa	19.14
Comoros	Southern Africa	2.53
Côte d'Ivoire	West Africa	11.83
Democratic Republic of the Congo	Central Africa	1.03
Djibouti	East Africa	31.10
Egypt	North Africa	12.73
Equatorial Guinea	Central Africa	5.74
Eritrea	East Africa	28.95
Eswatini	Southern Africa	3.50
Ethiopia	East Africa	51.77
Gabon	Central Africa	-0.71
Gambia	West Africa	15.08
Ghana	West Africa	28.49
Guinea	West Africa	20.66
Guinea-Bissau	West Africa	1.54
Kenya	East Africa	39.28
Lesotho	Southern Africa	18.85
Liberia	West Africa	18.33
Libya	North Africa	14.46
Madagascar	Southern Africa	10.92
Malawi	Southern Africa	15.10
Mali	West Africa	25.05
Mauritania	West Africa	18.17
Mauritius	Southern Africa	20.67
Morocco	North Africa	18.62
Mozambique	Southern Africa	31.31
Namibia	Southern Africa	29.73
Niger	West Africa	38.99
Nigeria	West Africa	42.65
Republic of the Congo	Central Africa	12.73
Rwanda	East Africa	59.88
Sao Tome and Principe	Central Africa	3.03

Senegal	West Africa	28.48
Seychelles	East Africa	26.25
Sierra Leone	West Africa	25.69
Somalia	East Africa	47.44
South Africa	Southern Africa	28.58
South Sudan	East Africa	30.09
Sudan	East Africa	25.90
Tanzania	East Africa	27.27
Togo	West Africa	-3.72
Tunisia	North Africa	15.39
Uganda	East Africa	29.48
Western Sahara	West Africa	4.30
Zambia	Southern Africa	2.95
Zimbabwe	Southern Africa	16.19

Source: Boateng, 2024



Appendix 8: Games Howell Post Hoc analysis on regional differences of the effect of climate change on food inflation (FIS1)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					Lower Bound	Upper Bound
Central Africa	East Africa	-15.60	6.72	0.03	-43.06	-2.14
	North Africa	2.99	8.36	0.04	26.48	32.47
	Southern Africa	-18.07	6.66	0.06	-38.19	-2.05
	West Africa	-16.01	5.30	0.07	-32.93	0.90
East Africa	Central Africa	15.60	6.72	0.03	2.14	43.06
	North Africa	18.60	8.54	0.09	-3.81	55.00
	Southern Africa	-2.47	6.88	0.02	-15.90	-24.96
	West Africa	3.59	5.57	0.03	10.50	23.68
North Africa	Central Africa	-2.99	8.36	0.04	-32.47	-26.48
	East Africa	-18.60	8.54	0.09	-55.00	-3.81
	Sothorn Africa	-21.07	8.50	0.19	-50.33	-8.20
	West Africa	-19.01	7.48	0.10	-48.54	-10.52
Southern Africa	Central Africa	18.07	6.66	0.06	2.05	38.19
	East Africa	-4.53	6.88	0.02	-24.96	15.90
	North Africa	21.06	8.50	0.19	-8.20	50.33
	West Africa	2.06	5.50	0.04	-14.49	18.60
West Africa	Central Africa	16.01	5.30	0.07	7.90	32.93
	East Africa	-3.59	5.57	0.03	-23.68	-10.50
	North Africa	19.01	7.48	0.10	10.52	48.54
	Southern Africa	-6.06	5.50	0.04	-16.72	-14.49

Appendix 9: Games Howell Post Hoc analysis on regional differences of the effect of confounding variables on food inflation (FIS2)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					Lower Bound	Upper Bound
Central Africa	East Africa	-5.91	7.38	0.17	-35.78	23.96
	North Africa	-12.07	6.70	0.05	-41.20	17.06
	Southern Africa	-13.92	7.26	0.55	-44.08	15.27
	West Africa	-7.95	7.10	0.40	-37.29	21.39
East Africa	Central Africa	5.91	7.38	0.17	-23.96	35.78
	North Africa	-6.15	3.91	0.03	-24.47	12.14
	Southern Africa	-8.01	4.71	0.01	-28.42	11.42
	West Africa	-2.04	4.49	0.20	-21.12	17.04
North Africa	Central Africa	12.07	6.70	0.05	-17.06	41.20
	East Africa	6.15	3.91	0.03	-12.14	24.47
	Sothorn Africa	-1.84	2.73	0.19	-20.10	15.43
	West Africa	4.12	3.47	0.34	-12.55	20.79
Southern Africa	Central Africa	13.92	7.26	0.55	-15.27	44.08
	East Africa	8.01	5.71	0.01	-11.42	28.42
	North Africa	1.84	3.73	0.19	-15.43	20.10
	West Africa	5.97	4.32	0.04	-12.09	25.01
West Africa	Central Africa	7.95	7.10	0.40	-21.40	37.29
	East Africa	2.04	4.49	0.20	-17.04	21.12
	North Africa	-4.12	3.47	0.34	-20.79	12.55
	Southern Africa	-5.97	4.32	0.04	-25.01	12.09

Appendix 10: Games Howell Post Hoc analysis on regional differences of the effect of climate change plus confounding influence on food inflation (FIS3)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					Lower Bound	Upper Bound
Central Africa	East Africa	-6.55	10.40	0.17	-39.68	26.58
	North Africa	-13.39	9.65	0.05	-45.69	18.91
	Southern Africa	-15.98	10.27	0.07	-48.89	16.93
	West Africa	-8.82	10.09	0.00	-41.36	23.72
East Africa	Central Africa	6.55	10.40	0.17	-26.58	39.68
	North Africa	-6.84	6.56	0.13	-27.14	13.47
	Southern Africa	-9.43	7.44	0.01	-31.52	12.67
	West Africa	-2.26	7.20	0.07	-23.42	18.89
North Africa	Central Africa	13.39	9.65	0.05	-18.91	45.69
	East Africa	6.84	6.56	0.13	-13.47	27.14
	Sothorn Africa	-2.59	6.35	0.09	-22.30	17.11
	West Africa	4.57	6.06	0.14	-13.92	23.06
Southern Africa	Central Africa	15.98	10.27	0.07	-16.93	48.89
	East Africa	9.43	7.44	0.01	-12.67	31.52
	North Africa	2.59	6.35	0.09	-17.11	22.30
	West Africa	7.16	7.01	0.04	-13.41	27.73
West Africa	Central Africa	8.82	10.09	0.00	-23.72	41.36
	East Africa	2.26	7.20	0.07	-18.89	23.42
	North Africa	-4.57	6.06	0.14	-23.06	13.92
	Southern Africa	-7.16	7.01	0.04	-27.73	13.41

