Climate Change and Food Security: Effects of Rainfall Variability on Sustainable Food Security in the Sahel of Northern Nigeria

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DECLARATION

I declare that this work and everything contained in it is my own original work.

I am the only author, and l have never submitted the whole or any part thereof it to obtain any degree or qualification.

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ABSTRACT

This study examines the effects of rainfall variability on sustainable food security in the semi-arid land of Borno State, northeastern Nigeria. The rural population in northeast Nigeria depends on agricultural resources for food security and employment, as about 80% of the population depends on agriculture. This makes the rural population vulnerable to climatic shocks, poverty and hunger. In addition to the issues of climate change, north-eastern Nigeria has suffered from intercommunal clashes and the Boko Haram insurgency, which has afflicted about 15 million civilians.

Both qualitative and quantitative data were used to analyse the household food security conditions, adaptation strategies and climate trends of the study area. Climate data analysis and statistical modelling were applied to examine precipitation patterns and food security outcomes. The household food security survey carried out among smallholder farmers revealed that the percentage of food-secure households decreases with additional members, and food-insecure households become more food insecure with additional members.

This study showed that age is significant in the food security conditions in Borno State; household heads aged 25 to 40 years are more food secure, while those above 40 years old are more likely to be less food secure. Again, households with a male as head are more food-secure than those with a female head. The incidence of severely food insecure (SFI) was prominent among household heads with no formal education (46.8%). About 99% of the household heads confirmed that they have not been affected by conflict. Food insecurity is more prominent among households that have experienced long periods of dry seasons and heat waves. Those who have access to credit tend to be more in the food-secure category, while households that do not have access to credit are food insecure.

Food insecurity coping strategies includes reliance on less preferred and less expensive foods, with 58.5% of the sampled households attested to using this strategy to cope food shortages, while 53% of the household relied on purchasing food on credit, 36.9% relied on limiting portion size at mealtimes, 31.2% depended on reduction of the number of meals eaten in a day, 25.6% coped by using restriction of consumption of adults for small children to eat, and 17.3% rely on borrowing food from a friend or

relative. Farmers use crop and pastoral farming to diversify income and change crop variety to adapt to climate change.

The study revealed that farmers employ both rain-fed and irrigation farming, combining crop cultivation with pastoralism as a diversification strategy**.** This strategy is one of the risk-reduction measures employed by farmers in the study area. Evidence from this study implies dual attribution of precipitation changes to both natural forces and climate change, which emphasises the need for improvement in the understanding of local perceptions and scientific evidence.

The analysis of the SPI carried out shows precipitation anomaly, a standard departure from the mean over the 70-year series. Severe droughts were pronounced at all the weather stations considered during the first three decades of the series (1950-1959, 1960-1969 & 1970-1979), with unprecedented drought experiences that have never been witnessed before in observation records in 1970, 1971 and 1973.

Relationships between aggregate food production and precipitation were explored over the series (1992 to 2020). Results revealed that there was dramatic low production of food crops identified with below-average precipitation between 1992 and 1994, and food production began to rise from 1995 to 2002 and 2004 and 2006, surprisingly through below-mean precipitation. This surge can be attributed to an increase in aid delivery and other food supplies from international organisations because of the concerted focus on this region following Internally Displaced Persons (IDP) that resulted from insurgency attacks. The correlation relationship between major food crops and precipitation in Borno State was carried out, and results showed a strong relationship between SPI and food production.

The causal links between conflicts, climate change, and food security examined using multiple regression showed there is no statistically significant correlation between them. This study showed precipitation is low and variable while temperature is less variable over the period considered. Among the crop yield data, the values for beans/cowpeas are more consistent and show less variability compared to other crops. The assessment for multicollinearity performed on the data showed only SPI, temperature and bean yield data do not have a strong correlation.

In terms of policy implications, food production will be strengthened if both federal and state governments support rural communities through livelihood-enhancing activities that rebuild assets depleted by precipitation deficits, banditry, and terrorism. National food policy should prioritise sufficiency for all citizens, with implementation cascading down to the state and local levels.

Policies must address the impact of climate change, which has amplified natural disasters, economic risks, and social vulnerabilities. High levels of poverty and food scarcity have historically triggered crises in parts of sub-Saharan Africa, underscoring the urgency of resilient food systems. The food security strategy plan introduced by the state government, if properly implemented, will translate to food security.

Diversification is equally crucial. Farmers should be encouraged to cultivate a mix of rice, beans, sorghum, maize, and potatoes, given their comparable nutritional value. Policies must promote crop diversity, blending scientific expertise with local knowledge systems and integrating customary rules and inclusive governance with international best practice. A pluralistic, participatory approach will improve alignment between community realities and policy objectives, avoiding the pitfalls of purely technocratic reforms

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ACRONYMS AND ABBREVIATIONS

DPFI	Direct Payment Framework Instrument
FAD	Food Availability Decline
CCVA	Climate Change Vulnerability Assessment Framework
FAO	Foods and Agricultural Organization
IPCC	Intergovernmental Panel on Climate Change
USAID	United States Agency for International Development
ITCZ	Inter-tropical Convergence Zone
OECD	Organization for Economic Cooperation and Development
WAMS	West Africa Monsoon Systems
UNEP	United Nations Environment Protection
NBS	National Bureau of Statistics
MAE	Mean Absolute Error
SMAPE	Symmetric Mean Absolute Percentage Error
RMSE	Root of Mean Square Error
MASE	Mean Absolute scale Error.
MR	Multiple Regression
HAZ	Height for Age Z score
GDP	Gross Domestic Product
UNICEF	United Nations Children's Funds
AU	African Union
CAADP	Comprehensive Africa Development Program
SPI	Standardized Precipitation Index
SOFI	State of food security and Nutrition in the world
NEZDP	Northern Arid Development Program
FMENV	Federal Ministry of Environment
GDP	Gross Domestic Product
UN	United Nations
UNFCC	United Nations Framework Conventions on climate
EIU	Economic Intelligence Unit

GAFSP	Global Agriculture & Food Security Program
GCM	General Circulation Models
SDG	Sustainable Development Goal
SLA	Sustainable Livelihood Approach
WFP	World Food Program
HFIAS	Households Food Insecurity Access Scale
HHS	Household Hunger Scale.
IDDEP	International Dietary Data Expansion
UKFSR	United Kingdom food Security Report
GECAFS	Global change and food systems
ILO	International Labour Organization

CHAPTER 1

1.0 Introduction

Today's world is faced with the challenges of feeding the over 8 billion inhabitants of the planet earth, and goal 2 of the Sustainable Development Goals (SDGs) of the United Nations is to end hunger in all its ramifications by 2030 (Brooks, 2016). Since time immemorial, humans have not ceased to make progressive attempts to be food secure; hence, the ability to be food secure and feed the population has always attracted the interest of researchers around the world (Baer-Nawrocka & Sadowski, 2019). The growing interest in food security studies results from the realisation that sufficiently feeding the world population sustainably requires not only the production of more food but also other aspects of food security that include dietary quality and nutrition, the impacts of its production and distribution on the environment, food system governance, drivers and actors within the system, and socio-economic effects of the supply chains (Bene *et al*., 2018).

The supply of dietary energy globally has transcended total human needs in the last few decades, and Africa continues to experience food insecurity due to low agricultural productivity and inequality in access to foods (Dow-Uribe *et al*., 2014). The importance of food security is further reinforced by its important connection to the level of development of countries, and political stability and climate change have also been argued to induce significant impacts on food security (Pere-Escamilla 2015, Wischnath & Buhaug 2014). Food security is multi-dimensional in nature with four major pillars that include availability, access, utilisation, and stability (FAO, 1996) and two other emerging dimensions, i.e., sustainability and agency, mentioned in Clapp *et al*. (2022). These dimensions are interwoven with agricultural systems, social capital, and global shocks (Guiné et *al*., 2021; Magrini & Vigani, 2016; Nosratabadi *et al*., 2016; Oakley *et al*., 2019).

FAO attributed the current upsurge in food insecurity in the world to three major causes that include high exposure and vulnerability to climate extremes and variability, economic meltdown, and conflicts (Boliko, 2019, SOF1, 2018). The climate of the world has in recent years been characterised by various extremes, with many countries exposed to it either because of their geographical locations, lack of capacity to withstand, and resources to manage the outcome. Evidence from FAO data on the State of Food Security and Nutrition in the world (SOFI, 2018) points to the fact that the prevalence of undernourished people is higher in countries with high levels of vulnerability and exposure to climate variability. The highest levels of prevalence of undernourishment are common in agricultural-dependent countries, and countries with vulnerability to production yields and extreme drought experienced the highest increase in undernourishment, followed by countries with production vulnerability or vulnerability to acute droughts (Boliko, 2019). Conversely, during the same period, countries which are less vulnerable to climate extremes experienced a reduction in the prevalence of undernutrition, which reiterates the fact that climate variability is one of the major determinants of food insecurity.

According to the FAO (SOFl, 2018), acute food insecurity and undernutrition have been identified in conflict-prone countries. Conflicts are responsible for driving acute food crises and become chronic where there are prolonged conflicts and weak institutions. Stavi *et al.* (2021) reiterate that civil disturbance and political instability and regional conflicts destabilise local economies in arid and semi-arid lands. Effects of conflicts include denying people access to food, which sometimes leads to riots and inflation of food prices. Research studies affirm that regional conflicts have changed and become increasingly difficult, and the cause and the effects are connected to climate variability and acute domination of natural resources. And, as such, studies affirm that climate change induces and aggravates food insecurity (Laderach *et al*., 2022). Loboguerro *et al*. (2020) argue that most times, the less privileged and the poorest in the communities are the most vulnerable to the hazards and are at the receiving ends of the social, economic, and political declines that result from the climate and food security nexus.

In peaceful countries, economic slowdown has been identified to cause food insecurity, where economic downturn has adverse effects on foreign exchange and fiscal revenues of the country by reducing the ability of the country to import food to fill the gap in food availability through imports and access by providing a cushion against domestic rises in food prices (Boliko, 2019). Out of 77 countries that witnessed upsurge in undernourishment between 2011 and 2017, 65 out this number experienced an economic downturn at the same time. Severe food insecurity has also correlated income inequality with 20 percent more in low-income countries than in high-income countries (FAO, SOFI, 2019).

Generally, the continent of Africa is identified as highly susceptible to climate change, especially the region south of the Sahara Desert (FAO, 2018; Thompson *et al*., 2010). This notion is centred on the coping capacity that rests on economic, social and political systems to manage the impacts of climate change (Gregory *et al*., 2005) and the attendant problems. One of the most important of these impacts is food security**.** Climate change is projected to have far-reaching effects on food security, especially cereal production in sub-Saharan Africa. More than 500 million people may be food insecure by the year 2030 (Khan *et al*., 2014). In recent times, studies on food security have expanded because it is now being perceived as a significant human society issue (Che *et al*., 2017) and has gradually become a subject of worldwide importance in analysis, policy documents, research and in the media (Garnett, 2013).

The climate model projects that warming on the continent of Africa will increase at an average of 3-4 degrees Celsius over the next century. In sub-Saharan Africa, the impacts of climate change on food production have been projected to be in the region of a 5.8% mean reduction in maize productivity and a reduction in fishery catches because of an increase in temperature. Again, climate projections suggest there will be an increase in mortality rates because of an increase in temperature with a proportionate increase in the incidences of malaria and cholera (IPCC, 2022). In West Africa, observed mean annual and seasonal temperatures have increased since the mid-1970s by 1.3°C in the Sahara and the Sahel (Gutierrez *et al*., 2021). And the climate model projects the mean annual temperature for West Africa to increase by 0.6°C, 1.1°C, and 2°C at 1.5°C, 2°C, and 3°C global warming scenarios (IPCC AR6, 2022). Reports by the IPCC reveal that agricultural productivity will decline in sub-Saharan Africa from 21% to 9% by the year 2080, and two-thirds of arable lands in Africa will be lost by 2025 because of rainfall deficits and droughts (Masipa, 2017; Liliana, 2005).

Goals one and two of the 2030 Sustainable Development Goals (SDG), identify the eradication of poverty and hunger/malnutrition -in all its ramifications and address the issue of ecocide and unending extinction of biodiversity and decimation of the planet's nature-given resources. Therefore, it is crucial to embrace activities that protect the planet so that millions of people can be protected from the potential effects of global warming, which is ultimately responsible for the changing global climate (IFPPRI, 2020). At the United Nations Secretary General's Food Systems Summit, one of the significant policy statements agreed upon was the recommendation of reforms in efforts to support the SDGs in many regions and countries and research to address the complex issues of hunger, malnutrition, and poverty and to encourage adaptation and investment policies that enhance the ability of nations to reach the SDG 2 by 2030 (Braun *et al*., 2020).

The Food and Agricultural Organization (FAO, 2012) estimated about 870 million people worldwide are consuming fewer calories than they require, with damaging consequences of physical and mental health, which makes food security a grave concern for public health practitioners (Andrew *et al*., 2013). These concerns and future projections of food insecurity have become motivations for many aid initiatives, governmental and international policy prescriptions, and of utmost importance is the World Bank's Agriculture and Food Security Program (GAFSP). In the year 2020, the number of hungry people in the world increased because of the COVID-19 pandemic. Between 720 and 811 million people in the world experienced hunger in 2020, which means an increase of 118 million people suffered hunger in 2020 more than in 2019. Africa was worst hit, as it experienced a 3-percentage-point increase in one year; 21% of the population of Africa faced hunger in 2020, which is more than twice the share of any other region of the world (FAO *et al*., 2021). Evidence points to the fact that even before the COVID-19 pandemic, the world was not on track to defeat global hunger and malnutrition in all its ramifications by 2030, and the breakout of the COVID-19 pandemic now makes it even more challenging (FAO *et al*., 2021).

Again, other growing concerns related to food security, which has been attributed to climate change-related shocks include conflicts, locusts, Fall Army Worms, infectious diseases like African Swine fever and COVID-19. All these challenges disrupt food production and supply chains and further compound the ability of people to access affordable and nutritious foods (FAO, 2020). The Economist Intelligence Unit (EIU) predicted that agricultural production must increase by 60% globally by 2050 to meet food demand alone (EIU, 2019). The UN (2019) projects the global population will hit 9.7 billion in 2050, with close to doubling of the population on the African continent. Kearney (2010) explains that other drivers of food demands, like urbanisation, globalisation, income changes, and the dietary transition, will increase demand.

In Sub-Sahara Africa, rural households are mostly dependent on the available natural resources for the provision of food and income to their families (Debela *et al*., 2015). The availability of these natural resources is dependent on favourable weather and climate conditions (Solomon *et al*., 2007). Mertz *et al. (2009)* argue that this is even more problematic in the dryland areas of Sub-Saharan Africa, such as in the Sahel of northern Nigeria, where the weather is highly variable. The inhabitants are dependent on dryland farming systems and rain, which increases the vulnerability of households and rural farmers to the adverse effects of weather variability and climate change.

The Intergovernmental Panel on Climate Change (IPCC) stresses that the Sahel is one of the most vulnerable regions to future climate change and weather variability (IPCC, 2022; IPCC, 2007). Substantial population growth is expected in the Sahel with an average rate of 3% per year. Demographic projection indicates that the population is expected to reach 100 million people by 2025. Given this context, food security for the region becomes more difficult to realise in the future without any intervention, as competition for resource control becomes fierce, land degradation continues unabated, and poverty and food insecurity increase (UNEP, 2010).

The Sahel region of West Africa has witnessed numerous wars, civil conflicts, increasing population pressures, widespread poverty and aid dependency (Laderach, 2022; UNEP, 2011). Following the persistent droughts witnessed in the Sahel in the latter part of the 20th century (OECD, 2010), the Sahel region of West Africa became a worldwide recognised geographical and political entity (Mann, 2015, Giannini *et al*., 2016). This climate anomaly started in the 1960s and reached its crescendo in 1972 to 1973, and observation data reveal that 1984 is the driest year on record (Biasutti, 2019).

These periods of continuous drought in the Sahel region represent one of the most significant instantaneous climatic changes that exist in the record (Giannini, 2003). Hulme (2001) observed that the pattern of droughts experienced in the Sahel towards the end of the twentieth century was prolonged, the type which has never been experienced in the Sahel or in any other dryland regions within the context of the observational record. During the dry period, the annual rainfall totals were consistently lower than the long-term mean of the century, intermittent with years of severe drought

(Brooks, 2004). This extended drought in the Sahel in the 1960s and 1980s had immeasurable consequences on economies and people, as farmers and herders were seriously affected and drought-related deaths of over hundreds of thousands were reported (Mortimore and Adams, 2001, UNEP, 2006).

In the Sahel region, production of food is by small-scale traditional farming practice that is rain dependent (USAID, 2012). Only about 8% of the land is suitable for farming (Nyong *et al*., 2007); farmers are only able to plant where the length of the growing season allows for crops to mature, as crops cannot survive without irrigation in any area where the rainfall is below 250 to 300 mm. Scientists and practitioners have argued that climate variability and rainfall deficit are the biggest barriers to reducing poverty and attaining food security in the Sahel region (UNEP, 2006).

Climate change and food security are intricately related due to the complex interactions between climatic, environmental, social and economic factors. Consistent assessment and monitoring of food security in sub-Sahara, especially in the Sahel region, are essential. This will be crucial for policy formulation appropriate to mitigate potential shocks like famine and chronic food insecurity prevalent in the region because of climate variability.

Generally, in Nigeria, reports over the years suggest widespread food insecurity and vulnerability, though the extent of this situation is not adequately documented (FAO, 2016). Nigeria pledged to achieve the 2030 Sustainable Development Goals (SDGs), and food security and achieving Zero Hunger by 2030 is paramount. Nigeria is ranked 28.3 in the Global Hunger Index (GHI) report of 2023; this suggests a serious hunger condition and ranks behind many other countries in sub-Saharan Africa.

In northern Nigeria, the challenges of production of food to feed its growing population become enormous because of persistent drought, erratic rainfall, wars and conflicts and population displacements and migrations resulting from climatic and ecological shifts. Borno State of Nigeria is especially vulnerable to the impacts of weather variability and climate change, and the food insecurity condition, especially production and availability, has been amplified by banditry and insurgency, which has led to the displacement of over two million people and thousands of deaths (FAO, 2016). Substantially, this vulnerability is related to the dependence on subsistence livelihoods with a high rate of poverty in the region, limited resources for adaptation to weather and climatic conditions, and failure of state apparatus. Agriculture is vital to sustaining the livelihoods of the inhabitants of this region. In the arid lands of northern Nigeria, the actual and potential risks associated with climate change and related consequences make food security plans become crucial.

1.1 Research Gap

Food security issues have been studied by many authors both in the Sahel and in northern Nigeria. However, most studies, including studies by international development agencies, have focused on the humanitarian consequences of climate variability and not the root causes of food insecurity as it relates to the vulnerability of the population and climate variability. Possible effects of climate change on food security in the Sahel have been studied by some authors, among others (Tankari, 2018; Giannini *et al*., 2016; Fahim, 2013; Thompson, 2010; Turner, 2010; Cohen, 2005), and in Nigeria (Osabohien *et al.,* 2020; Ajayi & Adenegan, 2018; Salleh & Mustafa, 2018; Matemilola & Elegbede, 2017; Ojo & Adebayo, 2012; Babatunde *et al*., 2007; Titus & Adetokunbo, 2007; Adejuwon, 2006; Adejuwon, 2005).

These studies have not engaged in the integral components of food insecurity issues and possible effects of climate change on other components of food systems. The adequacy of, and history of, policies and processes that have hindered and continue to hinder the food security conditions of the rural populations have not been thoroughly examined. Therefore, expanding knowledge on the root causes and strategies to address this problem becomes imperative, as the central focus of this thesis is to examine the impacts of climate change and rainfall variability on sustainable food production and security in the arid lands of Borno State in northeast Nigeria.

1.2 Rationale for the Study

Weather and climate are of great importance for the Sahelian population, especially rainfall because of the environmental and socio-economic effects they present to the population (UNEP, 2010). Agriculture is very important in the lives of the people of Borno state and West Africa in general because it is the main source of food to feed. The prevalent farming system in West Africa is mixed cereal and livestock, and agricultural systems are mainly rainfed and subsistence in nature (Nematchoua *et al*., 2019; Thornton & Herrero, 2015; IPCC, 2022). Favourable weather conditions for practicing agriculture are important in maintaining food security, preservation of peace and guaranteeing of social and economic security. Low adaptive capacity to climate variability is a major problem that is common to African countries, and therefore, they are vulnerable to food insecurity, low food production, inadequate food access, stocks and income (Fuller *et al*., 2018). Dumenu & Obeng (2016) emphasised that most poor households in West African countries exhibit low adaptive capacity, which makes them especially vulnerable.

In northern Nigeria, the rural population depends on agricultural resources for food security and employment, as about 80% of the population depends on agriculture (UNEP, 2010). As the rural population continues to grow, many people become vulnerable to climatic shocks. Many continue to experience poverty and hunger and, therefore, by extension, it becomes a barrier to the achievement of the 2030 United Nations sustainable development goals to which Nigeria subscribed.

In addition to the issues of climate change, north-eastern Nigeria, especially Borno State, has suffered from the Lake Chad crisis coupled with the Boko Haram insurgency, which has afflicted about 15 million civilians and created a crisis of refugees and internally displaced people (IDPs) of over 2.5 million, with an estimated 7000 women and girls either abducted or missing (FAO, 2016). The economic impact of this crisis was estimated to be about US$9 billion across northeast Nigeria, and of the huge damages, US$5.9 billion of it was in Borno state. This has a huge impact on agriculture and thus food availability in Borno State, as many households lack access to food because of a lack of physical security and financial resources (FAO, 2016).

As the practical experiences and scientific knowledge to respond to climate change continue to develop, there is the need to establish the linkages between climate change/rainfall variability and food security, as food insecurity is rife among the inhabitants of the rural remote areas of Borno state.

This study seeks to develop a rationale to improve food security and to formulate appropriate policy responses in terms of adaptation and coping strategies to climate variability in Borno State located in northeast Nigeria**.** Having the right policy will help improve the lives of the inhabitants of this region and their standard of living, and promote food security, community development and relations.

1.3 Study Problem

Over the last five decades, regional climate observations in the Sahel exhibit negative impacts of climate and weather variability on the availability of natural resources. The rainfall pattern of this geographical region has been described as the most sensitive in the world, and this is evident in the annual, interannual and decadal timescales (Nicholson, 2018). The rainfall has gone through changes in the past, and variations of the same proportion are projected to occur in the future (Biasutti, 2019; Nicholson *et al.,* 2018*;* Chadwick *et al*., 2016).

Agriculture is very important to the livelihood of the population of the semi-arid land of northern Nigeria; over 90% of farmers depend on rainfed agriculture (Alliance Sahel, 2024; Cooper *et al*., 2008), and it is characteristically sensitive to weather variability. This, in addition to other aggravating factors, led to fierce struggles for natural resources and inter-community clashes in Borno state, just like in other arid and semi-arid regions of West Africa (UN, 2013). Following this, families and communities find it challenging to cope with weather variability, especially droughts that are a threat to agricultural food products and other problems attendant to it, like socio-economic shocks. The difficulties experienced by some of the communities forced them to adopt negative coping or survival strategies such as selling of assets, including agricultural livestock, urban migrations, and, in some cases, pulling children out of school. This diminishes the ability of the people to cope with climate change, causing destitution, hunger and acute poverty (UN, 2013). Following the effects of declining rainfall in the 1960s to the 1990s, which was not given prominent attention in human management, and unfortunately, most governments resulted in sourcing technical and international financial interventions. These interventions have not in any way succeeded in reversing the trend of impacts of climate change in terms of persistent droughts and desertification (Mortimore & Turner, 2005).

Consequently, climate change effects on food security have been recognised as a grave concern because of the actual and potential outcomes it has on subsistence livelihoods and the shortage of resources for adaptation to cope (Thompson *et al*., 2010; FAO, 2005). In northern Nigeria, rainfall variability and rising temperatures have cascading effects on natural resource availability, which increases the vulnerability of the inhabitants to food shortages, malnutrition, and disease transmission (UNEP, 2015). The subsistence farming method practised in this region lacks modern scientific knowledge and technologies and has a lack of water storage facilities, with no access to services that expose the sector to weather and climate variability. In Borno state, the problem of weather variability and climate change that pre-existed was recently compounded by other dynamics that include continuous and expanding conflict situations with attendant decimation of cropland changes, effects of COVID-19, relocations because of resource constraints, high food inflation, and persistent lack of access in many of the local government areas.