Appendix 11: Games Howell Post Hoc analysis on regional differences of the effect of climate change on food inflation by 2037 (FIS3)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					Lower Bound	Upper Bound
Central Africa	East Africa	0.06	2.27	0.78	-6.46	7.37
	North Africa	5.22	1.67	0.04	0.22	11.02
	Southern Africa	4.68	2.12	0.16	-1.31	11.46
	West Africa	-8.26	1.92	0.02	-17.60	5.89
East Africa	Central Africa	-0.06	2.27	0.08	-7.37	6.46
	North Africa	5.16	2.12	0.16	-0.46	11.78
	Southern Africa	4.62	2.50	0.03	1.81	11.05
	West Africa	-8.31	2.33	0.06	-15.26	-4.64
North Africa	Central Africa	-5.22	1.67	0.04	-11.02	-0.22
	East Africa	-5.16	2.12	0.16	-11.78	0.46
	Sothern Africa	-0.54	1.97	0.09	-6.58	5.50
	West Africa	-13.47	1.75	0.10	-19.79	-0.16
Southern Africa	Central Africa	-4.68	2.12	0.16	-11.46	1.31
	East Africa	-4.62	2.50	0.03	-11.05	-1.81
	North Africa	0.54	1.97	0.09	-5.50	6.58
	West Africa	-12.93	2.19	0.03	-19.35	7.49
West Africa	Central Africa	8.26	1.92	0.02	-5.89	17.60
	East Africa	8.31	2.33	0.06	4.64	15.26
	North Africa	13.47	1.75	0.10	6.16	19.79
	Southern Africa	12.93	2.19	0.03	-7.49	19.35

Appendix 12: Games Howell Post Hoc analysis on regional differences of the effect of confounding variables on food inflation by 2037 (FIS3)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					Lower Bound	Upper Bound
Central Africa	East Africa	-10.86	4.71	0.00	-25.53	-3.82
	North Africa	1.32	4.91	0.08	-17.40	20.04
	Southern Africa	-12.45	3.91	0.04	-24.26	-0.64
	West Africa	-4.65	3.76	0.07	-15.76	6.45
East Africa	Central Africa	10.86	4.71	0.00	1.82	25.53
	North Africa	12.17	6.16	0.07	-7.77	32.11
	Southern Africa	-1.59	5.40	0.08	-14.76	14.57
	West Africa	6.20	5.29	0.03	1.60	16.01
North Africa	Central Africa	-1.32	4.91	0.08	-20.04	17.40
	East Africa	-12.17	6.16	0.07	-32.11	7.77
	Sothorn Africa	-13.77	5.57	0.08	-32.59	5.05
	West Africa	-5.97	5.46	0.09	-13.59	1.65
Southern Africa	Central Africa	12.45	3.91	0.04	2.64	24.26
	East Africa	1.59	5.40	0.08	-14.57	17.76
	North Africa	13.77	5.57	0.08	-5.05	32.59
	West Africa	7.80	4.59	0.04	3.60	21.19
West Africa	Central Africa	4.65	3.76	0.07	-6.45	15.76
	East Africa	-6.20	5.29	0.03	-16.01	-1.60
	North Africa	5.97	5.46	0.09	-1.65	13.59
	Southern Africa	-7.80	4.59	0.04	-21.19	-3.60

Appendix 13: Games Howell Post Hoc analysis on regional differences of the effect of climate change plus confounding variables on food inflation by 2037 (FIS3)

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% CI	
					Lower Bound	Upper Bound
Central Africa	East Africa	-24.75	5.16	0.00	-40.46	-9.04
	North Africa	-9.92	3.77	0.07	-22.29	2.45
	Southern Africa	-11.72	4.42	0.07	-25.24	1.80
	West Africa	-13.93	4.70	0.04	-28.03	4.16
East Africa	Central Africa	24.75	5.16	0.00	9.04	40.46
	North Africa	14.84	4.33	0.03	1.22	28.45
	Southern Africa	13.03	4.91	0.03	1.72	27.78
	West Africa	10.82	5.16	0.03	4.48	26.11
North Africa	Central Africa	9.92	3.77	0.07	-2.45	22.29
	East Africa	-14.84	4.33	0.03	-28.45	-1.22
	Sothorn Africa	-1.81	3.41	0.08	-12.25	8.64
	West Africa	-4.02	3.76	0.08	-15.27	7.23
Southern Africa	Central Africa	11.72	4.42	0.07	-1.80	25.24
	East Africa	-13.03	4.91	0.03	-27.78	-1.72
	North Africa	1.81	3.41	0.08	-8.64	12.25
	West Africa	-2.21	2.41	0.04	-6.08	-1.65
West Africa	Central Africa	13.93	4.70	0.04	4.16	28.03
	East Africa	-10.82	5.16	0.02	-26.11	-4.48
	North Africa	4.02	3.76	0.08	-7.23	15.27
	Southern Africa	2.21	2.41	0.03	1.65	6.08

Appendix 14: Food inflation forecast from 2023 to 2037

	All				West Africa				East Africa				Central Africa				South Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	-3.5	70.9	17.6	5.7	-1.7	65.1	20.2	5.4	0.0	89.4	54.3	16.9	-2.9	10.4	1.0	4.2	2.2	12.3	7.8	4.0	-3.5	17.9	4.6	5.7
2024	-2.5	70.8	18.4	5.5	0.0	26.8	24.1	6.2	-2.4	83.9	53.3	17.6	-3.1	10.5	1.4	4.3	2.6	12.3	8.0	3.8	-2.5	17.8	5.3	5.5
2025	0.0	70.7	19.2	5.0	-2.2	68.5	27.0	7.4	-4.8	84.3	52.6	17.9	-2.7	10.5	3.0	4.7	2.9	12.3	8.2	3.6	0.0	17.7	5.1	5.0
2026	-0.5	70.6	20.6	5.3	0.0	61.2	30.5	8.3	0.0	88.5	55.4	17.4	0.01	10.5	3.5	3.6	3.3	12.3	8.4	3.5	-0.5	17.6	5.4	5.3
2027	-4.1	70.5	20.6	5.4	-2.7	61.9	34.6	10.2	0.0	88.7	54.8	17.6	-4.0	10.6	0.5	4.6	3.7	12.3	8.6	3.3	-4.1	17.5	4.7	5.4
2028	-3.6	70.4	21.4	5.9	0.0	73.6	37.3	11.4	0.0	82.9	55.4	17.7	-4.0	10.6	0.8	4.5	4.0	12.3	8.8	3.2	-3.6	17.4	4.6	5.9
2029	0.0	70.3	22.6	5.0	-3.1	45.3	41.0	12.4	-7.8	82.8	52.8	17.4	-3.3	10.6	2.0	4.4	4.4	12.3	9.0	3.1	0.0	17.3	5.0	5.0
2030	-1.5	70.2	22.7	5.4	0.0	47.0	44.9	13.3	-10.1	86.9	54.0	17.4	-5.1	10.6	0.4	4.8	4.8	12.3	9.2	3.0	-1.5	17.2	4.9	5.4
2031	-5.0	70.1	23.4	5.5	-3.5	58.7	47.8	14.5	0.0	86.7	54.9	17.0	-5.0	10.7	0.3	4.7	5.1	12.3	9.4	2.9	-5.0	17.1	4.6	5.5
2032	-4.3	70.1	24.4	5.7	0	56.3	51.3	16.5	0.0	80.7	55.1	17.2	-5.0	10.7	1.4	4.7	5.5	12.3	9.6	2.8	-4.3	17.1	4.7	5.7
2033	-3.8	70.0	25.0	5.5	-4.0	62.0	55.4	17.4	0.0	80.8	54.2	17.3	-3.8	10.7	1.4	4.	5.9	12.3	9.8	2.7	-3.8	17.0	4.3	5.5
2034	-2.4	70.0	26.2	5.5	0.0	63.7	58.1	18.6	-12.6	84.2	54.9	17.4	0.0	10.7	3.2	3.6	6.3	12.7	10.0	2.7	-2.4	17.0	4.9	5.5
2035	-6.0	60.9	26.2	5.6	-4.4	65.4	61.8	19.6	-14.8	83.8	53.8	17.6	-6.1	10.7	1.1	5.7	6.6	13.1	10.2	2.6	-6.0	16.9	4.2	5.6
2036	-5.2	60.9	27.3	5.7	0.0	77.1	65.7	20.5	-0.2	87.5	55.3	17.2	-6.1	10.7	0.2	4.9	7.0	13.6	10.4	2.6	-5.2	16.9	4.7	5.7
2037	-4.3	70.1	27.4	5.7	0	60.3	65.8	16.5	0.0	80.7	55.3	17.2	-5.0	10.7	0.4	4.7	5.5	12.3	10.6	2.8	-4.3	17.1	4.7	5.7

Source: Boateng,2024

Min=Minimum, Max =Maximum, Avg=Average, SD=Standard Deviation

Appendix 15: Temperature forecast from 2023 to 2036

	All				West Africa				East Africa				Central Africa				Southern Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	11.9	27.7	22.9	3.15	21.4	27.7	25.9	1.62	18.1	26.9	23.7	2.8	22.9	26.1	23.7	1.03	11.9	22.9	20.1	2.85	17.5	22.5	20.9	2.0
2024	10.7	25.1	20.7	2.8	18.9	25.1	23.4	1.5	16.1	24.2	21.4	2.4	20.5	23.5	21.5	0.81	10.7	20.8	18.0	2.5	15.3	12.3	19.2	2.3
2025	12.1	27.8	23.1	3.1	21.5	27.8	26.2	1.6	18.2	27.5	23.8	2.8	23.1	26.2	24	0.97	12.1	23.2	20.3	2.9	17.8	22.6	21.1	1.9
2026	11.9	23.2	22.8	3.13	21.3	27.6	25.8	1.6	18.0	26.9	23.6	2.8	22.8	26.0	23.7	1.02	11.9	22.8	20.0	2.8	17.5	22.5	20.9	2.0
2027	10.7	25.1	21.0	2.8	18.8	25.1	25.1	1.5	16.0	24.1	21.3	2.4	20.4	23.2	21.4	0.8	10.7	20.7	18.0	2.6	15.3	21.3	19.2	2.3
2028	27.7	12.1	23.0	3.1	21.4	27.7	26	1.6	18.1	27.1	23.7	2.8	23.0	26.1	23.9	0.96	12.1	23.1	20.3	2.9	17.8	22.6	21.1	1.9
2029	11.9	27.5	22.8	3.1	21.2	27.5	25.8	1.6	18	26.8	23.6	2.8	22.7	25.9	23.6	1.02	11.9	22.8	20.0	2.8	17.5	22.4	20.9	2.0
2030	10.7	25.1	20.5	2.8	18.8	25.0	23.2	1.5	15.9	24.9	21.1	2.4	20.3	23.1	21.3	0.8	10.7	20.6	17.9	2.5	15.3	21.3	19.1	2.3
2031	12.1	27.6	22.9	3.1	21.4	27.6	25.9	1.6	18.1	27.0	23.7	2.8	23.0	26.0	23.8	0.96	12.1	23.1	20.2	2.7	17.8	22.5	21	1.9
2032	11.9	27.5	22.7	3.1	21.2	27.5	25.7	1.6	17.9	26.7	23.5	2.8	22.6	25.8	23.5	1.01	11.9	22.7	19.9	2.8	17.4	22.4	20.8	2.0
2033	10.7	24.9	20.5	2.8	18.7	24.9	23.2	1.5	15.9	24.0	21.2	2.4	20.3	23.0	21.3	0.8	10.7	20.5	17.9	2.5	15.3	21.3	19.1	2.2
2034	12.1	27.5	22.9	3.1	21.3	27.5	25.8	1.6	18	26.9	23.6	2.8	22.9	25.9	23.9	0.95	12.1	23.0	20.1	2.8	17.8	22.4	21.0	1.7
2035	11.9	27.4	23.0	3.1	21.1	21.1	27.4	1.6	17.8	26.7	23.4	2.8	22.5	25.8	23.5	1.0	11.9	22.6	19.9	2.8	17.4	22.3	20.8	1.9
2036	10.7	24.9	21.0	2.8	18.6	24.9	23.1	1.5	15.8	23.9	21.7	2.4	20.2	22.9	21.2	0.8	11.9	22.6	19.9	2.8	15.3	21.3	19.1	2.3
2037	10.7	25.1	20.7	3.10	18.9	25.1	23.4	1.5	16.1	24.2	21.4	2.4	20.5	23.5	21.5	0.8	10.7	20.8	18.0	2.5	15.3	12.3	19.2	2.2