Efforts by the Nigerian government and international organisations have been focused on intervention rather than empowerment. For example, realising the nexus between poverty and the depletion of natural resources, which is an agent of desertification and climate change, the Federal Government of Nigeria started a programme of poverty alleviation called the Northeast Arid Zone Development Programme (NEZDP), funded by the federal government of Nigeria and assisted by the European Union in the 1990s, National Environmental Action Plan (NEAP), Arid Zone Afforestation Plan, and River Basin Development Authority (RBDA) (Ibrahim, 2023). The main objectives are to assist the rural population with proper resource use and management to improve the standard of living of the rural population and mitigate environmental degradation. There is no evidence that these interventions have dramatically improved the lives of the people, and neither has it been sustainable.

More recently, in September 2023, the Cadre Harmonise Report of the United Nations estimated that 17.6 million Nigerians are food insecure due to emergency food and nutrition insecurity, out of which 3 million children are malnourished. This report showed that between March and May 2023, out of five top food and nutrition-insecure states in Nigeria, Borno state was second after Lagos.

Borno State has attracted food aid from many development agencies and international charity organisations, which has helped to address the immediate food security needs of some vulnerable populations in the short term, but food aid has not addressed the structural causes of persistent food insecurity.

Considering the recurrent irregularity of precipitation with attendant humanitarian crises in Borno state and other states located in the arid geographical zone of the northeast, it has become imperative for more research to be done. This research is primarily directed at the empowerment of the people to enhance their adaptive capacity to cope with the menace of the changing climate with the attendant impacts on the people's livelihood.

Deriving from the above, the following questions are proposed to address various aspects of food security challenges in Borno State, northeast Nigeria.

i. What is the prevailing state of household food security in Borno State, and how does it vary across different local communities and livelihood systems?

ii. How does the food security index differ among various demographic and socioeconomic groups across Borno State?

iii. What is the nature of the relationship between precipitation variability and food crop production trends in Borno State from 1950 to 2020?

iv. Which socioeconomic and demographic factors most significantly influence sustainable food production in Borno State, particularly within the context of prevailing violent insecurity?

v. What adaptation and coping strategies are adopted by subsistence farmers in Borno State to mitigate the impacts of climate change and rainfall variability on agricultural production?

vi. What policy and practical interventions can effectively promote sustainable food production and enhance adaptive capacity to climate change in Borno State and the broader Sahel region?

1.4 Aim of the Study

Food security, and in fact, availability, affordability and accessibility are imperative for the teeming and vulnerable population of Borno State. To guarantee the above, there is the need to embrace a workable adaptation measure by the farmers to cope with the harsh realities of climate change that manifest themselves in rainfall and water shortages that farmers need to plant crops and produce food. Considering the fact of the geographical location of Borno State in the arid zone of the Sahel, it makes the state more vulnerable to rainfall variability, just like any other region in the arid zone of the world. Given the context of these natural barriers, it is important to consider a new approach in terms of the adaptation strategy and agricultural systems transformations to create resilience for farmers to cope with climate change.

The key aim of this study is to assess the impact of rainfall variability on food security/insecurity in the Sahel of northern Nigeria. The study seeks to assess and examine how trends in precipitation influence agricultural production and food security. This will help develop policy recommendations for policy makers that can possibly improve and advance agricultural production and food security.

1.5 Specific objectives

i. Assess the household food security conditions in Borno State using quantitative and qualitative methods.

ii. Determine the food security index in Borno State from different demographics and socioeconomic groups in the region.

iii. Analyse the relationship between precipitation variability and food crop production in Borno State of northeast Nigeria using climatic and agricultural data between 1950 and 2020.

iv. Identify the socio-economic and demographic factors affecting sustainable food production in Borno State.

v. Evaluate current adaptation strategies concerning the coping capacity of the subsistence farmers in Borno State.

vi. Develop actionable recommendations that may help support the design and implementation of food security policies for sustainable food production. adaptation to climate change and coping strategies in the present and future, in Borno state and region-wide.

1.6 Structure of the Thesis

This thesis consists of six chapters. Chapter One commences with the introduction of the research followed by the research questions, specific objectives, the thesis rationale, and the structure of the thesis. Chapter two consists of the theoretical framework; Chapter three explores food security conceptualisation and literature reviews, and Chapter four dwells on the methodologies employed in the study**.** Chapter five discusses the results from four principal methods applied for the investigation, while chapter six discusses the summary findings, conclusions and policy recommendations (Fig. 1.1).

Chapter Summary

This chapter provided the background and context for the study, situating food security within the global agenda, particularly in relation to the United Nations Sustainable Development Goals (SDGs), with a focus on Goal 2: Zero Hunger. It highlighted that despite global food supplies exceeding demand, Africa, and especially Sub-Saharan Africa, continues to face acute food insecurity driven by low agricultural productivity, economic inequality, climate variability, and conflict. The multidimensional nature of food security was discussed, encompassing availability, access, utilisation, stability, and the emerging dimensions of sustainability and agency.

The chapter underscored the three main drivers of recent surges in global food insecurity: climate extremes, economic downturns, and conflicts. Specific emphasis was placed on the vulnerability of Sub-Saharan Africa, and particularly the Sahel, to climate variability, recurrent droughts, and population pressures. These dynamics were shown to exacerbate food insecurity, malnutrition, poverty, and socio-economic instability. Nigeria, and especially Borno State in the northeast, was identified as a critical case due to its combination of climatic challenges, insurgency, and displacement crises, making it highly food insecure despite numerous aid interventions.

The rationale for the study was established by linking the dependence of rural households in Borno on rainfed agriculture to their heightened vulnerability to rainfall variability and climate shocks. The study problem was articulated as the persistent food insecurity caused by climatic changes compounded by conflict, poverty, and ineffective policy responses. The research questions were framed to explore the extent

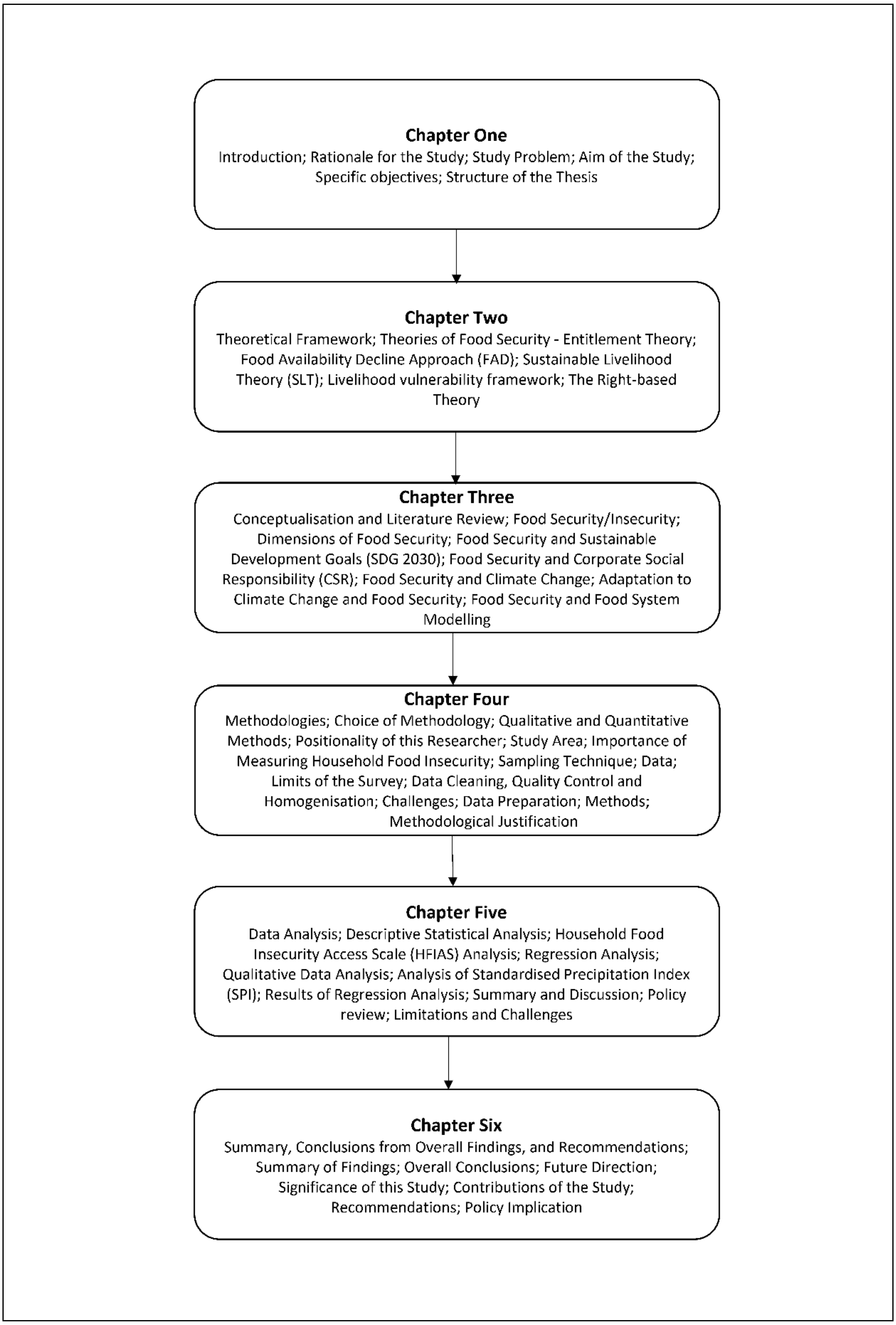


Figure 1.1: Diagrammatic Description of Chapters in the Thesis

of rainfall variability as a driver of food insecurity, its impact on agricultural production, household coping strategies, and the nexus between climate change, food security, and violent insecurity. The aim of the study was defined as assessing the impacts of rainfall variability on

food security in Borno State, with specific objectives including the evaluation of household food security conditions, determination of a food security index, analysis of the precipitation–production relationship, and the examination of current adaptation strategies. The chapter concluded with the outline of the thesis structure, comprising six chapters covering theoretical frameworks, literature review, methodology, results, and conclusions with policy recommendations.

CHAPTER 2

2.0 Theoretical Framework

2.1 Theories of Food Security

Research on food security has moved significantly over the years from focusing on environmental and demographic challenges to economic, social, and political causes. The theories of food security progressed from the economic model of Thomas Malthus (1798), which centred on a deficit in food availability in his principle of population. The Malthusian idea argues that food insecurity occurs because of too many people in relation to the amount of food production – 'Population when unchecked grows in geometric ratio, and subsistence food production grows in arithmetic order.' As a result of the necessity of food to the life of human beings, the two variables, i.e., population and food production, must be kept equal (Mende *et al*., 2015). The cardinal argument of Malthus's theory focuses on the necessity of food for human existence, although the population grows faster than the capacity of the earth to produce food. The Neo-Malthusian thinking casts a negative impact of population growth on food security until the 1960s, when an opposing argument emerged in the optimistic theory championed by Bostrup (1993), which argues that technological development would increase food production sufficiently to keep up with population growth and thus food security. Optimistic proposed that population growth is important to food production through agricultural development. Contrary to the Malthusian argument, optimistic theory stressed that with an increase in population, there would be more hands to produce food in terms of a larger workforce; if the population increases, more food will be produced with mechanisation, and there will be an increase in fertiliser usage with the increasing population, which will lead to more food produced and thus food security (Godfrey, 2011; Bostrup, 1993). The advent of the Industrial Revolution and the accompanying economic transformation allayed the presumed food deficit as feared in the Malthusian model.

2.1.1 Entitlement Theory

Malthusian and optimistic theories dwell on food supply, while the entitlement theory argues for wealth and material which can be bartered for food. This approach to food security relies on a person's entitlement to commodity bundles which is inclusive of food. This theory was pioneered by Sen (1984) and proposes that the set of alternative commodity bundles that a person can command in a society using the totality of rights and opportunities that is available to him/her or bundles. The entitlement theory emerged because of the contradictions surrounding the idea of a sufficient surge in the national food supply in the world, and millions of people are still hungry every day, especially in the developing countries, because of a lack of access to food and the inability of other theories to explain this paradox.

Entitlement theory provides that availability of food, which is synonymous with supply, does not guarantee food security. In a dire situation where substantial numbers of people in a geographical area do not have food to eat, it is referred to as 'famine' (Sen, 1977). Sen (1981) contends that famine is just one out of many factors that can lead to food shortages and explains that even with stable per capita food output, there could still be food shortages because of the instantaneous collapse of the endowment of some part of the population or groups and price changes which can cause part of the population to acquire sufficient food. Nyborg & Haug (1995) argue that disparity in access to resources can create imbalance in the distribution of food and opportunities and purchasing power of the population. The work of Sen (1981) pioneered the entitlement theory and claims that poverty among the population would deny people access to food even if the food is eminently available. Sen (1981) proposed that the ability of people to have food through legitimate processes present in the society, which entails the use of production possibility, trade opportunities, entitlements through the state apparatus and any other ways of acquiring food, is the focus of entitlement theory. According to Sen, entitlement consists of three categories: first, endowments; these are all legal resources that are available to be used to obtain food, like land, money, machinery, and animals, and other resources such as labour power, kinship, and citizenship; second, entitlement mapping (or E-mapping), this is inclusive of the terms of trade between endowments and food, goods, and the ratio between money wages and the price of food, or the input-output ratios in farm production; and third, entitlement-set, this refers to the basket of food, goods, and services that a person can obtain using his/her endowments. Food security is more guaranteed when these entitlements or some of them are available in a household (Mede *et al*., 2015).

In the Borno region, populations face challenges related to food security due to conflicts, displacements, and the absence of resource access. According to the entitlement theory, the ability of people to access food mainly depends on both its availability and the ability to command its availability (Zakari *et al*., 2022). In the Borno region, people have faced major displacements which limits their accessibility to land and money. As a result, they have limited ability to command food despite its availability in the market. This creates a situation where food may be available to the population but inaccessible due to poverty and a lack of resource entitlement. A case study of the Borno insurgency also explains how people in the Borno region had limited land and capital, which made them more vulnerable to hunger, even when food was readily available in the market (Badewa, 2022).

The entitlement theory shows strengths in deeply explaining the root causes of food insecurity in a population. It emphasises the role played by poverty and inequality in the proper distribution of resources. The theory mainly highlights that not just food availability is important (Mede *et al*., 2015). The population must have access to resources that ensure food acquisition is possible in a population.

One of the criticisms of the entitlement theory came from Woldemeskel (1990) in the composite theories, which explains that Sen's analysis of food access through entitlements rather than food availability focuses on possession. Still, food security is attained based on four components which include elements, availability, institutional elements, market forces, and possessions. The entitlement approach indirectly acknowledges the concept of food availability. Still, it disregards the roles of institutional provisions like extension services, credit facilities, and agricultural-related associations, and market forces, including prices that farmers can sell their agricultural products in the marketplace.

2.1.2 Food Availability Decline Approach (FAD)

The FAD approach was proposed by Sen (1981) and holds the belief that the primary cause of food availability decline is entitlement failure, which is possible to occur with or without any decline in gross food production. This theory portrays food insecurity to be result of shortages of food supplies which consequently lead to massive investments in technologies in the Green Revolution targeted to increase food supplies through increased food production at local and national levels to attain self-sufficiency and for exportation.

The central argument is that famine occurs because of the decline or shortage of food supply, whatever the cause. Therefore, to guarantee the absence of famine among the population, there must be a consistent supply of food relative to that population. The FAD model makes use of indicators to measure the food security status of a population and is accomplished by demonstrating the shortages in the basic food items concerning total population needs. Like the above, the nutritional status of individuals, also known as anthropometric measures, advances that food deficit or lack of food is the primary cause of malnutrition and undernutrition. As a result, factors such as resource endowment, climate, technology and its dissemination, prices, market opportunities, and the ability to augment one's own production were given to support the above view.

Bowbrick (2022) explains that the FAD approach is fraught with the belief that it has no universal application, i.e., to suggest that the food availability decline is caused by famine. It is not consistent with standard empirical economics, and FAD is a product of generalisation from only three famine observation events in Bengal. Evidence from extant literature suggests that availability of food alone does not guarantee access to food for all, and there are many other variables that could lead to malnutrition, like diseases, and that unequal access to resources will unavoidably attract disparity in food distribution, opportunities and purchasing power.

Fine (1997) argued that the FAD approach focused on the analysis of aggregate food supply instead of the component parts as related to individual access. Depriving an individual of access to a national food basket may lead to a catastrophic situation in which such an individual dies of famine. Therefore, it becomes necessary for the paradigm to shift attention to individual access to food and its contribution to the macro food supply with other sources of supply (Yaro, 2004).

FAD approach has not adequately explained the reason for the process that expands food supply and, at the same time, deprives some part of the population through the manipulations of other variables like access to jobs, terms of trade, distributions, and other social needs. The above diminished the FAD theory and led to the emergence of other theories.

In the case of the Borno region, food insecurity is mainly linked to disruptions in food production, conflicts, and climatic and environmental factors. The FAD model suggests that when crops are destroyed by aspects such as erosion or there is limited access to resources, there will be limited food availability in the region (Adelaja & George, 2019). Insecurity in the Sahel region has also reduced the food availability in the region. This situation is compounded by low agricultural productivity in the region and contributes to hunger and malnutrition (Zakari *et al*., 2022).

The model shows strengths in providing a direct link between food shortages and food insecurity. This makes it an immediate framework that can be used to address immediate food shortages in the Borno region. The model also encourages continuous production and the need for technological advancements to enhance food security in the region (Yaro, 2004). However, the model shows limitations in discussing major disparities in food access. In the Borno region, people have different levels of food insecurity, which is caused by a variety of differences in the magnitude of the occurrence of problems (Yaro, 2004). For example, some groups are more affected by conflicts and poverty than others, which causes different levels in the occurrence of food security. The theory also fails to account for other factors such as climate change, market access, and income levels.

2.1.3 Sustainable Livelihood Theory (SLT)

Sustainable Livelihood theory, hereon SLT, represents an analytical mechanism to break down the interrelationships and basic principles paramount to people's livelihoods and to increase their knowledge of what is required to promote their livelihoods (Phillip Nef *et al*., 2023). SLT theory was introduced by the Brundtland Commission for Environment and Development as a means of connecting socioeconomic and ecological thoughts together in a concise policy framework (Karki *et al.,* 2021). Agenda 21 of the United Nations Conference on Environment and Development (UNCED, 1992) proposed sustainable livelihoods as a framework that allows a policy framework to address development, sustainable resource management, and poverty alleviation at the same time. Livelihoods express the means, entitlements and assets, activities through which people make a living which determines the existence of a person in the society. An SLT is expected to guarantee enduring security for a person and make him free of worries (Karki *et al*., 2021).

DFID (1999) explains that the SLT framework has been useful in developing strategies to reduce livelihood vulnerability and enhance people's well-being. The sustainable livelihood framework has been useful in explaining food security, poverty and development and was popularised by Chambers (1983) and Chambers and Conway (1995). A livelihood is sustainable when it can endure stress and shocks, strengthen its assets and capabilities, and provide for future generations with opportunities that attract net benefits to other livelihoods at both global and local levels (Natrajan *et al*., 2022).

Addressing the drivers of vulnerability in respect of climate change and weather variability is imperative for food security and therefore requires an adequate understanding of vulnerability as it affects community populations. The World Bank (2016) explains that agriculture is central to the livelihood survival of over 2.5 billion people who live in the rural areas of the developing countries of the world.

SLT is flexible and pragmatic and therefore has been used by non-governmental organisations. SLT shares some characteristics with the entitlement theory, while the SL focuses on assets, both tangible and intangible, available to the households, closely related to the endowment concept; the entitlement theory emphasises means of guaranteeing a living (Burchi & De Muro, 2016). The main tenets of the sustainable livelihood theory focus on objectives, scope, and priorities for development activities and involve advancing the understanding of the way the poor and vulnerable live their lives and the effects of policies and institutions (Serrat, 2017). The idea of sustainable livelihood promotes the development activities that are people-centred, responsive and participatory, multilevel, conducted in partnership with the public and private sectors, dynamic and sustainable.

Serrat (2017) describes a livelihood component as consisting of capabilities, assets, and activities needed for a means of living. Livelihood is considered sustainable when it can endure with and recover from stresses and strengthen its assets and capabilities in the present and future without infringing on or compromising the natural resources. While vulnerability expresses a condition that negates the abilities of people, communities and geographical areas to combat or withstand shocks or negative processes that affect their well-being.

The notion of SLT expresses the combination of ideas and interests where various elements of development discourse meet. The linchpin of the SLT framework is its emphasis on the assets that poor people use and the approach they adopt to making a living instead of focusing on their needs in consistency with the earlier development approaches (Farrington *et al*. 2002). According to Scoones (1998), the SLT framework explains in different contexts how to achieve sustainable livelihoods by access to a variety of livelihood resources that are homogenised to seek different livelihood schemes.

SLT is rooted in the doctrine of the ‘people in places’ paradigm, which permits different experiences of people in different environments to affect the investigation of social phenomena. Essentially, the doctrine of ‘people in places’ captures ecological and political concerns and creates avenues for investigation through a livelihood approach that is made up of local knowledge, perceptions, and history. The components of livelihoods consist of assets and capabilities in materials and social resources that determine or are required to procure livelihoods (Kirki *et al.,* 2021; Yaro, 2004). When a livelihood has the capacity to deal with and recover from shocks and not impinge on the natural resources base, such a livelihood is sustainable (Chambers & Conway, 1992). The concept of livelihood emphasises sustainability as an approach that encompasses continuing poverty reduction, social and environmental and institutional sustainability (DFID, 2002).

2.1.4 Livelihood vulnerability framework

The concept of the livelihood vulnerability framework has been advantageous in analysing food insecurity by fusing into one analytical framework known as the livelihood vulnerability. The three subcomponents of this concept include threats to livelihoods, internal capacities of the unit of analysis and outcomes of livelihoods strategies. As vulnerability has become increasingly dynamic, so also the approach to vulnerability should be dynamic. Any functional vulnerability framework must imbibe the philosophy of diversity, asymmetry of impacts, dynamism and political strength in access to capital and provide pedagogical analysis of food insecurity (Sojola, 2012, Yaro, 2004).

The dynamic nature of vulnerability is derived from effective economic and institutional changes. By relating these economic changes, which invariably dictate the extent of vulnerability to climate change and an external emergency, the condition or state of vulnerability of farmers will depend on or be determined by the policy or approach in place to mitigate negative outcomes like food insecurity and starvation (Yaro, 2004; Leichenko & O'Brien, 2002).

The heterogeneity of the nature of social groups and spatial units attracts attention to the different nature of threats and impacts that affect people (Reyes, 1992). The importance attached to assets in vulnerability research has not considered the possible effects of political influence or manoeuvrings used in gaining access and combining assets in different livelihood structures (Yaro, 2002; Pretty & Ward, 2001). Some combinations of livelihood processes and structure reinforce Sen's (1995) theory that a household's food entitlement comprises food from the household's own food production, exchange and claims. However, it is imperative to stress that a household needs to be endowed with the right capital in the right quantities at the right time to provide the capacity required to withstand or cope with contingencies. To understand the social causality of contingencies, it is important to bear in mind that emergencies are not always driven by external forces (Yaro, 2004).

Sustainable livelihoods theory focuses on the recognition of realistic priorities for actions that are based on the perspective and interests of those concerned, but they are not a remedy (Fig. 2.1). It is, however, not a substitute or replacement for other methods such as sector-wide approaches, participatory development, and integrated rural development. Sustainable livelihood theory connects people and suitable environments that shape the outcomes of livelihood schemes. It also shows the intrinsic potential of people with reference to their skills, social networks, access to physical and financial resources, and ability to influence core institutions (Serrat, 2017).

Based on the postulation that there are strong connections between entitlement and wider political processes, the three components of vulnerability: entitlements, empowerment and political economy constitute the three-factor trilogy of the vulnerability framework (Watts & Bohle, 1993).