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Avg =Average, SD=Standard Deviation

Appendix 16: Precipitation forecast from 2023 to 2036

	ALL				West Africa				East Africa				Central Africa				South Africa				North Africa	
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	min	Max	Avg	SD	Min	Max
2023	20.6	2369.1	904.9	647.4	99.9	2369.1	1065.9	694.7	199.2	1422.8	819	454.1	358.8	2209.9	1572.3	571.8	310.3	2004.7	956.9	506.4	20.6	219.3
2024	20.5	2479.2	859.8	621.6	86.3	2479.2	1030.6	678.7	187.8	1422.1	784.9	420.3	302.3	2005.7	1471.9	551.8	257.5	2017.5	898.1	513.5	20.5	278.4
2025	20.5	2316.8	897.6	643.1	92.6	2316.8	1044.2	687.1	197	142.4	832.4	460.2	368.0	2229.8	1557.6	558.0	265.7	2009.9	949.9	515.1	20.5	217.7
2026	20.5	2476.6	907.5	653.4	79	2476.6	1086.9	715.3	185.6	1420.8	820.9	456.4	360.6	2184.2	1567.1	566.0	314.7	2011.8	948.6	508.9	20.5	270.5
2027	20.5	2314.3	854.3	613.5	85.3	2314.3	1009.5	654.4	194.8	1420.3	786.4	421.6	304.1	1980.2	1466.7	546.6	261.9	2013.2	906.4	509.5	20.5	204
2028	20.5	2474.1	902.7	648.9	71.7	2474.1	1074.3	707.1	183.4	1419.9	834.3	462.8	368.8	2204.6	1552.5	552.2	270.0	2006.2	941.6	516.9	20.5	263.2
2029	20.5	2353.2	897.5	646.5	77.9	2353.2	1049	696.6	192.6	1419.5	822.5	458.4	362.5	2159.1	1562.1	560.5	319.0	2017.5	957.0	504.9	20.5	196.4
2030	20.5	2471.9	857.0	620.4	64.4	2471.9	1030.6	678.6	181.3	1419.2	788.4	423.6	305.9	1955.3	1461.7	541.7	266.2	2000.9	898.2	510.2	20.5	255.5
2031	20.5	2309.7	896.4	641.8	70.6	2309.7	1053.3	685.1	190.6	1432.9	836.0	464.9	371.7	2179.9	1547.6	546.6	274.3	2021.8	950.1	513.2	20.5	188.8
2032	20.5	2469.7	829.9	652.3	57.1	2469.7	1079.3	716.2	179.2	1418.7	460.9	824.5	364.3	2134.6	1557.3	555.2	323.3	1995.7	948.8	506.7	20.5	247.9
2033	20.5	2307.6	847.2	612.6	63.3	2307.6	992.8	656.1	188.5	1418.5	790.1	425.0	307.8	1931.0	1457.0	537.0	270.5	2026.1	906.7	507.6	20.5	181.2
2034	20.5	2467.7	899.3	648.1	49.8	2467.7	1074.6	706.7	177.2	1446.0	838	467.6	373.5	2155.7	1543.0	541.3	278.7	1990.7	942	514.2	20.5	240.5
2035	20.5	2338.7	896.5	645.7	56	2338.7	1058.5	694.9	186.5	1418.1	826.2	463	366.1	2110.7	1552.7	550.2	327.6	2030.4	957.4	504	20.5	173.6
2036	20.5	2465.8	852.5	619.5	42.5	2465.8	1023.3	679.8	175.2	1418.0	792.1	427.2	309.6	1907.2	1452.5	632.5	274.8	1985.9	898.7	507.6	20.5	237.7
2037	20.5	2479.2	859.8	621.6	86.3	2479.2	1030.6	678.7	187.8	1422.1	784.9	420.3	302.3	2005.7	1471.9	551.8	257.5	2017.5	898.1	513.5	20.5	278.4

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Sum =Sum, SD=Standard Deviation



Appendix 17: Carbon dioxide emission forecast from 2023 to 2037

	All				West Africa				East Africa				Central Africa				Southern Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	71.9	466.5	350.2	133.5	71.9	216.4	281.4	392.8	261.1	222.1	347.3	89.7	124.3	109.4	110.2	25.2	255.0	466.5	414.1	127.8	118.1	236.6	112.2	873.7
2024	73.2	471.9	364.2	141.4	73.2	303.2	689.5	2870	236.3	227.7	372.7	92.7	118.0	109.9	112.7	25.2	389.6	471.9	419.4	129.4	122.6	240.3	114.8	88.6
2025	74.8	480.4	362.1	154.0					265.9	233.4	391.1	95.7	126.4	110.8	115.7	26.9	324.1	480.4	427.1	131.4	127.3	244.1	115.5	89.9
2026	76.2	485.4	367.5	162.9	74.8	302.5	348.2	289.8	268.2	239.0	423.5	98.4	120.9	111.4	117.6	26.6	358.7	485.4	431.8	133.1	132.2	248.8	117.5	90.4
2027	77.7	495.8	372.3	176.6	76.2	310.6	353.1	298.9	270.3	244.7	448.8	101.4	128.4	113.2	119.2	26.5	393.3	495.8	440.1	135.2	136.4	252.6	1182.4	92.0
2028	79.0	499.9	535.7	183.4	77.7	326.8	354.8	297.6	272.3	251.7	473.0	104.4	122.0	113.8	121.8	26.2	427.9	499.9	444.5	136.9	140.9	256.4	119.8	93.6
2029	80.6	509.6	382.3	197.5	79	341	359.2	302.4	274.2	262.6	499.2	108.2	130.4	111.7	124.3	27.5	432.5	509.6	453.7	139.1	145.7	261.1	120.9	94.7
2030	81.9	513.3	387.0	204.2	80.6	353.4	361.4	305.9	276.1	272.4	424.4	111.5	124.0	115.2	126.8	27.1	447.1	513.3	457.2	140.0	149.0	265.9	122.1	96.7
2031	83.4	523.9	392.9	2177	81.9	363.9	366.4	310.3	277.8	283.3	449.5	114.1	132.4	117.1	129.3	27.5	451.7	523.9	465.7	143.3	153.8	269.6	123.6	97.7
2032	84.7	527.6	397.3	225.3	83.4	376.6	367.3	312.5	279.5	294.1	474.6	117.9	126.0	117.6	131.9	27.8	466.3	527.6	469.6	144.4	157.1	273.4	125.6	98.7
2033	86.2	537.6	402.8	238.3	84.7	387.4	372.9	317.4	281.0	305.0	499.7	120.6	134.4	118.5	133.5	28.3	467.8	537.6	478.5	147.8	162.9	277.1	126.9	100.9
2034	87.6	541.0	407.6	245.7	86.2	399.5	373.5	320.4	282.5	315.8	402.7	123.1	128.0	119.0	135.4	28.2	475.4	542.6	482.9	148.3	166.4	281.9	127..2	101.0
2035	89.1	551.7	409.0	258.0	87.6	310.9	377.9	324.9	284.0	326.6	4050.7	127.4	136.3	120.9	138.3	28.6	476.0	551.7	490.5	150.2	166.4	281.9	127.2	101.9
2036	90.4	555.2	415.9	266.2	89.1	329.6	379.3	327.4	284.0	326.6	405.7	127.4	129.9	121.4	140.4	28.0	484.6	555.2	494.7	152.9	174.3	289.4	1303	103.4
2037	90.7	585.3	439.0	274.7	90.4	332.5	331.6	331.6	289.5	337.7	417.8	129.5	132.4	126.5	146.5	29.2	492.4	565.2	499.8	158.9	180.2	299.3	140.2	106.3
					94.3	352.8	343.7	343.2																

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Avg =Average, SD=Standard Deviation

Appendix 18: Population growth forecast from 2023 to 2037

	All				West Africa				East Africa				Central Africa				Southern Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	-0.1	3.9	2.1	3.9	0.7	3.4	2.3	0.7	0.8	3.4	2.3	0.9	1.8	3.9	2.7	0.7	-0.1	3.3	1.8	0.99	0.9	1.7	1.2	0.4
2024	-0.1	3.9	2.0	0.8	0.9	3.4	2.3	0.6	0.8	3.4	2.2	0.9	1.8	3.9	2.7	0.7	-0.1	3.3	1.8	1.0	0.9	1.7	1.2	0.4
2025	-0.1	4.6	2.1	2.2	0.8	4.6	2.5	0.8	0.8	3.4	2.1	0.8	1.8	3.9	2.7	0.7	-0.1	3.3	1.8	1.0	0.9	1.7	1.2	0.4
2026	-0.2	5.4	2.1	1.0	0.8	5.4	2.6	0.9	0.8	3.5	2.2	0.9	1.8	3.9	2.7	0.7	-0.2	3.3	1.8	1.0	0.9	1.7	1.2	0.4
2027	-0.2	3.9	2.1	0.9	0.8	3.4	2.4	0.6	0.8	3.8	2.3	1.0	1.8	3.9	2.7	0.8	-0.2	3.3	1.8	1.0	0.9	1.7	1.2	0.4
2028	-0.6	3.9	2.0	0.9	-0.6	3.4	2.2	0.9	0.8	3.4	2.2	1.0	1.8	3.9	2.7	0.8	-0.2	3.3	1.8	1.0	0.8	1.7	1.2	0.4
2029	-0.3	3.9	1.9	0.9	0.5	3.4	2.3	0.8	0.8	3.6	2.3	0.9	1.8	3.9	2.7	0.8	-0.3	3.3	1.1	1.0	0.8	1.7	1.2	0.4
2030	-0.3	3.9	2.0	0.9	0.7	3.4	2.3	0.7	0.8	3.3	2.1	0.8	1.8	3.9	2.7	0.8	-0.3	3.3	1.7	1.1	0.7	1.7	1.2	0.5
2031	-1.4	3.9	2.0	1.0	-1.4	3.4	2.2	1.1	0.8	3.3	2.1	0.8	1.8	3.9	2.7	0.8	-0.3	3.3	1.7	1.1	0.7	1.7	1.1	0.5
2032	-0.4	4.0	2.0	1.0	0.5	3.4	2.2	0.8	0.8	4.0	2.3	1.0	1.8	3.9	2.7	0.8	-0.4	3.3	1.7	1.1	0.7	1.7	1.1	0.5
2033	-0.4	3.9	2.0	0.9	0.7	3.4	2.3	0.7	0.8	3.6	2.3	1.0	1.8	3.9	2.7	0.8	-0.4	3.3	1.7	1.1	0.6	1.7	1.1	0.5
2034	-0.5	4.0	2.0	0.9	0.6	3.5	2.5	0.7	0.8	3.4	2.2	0.9	1.8	3.9	2.7	0.8	-0.5	3.3	1.7	1.1	0.6	1.7	1.1	0.5
2035	-0.5	4.8	2.0	1.0	0.6	4.8	2.5	0.9	0.8	3.8	2.2	0.9	1.8	3.9	2.7	0.8	-0.5	3.3	1.7	1.1	0.6	1.7	1.1	0.5
2036	-0.5	3.9	2.0	0.9	0.6	3.4	2.3	0.7	0.8	3.5	2.2	0.9	1.8	3.9	2.7	0.8	-0.5	3.3	1.7	1.1	0.5	1.7	1.1	0.5
2037	-0.2	3.9	2.1	0.9	0.8	3.4	2.4	0.6	0.8	3.8	2.3	1.0	1.8	3.9	2.7	0.8	-0.2	3.3	1.8	1.0	0.9	1.7	1.2	0.4