The empowerment component of vulnerability embraces freedom to make choices by people and recognition by the government of their negligence towards their

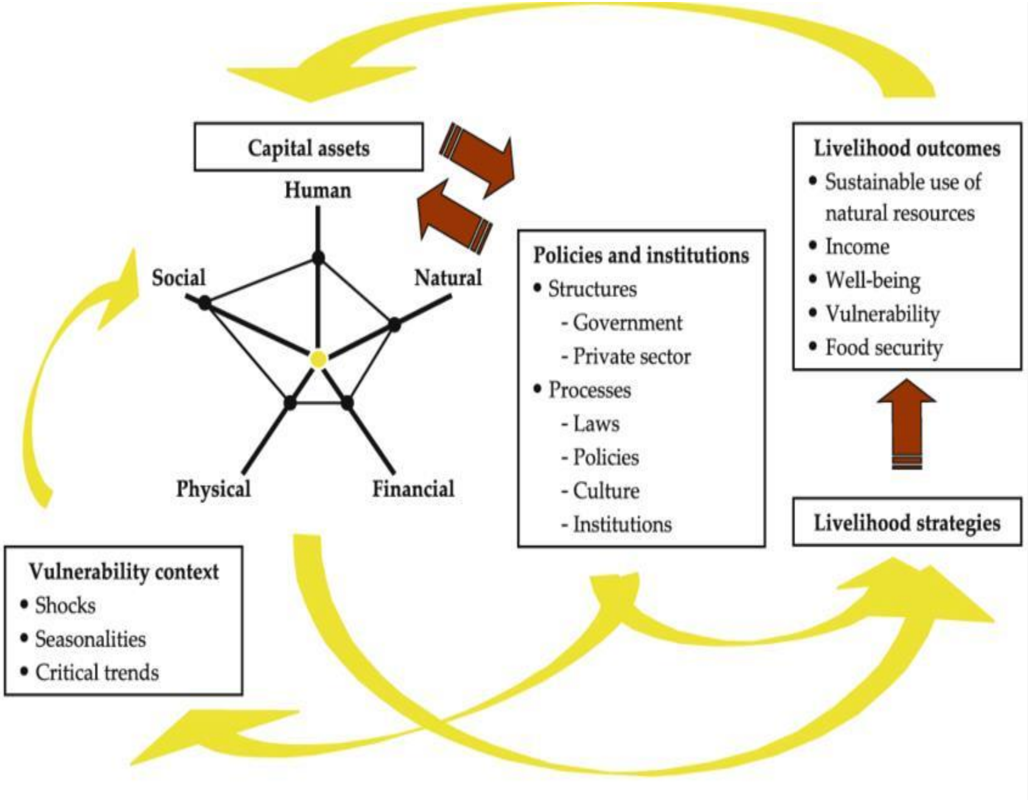


Figure 2.1: Livelihood Vulnerability Framework. Adapted from Serrat (2017)

responsibility to make sure the right of people to food is guaranteed and integral to the fundamental human rights (Dre'ze *et al*. 1995). Following from the above, vulnerability of people/households or communities will implicitly be dictated by the factors that impact the three sources of provision of food and welfare of people/households (Yaro, 2004). According to Watts & Bohle (1993), vulnerability expresses a lack of entitlements, powerlessness and exploitative practices. Accordingly, the vulnerability framework (Fig. 2.1) shows the causal structure of hunger, which is defined as the convergence of the three-factor trilogy of command over food (entitlement), state civil society relations seen in political and institutional terms (enfranchisement/empowerment), and the structural-historical form of class relations within a specific political economy (surplus appropriation/crisis proneness) (Watts & Bohle 1993).

Vulnerability will also suffer from the inherent political-economic activities of extraction, accumulation, social differentiation, and marginalisation. Ribot (1995) opines that the distribution of material stocks and opportunities to gain income, land and any other material resources inclusive of social security packages will dictate both the material and social conditions which underpin the vulnerability of a household.

In sub-Saharan Africa, where there are huge numbers of peasant communities, livelihood undertakings are a function of the opportunities and constraints they face and the pre-existing conditions or circumstances dictated by economic, political, cultural and physical factors. The propulsive effects of these factors form the external shocks that affect the livelihood outcomes of populations/households (Yaro, 2004). To achieve sustainable livelihood or entitlement sets, capital must combine in adequate quantity. The social class system is an indication of the diversity or heterogeneity of livelihoods, which, in effect, distribute external shocks unequally. In other words, the social class of an individual will dictate possible effects of external shocks; some people may utilise the shock for further gains while some incur losses. In a peasant population, the depth of the effects will depend on their sensitivity to external shocks relative to the type of livelihood activities and number of buffers they hold to mitigate the negative effects.

Again, the capacity to resist threat and shocks in the society could also be supported by traditional authority and cultural norms of the society by ensuring equity, respect, and adaptation in areas of production, exchange and claims. The institutions created by a combination of the traditional and governmental authorities and their effects are very important to the sensitivity analysis, resilience to shocks and commitment to the right to food.

The resilience and responsiveness attributes of society are reflected in the vulnerability of the society. Therefore, the sensitivity of peasants to capability analysis should be expressed in the complex processes that strengthen the conditions observed and as the target of analysis and not limited to the broad classifications of poverty and inequality indices (Yaro, 2004). What determines the resilience of peasant populations to weather vagaries or economic shocks is a function of their capital base in terms of human, financial, social, and physical resources and the approach they use in the livelihoods structure. According to Devereux (1999), whatever strategy was adopted by peasants to guarantee their continuous existence and the survival of their households and individuals in the communities has been found to be useful in the study of vulnerability. The strategies employed by peasants are influenced by the availability of and types of capital. However, peasant populations will invariably recover from any shocks depending on the strength of the coping and insurance strategies. The impoverishment slope induced by social, political and economic impacts is not falling steadily but increases to a point at which the forces of moral economy, aid from non-governmental organisations, or state and natural recovery is invoked. During the recovery process, the resilience of the households will hinge on pedagogical factors influenced by the condition of the state of the moral economy, public action and favourable natural factors (Yaro, 2004).

There are significant associations between strategies of the peasant population and vulnerability through the capital that is worked out within the political climate**.** The approaches engaged by the peasants' population are varying and cannot be studied without harmonious classification. One of the earlier explanations of various strategies the peasant population adopts was provided by Davis (1996) in her study of the peasant strategies in the Sahelian region of West Africa. Davis characterised the strategies within a typical livelihood system into (i) coping, which according to Davis, mean measures adopted by peasants in the short-term to neutralise shocks or coping strategies. These are a set of measures or responses applied by peasants to declining food availability and entitlements in anomalous seasons or years.

The strategies adopted to mitigate the failure of production are expected to be sufficient to cope until the arrival of the next harvest. (ii) Adapting strategies are kinds of adaptation measures that are permanent changes in livelihoods in which the normal cycle of activities of the household has been merged with certain adaptation strategies. (iii) Insurance strategies involve strategies used by the peasant population to avoid food and livelihood stress in the future, which are put in place because of previous experiences of disasters to mitigate any shocks that may result from future calamity. For the peasant population to achieve sustainable livelihoods, it will ultimately depend on several factors that include political capital which are influenced by norms, values, laws and actions of the state and other international donors and non-governmental organisations. Political capital constitutes the rights of people, resources, and their self-determination facilitated by varying levels of influence which improve consistently by processes, policies, structures and actions of people. The results of peasant strategies in the areas of production, claims and exchange are entitlement sets, and it could be positive or negative. Any entitlement sets which result in normal livelihood and sufficient food supplies and allowance of cash for other needs imply a secured household. On the other hand, entitlement sets which do not ensure the minimum food and cash adequate for survival in a political, social, and economic environment imply a frangible or weak, vulnerable household (Yaro, 2004).

In the Borno region, many households are highly vulnerable to shocks like conflicts, displacement, and climatic change. Those who have limited access to social, human, and financial assets, particularly upon displacement, face major challenges, as SLA suggests. Households have also been shown to apply different coping strategies to survive food insecurity (Mayhew *et al*., 2022). Major coping strategies applied by these populations have included reliance on aid and selling their livestock. Others have moved to urban areas to seek job opportunities that are more often unavailable in rural areas. Although these strategies are essential for survival, they may not be sustainable in the future (Hogson, 2004). Therefore, the government and NGOs should take the initiative to introduce effective agricultural methods and technology to provide long-term solutions to these populations.

The theory shows strengths as it explains food insecurity through a more holistic approach. SLT considers multiple dimensions of livelihood. It emphasises the importance of diverse assets such as human capital through education and social capital through networks that contribute to food security (Tomich *et al.,* 2018). SLT links food security to broader concepts of vulnerability and resilience. Such considerations are important in the Borno region, where the capacity to recover from conflict and post-conflict shocks is important.

One of the criticisms of the SLT is that part of its tangible components, like livelihood security, are difficult to measure because it is largely dependent on people's perceptions, which dictate behaviour and practice (Swift & Kate, 2001). Although lately, people's perception has started gaining popularity in the annals of qualitative social research. Secondly, Swift & Kate (2001) argue that the distributional issues are not adequately addressed in the SLA despite concern for the poor and the fact that SLA addresses issues at multiple levels, which implicitly points to the fact it stands for issues of distribution both within and between levels. It, however, did not directly advocate for equity but instead promoted the eradication of constraints and expansion of opportunities for the poor people.

Bryceson (2000) criticised the SLA on the grounds of its focus on images instead of real analysis. By this, it appears that SLA supplemented analysis with images, and this could lead to undue biases. Agriculture has been placed to play a central role in the SLA model; by so doing, it runs counter to the policy idea of reducing dependency on agriculture, especially in rural Africa.

The idea of connecting micro-realities to macro-policy levels has been criticised by Norton & Foster (2001) in that important theoretical issues that influence poor people's access to livelihood strategies are amalgamated into institutions, policies and process 'boxes' which appear to be too generalised to be a functional analytical method. The inadequacy of the SLA to establish important relational connections of objects in the policies, institutions and process 'box' and then work through the empirical material or real-life evidence in a stepwise manner might lead to wrong analysis and conclusions (Yaro, 2004).

Again, SLA has been criticised for being fraught with paradoxes and trade-offs between different components of the composite definitions. The SLA model structure and process are consistent with the neoliberal economic model of wealth accumulation and national development. Sound and positive as it is, it could promote poverty among the poor and serious damages to the environment in general. There is the need to balance the neoliberal inclination of the SLA to improve or create a safety net for the poor. This, in essence, will improve the usefulness of the SLA (Yaro, 2004).

2.1.5 The Right-based Theory

Recently, the question of food security, especially access to healthy food, is now being seen as a right and not a prerogative of people with economic advantages to purchase good food. This narrative has come to change the perspective at which we now see the genesis of insecurity and the solution to tackle it (Anderson, 2013). The central argument of the rights-based approach is to guarantee adequate food that empowers poor people and those who suffer food insecurity. This empowerment approach is a divergence from the benevolence approach of food aid but focuses more on enabling conditions for people to feed themselves and firmly takes away the responsibility of providing food from governments. However, if there are any shocks or situations that occur and households cannot feed themselves, the government must accept responsibility to help through policies that can mitigate hunger and protect vulnerable people (IFPRI, 2020). One significant advantage of a rights-based approach is that it provides a basis in law through which claimants could seek legal remedies to enforce their rights. The right to food cuts across economic and social rights, and it presents a good case of its interconnectedness.

The Rome Declaration on World Food Security (1996) emphasised the “right of everyone to have adequate access to safe and nutritious food and be free from hunger”. The notion of the right to food security emanated from the general human rights framework that guarantees the rights of every person without prejudice to their gender, race, religion and culture (Baro & Deube, 2006). This approach suggests that a combination of local, nongovernmental and international actors should come together to set out policy and actions to combat hunger. Hussein (2002) posited another important dimension of food security that should be considered for attention are: the responsibility of international institutions and states to ensure human rights, the agency of food-insecure groups to claim their legal rights and develop a right-based indicator into food security estimation.

The public perception of hunger and food insecurity has, over the last century, gone through progressive changes to being seen as moral issues that must be entrenched in the sociopolitical context and be confronted head-on. For example, under-nutrition and over-nutrition of all kinds are now being rooted in a social and political food policy framework. Unfortunately, the sustainable framework and the entitlement approach are not able to connect the culpability of food insecurity and famine to any authority but blame it on the people who are victims of famine for their inability to cope within the prevailing social and economic situation.

Consequently, there is no progressive approach towards tackling the causal process of poverty, which consists of asset deprivation, marginalisation, exclusion, banishment, punishment, victimisation, and corruption. To guarantee sufficient endowments required to ensure normal entitlement for all, there must be drives toward making food a human rights issue by creating the social and economic environment needed for it.

One important tenet of the right-based approach to food security is that it emphasises an indestructible connection between effective governance, poverty reduction and livelihood security and the importance of good governance in protecting the interests of the poor and most vulnerable (Johnson & Forsyth 2002). Consistent development can be achieved through the combination of civil and political rights that come through democracy and freedoms and the granting of social, economic, and cultural rights to the population. The chances of ensuring socio-economic and cultural rights to citizens are greater in a democratic state than in a dictatorship because politicians are accountable to the electorate, and it is of moral necessity for the state to consider the interests of the electorate in policy formulation and deliverables (Sen, 1989). The obligations of human rights rest with governments, institutions and agencies, and the failure of most governments to acknowledge the right of citizens to quality and healthy food and various actors to take responsibility to confront food insecurity effectively at the domestic front and full support of international efforts to combat hunger and chronic malnutrition (Anderson, 2013). This right-based notion emanated from the United Nations Universal Declaration of Human Rights and common development approach. Access to healthy food is accepted as a human right when it is inalienable, universal, interdependent with and indivisible from all other human rights.

Of paramount importance in the right-based approach to development is the participation of the poor both in the decision-making process, as it empowers them and gives people the opportunity to claim their rights. This in turn ensures social, economic and cultural development. Availability of resources will not translate to rights and entitlements if people are not empowered through participation policies and practices of service providers (Yaro, 2004). In the right-based approach, the right to food and housing are guaranteed when political and economic actors give claimants access to the apparatus of rights. The disintegration of traditional rights because of monetisation, modernisation, and climatic and biophysical changes has brought a new right that continues to manifest to challenge the new process and structure.

UNDP (2015) expresses the importance of the human rights approach model to food security by stressing the crucial role of the agricultural sector in food, trade and employment with the benefits of poverty reduction and economic growth. In developing countries, the spread of commercial seeds and privatisation has been said to have negative effects on agricultural biodiversity. The application of property rights that gives incentives to large-scale farmers and commercial agriculture may potentially impede the exchange or reuse of seeds. Traditional farmers should not be less favoured than the commercial farmers in terms of plant variety rights so that agricultural biodiversity would not be compromised to give way to monocultural practices. If this is allowed, it can obstruct food security and jeopardise the farmers' rights and livelihoods (UNDP, 2015). The UNDP advanced a framework to assess the national legal and policy framework that ensures the attainment of human rights around food security. The purpose of this tool is to ensure that the framework on the plant right captures the most vulnerable farmers, with an understanding of the functions of various seed systems.

The UNDP policy frameworks, tools and targets agriculture, poverty reduction, trade, environment and biodiversity, civil society, policy making and academia. The right based approach to food security has been critiqued based on the economic, social and cultural rights of people, which cannot be adequately enforced, and the lack of resources to implement policies. Again, the confusion in assigning rights to people and societies forms a barrier to proper implementation of this approach. Gualtieri (2013) suggested that attention has been too much focused on food availability, whereas the real problems lie in accessibility and adequacy. Without attention and improvement in local production and adequacy of foods, food aids will be of no purpose under the right approach.

In the Borno region, the government and international community have a major role to play in ensuring that everyone has access to food and is assured of food security. Everyone has the right to access adequate, safe, and nutritious food and be free from hunger. This right is, however, neglected in the Borno region due to frequent occurrences of conflicts that disrupt food and agricultural systems (Barret, 2002). Populations in the Borno region should enjoy access to and availability of food, which means that displaced people as well as people in the region should have economic and social means to access food (WFP, 2021). In this case, international organisations, local governments, and civil society groups should collaborate to guarantee the fulfilment of these rights.

The RBT shows strengths in developing a clear framework that can be used by governments and international organisations to enhance food security in deprived areas (Anderson, 2013). The theory emphasises accountability to ensure that vulnerable populations, such as those living in the Borno area, pressure local authorities and the international community to fulfil their food security needs (UNDP, 2015). The theory also empowers poor and marginalised communities to claim their rights. As a result, they raise their voices and are hence included in the decision-making process related to food and livelihood security.

A major limitation of the theory is its limited applicability in real-world situations. Governments and international organisations have not been able to fully address food insecurity challenges due to the existence of weak institutions to handle the challenge (Kregg-Byers & Schlenk, 2010). Additionally, the approach may not be applicable in all situations. Aspects such as climatic change cannot be mitigated by government policy. The right to food could also lead to overlooking economic and social challenges that are the main contributors to food insecurity. Governments may overlook aspects such as inequality and marginalisation, which means undermining factors that would provide long-term solutions to the food insecurity problem.

2.2 Conclusion

This thesis anchors on the Food Availability Decline theory (FAD), Sen's entitlement theory, the sustainable livelihood theory and right-based theory. The combination of these theories lays out a comprehensive lens for understanding the drivers of food insecurity in Borno State, presenting insights into both short-term adaptation strategies and long-term policy considerations.

The four theories complement each other by their strengths and weaknesses and perfectly address the central focus of this study and help to answer all research questions.

As scientific evidence points to the fact that there is a great tendency that climate change will continue to aggravate food production, possibly through erratic rainfall and higher frequencies of drought, floods and other catastrophic events, this study sees it as a paramount need to develop a food security implementation model for Borno State in northeast Nigeria, which will go a long way in mitigating food shortages in the state.

Borno State was chosen for this study because of its geographical location in the Sahel, latitude 10° and 13° degrees north and longitude 11° and 14° degrees east, which has experienced recurrent cycles of droughts because of rainfall deficit. Aside, Borno state has unfortunately since the late 1990s become the epicentre of terrorism and regional conflicts, which undermines the livelihood of her population. Furthermore, the inhabitants of this region depend on rainfed agriculture, which is the mainstay of their livelihoods.

The combination of the above factors makes the population of this region vulnerable to food insecurity. Therefore, to address the food insecurity problems, it is imperative to develop a situation-specific food security implementation model. Following the above, the following cause-effect climate change impacts on agriculture and food security framework adopted from Kiprutto *et al*. (2015) is applied for this thesis. This framework combines the elements of the four theories reviewed above to realise the research objectives of this study (Fig. 2.2).

Chapter Summary

This chapter reviewed the major theoretical perspectives that frame the study of food security, highlighting their evolution, core arguments, criticisms, and relevance to the

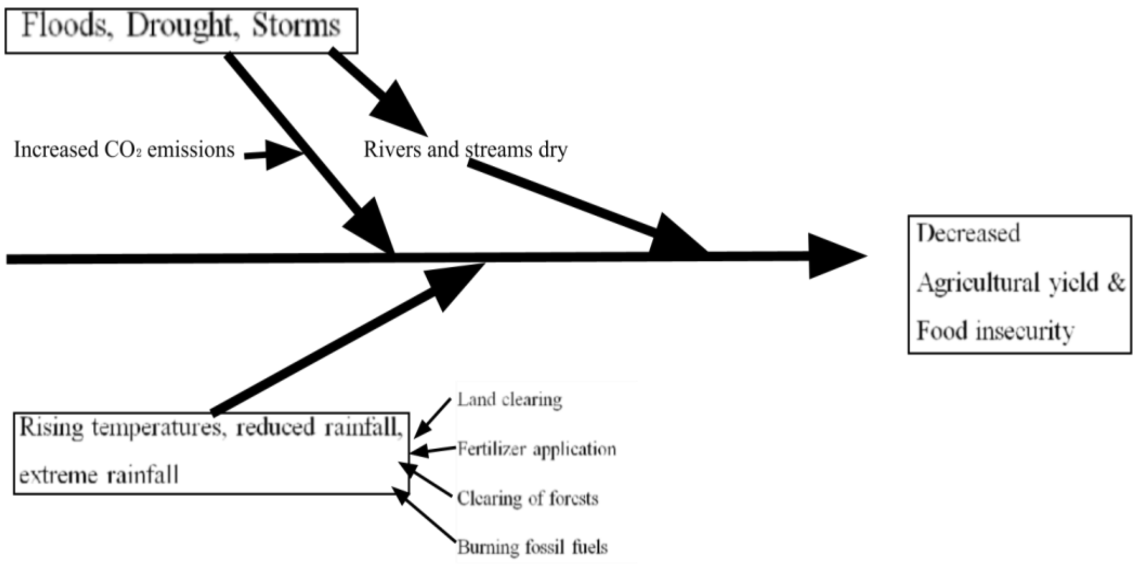


Figure 2.2: Cause effects model of climate change effects on agriculture and food security (Adapted from Kaprutto *et al*., 2015).

Borno region of Nigeria. It began with the Malthusian and Neo-Malthusian theories, which emphasise the relationship between population growth and food production, noting their usefulness in explaining resource pressures but also their limitations in ignoring technological innovation, access inequalities, and political contexts. The Entitlement Theory of Amartya Sen was then examined as a pivotal shift from food availability to food access, explaining famine as a failure of entitlements rather than production. Its relevance to Borno lies in the erosion of household entitlements due to displacement, poverty, and insecurity.

The chapter also considered the Food Availability Decline (FAD) hypothesis, which underscores the importance of supply-side shocks such as drought and conflict that remain salient in the Sahelian context. Further, the Sustainable Livelihood Theory and the Livelihood Vulnerability Framework were explored as holistic approaches that emphasise resilience, adaptive capacity, and the interplay of assets, strategies, and external shocks in shaping food security. Finally, the Rights-Based Theory was discussed as a normative framework that frames access to food as a human right, highlighting the role of governance and institutions in ensuring equitable distribution and accountability.

In reviewing these theories, the chapter demonstrated that no single framework sufficiently explains the complexities of food insecurity in conflict-affected and climate-stressed regions such as Borno. Instead, a multi-theoretical approach is required, combining insights from production-based, entitlement-based, vulnerability, and rights-based perspectives to capture the interconnected drivers of food insecurity. This theoretical foundation provides the lens through which the subsequent empirical analysis of rainfall variability and food security in Borno was undertaken.

CHAPTER 3

3.0 Conceptualisation and Literature Review

This chapter positions this thesis within the conceptualisation and extant reviews of literature on the effects of climate change/rainfall variability on sustainable food security with the focus on northeast Nigeria's Sahel and the Borno state example. Borno State faces major challenges in conflict, climate change, poverty, and limited access to resources. The recurrence of insurgencies in the region causes major displacement of people, which creates massive food insecurity. The discourse on food security has continued to take centre stage because of the impacts of famine, hunger, and starvation (Fig. 3.1).

3.1 Conceptualisation of food Security/Insecurity

From time immemorial, human survival has called for steps to guarantee food security. Throughout the history of human development and organisations, from primitive, cave, farmstead, and complex urban forms to the current state of the global community, food security is very elemental to human needs and existence (Matemilola & Elegbede, 2017; Kregg-Byers & Schlenk, 2010). Mariani-Costantini (2000) explains that life-sustainable food security has been shaped by diverse factors ranging from the environment where people live, the culture of the people and technological availability. According to Clapp *et al*. (2022), the scholarly discourse on food security began in the 1950s, while the policy discourse as it related to the developing countries started in the 1970s. The concept of food security has been defined severally, and many definitions abound in the literature. Literature reveals that over two hundred definitions exist in published papers (Gartaula *et al*., 2017; Ashley, 2016; Makombe, 2023). Some of these definitions reflect three main paradigms of food security thinking that include the global and the national to the household and individuals, from a food-first to a livelihood perspective, and from objective indicators to subjective perceptions (Makombe, 2023; Maxwell, 1996).

because of lack of money or access to food. Hunger can lead to deficiencies of micronutrients, described by Sanchez & Swaminathan (2005) as hidden hunger. Closely related to hunger is famine, which is defined by Scrimshaw, (1987), as a

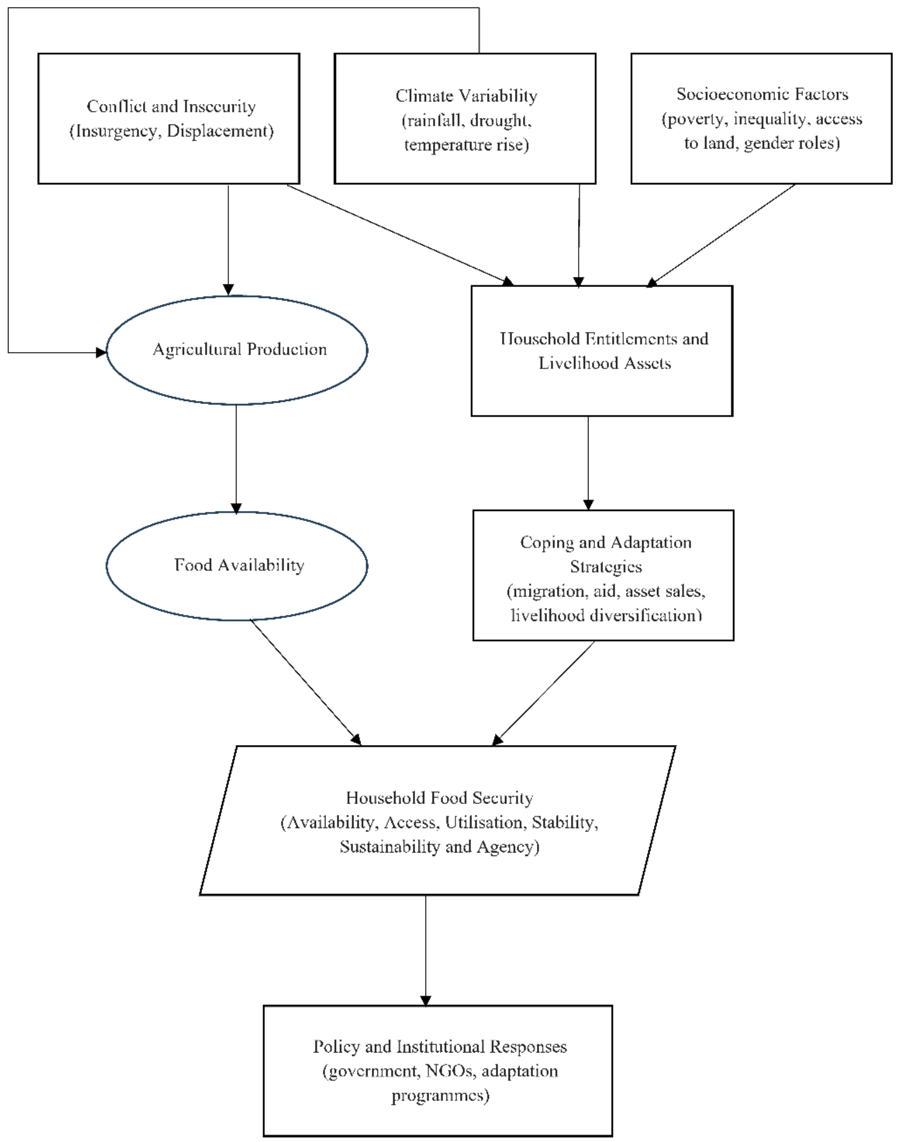


Figure 3.1: Conceptual framework showing the interactions between climate variability, conflict, socioeconomic factors, household entitlements, coping strategies, and food security outcomes in Borno State

condition where the level of food consumption of many people collapses. And a condition where people lack essential nutrients for a long period of time is referred to as starvation. Scrimshaw (1987) posits that there can be starvation without famine, which may be consequences of various factors ranging from poverty, lack of land, transport failure, and inequitable social systems to population expansions. Sub-Saharan Africa and, in particular, dry lands like the Sahel of northern Nigeria are more prone to famine, starvation, and food insecurity. In the Borno state, for example, the World Food Programme's (WFP) 2021 report states that over 3 million people in Borno state are classified as food insecure (WFP, 2024). A significant part of the population faces food insecurity due to ongoing conflicts and displacement.

Food insecurity and hunger are interrelated. Hunger is derived from lack of food or food insecurity. Hunger is more than just not being able to feed oneself or an empty stomach; it comprises interrelated subjects of poverty, climate change, inequality, conflict, weak government and institutions. The United Nations defines hunger as the time when people experience chronic food insecurity for example, being without food for entire days

The Food and Agricultural Organisation (FAO) of the United Nations enacted a mandate for increased levels of nutrition post-World War II by enhancing the standard of living for the world population through improved agricultural productivity (Kregg-Byers & Schlenk, 2010; Waddell, 2003). Following this mandate, nations started to be concerned about food insecurity issues and began to pay more attention to global adequacy of food supply instead of an increase in production. An unprecedented increase in world population demanded policy shifts; it was evident that the world would not be able to support its growing population with adequate food needs, and therefore, the need for reconceptualisation (Kregg-Byers & Schlenk, 2010; Hogson, 2004). Therefore, the shift from the old paradigm with emphasis on food production as the basis for food shortages to new policy discourse that entails other dimensions of food insecurity, such as access, distribution and utilisation (Barret, 2002). Even with the advent of modern technology and equipment for improved and mass production, food insecurity would still not be eliminated. This is because the modern equipment and technology would still not produce a suitable supply of nutritious food for the population. Again, some countries have no access to this technology.

Since the first World Food Conference in Rome (1974), the concept of food security has evolved with a plethora of definitions, which are influenced by geographical, socio-economic and biological factors (Campbell, 1991). The World Bank (1986) defines food security as a condition where all people constantly have access to enough food for an active and healthy life. This definition has in it the core elements of availability of food and ability to acquire it. The European Community (EC, 1981)'s definition summarised by Kennes (1990) defines food security as the absence of hunger or malnutrition with the necessary condition that households, villages, or countries must have enough resources to produce or otherwise obtain food. Consistent with the above definitions is the FAO (1989), which emphasises that the main object of food security must be to guarantee that all people constantly have physical and economic access to the basic food they need. In this definition, the aims are to ensure the production of adequate food supplies, maximise stability during supplies and secure access to available supplies for those who need them (Maxwell, 1990).

UNICEF data estimates that over 2 million people in Nigeria suffer from severe malnutrition. The malnutrition trends are highly common in the northern regions of the country, such as Borno, where populations suffer from muscle wasting and stunted growth. Therefore, all involved stakeholders should take initiatives to ensure populations in the vulnerable areas have food security to manage both hunger and malnutrition.

However, while food security is important, it is not a guarantee for access or effective utilisation (Bennett, 2010; Webb *et al*., 2006), and Pinstrup-Anderson (2008) argues that if the measure of food security is about the measurement of household or individual welfare, it must address access. As a result, the paradigm shifted in the 1990s from access to food at the household and individual levels to the concept of micronutrient undernutrition, and there emerged the concept of overall dietary quality (Jones *et al*., 2013).

The extant definition of food insecurity stresses that 'if a person or group of person lacks regular access to enough safe and nutritious food for normal growth and development and an active and healthy life, they are said to be food insecure.' This condition may result from unavailability of food and/or lack of resources to obtain food (FAO, 2024). It could be literally regarded as the opposite of food security. It is synonymous with food shortage and could be expressed as lack of access to good nutrition and safe food, mostly because of poverty (FAO, 2008), a result of insufficient intake of nutritionally adequate food required for the chemical and physiological development of the body (Oyinloye, 2018). Balistreri (2016) described food insecurity as the absence of steady access to enough food. Food insecurity is synonymous with social and economic challenges due to lack of food because of lack of resources or any other constraints that are not voluntary or the result of illness. In addition, food insecurity exists when there are problems with the smooth running of the food production and consumption pathways (Peng & Berry, 2019); it is a condition where the ability to obtain food in socially acceptable manners is in the balance. Again, food insecurity exists when the following conditions are fulfilled: (1) uncertainty about future food availability and access, (2) insufficiency in the amount and kind of food required for a healthy lifestyle, or (3) the need to use socially unacceptable ways to acquire food (USDA Economic Research Council, 2014a).

This definition characterises the food insecurity concept as uncertainty of availability, which means having a limited amount of food and access to food not guaranteed. The two characteristics of this definition, i.e., availability and access, are intricately connected in the sense that food insecurity is not only about availability but must also be accessible, safe for consumption and nutritionally adequate (Schroeder & Smaldone, 2015). The USDA's definition reveals that having plenty of food around does not translate to being food secure, and food security must include obtaining foods in ways that is socially acceptable. One important characteristic of households with low food security is disrupted eating patterns and reduced food intake (USDA Research Service, 2014a).

A sweeping definition of food insecurity is derived from the FAO definition – "inability to obtain or consume enough diet quality or sufficient quantity of food in socially acceptable ways or risk of one will not be able to do so because of income constraints". Tarasuk (2005) argues that household and community food insecurity differ in that household food insecurity is income-associated food access, while community food insecurity refers to wider societal affairs of shortages related to production and distribution.

FAO (2024) mentioned moderate or severe food insecurity. The presence of moderate or severe food insecurity among the population using the Food Insecurity Experience Scale (FIES) refers to the "derivation of the percentage of a country's population that experiences difficulties accessing sufficient safe and nutritious food for normal growth and development and an active, healthy life." This is one metric that is being used to monitor the world's progress toward achieving the SDG2 by 2030. In developing countries, food insecurity may be caused by a drop in agricultural production because of persistent drought and famine, unexpected pest attacks on agricultural produce, poor network distribution, and poverty and hunger. For a country to be food secure, there will be access to food in adequate and acceptable quantity and quality, consistent with decent existence always for most of the population (Davis, 2009). According to the World Food Programme (WFP, 2021), about 258 million people in 58 countries are experiencing chronic-level food insecurity. At crisis levels, people affected will have so little food that their livelihood and lives are in jeopardy, and this category of people is the highest on record globally for the fourth consecutive year. Some other drivers of chronic food insecurity include wars, conflicts, economic crises, and weather events like droughts, which have the propensity to displace people from their homes. And because of this, they become vulnerable and lose their access to indispensable resources like food, health care, and water. The population of people who were forcibly displaced, the refugees and the internally displaced (IDPs), was estimated to be about 110 million in 2023. Food security is not merely about the availability of food only, but also the ability of households to physically and economically acquire food safely. In the Borno region, food insecurity has been increased by high levels of conflict, which makes it unsafe to grow crops and engage in businesses that generate income for the population (Momale, 2024). The ongoing insurgency in the Borno region has displaced millions of settlers, contributing to an increased food insecurity level. Displaced people have often relied on external assistance due to their limited access to food, water, and healthcare.

Conclusively, the concept of food security is broad and multidimensional; it also may be described as a goal that is measured by the absence of hunger or when hunger is not pervasive or broadly described as lack of hunger or food insecurity (Anderson, 1990; Keenan *et al*., 2001).

Arising from this point of view, the connotation of hunger as the feeling of lack of food may not be different from food insecurity but represents a severe state of the experience of it. When a household lacks resources to simply meet its basic needs, which in its worst form results in hunger for the members of the household, this implies food insecurity (Keenan *et al*., 2001).

In a wider context, food security relates to the sustainability in both food and agricultural sectors with the commitment to the interests of present and future generations in environmental, economic, and social contexts (Berry, 2015). This concept has been emphasised by the United Nations by integrating it into the Sustainable Development Goals (SDGs), in terms of the zero hunger by the year 2030, goal 2 of the SDG goals.

The UN defines a sustainable food system as the one that brings food security and nutrition for all, which entails processing, packaging, and transporting to consumers. Food is delivered in a way that the present basis of food security does not impinge on the ability of the future generation to be food-secured (FAO, 2018b). Food and Agricultural Organisation (FAO) define food security as "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (Clapp, 2011, FAO, 2003). The International Research Program of Global Environmental Change and Food Systems (GECAFS) posited that food security should be measured in three main dimensions: (1) according to availability, focusing on production, distribution, and exchange; (2) according to access, focusing on affordability, allocation, and preference; and (3) according to utilisation, with the focus on nutritional value, social value, and safety (GECAFS, 2006). Food security describes a condition of access to enough food to meet the dietary and energy requirements of, self-sufficiency of or demand of a population. This perspective has a direct relationship with the FAO (1996) definition, where food security is defined as "when all people, always, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life." This definition identifies four dimensions of food security coined out of the World Food Summit 1996 definition, i.e., physical availability, economic and physical access, food utilisation, and stability of other three dimensions and all four dimensions must be met simultaneously to meet food security objectives**.** Berry *et al.* (2015) added a fifth dimension of food security recently, which is the sustainability dimension, a consideration of the long-term importance of food security which involves maintenance of ecology, biodiversity, and socio-cultural and economic factors such that it will not impinge on future food security.

Because of the multifaceted nature of food security, the UKFSR (2021) organised food security into five main headers, and each theme addresses a significant integrant of modern-day food security in the world. First, food availability, which describes supply and demand matters, trends and risks on a global scale and the effects on a state's food supply. Second is household-level food security, which relates to the matters of affordability and access to food and food safety. Third is supply chain resilience, which deals with the physical, human and economic infrastructure that underpins the supply chain and associated vulnerabilities. The fourth addresses the main sources of food at home and abroad, and the fifth component addresses consumer confidence, which details food crime and safety issues.

To best reflect the focus of this investigation, this thesis adopts the FAO (2017) definition: "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". Following from this definition, FAO (2018b) characterised food security as food availability, economic and physical access to food, food utilisation and food stability over time, and added that the main outcome of the food system is food and nutrition security. This will allow the integration of other variables of food insecurity, such as climate change, political instability and security challenges, as among the drivers of food insecurity, the sustainability pillar of food security was added as proposed by Berry (2015).

3.2 Dimensions of Food Security

Food security has gained relevance in recent years, especially in academic and international debates because of its global social and economic impacts. Ensuring food security globally has been a major medium- and long-term strategic objective of the Food and Agricultural Organisation (FAO, 2012), i.e., eradicating hunger, malnutrition, and food insecurity. Despite the international attention to food security, many aspects of it have not been investigated, and the concept of food security itself is beset with many broad definitions (Santeramo, 2014). Vulnerable populations, such as those living in the Borno state in Nigeria, continue to struggle with food insecurity issues due to unsolved social and economic factors revolving around this challenge (Momale, 2024). Several indicators have been advanced for food security because of the complex nature of it, with social, economic, and environmental elements attendant to it (Matemilola & Elegbede, 2017).

The complex nature of food security makes it impracticable to be measured directly, but the difficulty in its definition can be untangled by engaging with its four interwoven dimensions as proposed by FAO (2008), which include food availability, accessibility, stability and utilisation (Kumar, 2019). The following section explores the various dimensions of food security.

3.2.1 Food Availability

Food availability is the oldest and most influential dimension of food security, known as Malthusian theory. This dimension emphasis the relationship between population and food; that is, there must be balance between the rate of population growth and the rate of availability of food. Implicit in this view, food security refers to per capita food or aggregate food availability, which is a function of food production and stock in an independent economy and food trading in a closed economy (Burchi & De Muro, 2016).

This dimension became the reference point for the food security definition; for example, the definition adopted at the United Nations World Food Conference (WFC, 1974) expressed that ‘availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices’. This definition emphasised reduction in fertility rate and boast per capita food production by increasing agricultural food production through policy frameworks.

A country achieves food availability when enough quantities of food are available to all individuals, and channels of supply of such food include household production, any domestic output and commercial imports (Riely *et al*., 1999). Accordingly, food availability is a function of many variables, including domestic food stocks, commercial food imports, food aid, and domestic food production. These variables could have many primary controlling factors. The food availability dimension is most generally applied with reference to the regional or national level (USAID, 1995).

In the Borno region, food availability has been highly affected by local conflicts as well as socio-economic factors. The ongoing insurgency has led to large displacements of people, which has led to decreased domestic food production. Disrupted trade routes have also increased food insecurity in the region (FAO, 2017). The displacement has also decreased household incomes, which has further affected the overall purchasing power of the household heads. Borno is among the poorest regions in Nigeria, and this highly contributes to inadequate access to food.

3.2.2 Food Accessibility

Food accessibility refers to "when households and all individuals within them have adequate resources to obtain appropriate foods for a nutritious diet". This is also known as the entitlements, which is the set of all commodity bundles for which a person can establish control under the legal, political, economic and social arrangements of the community in which they dwell; it is the access by individuals to adequate resources to acquire the right foods for a good dietary need (Kumar, 2019).

Accessibility to food depends on the income available to the household, on the distribution of income within the household, and on the price of food (Riely *et al*., 1999). Access to food is influenced by the ability of households to acquire foods through their own production, markets and stocks. This will wholly depend on the resources available to the household, which will determine the type of productive activities they can engage in to achieve their food security objectives.

Additionally, access to food is a function of the physical environment, social environment and policy environment that influences how households utilise their resources for them to be able to achieve their food security objectives. Accordingly, if any shock, like drought or social conflict, occurs, it will interfere with production strategies and disrupt food access for households. One or a combination of these shocks can cause loss of productive assets such as livestock or impact the future productive capacity of the households and thus food security. Households will typically adjust to these shocks of likely decline in food access by adjusting their consumption patterns and reallocating their resources to more resilient activities from the possible effects of these risks. At a lean period, possibly induced by droughts or any other shocks, households may seek non-farm wage employment instead of crop production and may even dispose of some assets for money to continue to have income. Households may also adjust their consumption patterns, reduce dietary consumption, rely on loans and transfers and cut down on crop production and market purchases to achieve their immediate food needs (USAID, 1995). In the long run, if the cascading effects of the shocks become expansive and prolonged, the responses of the households become costly and may cause households to lose their productive assets, which will eventually affect their future livelihood and consequently make them food insecure.

3.2.3 Food Utilisation

This emphasises the nutritional utilisation of food with sufficient diet, clean water, health care and sanitation to achieve a good state of nutritional well-being that meets all the physiological needs of the population (Kumar, 2019). Several factors, ranging from a large measure of knowledge within the household of food storage and processing techniques to basic principles, proper childcare, and illness management, determine effective utilisation of food.

The nutritional status of an individual or household is a function of food utilisation and is determined by the quality and amount of dietary consumption and feeding practices, along with health conditions and their determinants. Major determinants of poor health and nutrition are inadequate access to, poor quality of food and poor infant feeding practices. This directly affects human well-being and improved food utilisation and can have feedback effects through its impact on the health and nutrition of household members and labour productivity and household income-earning ability (Riely, 1999). In the Borno region, populations suffer from malnutrition and contaminated diseases due to their limited access to clean water. Approximately half of the children in the region suffer from stunted growth and poor academic performance due to inadequate nutrition and reduced access to healthcare resources (UNICEF Nigeria, n.d.).

3.2.4 Stability Dimension

Stability dimension concerns a condition when a population, household, or individual is not in danger of losing access to food because of unexpected shocks from climate change, economics, or seasonal food insecurity. The population must always have access to adequate food. Stability possesses the characteristics of both availability and access to food security. The stability of food security in the Borno region is at risk of shocks related to climatic change and ongoing conflicts. Over decades, the region has experienced seasonal droughts which regularly disrupt food supply systems in the Borno region (Reynolds *et al.,* 2015). Such disruptions leave households with limited food access during crisis periods.

3.2.5 Sustainability Dimension

Food security has been challenged by the recent widespread disparity in the food system because of inequality in power games and climate change crises, which calls to question the adequacy of the earlier four pillars of food security. Therefore, to achieve an integrated sustainable food system, there is the need to combine sustainable consumption with food security. FAO (2012) maintains that for a dietary consumption to be sustainable, it must be protective and respective of biodiversity and ecosystems, culturally acceptable, accessible, and economically fair and affordable; nutritionally adequate, safe and healthy, while optimising natural and human resources." Also, a food system is said to be sustainable when it guarantees food security and nutrition for all and does not affect the economic, social and environmental conditions of future generations. Scientific evidence points to the fact that climate change is a threat to sustainable food security, but food production and allied activities contribute about 20%-30% of the total greenhouse gas (GHG) emissions attributed to humans (Garnett *et al*., 2016). Therefore, there is a need to develop a dynamic and integrated approach that mitigates any negative effects of GHG emission**s** on the environment because of food systems. (Peng & Berry, 2019)

Clapp *et al*. (2022) suggested the agency dimension, which is "the capacity of individuals and groups to exercise a degree of control over their circumstances and to provide meaningful input into governance processes". Evidence points to the fact that hunger has continued to rise, with 2.37 billion people around the world suffering food insecurity at moderate or severe levels in 2020 (FAO, 2021), and the advent of COVID-19 pandemic has worsened the condition of food insecurity since 2020. Following the upsurge in food insecurity and hunger in recent years, the capacity of the basic four dimensions of food security to address the subject of food insecurity, especially in the aspect of policy formulation, was called into question. This led to a different way of thinking and the emergence of an agency dimension to address the rising inequality and hunger that is prevalent among the underprivileged in the society, regarded as a human development perspective in food security studies. This missing element was rooted in Sen (1985), which stresses the significance of making sure that people have the agency to shape their own relationships with food systems that helps to address power disparity within the system. Accordingly, Neufeld *et al*. (2021) submit that the existence of power imbalances and inequality in communities, households, and national and global levels impedes the capacity of the food systems to provide sustainable livelihoods, reduce poverty, and be equitable.

In the Borno region, sustainability is limited as populations tend to seek short-term solutions to the food insecurity challenge and not long-term sustainable solutions. Most of the population depends on help from their local government and international organisations, which may not be sustainable in the long term (Tomich *et al.*, 2018). Sustainable solutions would include adopting new technologies in farming to enhance technology or finding solutions to ever-existing conflicts in the region

3.3 Food Security and Sustainable Development Goals (SDG 2030).

One of the key messages of the 2030 Agenda for Sustainable Development (SDG) is the drive to end hunger, attain food security, improve nutrition and encourage sustainable agriculture. Some of the significant outcomes will include guaranteeing every citizen access to adequate food all year round through sustainable food systems, increasing smallholders' productivity and incomes, eradicating cases of stunting among children and reducing food waste. No one left behind in the pursuit of food and nutrition security is the key motivation behind the goal to attain Zero Hunger and nutrition in 2030 (Global Hunger Index, 2022). These cardinal global development prospects are confronted with some challenges that include climate change, conflicts, wars and the recent COVID-19 pandemic, which amplifies the existing structural deficiencies in the global food systems and creates barriers to the process of achieving the sustainable development goal of ending poverty and hunger in 2030, as anticipated by the United Nations (Web *et al*., 2020). FAO (2005) stressed that food security governance is central to guaranteeing food security for all citizens and very important for the stability of all nations.

3.3.1 Theories of the Sustainable Development Goals.

Sustainable development theory emphasises the protection of the natural Earth from destruction because of abuse, resulting from the exploitation of nature-given resources. Today, the world remains highly unequal, and for many, sustainable development implies achieving a balanced level of development across all regions. Resources should not be concentrated in the hands of a few individuals or nations; instead, they should be distributed equitably to ensure that the resource base meets the needs of both present and future generations.

However, the approach to achieving sustainable development often reflects the material, economic, and cultural priorities of different societies. While some countries adopt the United Nations' blueprint for sustainable development, others choose alternative paths that align with their unique cultural, economic, and material circumstances. This may be a challenge for the realisation of the SDG goals (2030) as stipulated by the United Nations (Ozili, 2025).

Some theories have been proposed to explain the different approaches and dispositions toward the sustainable development agenda. Sustainable development theories help to expose the different narratives on the value and urgency of sustainable development and individual responsibilities towards achieving it. These theories set up the basis for debates among scholars, researchers and policy makers. Ozili (2025), identify five theories as follows: Extinction Avoidance Theory, Collective Stewardship Theory, Rogue Agent Theory, Divine Intervention and Providence Theory, and Resource-Resilient World Theory. These theories are laced with some limitations, but they at least provide a useful platform for understanding the diverse perspectives on sustainability. Together, they offer a foundation point for identifying relationships and interconnections that shape global conversation about sustainable development and set up the basis for debates among scholars, researchers and policymakers. These theories help to expose the different narratives on the value and urgency of sustainable development and individual responsibilities towards achieving it.

3.3.1.1 Extinction Avoidance Theory

The central argument of this theory is that if natural and man-made resources are properly managed and they become extinct, future generations will not have the resources needed to live good lives. For this kind of catastrophe to be avoided, it has been argued that sustainable development becomes important (essential to avoid resource extinction) (Punt, 2000; Swanson, 2016).

It is imperative to safeguard both existing natural and man-made resources if extinction is to be avoided. We must ensure the prevention of reckless use of existing natural and man-made resources and encourage responsible and sustainable use of available natural and man-made resources to guarantee that these resources are available to attain the purpose of transgenerational equity, both for the present generation and for future generations (Ozili, 2025).

Generally, the extinction avoidance theory has broad applications across different disciplines like natural, life, and physical sciences and emphasises preserving living organisms and natural ecosystems. The extinction avoidance theory reinforces the fact that resources are finite in supply and can be depleted until they become extinct. Again, it acknowledges that the reason why resources become extinct is due to neglect or use and overuse of resources.

Mao *et al*. (2021) argue that the views that natural and man-made resources can become completely extinct are controversial. This is because such resources do not necessarily disappear entirely; rather, they often transform from one state to another after being used. In this sense, resources continue to exist, albeit in a different form. Therefore, it can be argued that resources may not undergo total extinction but instead experience transformation.