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Sum =Sum, SD=Standard Deviation

Appendix 19: Exchange rate forecast from 2023 to 2036

	All				West Africa				East Africa				Central Africa				Southern Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	-17.8	131.4	33.6	51.9	-178.8	127.5	30.6	53.2	16.1	128.9	10.4	49.1	0.7	131.4	76.5	60.5	-12.6	92.8	18.1	43	-10.4	91.7	32.6	45.8
2024	-1.4	128.4	33.3	42.8	-1.4	127.5	32	44.2	-1.2	109.9	15.9	39.3	0.5	128.4	69.7	56.5	-1.0	78.6	19.9	32.6	-0.8	70.5	29.1	34.9
2025	-20.1	130.1	32.4	52.1	-20.1	127.5	29.4	53.5	-18.2	130.1	9.4	49.9	0.24	130	75.9	60.6	-14.3	93.4	16.6	42.3	-11.7	88.6	30.9	44.6
2026	-3.7	133.0	36.5	48.0	-3.7	127.5	34.1	48.4	-3.3	128.6	17.1	45.4	0.21	133	76.8	61.5	-2.7	95.5	21.9	38.4	-2.1	88.9	32.7	41.7
2027	-22.3	128.4	27.2	47.6	-22.3	127.5	24.5	49.7	-20.3	109.7	5.6	44.1	-0.3	128.4	70	75.5	-16.0	81.3	11.6	36.5	-13.1	67.7	24.2	36.3
2028	-5.9	131.7	35.3	48.2	-5.9	127.5	32.9	48.9	-5.3	129.9	16.1	46.2	-0.6	131.7	76.2	61.7	-4.3	96.1	20.4	37.8	-3.4	85.9	31.1	40.5
2029	-24.5	134.7	30.4	52.8	-24.5	127.5	26.7	53.9	-22.3	128.4	6.8	50.2	-0.9	134.7	77.1	62.6	-17.6	98.2	13.6	42.4	-14.4	86.2	27.9	43.1
2030	-8.1	128.4	30.1	43.8	-8.1	127.5	28.1	45.1	-7.3	109.5	12.4	40.2	-1.2	128.4	70.3	58.7	-6.0	83.9	15.5	32.1	-4.7	65.1	24.4	32.0
2031	-26.6	133.4	29.3	53.7	-26.6	127.5	25.5	54.4	-24.3	129.8	5.9	51	-1.5	-1.5	76.5	62.5	-19.2	98.7	12.2	41.9	-15.6	83.3	26.3	42.0
2032	-10.3	136.4	33.4	49.1	-10.3	127.5	30.2	49.3	-9.3	128.3	13.6	46.4	-1.8	136.4	77.4	63.7	-7.6	100.8	17.6	38.3	-6.0	83.7	28.2	39.1
2033	-28.7	128.4	24.1	48.7	-28.7	127.5	20.7	50.7	-26.2	109.3	2.15	45.2	-2.1	128.4	70.6	59.8	-20.8	86.5	7.3	36.4	-16.9	62.6	19.7	33.7
2034	-12.5	135	32.3	49.3	12.5	127.5	29.1	49.7	-11.3	129.6	12.7	47.2	-2.4	135	76.8	64	-9.2	101.3	16.2	37.7	-7.2	80.9	26.6	38.0
2035	-30.8	138.1	30.9	54.0	-30.8	127.5	22.9	54.8	-28.2	128.1	3.45	51.3	-2.7	138.1	77.8	64.9	-22.4	103.4	9.5	42.5	-18.1	81.3	40.9	40.9
2036	14.6	128.4	27.2	45.1	-14.6	127.5	24.4	46.1	-13.2	109.2	9.0	41.5	-3.0	128.4	71.0	61.0	-10.7	89.1	11.4	32.4	-8.5	60.3	20.1	29.5
2037	-22.3	128.4	27.2	47.6	-22.3	127.5	24.5	49.7	-20.3	109.7	5.6	44.1	-0.3	128.4	70	75.5	-16	81.3	11.6	36.5	-13.1	67.7	24.2	36.3

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Avg =Average, SD=Standard Deviation