3.3.1.2 Divine Intervention and Providence Theory

The Divine Intervention and Providence theory holds the belief that human capacity to protect and restore natural resources is limited. It was observed by Locke (1847), and argued that humans do not have the capacity to recreate lost natural resources or restore extinct life forms to its original conditions, but many species, and resources—such as marine life, minerals, and aerial creatures—have been preserved through natural regenerative processes without any human intervention. This theory has also been referred to as the “God Theory” of sustainable development, asserting that God replenishes and preserves essential natural resources that humans cannot restore.

The above observation started the debate, and scholars like Narayanan (2013) argue that the earth and its resources are sustained through divine providence, which may or may not be visible to humans. This divine care ensures that life-supporting resources remain available for present and future generations. Without such intervention, humanity would be unable to sustain these resources. The theory assumes the existence of God and His active role in protecting, preserving, and restoring depleted resources critical for life on earth (Moyer *et al*., 2012). The strength of this theory lies in the fact that it acknowledges the limitations of human efforts in safeguarding the planet's natural resources. It implies that resources of the earth will continue to be replenished and available for future generations with or without any human interventions. This theory recognises that human beings cannot do too much to protect or preserve the natural resources of the earth (Ozili, 2025)

3.3.1.3 Resource-Resilient World Theory

This model discusses individuals' capacity to adapt, recover and grow in the midst of difficulty, stressing the dynamic relationship that exists between risk and protective factors. The main idea is that the resources being depleted today are the same resources needed to withstand and recover from internal and external shocks now and in the future. Consequently, natural resources must be conserved and strategically utilised to provide protection against such threats. This theory provides that the world already possesses the resources required to remain resilient, provided they are used responsibly and cooperatively. Resource owners and stakeholders should work together to safeguard existing resources and develop resource-based defences to counter shocks. Some of the internal shocks that threatens resources includes wars, hunger, poverty, disease outbreaks, hurricanes, earthquakes and climate change. The core component of this theory includes: emotional regulation cognitive flexibility, optimism, and social support (Copley & Norje, 2025). Accordingly, the theory stressed leveraging all resource categories like, natural, physical, technological, human, renewable, marine, financial, informational, environmental, and intangible, to ensure present and future generations have sufficient reserves to withstand or recover in the short term from any shocks. The implication of this theory is that the resilience of world resources can be enhanced by harnessing all available resources to build protection against internal and external threats. It also explains that cooperation among resource owners is central to building resource-based protection and a resource-resilient world. However, the theory erred by not acknowledging the fact that it may be impossible to experience a complete recovery from shocks even with the availability of abundant resources.

3.3.1.4 Rogue Agent Theory

The aim of this theory explains the behaviour and dispositions towards the sustainable development goals. This theory addresses the possibility for individuals or group of people to use resources for personal gains at the detriment of the society as a whole (Burns, 2019). Mazzolini & Celani (2020) maintain that these individuals or custodians, influenced by perverse incentives, might misuse resources irresponsibly, causing harm to people, society, and ecosystems, and this type of behaviour is at cross purposes to sustainable development. The theory advocates for strong mechanisms, checks, and balances to ensure that resource managers and custodians act responsibly and sustainably, using resources in ways that benefit society and the environment rather than pursuing personal gains.

The advantages of agent theory include that it acknowledges that agents manage resources on behalf of others, acknowledges that resources can be used for both positive and negative purposes, emphasises the responsibility of agents for sustainable or unsustainable resource use, identifies the influence of perverse incentives on agent behaviour, and aligns with real-world practices, as many societies already implement accountability systems to prevent it.

However, rogue agent theory has been argued to be too generalised because a human agent may not be involved in the depletion or extinction of certain resources as presumed.

3.3.1.5 Collective Stewardship Theory of Sustainable Development

This theory represents a proactive and collaborative perspective to sustainability transformation, with all actors working together to promote networks, and an approach that promotes social-ecological systems. The basic principle of this model is that human and planetary health are interconnected, and it provides an organised approach for converting shared values into a harmonised and impactful action. Chapin *et al.* (2010) maintain that the planet's resources are all humanity has, and if we fail to take collective responsibility for their protection, management, and preservation, no one else will. This theory stresses that every individual is a steward of the earth's resources and is expected to act in the planet's best interest by using resources in ways that benefit society, the environment, and future generations (McAfee, 2019).

According to Davis *et al.* (1997), the theory supposes that if people are left to their own choices, they may likely act responsibly as caretakers of the resources they control. It further suggests that, given the option between selfishness and promoting societal and environmental welfare, individuals will choose the latter. Chapin *et al*. (2010) maintain that the above belief is grounded in the presumption that humans possess moral and ethical values that guide them toward preserving and efficiently using limited resources for the greater good.

In a practical sense, the idea of collective stewardship is more evident through partnerships between government and communities in a condition where the two work together as co-stewards of the joint resources. Collective stewardship theory encourages more sustainable and just communities, which invariably benefits the current and future generations.

The theory, however, has the disadvantage of overlooking the reality that many individuals can act selfishly, exploiting resources for personal gains. It also assumes universal cooperation toward a common goal, which is unlikely due to differing interests, priorities, and preferences.

Generally, theories have the capacity to help in the understanding and successful implementation of a sustainable development agenda. Despite the abundance of these theories and their merits, the targets set by the United Nations for the achievement of the SDGs globally are struggling and lagging to meet up with the 2030 timeline.

3.3.2 Global Efforts Toward Achieving Zero Hunger and the Interconnected SDGs Agenda

In recent years, there have been several international summits to promote the SDG goals of eradicating hunger and poverty; von Braun *et al*. (2021) highlighted a few, including the UN Food Systems Summit in September 2021, the UN Climate Change Conference (COP26) in November 2021, and the Nutrition for Growth Summit in

December (2021). As a result of the diverse nature of food systems, which include environment, humanitarian assistance, gender, markets and trade, health, agriculture, and governance, it is almost always difficult for these competing interests to pull in the same direction to realise policy consistency to achieve a common goal (Global Hunger Index, 2022). Efforts to improve food security and eradicatehunger in all its ramifications get more difficult with the rising divisions in global political/economic cooperation. The process of achieving the SDGs and how SDG 2 would be realised has attracted diverse opinions among scholars. Caron *et al*. (2018) argue for the existence of indestructible relationships that exist between climate, agriculture and food; because of their importance, local development and initiatives should be at the centre of both global and regional food systems change. Because of the intricate connections between food security, human health and nutrition, climate change, social justice, and ecosystem diversity, the best progressive approach is to integrate agriculture and food systems policies into the SDG 2030 agenda.

The SDG2 consists of four ambitious targets that include adequate food, no malnutrition, increased incomes for smallholders, and greater sustainability, and to successfully realise these targets will require a synergistic and conscientious implementation. Valin *et al*. (2021) submit that the compatibility of these objectives rest on the dynamic interaction of future food demand drivers and gains derivable from productivity in the food system. A copious analysis of the SDG goals shows that there exist strong relationships between SDG2 (Zero Hunger) and Goals 1 (no poverty) and 3 (good health and wellbeing), and to succeed in achieving Goal 2 (Zero Hunger), the three goals need to be jointly addressed. From a socio-economic point of view, these other two goals are important enablers of SDG2.

It is unequivocal that the Zero Hunger goal is closely related to poverty elimination (SDG1), and another is good health and well-being (SDG3), and the need for clean drinking water (SDG6) are all crucial to food access. In addition to these, there are other socio-economic SDGs that serve as enablers that support the achievement of SDG2, which includes SDG4, 5, 8, 10, 11, 16, and 17, and they all need to synergise to achieve the SDG objectives by 2030 (Valin *et al*., 2021). To be food secure, there must be access and availability of it. It is important to put this into consideration when studying individual and household food security to have a correct representation of it.

Laborde Debucquet & Martin (2018) studied 300,000 household samples in 29 developing countries to examine the implication of economic growth slowdownon poverty. Results showed that in 50% of the countries, above 5% will remain in extreme poverty by the year 2030. On a larger scale, Hallegate & Rozenberg (2017) applied simulation to study the effects of a shift in agricultural prices and farm income due to climate change on 1.4 million sample households, and they revealed that the effects of higher prices correlate to an increase in poverty and a consequent increase in stunting. Hertel (2015), argues that higher prices could increase famers revenue, and result in food security benefits, and Headey & Martin (2016), proposes that if high food prices if food price increase has negative effects on the poor, sustained food prices could benefit the smallholders in the long run through the reduction of rural poverty (Valin *et al*. 2021), suggests food security and poverty reduction be regarded as one and same challenge, therefore, poverty reduction should be confronted through lower food prices and higher income, and access to land, natural resources and technologies and exposure to climate risks by poor households, are all requirements of the SDG1.

There is a strong connection between good health and wellbeing (SDG2 & SDG3) because good health requires good nutrition. Challenges of poor nutrition and health are more pronounced in the developing countries. Black *et al*. (2013) explain that shortages of nutrients in breastfeeding resulting from maternal undernourishment can aggravate foetal and child development issues. This has also been linked to increased mortality risks through exposure to infectious diseases. Conversely, good food and nutrition enhance good health and prevent the prevalence of diseases, such as non-communicable diseases, such as cardiovascular diseases, diabetes, or cancer (Valin *et al*. 2021**).** Studies have linked co-benefits to health and sustainable agriculture arising from GHG emissions-intensive products like red meat. Studies point to the fact that switching to a vegetarian diet instead of the conventional omnivorous diet will produce a great health benefit and reduce the risk of exposure to diseases such as diabetes and cancer by 5 to 40% (Tilman & Clark, 2014).

Further, FAO (2020) analysed the need for healthy diets and its relationship with SDG1, explaining that healthy diet foods would command a higher cost compared to a minimum energy diet. This analysis concludes that to guarantee access to a healthy diet, make progress in poverty elimination (SDG1), and increase the income base of poor households, which would allow access and affordability for all.

Again, there exists a synergy between environmental health and more practice of sustainable agriculture, i.e., SDG2 and SDG3. Agricultural activities have been linked to contributing to global pollution. Stokstad (2014) explains ammonia emissions through agricultural activities contribute to human ill health by the formation of fine particles in the air contributing to many premature deaths globally. And Landrigan *et al*. (2018) submit that bush burning and land clearing pollute the air through fuel combustion emissions and have been said to be one of the largest sources of pollution-related ailments. Evan *et al*. (2019) argue that the use of fertilisers and manure on farms, especially the use of pesticides, adds more complex compounds to both overland and groundwater and pollutes them, becomes harmful to plants, animals, and humans, and risks of diseases have been found to increase through repeated exposure to pesticides by farmers (Landrigan *et al*., 2018).

Valin *et al*. (2021) discussed the interrelationships between food systems and socioeconomic enablers and outcomes, i.e., education, gender equality, decent work and other socioeconomic enablers. There is no doubt that these socioeconomic enablers are needed and interact with SDG2. These SDGs include SDG4 (Education), SDG5 (Gender Equality), SDG8 (Decent Work and Economic Growth), SDG10 (Reduction in Inequality), SDG11 (Sustainable Cities and Communities), SDG16 (Peace, Justice and Strong Institutions), and SDG17 (Partnership for Goals). Hiza *et al*. (2013) pointed out the importance of education (SDG4) as an influencer of healthy diet and sustainable lifestyle, supports food systems through training in science and technology research, and sustainable management, and reduction in maternal-child malnutrition (Alderman & Headey, 2017). Attention to gender equality (SDG5) will promote food security, especially in developing countries where women constitute a large percentage of the workforce in the agricultural sector.

SDG5 can enhance the income and productivity of rural women farmers and promote their opportunity to access natural resources and land for cultivation. Female workers constitute 40 to 50% in some countries, while it's even higher, up to 70%, in others (FAO 2017). Studies confirm that women face challenges in getting access to land, education, financial support, livestock, and equal wages with men (Valin *et al*., 2021). Undernourishment could be reduced by 100 to 150 million persons if these inequalities are sufficiently addressed, and apart from this, women are responsible largely for the nutritional standards that bear on their children and the food security of their households (FAO, 2011; Black *et al*., 2013). Easy access to healthy food and economic resources by households are achievable by integrating SDG 8 (Decent Work and Economic Growth) and SDG 10 (Reduction of Inequality) to support SDG 2. Additionally, focusing on technological upgrading, diversification, productivity, promotion of small-scale enterprises, and resource efficiency will all enhance food security at household levels.

It is equally important to emphasise that SDG16 (Peace, justice and strong institutions) is also important and have a major part to play for SDG2. FAO (2017) reiterates that war and conflicts are prominent drivers of food insecurity and crises, especially in developing regions. Furthermore, small-scale farmers should have easy access to land and be backed by strong institutions to guarantee regular and secure income. In developing countries, partnerships with development agencies (SDG17) to enhance rural economy and economic growth support any country in food crisis through humanitarian and foreign aid (Valin *et al*., 2021).

The United Nations Economic and Social Council (UNESC, 2024) reported that the entire world is off track to achieving the SDG 2030 agenda. The trend data analysed suggests that, of the 135 targets in the trend data, and with support insights from sister agencies, only 17% of the 135 are on the right trajectory to be achieved by 2030. About 48% show moderate to acute departures from the expected trajectory, while 30% and 18% exhibit marginal and moderate progress, respectively. And of major concern is that 18% and 17% have stagnated and regressed below the 2015 baseline, respectively. In 2022, 1 in every 10 people in the world are hungry, and 2.4 billion people suffered moderate to severe food insecurity. Again, about 60% of countries in the world experience increases in the prices of foodstuffs because of crises and conflicts that interrupt food chains (UNESC, 2024).

The hope of achieving SDG2 by the year 2030 as proposed by the UN is fading, especially in developing countries. Realising the SDG2 by 2030 has been faced with numerous challenges, and achieving success of the SDG by 2030 requires a lot of effort, ranging from changes in consumption patterns, new investments, strong institutions, effective market systems, and fundamental changes in demand and supply sides.

3.4 Food Security and Corporate Social Responsibility (CSR)

In the last 75 years or so, agricultural food production has witnessed rapid technological inputs that led to dramatic increases in crop yields and livestock productivity, particularly in developed countries. The improvement in agriculture due to technological inputs has contributed to food security but has come with a cost of impacts on the environment through the emission of greenhouse gases, decline of biodiversity, and pollution of water and air (Springmann *et al*., 2018)**.**

Prahalad (2004) postulates that ethics and social responsibility of food security rest on the assumption that life in a community is a social or public good that should be of benefit to and available to all in the society, otherwise be non-excludable and non-rivalrous. Food security has been seen as cardinal to the welfare of the society, but the state of the existing food system models as related to production, distribution and supply chain has not been positioned rightly; therefore, it can affect power negatively and reduce communities to minority (Murrel *et al*. 2022). Utami (2021) argues that given the fact that the responsibility of managing the issues of food insecurity and hunger in the society traditionally belongs to the public sector, the participation of the private sector becomes crucial to provide support for the marginalised and food insecure so the private sector too can take advantage of the market of the value-demanding consumers that abound in the communities. Building an ethical food system requires the identification of the communities that are food insecure; with this information will lead to awareness and understanding of the present condition of the communities concerning food availability, accessibility and affordability, which will form the basis for policymakers to address the problems (Murrel *et al*., 2022).

Food insecurity as an ethical issue centres on the principle of the right of access to food, which is a generally acceptable norm for individuals and society. Birkenmaier *et al*. (2013) maintain that there are strong relationships between ethics, public health and human rights, and without a healthy lifestyle, the rights and dignity of people would be in jeopardy. This is synonymous with the view that environmental, economic and social sustainability are intricately related in their impacts on society. Following this argument, Sharma *et al*. (2022) opine that the prevalence of food insecurity in communities and its negative impacts have been seen from a human rights point of view, a violation of ethics and social responsibility. And Zenk, *et al*., (2005) likened food insecurity to issues of discrimination, disparity, or inequality. Gallagher (2006) argues that when economically and socially disadvantaged people experience food insecurity, it raises the issues of social justice, economic equality and discrimination within the society, community and the food system itself. Banerjee *et al*. (2021) highlight several ethical issues related to food security by emphasising that if benefits and associated burdens are not distributed equitably, the impact could spread across various social dimensions of income, food, economic wealth, education, shelter, power, and provision of health care.

Food security has also been argued or seen as a social responsibility issue. For example, O'Hara & Toussaint (2021) discussed that in the United States, the prevalence of food insecurity has been found to be connected to the inherent conflict that exists between the free market food system and the general needs of the local communities and societies, or common good. The issue of the common good has been argued as a prime ethical concept in society and argues that environment and social systems must work for the benefit of everyone. Prevalent business practices, especially in developing countries, are not socially responsible, lack investment in education, amplify environmental pollution through their operations, and do not support communities to reduce the rate of poverty and crimes. This is contrary to the notion of common good and has given rise to concerns about the rise in global disparities and marginalisation, especially among people of low-income brackets (Murrell, 2022). Yadav *et al*. (2022) suggest that large corporations are in control of the current global food system, which results in the marginalisation of small-scale food producers and reduces the variation of companies participating in the food chain system.

Gender and food security research suggests that CSR interventions have helped in supporting women to play an important role in food and nutritional security through integrated policies on gender, agriculture, nutrition, health, and trade. It has enhanced sustainable approaches to food production through sustainable farming and women's empowerment, especially in sub-Saharan Africa, where women play important roles in farming and food production (Uduji & Okolo-Obasi, 2023).

FAO (2013) discusses food insecurity as gender discriminatory based on the fact that women and girls are the most deprived because of the inequality in the global economic and food systems. Men tend to be naturally positioned to control assets, for example, land, money and technology to produce food. While rural women carry the burden of household welfare and work as private meal suppliers, their roles are not valued or supported.

Camillus (2008) explains that food is central to the welfare of the society because of its importance in maintaining health and dignity, and it's the driving force in realising an individual's potential within the society. Food is important to our lives to meet our fundamental biological requirements, without which the well-being of an individual would be guaranteed. Food insecurity is a complex ethical issue with multifaceted causes, not easy to describe, and Lönngren & Van Poeck (2021) propose that arriving at an effective solution to food security ethical problems will require a multidimensional approach and solution.

There are various ethical issues confronting current food and agricultural systems because of the long and continuing cycle of alienation of humans from food, experiences and work of food producers, consumers and ethicists (Korthals, 2014). One of the ethical issues confronting food in the world is the question that bothers on the availability of food to feed the estimated world population of about 8.12 billion people on earth, with over 1 billion people still suffering from hunger and malnutrition (FAO, 2010). This is consequent upon lack of jobs, no money to buy enough food, and lack of their own plots to farm and produce food among populations. With the pressure of continuous population expansion and consequent high demand for food, the issues of food security become more imperative. Pinstrup-Anderson (2007) expressed that high food demand because of more mouths to feed and an unprecedented increase in household budgets because of a rise in food prices have been found to lead to social upheavals and unrest in some countries.

Related to the above is malnutrition among the population, especially in poor areas where people eat foods without good dietary components of minerals and vitamins; this, in effect, leads people to suffer severe conditions such as blindness and stunted growth (Korthals, 2014). And on the other hand, diseases such as obesity, type 2 diabetes and cardiovascular disease are common in richer areas (Critser, 2003; Korthals, 2011). The unhealthy effects of the prevailing food system, what is to be done about malnutrition, and who is responsible for addressing these issues remain contentious.

The sustainability of the current food and agricultural systems has been questioned. The current agricultural practices have contributed to depleting natural resources like trees on land and fish in freshwater and seas, consumption of animals as food, and increased carbon emissions and thus climate change. Agricultural intensification has led to soil degradation, deforestation and pollution by chemical fertilisers. Tansey (2008) submits that these human actions are at a cost to people and nature.

Another ethical issue of concern in agricultural food production is the use of animals by humans, as the animals have no voice and endure inhuman treatment and slaughtering and crowded pens, being treated like ordinary objects. The Humane Society of America reported in 2023 that 92.2 billion animals are used and killed for food every year worldwide. These concerns give rise to some interventions through governmental regulations and non-governmental organisations (NGOs) to forestall the abuse of animals.

Given this large-scale abuse of animals and its ethical implications, the mainstay of the economy and livelihood of the poorest people in communities and villages on earth depends on mixed farming/animal farming (Korthals, 2014). Palmer (2011) opines that the complete elimination of animal abuse remains to be seen.

The agro-monopolies inherent in the current food systems, which have become a dominant part of the global food system to regulate production, lower the population of organisms used for agriculture, and decrease agrobiodiversity, will consequently enhance the risk of outbreaks of disease and pests. De Schutter (2010) explains that this attracts serious economic implications, as the agro-companies with operations in the free market at the global stage become more powerful than individuals. This is capable of opening the food trade to speculations, and this, by implication, stands the risks of price instability and thus food insecurity.

Korthals (2014) discussed the risk inherent in food safety that is derived from technological advancement. Apart from the problem of possible contamination and pollution that surrounds food production and consumption, the production of genetically modified food through technology and its consumption among populations, especially in developing countries, has been a subject of debate and ethical concerns. This has created distrust between scientists and consumers because of genetic modifications of agricultural plants and animals and the denaturalisation that follows. Even with its seeming advantage of lowering farm costs, as submitted by scientist Thompson (2007), it is argued to attract many environmental costs related to pollution, other attended hazards and food safety. Science and technology have the merits of reducing labour requirements and concentrating on monoculture farming through plantation, fostering social and biological diversity by educating the labour force, and making them work in a more conducive environment, where they are more productive and expend less energy. It has also been argued that science and technology could combine with indigenous methods to increase harvest quality and quantity for the farmers and market. However, from an ethical point of view, the current agriculture and food system is no longer sustainable. The socioeconomic concern around the current practice demands immediate attention; for example, about 12% of the world's population are jobless, many are living in slums, and only 2% produce food for the rest to eat (Korthals, 2014).

Luhman & Theuvsen (2017) declare that CSR provides an opportunity for farmers and agriculturally based business players to fulfil their ethical responsibilities to society. In recent years, business, producers and retailers have become committed to CSR and sustainability initiatives for example, environmental and animal welfare. farmers are now taking the initiative to report the impact of their various issues of sustainability (de Olde & Valentinov, 2019; Whitehead, 2016). Consumers of foods are now increasingly interested in how foods are produced, the farming practices and the values. Despite this seeming progress, some schools of thought still hold the belief that there is little CSR can do to resolve the inherent disconnect between agriculture and society because of the many controversies and moral complexities surrounding agriculture (Woermann, 2013). De Olde & Valentinov (2019) submitted that there is no evidence that agricultural CSR will diminish or lose its relevance in the future but may not garner a widespread moral acceptance of what legitimate agriculture should be.

3.5 Food Security and Climate Change

FAO *et al*. (2018) projected that climate change will negatively affect the four pillars of food security, i.e., availability, access, utilisation and stability. Impacts and interactions from the four pillars will create systemic effects by increasing undernourishment as the food system is affected by climate change, the increased rate of obesity and ill health, the surge in environmental degradation and greenhouse gas emissions, and food insecurity will become expanded because of competition for land and natural resources.

Records of climate change observation show that climatic variability is now impacting food security, with clear evidence in increasing temperatures, precipitation pattern changes, and frequent extreme events**.** Studies confirm that climate change is also affecting crop yields negatively, for example, maize and wheat in the lower latitudes. Climate projection confirms that food security will be affected by climate change in the future of socio-economic streams, and cereal crop prices will increase between 1-29% by 2050. It is projected that consumers with low income are particularly vulnerable, with more people at risk of hunger; an increase in carbon dioxide will benefit crop production at reduced temperatures, and nutrition quality will be reduced, as stated in the model projection (Mbow *et al*., 2020).

Following the incessant discharge of greenhouse gas (GHG) from anthropogenic sources, the mean global temperature has continued to increase since the Industrial Revolution, and this increase is expected to continue as much as 1.5°C by 2050 (Eftekhari, 2022). The GHGs prevent the infrared radiations from escaping from the atmosphere and cause heat trapping, also known as the greenhouse effect. Major GHG sources mentioned by Song *et al*. (2022), are principally from fossil fuel consumption, soil management, bush burning, manuring, livestock production and land conversions. Extreme weather events that result from an increase in anthropogenic footprints lead to an increase in temperatures, irregular precipitation patterns, and sea level rise, which is a threat to Africa in the areas of food and water security, health and safety, and socio-economic development (UN, 2020). Aakko-Saksa *et al*. (2023), explains that the continuous increase in GHG will have long-lasting effects on terrestrial, marine and freshwater ecology. This problem of climate change is globally recognised as one of the daunting challenges facing humanity in the 21st century.

Climate change is projected to cause long-term resource shortages and deplete the soils, resulting in drought, desertification, disease outbreaks on crops and livestock and sea level rise. Without adequate responses to climate variability, the region-specific effects will be grievous, especially in the developing regions with low capacity to respond and which are more vulnerable. Many efforts have been made by countries and international organisations to alleviate food insecurity, hunger and malnutrition in the world, but it continues to pose a serious challenge, especially in developing countries. Achieving food security is a high priority for any government, and it is desirable in developing nations of the world, considering the vulnerability of the population to climate change with its attendant extreme events. These extreme events, such as floods, droughts, and extreme variability in temperature or rainfall, pose danger to food security in this region (Pawlak & Kołodziejczak, 2020; Ahmed *et al*., 2017).

Pawlak & Kołodziejczak (2020) argue that an increase in demand for food without a corresponding increase in crop productivity, with high food prices and inequalities of income, will negatively impact the accessibility and availability of foods to poor households. The main causes of hunger and malnutrition in the world have been attributed to climate change, war and conflicts, natural disasters and continuous population expansion (Prosekov & Ivanova, 2018). The effects of these drivers are more likely to affect the most vulnerable populations and, in effect, would demand a human rights approach and innovations both at international and local levels to adequately address the needs of these vulnerable populations (Ayala & Meier, 2017).

In developing countries, the zero hunger of the Sustainable Development Goal (SDG) is at risk because of the climate change shocks and low capacity to adapt in terms of resources and technology. In 2023, the Global Hunger Index (GHI) shows that the world has made significant progress since 2015, with a 2023 GHI score of 18.3, which is considered moderately below the 2015 global score of 19.1. This index notwithstanding, the number of undernourished has climbed from 572 million to about 735 million. Africa south of the Sahara recorded a GHI of 27.0, which indicates a serious hunger (Global Hunger Index, 2023). In this region, vulnerable groups such as children, widows and women, and people with disabilities are more susceptible to food insecurity. Escamilla (2017) recorded that about 800 million people globally are hungry because of their inability to have enough food to consume and live an active and healthy life; over 2 billion lack micronutrients, and 60% of people in developing countries are food insecure**.** Khodjayeva (2020) submits that over 820 million people around the world are suffering hunger today, bringing to the fore a huge challenge of achieving the Zero Hunger target of the SDG by 2030.

In sub-Saharan Africa, the food production system continues to be in danger because of climate change, with the reduction in yields already apparent even at a below 2°C rise in temperature. A rise in temperature above 2°C is predicted to have profound negative effects on food security and consequently reduce economic growth, exaggerate poverty, diminish species composition and ecosystems, and impact livestock livelihoods and crop productivity (World Bank, 2013). Estimates by the FAO assert that about 90 percent of people in sub-Saharan Africa suffering hunger suffer from persistent malnutrition. Over 80% of the hungry persons in the world reside in rural areas, and more than half of them practise peasantry in smallholdings; landless labourers constitute 22 percent, and 8 percent live by using natural resources, such as pastoralists (GAO, 2008). Effects of inadequate food and nutrition can be very profound. It has cascading impacts on children because undernourishment gives them little chance to survive, and some may suffer enduring mental and physical damage, and in adults, undernourishment can impair work productivity.

The negative impacts of human activities on climate variability are seen as threatening the survival of communities with low resistance capacity throughout the world and have created a serious challenge of how to manage it by the global bodies that are supposed to govern it both by control and response to the impacts (Mearns & Norton, 2010). It calls into question the fundamental core elements of our knowledge of the right socio-economic policy and the relationship between prosperity and sustainable food security, sustainable development, equity, and growth (Mearns & Norton, 2010).

The question of the vulnerability of African countries, especially the regions south of the Sahara, is unequivocal. It is compounded by other challenges inherent to most nation-states in this region, and these challenges are both local and transnational in nature, like domestic and regional terrorism, youth unemployment, armed conflicts, inter- and intra-regional conflicts, political crisis/instability, wars, famines, drug trafficking, maritime piracy, undernourishment, institutional corruption, absence of good political leadership, complete neglect of farmers and lack of direct investment in the agricultural sector (Dodo, 2021). Aside from the above-mentioned internal factors, Dodo (2021) identifies some external factors that aggravated food insecurity in Sub-Saharan countries, which include the role of international financial institutions and their policy directives to African governments. The International Monetary Fund (IMF) and the World Bank (WB) in the 1980s and 1990s handed down economic policy prescriptions to African countries which made it worse for countries that already suffered setbacks because of internal factors. For example, African governments were asked to cut aid and subsidies to farmers and allowed the market forces of demand and supply to run the economy; that is, to privatise and liberalise the economic policies to situate with the global economic order and modernise Africa.

This policy prescription consequently had negative effects on African farmers as they lost income supports because of the loss of support of their respective governments; this became a recipe for food insecurity for families, especially low-income ones (Dodo, 2021).

These factors combine with climate change and weather variability to become barriers against the total eradication of hunger and achievement of food security in Sub-Saharan Africa**.** Summoning the above inherent challenges should be central to African countries' political and policy discussions; otherwise, achieving Sustainable Development Goal 2 (SDG, 2030), that is, achieving food security and nutritional needs, will become just as discombobulated a policy agenda as any other one that has failed in the past. This will lead the continent of Africa to continue to lag other regions of the world in areas of social, economic and human development.

Tirado *et al*. (2013) argue that the effects of climate change will exacerbate hunger and malnutrition and consequently lead to the vulnerability of populations to food and nutrition insecurity derived from economic, social, and political processes. This is especially true for developing nations, and the effects will be more serious on the poorest and most vulnerable, as is being emphasised by researchers and international organisations. Further to the above are other factors attendant to climate change challenges, like population displacement, urbanisation and violent conflicts, which place enormous pressures on food production and distribution. Nelson *et al*. (2016) observe that the propensity of climate-induced events does not determine climate change-related catastrophe, but the vulnerability and exposure of the population and the environment does.

According to the United Nations (UN, 2010), vulnerable populations like women and children living in the rural areas are more likely to suffer the impacts of climate change. Studies affirm that families, especially in rural and vulnerable communities, have been adopting negative coping methods such as skipping meals and reducing quality and quantity, most especially among children. This inevitably provokes the risk of malnutrition.

Following the above line of argument, Nelson *et al*. (2016) submitted that reducing vulnerability in disaster management to build resilience so that affected populations can be better equipped for the potential effects of climate change entails building strong food security and should be the focus of any policy direction and efforts.

Climate change has long been considered politically as an environmental issue, and other areas of its potential effects have been neglected. Recently, scientific inquiries have shifted to other areas as climate change is now being connected to development and human rights issues, especially when mitigation and adaptation to climate change are being considered in efforts to achieve food security among vulnerable populations (Ayala & Meier, 2017). The United Nations Framework Convention on Climate Change (UNFCCC, 1992), which represents the first international agreement on climate change, placed emphasis on a voluntary mitigation approach by countries to climate change and reiterated the significance of a human rights-based view of climate change. This human rights approach was passed as a resolution by the UN later in 2008 to bring out the possible human rights ramifications of climate change on sustainable development. The above resolution went further by acknowledging the fact that the poorest of the societies are more vulnerable to the effects of climate variations because of their weak capacity to cope (UNHRC, 2008). The advent of the Paris Agreement in April 2016 recognised that climate change issues demand urgent attention by promoting resilience and more focus on adaptation strategies to combat food insecurity and reduce the effects of climate change on developing nations (UNFCCC, 2015).

Ayala & Meier (2017) advocated that people should be at the centre of any policy strategy to combat climate change, and focus should be towards diminishing social factors that enhance high vulnerability to food insecurity among populations. It is pertinent to note that it is not only the rural and remote populations that are vulnerable to climate change-induced food insecurity. The world urban population is projected to be over 2.5 billion people by the year 2025, while that of the rural population is projected to remain constant, and 90% of the growth is expected to happen in the developing nations of Africa and Asia (UN, 2017). More than ever before, the increase in rural-urban migration, especially in developing nations, putting more pressure on urban cities and the high cost of living in urban centres making it even more difficult for urban poor to afford good food, is a threat to food security (Ayala & Meier, 2017). Research studies confirm that most urban poor spend a reasonable percentage of their income on food, and if there is an unexpected increase in food prices, it can easily leave this population vulnerable to food insecurity. And many developing countries, like those in Africa, are experiencing an unprecedented upsurge in population growth that is faster than their ability to carry out appropriate economic, social and political reforms that guarantee food security for their vulnerable populations (ibid.). With continuous increases in world population, it is projected that food supply will become a serious challenge by in the coming decades. FAO proposed increases in food supply to mitigate the challenges that come with population increase and urbanisation and changes in the consumption patterns of the population. FAO further argues that the supply of food needs to increase and be more efficient to be sustainable within available natural resources and technology. The World Bank (2015) submitted that to feed the estimated world population of 9 billion by 2050, there is the need for an agricultural system that will produce 50% more food than the present.

Following the above concerns, the World Bank (2015), through its policy framework, focuses on five main areas of agriculture that include raising agricultural productivity, linking farmers to markets and strengthening value chains to improve market access, facilitating rural non-farm income, reducing risk, vulnerability, and gender inequality, and enhancing environmental services and sustainability. Mearns & Norton (2010) argued that the understanding of vulnerability, as to who is vulnerable to the effects of climate change, where, how, and why, will be central to the question of mitigation and adaptation to climate change. This will include and not be limited to how climate change added to the misery of vulnerability and how policy directives to tackle climate and other response measures may possibly exacerbate the consequences of the many inherent drivers of vulnerability. Consequently, the severe impacts of climate change may be less on the poor people of Sub-Saharan Africa than the effects of inappropriate policy measures to mitigate climate change or complete policy failure. As a result, policy direction should be towards exploring climate action to the benefit of the poor.

For the world to cope with the problem of food insecurity, Agriculture will play a vital and strategic part in achieving food availability and thus food security. Cook *et al*. (2011) observe there is uncertainty around global agricultural capacity to cope with the global demand for food; therefore, there is the need for agricultural innovation and revolution and expanding the range of agricultural land to expand food supply.

Agricultural practices, food production and climate are intricately related (Fig. 3.1), and this proposition is more exerting in that the world annual production changes of major crops such as maize, rice, wheat, and soybean of about 2 to 22 million tons are currently explained by climate, and this represents the global crop yield variation of about 32% to 39%. Following from the above, it is estimated that agriculture and livestock rearing combine to generate about 11% of the world's greenhouse gas emissions (CIGIAR, 2020). As the world population continues to increase and consumption patterns continue to shift, there will be a need for agricultural food delivery to increase by 60% by 2050. And conversely, with every increase of 1 degree Celsius of global warming above historical level, it will possibly lead to a 5% decrease in crop output (CIGIAR, 2020).

The relationships between climate change and food security are complex, and food security can be affected by many factors that include access to food supply and stability; markets; impacts on prices; infrastructure across the food chain; reduced incomes; and increases in the incidence of infectious and diarrhoea diseases (Dasgupta & Robinson, 2022; Kerr *et al*., 2022). The causal relationships between climate change and food security have been studied, which reveals the links between food security and climate change that centre on climate variability and agricultural food production (Myers *et al*., 2017), and variability in temperature and precipitation is connected to reduction in consumable food calories. Peng *et al*. (2020) discussed that climate change can enhance the outbreak of locusts that can destroy crop production, especially during long-term droughts.

In developing countries, food insecurity can induce the rate of obesity. Research evidence shows that the prevalence of obesity is higher in communities where there is a lack of healthier foods in the local stores and low-income communities (Park and Nelson, 2008). Other nutrition-related diseases like type II diabetes, which is associated with unhealthy and less expensive foods, are also common in conditions of food insecurity (Hampton, 2007). Declining economic conditions globally have prompted increased attention to the issues of food insecurity. There was the realisation that government and nongovernmental supports are no longer sufficient and are having trouble in exercising their mandate. This led to the paradigm shift and brought about the involvement of NGOs, international agencies, and volunteers, supporting the vulnerable subgroups through funding to meet health, food, and nutrition needs (Kregg-Byers & Schlenk, 2010).

The continent of Africa is heavily dependent on agriculture for the livelihood of its population, and it is largely rain-fed. In the sub-Saharan Africa, the FAO remarked that the number of undernourished populations of this part of Africa has increased by 45.6% since the year 2012. As a result, Africa is highly vulnerable to the threat of climate variability (UN, 2020). The warming projection by the IPCC also points to the fact that crop production and food security may be acutely affected (IPCC, 2018). Given the above facts, reduced productivity because of heat and water deficiency stress, floods' impact on food system infrastructure, and pest damages are factors that may singularly or combine to cause unpropitious effects on food security and the livelihoods of individual households at national and regional levels (UN, 2020).

The worst climate scenario predicts there will be a low average yield of 8% in Central and East Africa, 11% in North Africa, and 13% in West Africa (IPCC, 2018). Research evidence suggests that some crops, like millet and sorghum, have higher resilience and are therefore promising crops with a lower percentage loss of 5% and 8% by the year 2050; conversely, rice and wheat have lower resilience and are expected to be highly vulnerable crops with a yield loss of 12% and 21% by 2050, respectively (UN, 2020).

According to the IPCC, agriculture is directly responsible for 8.5% of all greenhouse emissions, with an additional 14.5% from deforestation that is prevalent in developing countries to clear land for agricultural food production and methane from livestock rearing. In addition to the above is the emission generation by crops and other derivatives in the process of moving them around shipping, aeroplanes and moving around with vehicles for several kilometres before they are sold. Agriculture emits carbon dioxide (CO_2), methane, and nitrous oxide; it also has the capacity to trap them, and the intensity of the effects of these gases depends on the land use, crops, manures, soils, and energy management (Fig. 3.2) (Pant, 2009). Again, soil nitrogen

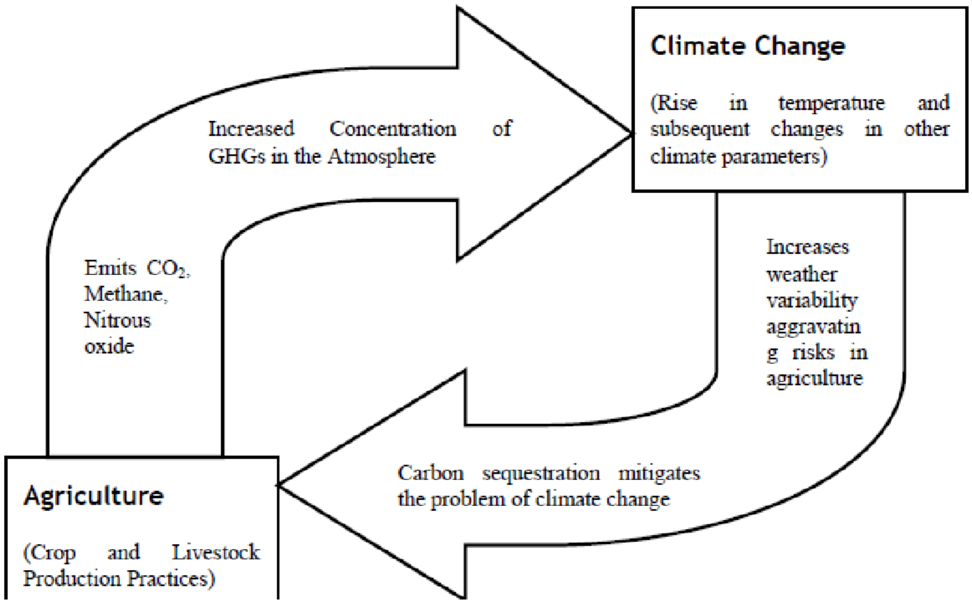


Figure 3.2: Interlinkages between climate change & agriculture. (Adapted from Pant, 2009)

management from wet soils containing nitrogen-fixing plants can be a source of the emission of nitrous oxide, and the application of fertilisers can emit nitrous oxide. Isbell *et al*. (2017) posit that land, including the water bodies, provides the livelihood support for humanity through net production of food supply, bioenergy, the delivery of ecosystem services and biodiversity. The International Monetary Fund (IMF), in 2011, estimated the annual value of the world's total terrestrial ecosystem services to be about 75 trillion USD, totalling the equivalent of the entire world Gross Domestic Product (GDP). Land use for agriculture and food production has been injurious to earth systems through deforestation and bush burnings, and balancing the earth ecosystem is important to the climate systems. Ciais *et al*. (2014) explain that the land ecosystem has an important role to play in climate system agriculture because human activities like grazing, timber extraction, conservation or city dwelling all alter the terrestrial ecosystems because about one quarter of anthropogenic GHG emissions are mainly from deforestation, plant-eating livestock and agricultural fertiliser inputs (Le Quere *et al*., 2018). One of the major challenges of agriculture in this century is how to integrate environmental, social, and economic development together with agriculture and make it sustainable in meeting the needs of the current generation without impinging on the needs of the future generation.

The world population is expected to increase by 3 billion in the next 50 years, and this increase is projected to be mostly in the developing nations. Presently, the world is witnessing about 800 million people living below $1 per day; implicitly, the world cannot solve the problem of food insecurity and poverty without conscious and concerted efforts to tackle the problem of sustainable agriculture and rural development (Pant, 2009).

Agricultural sustainability is an integral part of the wider concept of sustainable development that is to meet the economic, environmental and social goals of the society in an efficient manner without impinging on future production possibilities and welfare (Legg, 2006). To achieve sustainability, the levitation of economic growth becomes very important because of its direct connection to realising food security, sustainable agriculture and boosting nutrition (UN, 2018; Arora, 2018). Arora (2018) argues that emphasis should be laid on the use of native biological methods in combination with biotechnology and bioengineering; this will lead to the attainment of sustainable food security via sustainable agricultural techniques. The development of agricultural practices is central to the survival and expansion of the human population on earth, and pressure on agriculture soars with an unprecedented increase in the human population.

Fertile lands became scarce resources as there was a need to feed the growing human population. Following this, the introduction of chemical fertilisers and pesticides started in the 19^{th} century to boost production. The ever-growing human population began to enjoy the food production booms resulting from the use of fertilisers (Arora, 2018). With the success achieved in agricultural technology, evidence from a survey by FAO (2012) suggests that over 870 million people are still hungry in the world because of striated resource scarcities. To feed the 9 billion human population projected in 2050, there is a need to increase the agriculture production by 60% (FAO, 2012). The use of chemical fertilisers and pesticides has enhanced production and has been encouraged by various governments around the world. The downside of this resides in the excessive use, which resulted in acute environmental problems that include soil and water pollution, air pollution, soil salinity, development of pest resistance, loss of soil fertility, and, by extension, posing serious threats to food security, biodiversity and human health (Arora, 2018). It has also increased the rate of extinction, decimated some plant species, and increased the rate of greenhouse gas (GHG) emissions, cascading to global warming and climate change. Considering the above problems, it has become imperative to embrace farming methods that are ecologically sustainable to enhance food security (Arora, 2018).

Sustainable development of agriculture and food security in recent years has attracted a plethora of economic policy measures, and further understanding of it will continue to expand as these policies are implemented across regions and different countries (Bazgar, 2014), especially in sub-Saharan Africa. There are strong connections between a country's economic stability, food security and agriculture, which are influenced by other factors that determine food security in a country, which include the agricultural policies of the country, price volatility, sustainability outcomes, public/private partnerships and the agricultural potentials.

Agriculture has contributed indirectly to damaging the environment by spilling pesticides and disposal of livestock wastes into the streams and rivers and fertilisers runoffs into streams and groundwater. The combination of the above affects the environment by harming the welfare of animals and ecosystems by damaging the wildlife habitats. Conversely, agriculture provides landscapes and green spaces that benefit the environment by standing as a control for water flow and reducing erosion by covering the soil surface with crops to avoid floods and droughts. Implicitly, it is not in the best interest of the farmers to destroy the resources on which their livelihood depends. Legg & Viatte (2001) argue that the problem with the above is that consumers want all-year-round food of good quality from farmers, but to produce food that is environmentally friendly and sustainable will be costlier for farmers to produce.

The main aims of sustainable agriculture are economic efficiency, environmental quality, and social responsibility. To be economically efficient means meeting global food demand that is on the increase at a lower cost and, at the same time, responding to dynamic preferences for a variety of foods while adjusting to structural changes within the agricultural food products and the economy in total. In the same vein, sustainable agriculture will mean farmers need to meet the public demand for environmentally sustainable practices by cutting down on pollution from agricultural practice and conserving the natural resources at the same time, creating environmental wellbeing. All the above must be achieved in socially acceptable ways through improvement in farmers' education and skills, guaranteeing of animal welfare and acceptable income for workers (Legg & Viatte, 2001).

Field *et al*. (2014) explain that food insecurity is rife due to many different reasons that may be aggravated by population growth and climate change. Horton *et al*. (2016) argue that the current food supply systems and practices not only deliver insufficient food but are also economically and environmentally unsustainable, lacking in resilience, inequitable, and risk a human health disaster**.** The current global food system, where about 1.5 billion are overnourished and one billion people are undernourished, is a pointer to colossal failure (Horton *et al*., 2016). Studies suggest an urgent need to address the above problem by increasing crop production by two to three times depending on the amount of global development and future diet expected (FAO, 2009). Horton *et al*. (2016) posited that using the current agricultural method to increase production would lead to considerable increases in the consumption of natural resources which will not be sustainable. Following this concern, Garnett *et al*. (2013), argue for sustainable intensification through new technologies, and Smith *et al*. (2013) proposed increased resource efficiency.

This argument is based on the failure of many of the estimates needed to increase production, which could likely impinge on the primary productive capacity of planet Earth. Improved technology has been advocated as a solution to solving the problem of food insecurity with minimum effects on the productive capacity of the planet (Horton *et al*., 2016). Hertel (2012b) argues that productivity increases could economically lead to contradictory outcomes; for example, reduced demand of resources per unit of output will attract some environmental benefits, and reduced prices that result from total factor productivity gains can attract consumption recovery and increased exports, which will invariably lead to partial or total offset of the accrued benefits. These paradoxical effects were pointed out by Phalan *et al*. (2016) as more pronounced with cropland intensification and with irrigation agriculture, as discussed in Grafton *et al*. (2018). The food security strategies of increased yields through increased production have the propensity to lead to trade-offs in direct conflict with the environment, especially the environmentally sensitive lands because of technological advancement (Valin *et al*., 2021).

In the environmental Kuznets curve theory (Stern, 2004), environmental conditions will deteriorate as income rises or when economic conditions improve. However, after a certain threshold is crossed, there will be a slowdown in the process. Then, the condition will reverse itself, leading to a positive correlation between economic development and environmental quality. Implicit in this theory is that with economic growth and expansion, there will be a change in taste, environmental investments, and technology in favour of resource conservation. Efficient use of natural resources will be accomplished through technology which will guarantee the maintenance of resource conditions in the long term (Huisman *et al*., 2016). However, the advancement in agricultural technology to improve food production has its pitfalls in the Borlaug hypothesis advanced by Norman Borlaug.

Norman Borlaug (2002) argues that advances in agricultural technology will empower farmers to produce more food from a given portion of land, leading to growth in food supply without necessarily leading to increase in deforestation or distorting the natural vegetation and biodiversity (Huisman *et al*., 2016). The above idea is one of the arguments against the Malthusian idea that geometric population growth will result in food shortages and food demand. Borlaug's argument pointed out that technological change could help keep pace with food demand and reduce the effects on resources. There has been evidence of substantial increases in global agricultural productivity in many parts of the world because of the Green Revolution (Fuglie, 2010), and as innovation and technologies continue to emerge, there will be increases in productivity and an increase in food security (Herrero *et al*., 2020). One of the cardinal objectives of SDG2 is for the income and productivity of smallholders to align; this will be central for future food security to enhance capacity to support income and reduce food prices (Hertel *et al*., 2016). Valin *et al*. (2021), emphasises that to achieve land productivity, it is important to mitigate the impact of climate change on production because of its important role in economic development. Modelling studies by Stehfest *et al*. (2019) suggest yield increases in the future show an upward positive trajectory. There are technical gaps to close to attain the global yield needs, and this can be attained by improved technologies. It has been suggested that closing the yield gaps globally will have the benefits of raising global yield production by about 45% to 70% (Muller *et al*., 2012). Van Zeist *et al*. (2020) applied simulation models to assess and anticipate future yield development.

Borlaug's idea has been highly successful in Asia, where high-yielding crop species and the use of fertilisers, irrigation, and pesticides have led to agricultural development and preserved several millions of biodiversity (Stevenson *et al*., 2013; Huisman *et al*., 2016). Although the land and biodiversity-sparing effects can hold ground at the macroeconomic level, when considering the microeconomic scale, other factors might come into play to cause other dynamics which can manifest in the 'Jevons effect' or the 'Jevons paradox'. This paradox advanced that improvements in technology and thus efficiency would not necessarily lead to a reduction; instead, it may increase in resource consumption (York, 2006). These effects will occur in agriculture when high yields enhance profitability, which invariably attracts more land into cultivation rather than less. Following the above, the balancing of technological advancement in agricultural technology to improve production and thus food security on one hand, and the preservation of environment and resource conservation on the other hand will become necessary to realise consistent and sustainable food security.