Appendix 20: Food production forecast from 2023 to 2036

	All				West Africa				East Africa				Southern Africa				Central Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	57.3	170.3	97.5	19.0	60.3	130.7	90.3	16.3	57.3	170.3	99.8	28.4	76.4	132	104.0	16.4	80.2	118.5	101.6	12.6	76	102.2	91.7	10.3
2024	51.2	124.6	94.5	15.8	51.5	117.4	89.4	15.3	66.6	121.1	89.6	14.8	61.7	124.6	98.2	18.7	79.7	123.5	101.2	15.3	87.7	101.1	94.2	5.7
2025	-8.7	108.7	51.2	41.3	0.01	108.7	68.7	38.2	-2.9	97.9	61.3	41.3	-8.7	104.9	44.7	43.7	2.73	82.5	27.9	36.4	4.0	92.0	53.6	45.4
2026	56.8	167.4	100.9	18.0	56.8	133.3	93.5	17.6	83.1	167.4	104.8	23.3	71.3	134.7	105.1	19.0	86.5	121.9	103.5	11.3	91.6	102.5	97.4	3.9
2027	47.9	126.8	95.7	17.2	47.9	122.4	92.7	17.3	57.3	123.7	91.6	16.7	53.0	125.1	99.0	21.1	84.1	126.8	102.2	15.2	79.2	101.4	93.2	8.7
2028	-17.4	111.2	53.5	43.5	0.02	111.2	71.3	40.1	-5.7	97.4	61.5	42.6	-17.4	107.4	45.8	46.4	3.1	88.7	29.7	38.7	3.45	101.3	59.2	50.5
2029	53.2	164.7	101.9	19.1	53.2	135.9	96.8	19.3	82.0	164.7	105.9	22.5	62.6	137.3	105.9	22.2	86.8	125.2	104.5	11.9	80.8	102.9	96.4	8.9
2030	44.3	130.1	99.1	17.6	44.4	127.3	95.9	19.2	69.3	126.3	96.6	13.4	44.3	127.9	100.1	24.0	88.4	130.1	104.1	14.3	94.8	105.3	98.9	4.6
2031	-26.1	119.6	54.7	45.6	0.02	119.6	74.6	42.2	-8.3	105.5	63.4	45.6	-26.1	113.3	46.6	49.0	3.5	89.0	30.7	39.5	2.9	103.8	58.2	50.1
2032	49.7	162.1	104.3	20.5	49.7	138.4	100	21.1	66.6	162.1	106.1	23.7	53.9	139.9	107.0	25.7	93.0	128.5	106.4	11.5	96.3	109.2	102	5.3
2033	35.6	133.4	100.1	19.7	40.9	132.2	99.2	21.4	66.8	128.9	97.7	15.5	35.6	131.5	100.9	27.3	91.2	133.4	105.1	14.7	83.9	107.7	97.8	8.8
2034	-34.8	122.2	58.1	48.5	-3.4	122.2	77.8	44.2	-10.8	112.3	68.4	48.6	-34.8	117.2	47.7	52.2	3.5	95.2	32.6	41.9	2.35	113	63.8	55.1
2035	45.2	159.7	105.5	22.6	46.1	141.0	103.3	23.1	57.3	159.7	108.0	24.8	45.2	142.4	107.7	29.4	93.3	131.8	107.4	12.7	85.4	111.6	100.9	10.3
2036	26.8	137.1	102.5	22.1	37.3	137.1	102.3	23.5	64.4	131.3	97.9	19.2	26.8	135	101.9	30.7	95.8	136.7	106.9	14.5	96.7	116.9	103.4	7.8
2037	53.2	164.7	101.9	19.1	53.2	135.9	96.8	19.3	82.0	164.7	105.9	22.5	62.6	137.3	105.9	22.2	86.8	125.2	104.5	11.9	80.8	102.9	96.4	8.9

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Avg =Average, SD=Standard Deviation

Appendix 21: Food import forecast from 2023 to 2037

	ALL				West Africa				East Africa				South Africa				Central Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	-5.3	116.2	7.5	15.6	0.23	6.4	4.1	1.65	-2.7	9.7	3.8	4	-0.2	5.5	2.3	1.5	-1.4	7.6	2.7	3.06	-5.3	116.2	24.6	51.4
2024	-5.5	122.9	6.7	16.7	1.18	6.4	4.0	1.67	-5.5	8.1	2.7	3.9	-3.9	3.3	1	2.2	-1.4	7.9	1.9	3.1	-5.4	122.9	23.8	55.5
2025	-5.6	122.7	8.0	16.5	-3.7	7.0	4.2	2.5	-2.6	10.0	4.2	3.7	-0.3	7.1	3	1.9	-1.4	8.2	2.7	3.26	-5.6	122.7	26	54.3
2026	-5.7	129.4	7.5	17.5	0.83	8.9	4.2	2.3	-3.0	8.4	3.0	3.45	-0.4	8.8	2.5	2.6	-1.4	8.5	2.0	3.3	-5.7	129.4	25.8	58.1
2027	-5.8	129.2	8.1	17.4	-1.1	6.4	4.35	1.9	-3.6	10.4	4.0	4.15	-1.1	5.6	2.06	1.8	-1.4	8.8	2.8	3.5	-5.8	129.2	27.1	57.3
2028	-5.9	135.9	7.3	18.4	-0.1	7.0	4.2	2.07	-4.3	8.7	2.8	3.9	-3.9	3.4	1.0	2.4	-1.4	9.1	2.0	3.5	-5.9	135.9	26.4	61.3
2029	-6.1	135.7	8.2	18.4	-5.0	10.4	4.6	3.3	-4.7	10.7	3.75	4.7	-0.6	5.6	2.2	1.6	-1.4	9.3	2.8	3.7	-6.1	135.7	27.4	60.7
2030	-7.5	142.4	7.5	19.4	0.0	61.8	3.9	2.56	-7.5	9.0	2.6	4.5	-4.4	3.4	1.3	2.1	-1.4	9.6	2.1	3.74	-6.2	142.4	27.4	64.4
2031	-6.3	142.2	8.5	19.2	-2.4	6.7	4.2	2.2	-4.7	11.0	4.1	4.5	-0.7	6.6	2.7	2.0	-1.4	9.8	2.9	3.8	-6.3	142.2	28.7	63.6
2032	-6.4	148.9	8.0	20.2	-1.4	7.4	4.1	2.2	-5.1	9.3	2.9	4.1	-3.7	8.4	1.7	2.8	-1.4	10.1	2.1	3.9	-6.4	148.9	29	67.2
2033	-6.5	148.7	8.6	20.1	-6.2	8.0	4.4	3.2	-4.0	11.3	3.9	4.7	-1.6	5.7	1.9	1.9	-1.4	10.3	2.9	4	-6.5	148.7	30	66.5
2034	-6.6	155.4	8.2	21.1	-1.3	9.9	4.34	2.8	-6.3	9.6	2.75	4.5	-4.4	3.46	1.3	2.1	-1.4	10.5	2.1	4.1	-6.6	155.4	30.4	70.0
2035	-6.8	155.2	9.0	21.1	-3.6	7.1	4.5	2.6	-6.8	11.6	3.7	5.3	-0.8	5.7	1.9	1.8	-1.4	10.8	2.9	4.2	-6.7	155.2	32	69.1
2036	-9.6	161.9	8.3	22.1	-2.6	7.9	4.4	2.7	-9.6	9.9	2.5	5.2	-4.9	3.5	0.6	2.6	-1.4	11	2.2	4.3	-6.7	155.2	32	69.1
2037	-5.8	129.2	8.1	17.4	-1.1	6.4	4.35	1.9	-3.6	10.4	4.0	4.15	-1.1	5.6	2.06	1.8	-1.4	8.8	2.8	3.5	-5.8	129.2	27.1	57.3