The IPCC Fourth Assessment Report suggests temperature is expected to increase more than the global average with an expected deficit in rainfall in some parts of sub-Saharan Africa (SSA). There are differences in the outcomes of model predictions for changes in precipitation, with some exceptions that precipitation will decrease from June to August in southern Africa and increase from December to February in eastern Africa. The future precipitation condition in the Sahel remains a subject of uncertainty based on the Global Circulation Model (GCM) prediction (Ringler *et al*., 2011). Following the fact of limited agreement of the GCMs on the possible changes in precipitation, a global comprehensive climate change scenario ensemble of 17 models based on their past performance in predicting temperature and precipitation was developed by the joint efforts of the University of Illinois and the International Food Policy Research Institute (IFPRI). Results from this model were integrated with a process-based crop simulation model and IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) to assess climate change outcomes for sub-Saharan Africa (IFPRI, 2008).

It is projected that cereal production will decline by 3.2% in 2050 because of climate change in sub-Saharan Africa. Negative impacts are projected for wheat and sweet potatoes, while millet and sorghum are projected to yield higher under climate change because of their high tolerance to drought stress and higher temperatures. Under the ensemble climate change projection on agriculture, food prices will go up on most staple food crops as weather variability and climate change serve as additional stressors on already strained prices. The climate change scenario suggests maize, rice, and wheat are projected to be 4%, 7%, and 15% greater by 2050, and prices of crops like potatoes, yams, cassava, millets and sorghum will increase by 26%, 20%, 5%, and 4%, respectively, when compared with the historic climate scenario (IFPPRI, 2008, FAO, 2018). FAO (2018) estimates that between 2015 and 2050, total calorie demand will increase by 39%, and during the same period, agricultural output will increase by between 40% and 45%. Keyzer *et al*. (2005) added that because of the production of feedstuffs for the consumption of livestock. Tilman *et al*. (2011) projected an increase of crop needs by 50% in the year 2050, while Bijlert (2017) estimated that food demand will rise by 30% by 2050.

Effects of the El Niño Southern Oscillation phenomenon, which is one of the most influential climate phenomena on earth with its associated cycles of droughts and flooding events, have been documented to explain between 15% and 35% of global yield variation in wheat, oilseeds, and coarse grains; this existing sensitivity explains why a changing climate will have subsequent impacts on agriculture (Howden *et al*., 2007). Smit & Skinner (2002) noted that agriculture is inherently sensitive to climate conditions and is among the most vulnerable sectors to the risks and impacts of global climate change. Easterling *et al*. (1993) also argued that, without adaptation, climate change is generally problematic for agricultural production and agricultural economies and communities, but with adjustment, the vulnerability can be reduced, and there are numerous opportunities to be realised.

3.6 Adaptation to Climate Change and Food Security

The need for agricultural adaptation becomes more critical and of great concern, especially in developing countries where vulnerability is high because the ability of the farmers to adapt is low. The IPCC (2007) defines adaptation as 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities'. The IPCC expressed that about 170 countries now consider adaptation policies, but this idea has not been implemented. Resilience measures are progressing on a small scale but are largely reactive and done incrementally with a focus on extant effects or immediate risks. The disparity between the adaptation required and the current levels rests on a lack of financial capacity. To adapt to climate change, the IPCC estimated that the developing countries alone would require $127 billion per annum by the year 2030 and $295 billion per year by the year 2050. Currently, adaptation funds of the tracked climate finance are in the region of $23 billion - $46 billion from 2017 - 2018, representing 4% - 8%. According to the World Resources Institute (WRI, 2023), communities can engage in ecosystem-based adaptation to help them adapt to the effects of climate change that is impacting their lives and livelihoods and, at the same time, protect biodiversity, promote food security and economic benefits and improve health outcomes. WRI (2023), suggested the following: ecosystem-based adaptation, restoration and sustainable management of ecosystems, sustainable agricultural practices like tree planting within farmlands, promotion of crop diversity, and collaboration with indigenous and local communities. The ecosystem adaptation systems are a plan to account for the impacts of future global increases in temperature on ecosystems.

Climate change is one significant threat that will impact food supply systems to meet the ever-increasing demand for food in the world by the year 2050. Climate change impact has already been felt in the low productivity of major food crops and thus food supply (Jones *et al*., 2015; Bour, 2014). Sultana (2010) opines that the issues of climate change require transformational changes in agricultural systems because of the challenges it poses to decision-making. This opinion becomes more exerting when adaptation to climate change decisions is required, especially in agricultural food production systems.

Climate change and strategies to adapt have profound interlinkages with agricultural production, and the extent of these relationships was put into consideration in the outlook's production projection in the Aglink-Casimo model. Several factors determine agricultural yield variations, including weather factors of rainfall and temperature, production system, crop variety, diseases, and pests. The consequences of climate change on production output become more intense because of the irregularity of temperatures and rainfall, the increasing frequency and severity of extreme weather events, including droughts, floods, heat waves, and storms, and disruptions to ecosystem services (OECD/FAO, 2024). Accordingly, farmers respond to climate change in many ways depending on individual needs and conditions, including shifting planting dates, use of technology, mix cropping, diversification of farming activities, the use of integrated pest control, and other climate-smart agricultural practices. The capacity of farmers to adapt to climate change through technology and innovation, or Climate Smart Agriculture (CSA), is limited because of a lack of incentives and resources among poor farmers who are highly vulnerable to climate change. The effects of climate change on potential yields became prominent through the Aglink-Cosimo model, especially the ability of the model to account for ten-year yield projections, and autonomous adaptation in many ways lowers the negative effects of climate change.

3.7 Food Security and Food System Modelling

Sustainable food system is central to the concept of Sustainable Development Goals

(SDGs) of the United Nations, which requires a significant shift in the current agriculture and food systems that puts an end to hunger, ensures food security, and enhances nutrition by the year 2030. A food system consists of agricultural or farming systems, waste management systems, input supply systems, health systems, energy systems, and trade systems, and any changes in any of these components can induce structural change in the food system. The main aim of a sustainable food system is to deliver food security and nutrition that is economically, socially, and environmentally acceptable for all and not impinge on the ability of future generations to live.

Achieving the SDGs requires the changes to the global food systems to be more productive, inclusive of the marginalised and the poor, resilient, and environmentally sustainable, and to provide all with a nutritious diet (FAO, 2014).

Following from the foregoing, efforts at enhancing and examining the interaction of various components of food security through modelling abound in the literature; models have been used in food systems to express the interconnectedness between the principal variables that coherently constitute the food systems (Valin *et al*., 2021). Some of the useful models are the Integrated Assessment Model Consortium (IAMC, Van Vuuren *et al.*, 2011), the Global Trade Analysis Project (GTAP - Hertel, 2012), the Inter-Sectoral Impacts Model Intercomparison Project (ISIMIP - Warszawski *et al*., 2013), and the Agricultural Model Intercomparison and Improvement Project (AgMIP - Rosenzweig *et al*., 2013). Global food systems and relationships between socio-economic and environmental components have also been represented in models, for example, the agricultural and trade models by Tongeren *et al*., 2001; von Lampe *et al*., 2014; land system models by Foley *et al*., 1996; Haberl *et al*., 2007; climate and environment by Parson and Fisher Vanden, 1997; and the household-level microsimulations by van Wijk *et al*., 2014.

Some groups of models in the literature approached food security systems through the lens of food availability, focusing on three issues of long-term food need prospects, the threat of climate change, and the environmental impacts of food systems expansion (Valin *et al*., 2014; van Dijk *et al*., 2021; Valin *et al.*, 2021; Gerten *et al*., 2020). Valin *et al*., (2014) examines access to food by modelling the effects of exogenous increase of income, and Hasegawa (2018) considered the effects of rising agricultural prices on consumers, Hallegatte and Rozenberg (2017) examined the favourable income effects of rising prices on people employed in agriculture in the CGE modelling and household simulations. Soergel *et al*. (2021) applied the IAMs model to examine poverty and access to food inequality reduction, and food utilisation was attempted by Van Meijl (2020), while modelling efforts on food stability and resilience because of climate change are still developing (Valin *et al*., 2021).

Again, several agricultural models have been proposed in the literature that support adaptation to climate change to meet food security objectives of nation-states, especially the highly vulnerable countries of sub-Saharan Africa. The challenges posed by climate change to agricultural production vary according to the region under consideration and the production systems in use.

The application of the models for decision support adaptation and planning varies in the short and long term. Farmers can circumvent the climate change challenges by making use of scientific potentials in terms of adaptations in agricultural management. Opportunities for adaptation by farmers can be short-term incremental responses where farmers will choose to independently respond to changes depending on their local knowledge and experiences. Second, farmers can make use of the long-term transformative responses which are always executed on an expansive spatial scale.

Holzkämper *et al*. (2017) identified five different agricultural models which include empirical crop models, regional suitability models, biophysical models, meta-models, and decision models. Some of these models have their relative advantages and disadvantages; for example, the Empirical Crop Models (ECMs) assess the productivity of land relative to agricultural crops. This model has the merit of generating crop phenology using both temporal and spatial climatic and soil data; it is relevant to adaptation if the model is based on long-term series. Gornott and Wechsung (2015) found in their study that the use of autonomous adaptation by farmers, for example, shifts in sowing dates and cultivar options chosen, is completely accounted for in the empirical crop model. Lobell *et al*. (2008), however, argue that the empirical crop model method is only good for agricultural impact assessment not suitable for adaptation responses.

The Regional Suitability Models (RSMs) make use of biophysical land use potential on a regional scale both in the present and future conditions (Pelizaro *et al*., 2011).

This model has been used for fish habitat suitability information to predict gathering structures in an individual river segment within base-flow reductions (Zorn *et al*., 2012). The fish response curve was used to spot streamflow decline resulting in adverse consequences on resource-to-fish populations. A species distribution model was used to study Simarouba glauca under climate change conditions by Malviya *et al*. (2013); the result of this study suggests where the planting of this species can be suitable under certain adaptation options.

The Biophysical Models (BMs) simulate biophysical systems by using mathematical formalisation of the physical properties of the same system and are useful for predicting the effects of biological and/or physical elements of a complex system. A good example is the process of plant growth, nutrients and carbon dynamics, flood inundation and water cycles, which are mathematically formalised based on the understanding of it.

This model allows the effects of climate and weather change interactions to be tested; therefore, it allows the combination of climate change and agricultural ecosystem functions with adaptation options, for example, choices to prevent stressors like droughts, which can be managed by irrigation (Holzkamper *et al*., 2017).

Meta-models (Mms) have the advantage of helping decision-makers in terms of choice and suitable climate change adaptation because of their integrative capacity; they enhance social learning and foster integrative system thinking among decision-makers and increase the viability of the model when using it for analysis because of its link to the neutral network method (Holzkämper *et al*., 2017; Audsley *et al*., 2014).

Decision support models (DSMs) enhance farmers' decision-making when considering climate change adaptation and other attendant economic and social conditions. Decisions are integrated into this model, and climate change adaptation decisions of farmers in response to biophysical and economic shocks are replicated by the model. This idea was tested by Berry *et al*. (2011), on the extent to which adaptive practices associated with self-assessed health using hierarchical linear regression modelling, the study aims at estimating the determinants of adaptive capacity or ability to respond to climate and economic changes.

Generally, adaptation models are useful because they have the capacity to combine many interacting entities to better understand the effects of different drivers of climate change. Communicating the findings effectively for planning purposes will require the coming together of all stakeholders and depends on the level at which adaptation decisions are made. The use of these models for agricultural decision support and adaptation planning to climate change is fraught with limitations. In a wider context, there is the possibility of maladaptation with implicit negative outcomes in the long run. It is one of the critical challenges of agricultural adaptation planning that needs scrutiny**.** Strategies to adapt to climate change could go wrong and lead to maladaptation, where the action taken to minimise or reduce exposure to the impacts of climate change leads to increased exposure, and people become more likely to be impacted by the implementation of the adaptation strategies (Schipper, 2020). This could also impact agricultural production systems because of inadequate understanding of possible future impacts of climate change and become anathema to the interrelationships between agriculture and ecosystems if adaptation plans and their implementation is not accurately positioned (Holzkamper *et al*., 2017). Therefore, to achieve good outcomes in climate change adaptation in the long run, there should be frameworks for keeping track of managing adaptation, and the effects should be entrenched as institutions.

Increasing evidence points to the weaknesses of human ability to adapt to climate change; this limitation is both physical and social in nature (Nelson, 2011). Considering the scale of some events like deep-ocean currents controlled by temperature differentials and salinity, it will be a great challenge for humans to adapt to the physical consequences of these transformations. The global wide effects on ecology of loss in biodiversity and its effects on biogeochemical flows may be too massive to be adapted (Lenton *et al*., 2008). Adger *et al*. (2009) argue for human limitations to accurately define adaptation as it relates to the plural world; for example, culture, individual perceptions, and social settings will determine people's ability to act or react to climate shocks.

Agriculture will be affected by reduced growing seasons and higher temperatures; rain-fed crop yields in some countries will decrease by 50 per cent, and an estimated 50-250 million Africans will face increased water stress by 2020 (IPCC, 2007). Jones & Thornton (2003), in their study, found in Africa and Latin America that the aggregate yields of maize by smallholder rain-dependent agricultural systems are likely to decrease by approximately 10% by 2055.

In sub-Saharan Africa, about 80% of the people depend and will continue to depend on agriculture for their livelihoods. Agriculture in sub-Saharan Africa is characterised by very low yields due to agro-ecological features, poor access to services, lack of knowledge and inputs, and low levels of investment in infrastructure and irrigation (Calzadilla *et al*., 2008). The pressure of high population growth rates on agricultural production and natural resources, especially in rural areas, further complicates the challenges of reducing poverty. In Sub-Saharan countries, many agricultural systems are already close to crisis point even without the problem of climate change. The provision of food for a rapidly rising global population is taking a heavy toll on farmlands, rangelands, fisheries and forests, and water is becoming scarce in many regions. Climate change could be the additional stress that pushes systems over the edge (CGIAR, 2009). Given these existing problems and the potential for climate change to exacerbate the issues, the future of agriculture in sub-Saharan Africa is at risk. To stand up to these challenges, the region's farmers, especially rural subsistence farmers and pastoralists, must adapt technologies to increase productivity, stability, and resilience of their production system.

Morton (2007) argues that subsistence and agro-pastoral systems practised in marginal areas with high rainfall variability and natural hazards, as in the Sahel, have evolved a kind of livelihood strategy that helps them to reduce overall vulnerability to climate impacts, referred to as 'adaptive strategies' or 'coping strategies' to manage the impacts.

Some studies have also suggested that peculiar characteristics of livelihoods in dry land in rural Africa could be regarded as strategies to climate variability. Mortimore & Adam (2001) enumerated five important elements of these adaptation strategies as available in northern Nigeria: "negotiating rain" – that is allocating farm labour over the season according to the unpredictable seasonal rainfall variations, the use of biodiversity in cultivated crops and wild plants, combining of livestock into farming systems, working land harder in terms of labour input per acre and livelihood diversification. Hansen *et al*. (2012) explain that scientific study of global warming conditions points to a more stable long-term trend with natural changes in local weather and climate. This infamous local variation in climate condition with its tendency for long-term trends makes it challenging for local rural farmers to understand climate change (Debela *et al*., 2015). Madison (2007) argues in those studies carried out in Africa on smallholder farming systems that education attainment of rural farmers has a direct influence on their understanding of the impacts of climate change around them.

Ngigi (2009) posited that the impacts of climate change would be more significant on smallholders and subsistence farmers, especially with only about 6 per cent of African croplands irrigated. This direct effect on agricultural production and food security will be exacerbated by greater exposure to malaria and other climate-influenced diseases that reduce labour productivity and employment opportunities.

Sissoko *et al*. (2011) observe that countries of West Africa have low capacity to withstand the threat of climate change, especially rural community households. To adapt to the changing climate, there is a need to change the agricultural practices to improve the livelihoods and food security of the rural households (Vermeulen *et al*., 2012). Traditional agricultural adaptation practices have been practised and have been advocated in most West African communities to deal with weather variability like droughts and climate change.

In light of the available literature, studies have focused on the effects of climate change on farming in general, decreased productivity, land degradation, negative effects on livelihood and increased malnutrition, and adaptation techniques to surmount the problem of adverse food security in general reference to the Sahel region (Thompson *et al*., 2010), and little attention has been given to rural subsistence farming and food production with specific attention to Borno State of northeast Nigeria, latitude 12° and 14° north and longitude 9° and 10° east.

This geographical location in the dry land makes it vulnerable to the impact of climate change and, in recent years, been confronted with persistent droughts, floods, terrorism, and banditry which has impacted the livelihood and agricultural food production of the population (FAO, 2019).

Borno state's economy is substantially agricultural-dependent, with 70% of the population depending on it and practising subsistence farming, which is the source of food for the population. There is little support for the rural communities' efforts to cope with their changing environment, but, more importantly, opportunities for adaptations should be central to enhancing the capacity and securing the well-being of subsistent farmers by any proposed intervention**.**

This study intends to fill this gap by looking at the effects of climate change on sustainable food production and supply among smallholder farmers and exploring the challenges to climate change adaptation in Borno State, northeast Nigeria. The result of this study is expected to be useful for policy support to help rural farmers adapt to climate variability that affects their livelihood and food production. It will also serve as a useful template for any other community of similar problems in sub-Saharan Africa.

Chapter Summary

This chapter provides the conceptualisation and literature review on climate change, rainfall variability, and their impacts on food security, with particular reference to the Sahel region of northeast Nigeria, using Borno State as an example. It begins by situating food security as a fundamental human need, tracing its historical, scholarly, and policy evolution from the 1950s to the present. Over two hundred definitions of food security exist, but the Food and Agriculture Organisation (FAO) and related institutions highlight four main pillars—availability, access, utilisation, and stability—later expanded to include sustainability and agency.

The chapter underscores how hunger, famine, and malnutrition are intertwined with poverty, conflict, climate change, and weak governance. In Borno, food insecurity is acute due to insurgency-induced displacement, poverty, and restricted access to resources. It reviews how definitions of food security shifted from a production-based focus to broader perspectives incorporating access, distribution, nutrition, and human rights. UNICEF and WFP data confirm alarming rates of malnutrition and food insecurity in the region.

The multidimensional nature of food security is then explored across its dimensions:

i. Availability – ensuring sufficient food supply, challenged in Borno by conflict, displacement, and disrupted trade.

ii. Accessibility – households' economic and physical ability to obtain food, constrained by poverty, shocks, and social inequality.

iii. Utilisation – proper nutrition, safe water, health, and sanitation, undermined in Borno by malnutrition, stunting, and poor health access.

iv. Stability – consistent access over time, threatened by climate variability and insurgency.

v. Sustainability – long-term resilience of food systems amid climate change and inequality.

vi. Agency – the capacity of individuals and groups to influence food systems and governance.

The chapter further links food security to the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), noting strong synergies with poverty reduction, health, gender equality, decent work, and environmental sustainability. Despite international summits and commitments, achieving SDG2 by 2030 remains uncertain due to climate change, conflicts, economic crises, and structural inequalities.

The literature also highlights Corporate Social Responsibility (CSR) as an important factor in food security, especially in addressing ethical concerns such as inequality, gender disparities, environmental degradation, and animal welfare.

Finally, the chapter reviews the complex interrelationship between climate change and food security, emphasising that rising temperatures, erratic rainfall, droughts, and extreme events reduce yields, threaten livelihoods, and exacerbate hunger and malnutrition, especially in vulnerable regions like Borno. While technological innovations, sustainable agriculture, and improved governance offer pathways forward, the chapter concludes that food security is a multidimensional, ethically charged, and climate-sensitive issue requiring integrated and context-specific solutions.

CHAPTER 4

4.0 Methodologies

This chapter explains the material and methods employed to acquire and analyse data for household food security issues in this study. Research was carried out using both primary and secondary data sources, and to meet the set objectives of this thesis and balance the investigations, three different methodologies, viz., descriptive statistics and ordinal logistic regression analysis, were used to assess the food security condition of households in the study area. Second, the Standardised Precipitation Index (SPI) was used to assess any observed changes in precipitation over the series of 1950-2019 and its possible effects on agricultural food production and supplies, and third, Multiple Regression Equation (MR) was used to investigate the relationships between weather variables, security challenges and food security. Each of the three methods was employed to address the aim and objectives of this research. Each method begins with the introduction, which lays out the broader perspectives and sets out specific aspects and arguments for food insecurity based on available data in the study area.

4.1 Recapping the Research Questions and Study's Objectives

Food security, and in fact, availability, affordability, and accessibility are imperative for the teeming and vulnerable population of Borno State. To guarantee the above, there is the need to embrace a workable adaptation measure by the farmers to cope with the harsh realities of climate change that manifest themselves in rainfall and water shortages that farmers need to plant crops and produce food. Considering the fact of the geographical location of Borno State in the arid zone of the Sahel, it makes the state more vulnerable to rainfall variability, just like any other regions in the arid zone of the world. Given the context of this natural barrier, it is important to consider a new approach in terms of the adaptation strategy and agricultural systems transformations to create resilience for farmers to cope with climate change. The key aim of this study is to assess the impact of rainfall variability on food security/insecurity in the Sahel of northern Nigeria. This study seeks to assess and examine how trends in precipitation influence agricultural production and food security. This will help develop policy recommendations for policy makers that can possibly improve and advance agricultural production and food security.

4.1.1 Research Questions

In Borno state, rainfall variability and rising temperatures have cascading effects on natural resources availability, which increases the vulnerability of the inhabitants to food shortages, malnutrition, and disease transmission. Borno State's population are 80% dependent on agriculture, and farming in this region and indeed in Nigeria is dominated by crop agriculture, practised in small holdings and heavily dependent on rainfall. This subsistence farming method lacks modern scientific knowledge and technologies and has a lack of water storage facilities, with no access to services, which exposes the sector to weather and climate variability. The above problems have recently been aggravated by terrorism and banditry, which took over the entire northeastern Nigeria and have significant effects on farming and thus food production.

Given the importance of precipitation in the agricultural livelihood and thus food production of the population of Borno State, it has become imperative for more evidence-based research to be done to establish or otherwise the causal mechanisms between precipitation variability and food security in Borno State. This research is primarily directed at the empowerment of the people to enhance their adaptive capacity to cope with the menace of the changing climate with respect to precipitation with the attendant impacts on the people's livelihood. Derived from the above concerns, the following questions are proposed to address various aspects of food security challenges in Borno State, northeast Nigeria.

i. What is the prevailing state of household food security in Borno State, and how does it vary across different local communities and livelihood systems?

ii. How does the food security index differ among various demographic and socioeconomic groups across Borno State?

iii. What is the nature of the relationship between precipitation variability and food crop production trends in Borno State from 1950 to 2020?

iv. Which socioeconomic and demographic factors most significantly influence sustainable food production in Borno State, particularly within the context of prevailing violent insecurity?

v. What adaptation and coping strategies are adopted by subsistence farmers in Borno State to mitigate the impacts of climate change and rainfall variability on agricultural production?

vi. What policy and practical interventions can effectively promote sustainable food production and enhance adaptive capacity to climate change in Borno State and the broader Sahel region?

4.1.2 Study objectives

i. Assess household food security conditions in Borno State using quantitative and qualitative indicators.

ii. Calculate the food security index for different demographic and socio-economic groups in the region.

iii. Analyse the relationship between rainfall variability and food crop production using climate and agricultural data from 1992 to 2020.

iv. Identify key socio-economic and environmental factors affecting sustainable food production in Borno State.

v. Evaluate current adaptation strategies employed by smallholder farmers in response to climate variability and food insecurity.

vi. Develop actionable policy recommendations for improving food security through climate adaptation strategies, access to financial resources, and sustainable agricultural practices.

4.2 Research Philosophy

What a researcher believes or perceives to be truth, reality and knowledge is referred to as research philosophy. Saunder *et al*. (2012) define research philosophy as the doctrine that underpins the acquisition of knowledge and the nature of that knowledge in relation to the research. It is the philosophical position that informs and determines research methodology (Crotty, 1998), while Easterby-Smith *et al*. (1999) describe it as a significant part of research because of its usefulness in determining the type of research design to use and the reason why it has been chosen.