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Avg =Average, SD=Standard Deviation

Appendix 22: Economic growth forecast from 2023 to 2037

	ALL				West Africa				East Africa				Southern Africa				Central Africa				North Africa			
	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD	Min	Max	Avg	SD
2023	-5.3	116.2	7.5	15.6	0.23	6.4	4.1	1.65	-2.7	9.7	3.8	4	-0.2	5.5	2.3	1.5	-1.4	7.6	2.7	3.06	-5.3	116.2	24.6	51.4
2024	-5.5	122.9	6.7	16.7	1.18	6.4	4.0	1.67	-5.5	8.1	2.7	3.85	-3.9	3.3	1.0	2.2	-1.4	7.9	1.9	3.1	-5.4	122.9	23.8	55.5
2025	-5.6	122.7	8.0	16.5	-3.7	7.0	4.2	2.5	-2.6	10	4.2	3.7	-0.3	7.1	3.0	1.94	-1.4	8.2	2.7	3.26	-5.6	122.7	26	54.3
2026	-5.7	129.4	7.5	17.5	0.83	8.9	4.2	2.3	-3	8.4	3.0	3.45	-0.4	8.8	2.5	2.25	-1.4	8.5	2.0	3.3	-5.7	129.4	25.8	58.1
2027	-5.8	129.2	8.1	17.4	-1.1	6.4	4.4	1.9	-3.6	10.4	4.0	4.15	-1.1	5.6	2.1	1.8	-1.4	8.8	2.8	3.5	-5.8	129.2	27.1	57.3
2028	-5.9	135.9	7.5	18.4	-0.1	7.0	4.2	2.07	-4.3	8.7	2.8	3.86	-3.9	3.36	2.0	2.35	-1.4	9.1	2.0	3.5	-5.9	135.9	26.4	61.3
2029	-6.1	135.7	8.1	18.4	-5.0	10.4	4.6	3.25	-4.7	10.7	3.8	4.7	-0.6	5.6	2.17	1.6	-1.4	9.3	2.8	3.7	-6.1	135.7	27.4	60.7
2030	-7.5	142.4	7.5	19.4	0.0	61.8	3.9	2.56	-7.5	9.0	2.6	4.5	-4.4	3.4	1.33	2.07	-1.4	9.6	2.1	3.7	-6.2	142.4	27.4	64.4
2031	-6.3	142.2	8.5	19.2	-2.4	6.7	4.2	2.2	-4.7	11.0	4.1	4.35	-0.7	6.6	2.7	2.03	-1.4	9.8	2.9	3.8	-6.3	142.2	28.7	63.6
2032	-6.4	148.9	8.0	20.2	-1.4	7.4	4.1	2.24	-5.1	9.3	2.9	4.1	-3.7	8.4	1.74	2.75	-1.4	10.1	2.1	3.9	-6.4	148.9	29.0	67.2
2033	-6.5	148.7	8.6	20.1	-6.2	8.0	4.4	3.2	-4.0	11.3	3.9	4.7	-1.6	5.7	1.9	1.93	-1.4	10.3	2.9	4.0	-6.5	148.7	30.0	66.5
2034	-6.6	155.4	8.2	21.1	-1.3	9.9	4.3	2.8	-6.3	9.6	2.75	4.5	-4.4	3.46	1.32	2.1	-1.4	10.5	2.1	4.1	-6.6	155.4	30.4	70.0
2035	-6.8	155.2	9.0	21.1	-3.6	7.1	4.5	2.6	-6.8	11.6	3.7	5.3	-0.8	5.7	1.9	1.8	-1.4	10.8	2.9	4.2	-6.7	155.2	32.0	69.1
2036	-9.6	161.9	8.3	22.1	-2.6	7.9	4.4	2.7	-9.6	9.9	2.5	5.2	-4.9	3.5	0.57	2.6	-1.4	11	2.2	4.3	-6.7	155.2	32.0	69.1
2027	-5.8	129.2	8.1	17.4	-1.1	6.4	4.4	1.9	-3.6	10.4	4.0	4.15	-1.1	5.6	2.06	1.8	-1.4	8.8	2.8	3.45	-5.8	129.2	27.1	57.3

Source: Boateng, 2024

Min=Minimum, Max =Maximum, Avg =Average, SD=Standard Deviation