Research consists of four main philosophical realms, namely: ontology, epistemology, axiology and logic of inquiry (Al-Ababneh, 2020). Different research philosophies allow scientific research to be approached and understood in different ways and enable researchers to understand the substantive literature surrounding the subject of investigation. Tamminen & Poucher (2020) allude that research philosophy means a worldview of a researcher, the nature of the world, individual place in it, and different possible relationships to the world and its parts. Pring (2012) emphasised how imperative it is for a researcher to define and explain the research philosophy that underpins his/her thesis or dissertation. Research philosophy occupies a very important part in research procedure and guides researchers in the process of finding answers to enquiries (Sefotho, 2015). It describes the beliefs and values which direct the plan, collection and analysis of data in any research, and the choices made complement the philosophical principle (Ryan, 2018).

Creswell & Clark (2011) explain that determination of researchers' philosophical stances entails knowledge of the differences between categories of stances with thoughtful awareness of the assumptions the researcher holds about knowledge acquisition and testing. Consequently, the aims and objectives of the research are prognosticated on assumptions as to the way knowledge is acquired, which gives an insight into the direction of the research inquiry. The process of carrying out a systematic and thorough investigation with the purpose of discovering and interpreting the facts available in a certain reality is called scientific research (Queiros *et al*., 2017).

Crotty (1998) highlighted the four elements of the research process, i.e., epistemology, theoretical perspectives, methodology, and methods, and how they are related to one another. Epistemology dictates theoretical perspectives, theoretical perspectives dictate research methodology, and methodology determines the method of research.

4.2.1 Ontological Perspective

Ontology is referred to as the theory of existence, and what exists is rooted in the tenets of a specific paradigm relating to truth and reality (Hitchcock & Hughes, 1989; Žukauskas *et al*., 2018). It is about the assertion of the existence of reality in the researchers' minds, whether objective or subjective. Bryman (2008) describes ontology as the values a researcher holds about what a real world is and what one believes to be truth. It is fundamentally related to the reasoning whether social entities are to be viewed as objective or subjective (Saliya, 2023) and the study of the conception of being or reality (Sefotho, 2015). It is a philosophical concept that studies the nature of reality, and in the present study – climate and food security studies – it defines the nature of reality and how there may exist different perceptions of what we know or whether the world exists independently of the researcher's perception. Scotland (2012) declares that researchers are required to take a position on their perceptions and true position on things and how things truly work; therefore, researchers must align with one ontological position, which must be clearly expressed in the ontological assumptions of the research.

The ontological belief of a researcher moulds the decision of the researcher concerning the methodology to use, and this hinges on what the researcher perceives as an experience, a constructed reality that is contingent on social and human conception.

The perception of the researcher will invariably determine whether a qualitative approach that comprises a subjective and interpretive research or a quantitative approach that is suitable for an objective and measurable study, or a mixed-method approach (Jackson, 2013).

The researcher's position that knowledge is real and objective and is out in the world for the researcher to capture, observe, measure and quantify determines the methods and procedures to use for the research (Sikes, 2004). On the other hand, if the researcher's assumption is experimental, personal and subjective, it will be followed by the question of who is involved. Oliver (2010) explains that the ontological belief of a researcher is related to the decision about data collection for their research, and this is connected to how we view the truth.

Denzin & Lincoln (1998) explain that ontological-related questions bother on real existence and different types of knowledge pertaining to reality or epistemology; these epistemological questions assist a researcher to find the nature of association between the researcher and the subject. To make any assumption regarding true reality, researchers must follow the rules of objectivity and value distancing position to understand what reality is and the process of its existence. Methodological questions will assist researchers to address the research questions to know the truth about the reality of the subject under investigation.

4.2.1.1 Ontological Assumptions of this Researcher

The goal of this research is to combine qualitative and quantitative analysis of data from surveys, interviews and historical data to examine the effects of precipitation variability on sustainable food security in the dryland of Borno State, northeastern Nigeria.

Precipitation is an important element of weather and climate. Given the fact of the upsurge of carbon dioxide (CO_2) concentration in the atmosphere since the 1800 industrial revolution, climate change impacts have been projected to be more severe among the vulnerable populations in the developing countries, particularly the rural 'smallholder' farmers. Africa south of the Sahara has been identified by the Intergovernmental Panel on Climate Change (IPCC, 2023) as a hotspot with various social and economic demographics, livelihood vulnerabilities, and security challenges facing the region. A few or a combination of these factors limit the region's capacity to adapt to climate change.

The perception of climate change is based on long-term experience of weather variability, especially temperature and rainfall, and recent experiences of the irrationality of weather phenomena with their characteristic intensity never witnessed before. This resulted in devastations that affect farming and smallholder farmers in their ability to plant and produce food crops.

The effects of these changes on the rural agro-dependent food security situation of the rural population of Borno State, northeast Nigeria, can only be adequately measured by a qualitative approach to encourage research participants to describe their experiences. This will be followed by an interpretive approach to analyse their description to determine perceptions; this was supported by quantitative data derived from the survey and analysed quantitatively by descriptive and inferential means.

Climate change and its effects on food security is a scientific body of knowledge, and to know the truth and prove it scientifically, a process must be followed to reach the answers to the problems. From an ontological perspective, this researcher takes a contrasting view by conceptualising climate change as a human conceptualisation, a phenomenon that is being witnessed around the world. Studies show that the science of climate change is beset with multiple ontologies (Goldman *et al*., 2018). This researcher sees climate change not as an external body of facts but as a perception created by individual relationships and perceptions of it, making sense of it, and expressions of personal understanding of it. Following from the above, climate change can be regarded as a human construction and result of human interpretation of the phenomenon. From this ontological perception, the focus of this research is not the science of climate change and food security per se but the relationship between climate change, food security and the effects on rural community households in Borno State.

4.2.2 Epistemological Perspective

Epistemology is defined as a branch of philosophy that concerns itself with the questions of the nature of knowledge and how the knowledge is acquired and validated. Epistemology focuses on the question of what is real and whether the knowledge is different from others. Sharp (2009) described it as what counts as knowledge and how it is. It is expressing the nature and scope of knowledge and how the knowledge relates to truth, belief, and justification.

Following the above definitions, research by nature is concerned with searching for new knowledge, and the researcher's epistemological position is important, as well as the type of methodology chosen in relation to its purpose and goal. Jackson (2013) opines that the rigour of the methodology applied in research is directly connected to the strength of the claims of new knowledge. The ontological perspective of a researcher is associated with his/her epistemological views and the ontological view as related to the reality of the world and the epistemological position as related to the knowledge of the same world.

Sieber & Hackley (2015) argue that when epistemology is applied to a researcher's area of specialisation or domain, epistemology will represent the way that area of specialisation is understood, which is also regarded as a paradigm. Specific epistemology is associated with prejudices, biases and foreknowledge that has been established to become a norm or institutionalised. Searle (1995) described this as social constructivism, that is, epistemologies derived from choices related to individual domains and how these choices are institutionalised to norms.

4.2.2.1 Epistemological Assumptions of this Researcher

Broadly speaking, climate change research studies the philosophy of science dimensions of climate and Earth system science, causal and elucidative strategies for extreme weather events, and the critical points in both natural and social systems in the context of climate variability and environmental challenges attendant to it. This study focuses on the epistemic and methodology that underpins climate variability and the causal links to food insecurity among vulnerable populations in the drylands of Borno State, northeastern Nigeria. Research aims to carefully examine the effects of climate variability on sustainable food security in the dryland of Borno State, with particular emphasis on smallholder farmer households, with the goal of providing support for addressing food insecurity problems that are pervasive in northern Nigeria. Establishing the possible causal links between climate change and food insecurity with the intent to provide a point of view on this issue from a philosophical perspective with the expectation that such a perspective will improve the understanding of the causal links between climate (precipitation) variability and food insecurity. It is also expected that the attention of policy makers at national and regional levels would be drawn to the problem in this region with the expectation of using the mitigation and adaptation strategies recommended to address the problems countrywide.

The way climate change is perceived has profound effects on the farmers' ability to adapt to climate change and ensure food security. Climate change science, on the one hand, can be seen as an existing body of truth that needs to be studied by procedural methods that lead to understanding and knowledge as opposed to a relational understanding of it.

As opposed to the above, climate change can be perceived or be understood through practical experiences, especially by the rural farmers/smallholders, and solutions to the problem of climate change could evolve through the practical experiences of the farmers over time.

Following from the above, the researcher's ontological view of climate change is construed as human construction formed through the relationship that exists between the experience of climate change and the experience of climate variability, which supports the epistemological view of climate variability through subjective and interpretative coherent meaning. In view of this reason, it has profound effects on the method the researcher decides to use to source data regarding climate change and food security and the way the data is analysed in terms of how climate change knowledge is brought about and how the new knowledge that results from the research is arrived at.

In this research, to determine the perceptions of climate change among farmers and groups of households, the researcher's positionality is open to the likelihood of bias, so the methodology adopted is such that the participants were free to say their view without any fear of consequences, without any leading questions from the researcher and with no judgement. Before data were collected, the methodology to be used was decided, and the aspect of data collection was clear and unambiguous in light of the philosophical approach that underpins this research.

To determine the wide variety of climate change perception among a group of farmers' households, all data collected were adjudged to be true to what the participants had to say. Participants were allowed to freely discuss their experiences of climate change and how it has affected their livelihood and family. Analysis was done such that all answers and descriptions were interpreted to ascertain the range of perceptions of climate change in a reliable and valid manner.

The ethical dimensions of the research design were well considered at this point of the research design. Again, it is also important to mention that the effects of climate change could be very punitive or grave, as they could leave painful memories with the participants that experienced it; therefore, the protection of potential participants recalling emotional and painful memories of climate change experiences was taken into consideration.

Connecting ontological perspectives to the epistemological view of knowledge in relation to the positionality of the researcher regarding perceptions of climate change, the emphasis on relationality between the farmers and climate change, the creation of climate change perceptions from subjective climate change experience, and the creation of new knowledge regarding climate change perceptions from interpretive analysis, subjective expressions of climate change experience. The above line of thoughts began to shape the mind of the researcher regarding the type of methods to use for the data collection and analysis.

4.3 Choice of Methodology

One important aspect of selecting a research methodology rest on researchers' positionality (Sikes, 2004). Other significant factors that shape the selection process are the philosophical assumptions of the researcher as they relate to values, beliefs, epistemology, ontology and relationality, following the belief that research is subjective with the most scientific, positivist, objective and quantitative. Researchers will make a subjective choice of statistical method to use and the type of interpretation that follows according to the researcher's perception, which is important to making decisions at every stage of the study (Jackson, 2013). As proposed by Kincheloe & Berry (2004:6), assumptions determine the results, and the type of methodology used in research influences the outcome. Following from the above and taking into consideration the many ranges of research paradigms available in food security studies, but with no sound understanding of how they evolved and what they entail, it will be inadequate to choose one paradigm over the other. Notwithstanding, a philosophical paradigm must expressly underpin the methodology and research design of a researcher. Understanding the research paradigm and the principles that underlie it will assist the researcher to make evidence-based decisions about research design and methodology and ultimately allow the researcher to justify the decisions made.

4.4 Research Paradigm

According to Kivunja & Kuyini (2017), 'paradigm' is a term that derived from the Greek word that means 'pattern'. It is a collection of basic beliefs, a set of methods or methodologies, on how we perceive the world as it relates to the subject of investigation or research. This ultimately impacts a researcher's view of the topic being investigated. Guba & Lincoln (1989) explains that paradigm 'is the researcher's perception of the world, individual place in it and the range of possible relationships with that world and its parts'. Fraser & Robinson (2004) submit that 'paradigm' refers to a set of beliefs in respect of how problems exist and the agreed process for the problem to be investigated. Guba & Lincoln (1994) characterised world views of research into four categories: positivist, postpositivist, critical, and constructivist, according to their ontological, epistemological, and methodological beliefs. Burrell &

Morgan (1979) proposed that “all social scientists approach their subject either through explicit or implicit assumptions in respect of the nature of the social world and the way in which it may be investigated”. Paradigm underpins the specific way a researcher sees the world and makes sense of it (Hughes, 2010).

Kuhn (1962) characterised a paradigm as a worldview that consists of the beliefs of the scientists. He argues that different scientists with different views of the world would not be able to interface with each other because of the basic defences in their definitions of reality and methodology. Kuhn explained further that a paradigm shift does occur in the scientific community when past methods are no longer suitable to explain a phenomenon; a new method would emerge. Guba & Lincoln (2005) disagree with the notion of replacing one dominating method from the past with a new one by researchers. By contrast, a paradigm was seen as a set of assumptions that is the subject of ethics, ontology or reality, and epistemology that results to different assumptions with regard to the nature of systematic inquiry (Mertens & Wilson, 2012).

Besta (2010) argues that the whole idea of a paradigm is at cross with the fundamental idea of three paradigms, i.e., quantitative, qualitative, and mixed methods. Further, the terms 'qualitative' and 'quantitative' express the type of data, not the epistemologies, methodologies, designs, and ontological assumptions that are related to different research frameworks.

4.5 Methodological Justification

The methodological choices adopted in this study are justified by the complexity of the research problem and the need to capture both measurable climate patterns and the lived realities of food insecurity in Borno State.

4.5.1 Research Philosophy and Strategy

The study is guided by a pragmatic philosophy, which prioritises the research problem over strict allegiance to positivist or interpretivist paradigms. Pragmatism allows the integration of quantitative methods (e.g., rainfall analysis, household food security surveys) and qualitative methods (e.g., interviews and focus groups). This is consistent with the study’s aim of examining rainfall variability and food security outcomes while also exploring how communities experience and respond to these challenges.

Considering the nature of the current research, the mixed-method approach is adopted, which is rooted in pragmatic philosophy, which implies that an idea is true or what works successfully in practice is able to solve the problem under investigation and achieve a positive and satisfactory experience pertaining to the real world.

Green & Hall (2010) explain that a philosophical framework underpins the use of mixed methods on the premise that there is no one set of methods that is suitable but what is appropriate for the research under consideration. Consequently, Denzin (2012) discussed the danger of oversimplified use of the pragmatic philosophy in research, especially the idea of 'if methods fit, then apply'.

Biesta highlights the core principles of pragmatism as a philosophy relevant to mixed methods research, noting that Dewey argued no knowledge claim can be regarded as absolute "truth". Instead, different claims emerge from different ways of engaging with the social world.

Similarly, the transformative paradigm offers another philosophical lens that can justify the use of mixed methods, particularly when such methods advance human rights and social justice (Mertens, 2009; Mertens *et al*., 2010; Mertens & Wilson, 2012). This paradigm is grounded in an ethical stance prioritising equity and justice. From this axiological foundation, researchers derive assumptions about reality, knowledge, and inquiry that align with this ethical commitment.

Reality, in this view, is seen as multifaceted and shaped by power dynamics within society. Competing versions of reality are assessed based on their potential to challenge oppression, leading to an epistemology that values community engagement and cultural respect. Mixed methods design often align with the transformative paradigm because they allow researchers to capture both qualitative and quantitative dimensions of complex social issues, thereby supporting inclusive and justice-orientated solutions.

A mixed-methods strategy was chosen, specifically a convergent parallel design, which enables the collection of quantitative and qualitative data simultaneously. The choice ensures triangulation, where insights from climate data, household surveys, and qualitative narratives are cross-validated to enhance the credibility of findings.

4.5.2 Qualitative and Quantitative Methods

Methodology is a very important instrument for exploring scientific research; it involves the analysis of methods and instruments required for elaborating any scientific work. The scientific method is an important tool for finding the truths about the world, investigating theories and executing empirical validation (Flanagan, 2013). The goal of this research is to combine qualitative and quantitative data sets using focus interviews, survey data, and historical data sets to examine the effects of rainfall variability on sustainable food security in the dryland of Borno State, northeastern Nigeria.

The use of quantitative and qualitative methods in one single research study has become common in many areas of research studies, and especially in social sciences. Each of the qualitative and quantitative methods are associated with a specific paradigm, with a set of assumptions related to reality or ontology, knowledge of the said reality or epistemology, and the ways of understanding of that reality or methodology (Sale *et al.,* 2015*;* Guba, 1990).

Several arguments have been presented in favour of the mixed-method approach to research study. According to Haase & Myers (1988), the combination of qualitative and quantitative in a single study has the common aim of interpreting the world we live in; both methods provide a common rationale, and the method of inference is the same for both methods (Sale *et al*., 2015; King *et al*., 1994). Sale *et al*. (2015) explain that qualitative and quantitative methods are accordant because they are rooted in theory-based facts, errancy of knowledge, dominance of personal opinions in the inquiry process, and undefined theoretical tenets. Mix-method research has the commitment to enhancing the human condition by providing knowledge for human practical use, responsibility for diligence/accuracy, and appraisals of the study process. Another point of view in favour of mixed-method research is that it is convenient for solving problems, especially when the phenomenon under investigation requires complex data with different approaches (Clark and Yaros, 1988). However, Miles & Huberman (1984) warned that the debates that surround the mixed-method approach should not become a preoccupation of a researcher, the debate may not go away in the foreseeable future, and that the rightness of epistemology does not do research.

The quantitative research method is rooted in positivism and more related to empirical research, with the belief that all phenomena can be shortened to empirical indicators that denote the truth. Therefore, in the quantitative paradigm, the ontological stance is that there is only one truth, and unbiased realities exist without the interferences of the researcher or the researcher being influenced by the phenomenon. That is, the investigator and the phenomenon being investigated are epistemologically independent entities. This allows measurement of the causal relationships between variables to be a value-free scheme (Sale *et al.,* 2015; Guba & Lincoln, 1994).

The qualitative method, in contrast, is rooted in interpretivism and constructivism paradigms (Guba, 1994; Altheide & Johnson, 1994). The ontological principle of this method is that there are multiple truths contingent upon the researcher's construction of reality.

And the epistemological consideration is that reality does not exist independent of the mind of the investigator; the object under investigation and the researcher are connected, and findings are commonly created within the circumstances framing the research. Smith (1983) suggests that reality does not exist before the activity of research and will cease to exist when the investigation ends.

Qualitative research is more concerned about advancing the understanding of a given problem rather than the numerical representation of it. The main goal of qualitative research is to generate in-depth and elucidatory information that explains the various ramifications of the problem under investigation. It studies the aspect of reality that cannot be quantified with emphasis on the understanding of and the dynamics of social connections (Queiros *et al*., 2017). And the researcher is regarded as the object and subject of the investigation.

In cause-effect relationship research, as in this current study, both quantitative and qualitative methodologies are used to test hypotheses using a deductive approach, an objectivist perspective as epistemology, positivist philosophy as a theoretical view, a survey strategy as research methodology, a qualitative method of content analysis as research methods and a quantitative method for statistical analysis (Al-Ababneh, 2020).

4.5.3 Sampling Design and Bias Handling

Households were sampled using stratified random sampling to ensure representation across socio-economic and demographic categories, while purposive sampling was used for focus groups and key informant interviews to capture specific expertise and experiences. The sample size of 398 households was statistically adequate (95% confidence, 5% margin of error) and logistically feasible given the insecurity context. Potential sampling bias was mitigated by:

i. Including both farming and non-farming households.

ii. Translating questionnaires into local languages (Hausa and Kanuri) to avoid exclusion.

iii. Training enumerators to ensure consistency and minimise interviewer bias.

4.5.4 Data Collection and Saturation

Quantitative data were gathered through structured household surveys and secondary datasets (rainfall, crop yields), while qualitative data were obtained from FGDs and key informant interviews. Qualitative data collection continued until thematic saturation was reached, ensuring comprehensive coverage without overburdening participants in a conflict-affected setting.

4.5.5 Validity, Reliability and Trustworthiness

The study employed several measures to ensure methodological rigour:

i. Validity was enhanced by using internationally recognised indices (e.g., Household Food Insecurity Access Scale, Standardised Precipitation Index).

ii. Reliability was reinforced through pre-testing, enumerator training, and standardised tools.

iii. Trustworthiness of qualitative data was assured through triangulation, member checking, rich contextual descriptions for transferability, an audit trail for dependability, and reflexivity for confirmability.

4.5.6 Analytical Approach

Quantitative data were analysed using descriptive statistics, logistic regression, SPI for rainfall variability, and multiple regression to model linkages between rainfall, conflict, and food production. Qualitative data were analysed thematically, with coding and cross-checking to ensure interpretive consistency.

4.5.7 Positionality of this Researcher

Research is defined as a process, and the value of research needs to extend beyond the completion and sharing of the results, i.e., it continues with the researchers' reflections on the development of ideas, data collection, findings and implications (England, 1994; Bourke, 2014). Research consists of a common platform for both researcher and participants, and their identities have the possibility of impacting the research procedure. Bourke (2014) explains that researchers' identities influence their perceptions, and researchers' biases mould the research process. People have numerous and overlapping identities according to the positionality theory, and people perceive things from different aspects of their identities. A researcher can be an insider, which means the researcher shares similarities with the participants or subjects in respect of race, religion, cultural background, and education. In qualitative research, it ensures the advantages of understanding the culture of the subjects by the researcher (Bayeck, 2022). A researcher can also be an outsider, which means he or she is a stranger to the culture and background of the participants, and as such, the culture of the participants could be misunderstood (Greene, 2014). Britton (2019) submitted that a researcher's background and beliefs have profound effects on the research process.

To understand how we might approach, for example, a study environment, groups, and how we may engage with the subject or participants, the recognition of biases becomes important. Positionality in research is a function of where one stands in respect of the other, and as a result, a researcher's position can vary according to time, moment and space (Merriam *et al*., 2001).

In the current research, the positionality of this researcher is shaped by his epistemological belief. Culture, religion, and education are easily surmounted during the research process by recruiting research assistants of the same culture, religion, and language background as the participants. They help to translate and bridge the gap between the researcher and the participants.

Food security issues are intricate in nature and, as a result, attracted diverse interpretations and varying approaches to addressing them. Consequent upon this, at the World Food Summit (1996), food security was perceived to exist – "when all people, always, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." Following this perception, food insecurity is perceived as a lack of or absence of food security, and even more important here is the availability of adequate food always and access to foods. From the foregoing, the challenging aspect of it is meeting food and nutritional needs at individual household levels, especially in low-income households in developing countries like Borno State, Nigeria, where about 80% of the population is agriculturally dependent and lives in rural communities.

The researcher's positionality here rests on the premise that climate variability, especially precipitation perception, has profound effects on food security because rural populations in Borno State depend on rain-fed agriculture, which is the main source of their food and livelihood through planting and cultivation as smallholder rural farmers. Researchers also believe that knowledge of weather and climate variability will help the rural farmers adapt to it and be able to withstand the effects of precipitation variability on the planting and harvesting of their food crops.

The researcher acknowledges a partial insider–outsider positionality: Nigerian, with cultural familiarity, but not a resident of the studied communities. This position enabled empathetic engagement while maintaining analytical distance. Security constraints necessitated the use of local enumerators, which influenced data interpretation but also improved access and trust.

4.5.8 Axiology of this Research

The axiological stance guiding the research is pro-poor and human-centred, recognising that research is value-laden. Ethical principles of beneficence, respect, and justice informed all interactions, particularly given the vulnerabilities of conflict-affected and displaced populations. Informed consent, confidentiality, and sensitivity to trauma were strictly observed. It is centred on value or value-loaded, and it plays a prominent role in the interpretation of the results and relies on objective and subjective views because of the dual methodology adopted.

The use of a pragmatic approach in this research is based on the multidimensional nature of food security studies, which precludes food insecurity assessments from relying exclusively on one method to adequately collect data and interpret it. The difficulty in the assessment of food security using one methodology is more exerting in the characterisation of food security by the Food and Agricultural Organisation (FAO, 1996, FAO, 2017) definition, i.e.,

- The availability of sufficient quantities of food of appropriate quality, supplied through domestic production or imports.
- Access by individuals to adequate resources (entitlements) for acquiring appropriate foods for a nutritious diet.
- Utilisation of food through adequate diet, clean water, sanitation, and health care to reach a state of nutritional well-being where all physiological needs are met, and
- Stability, because to be food secure, a population, household or individual must always have access to adequate food.

Following from the above perspectives, it will not be practicable to assess the food security condition of a geographical region, households or cities in the broader perspective with a single-frame methodological approach. In philosophical debates, mix-method research approach is believed to be rooted in pragmatism (Denscombe, 2007; Mkansi & Acheampong, 2017). The research approach that embraces operational decisions that centre on what works best to find solutions to the questions under study is referred to as pragmatic research. This philosophical paradigm allows the researcher to carry out the study in innovative and dynamic manners to arrive at solutions to the research problem. A pragmatic approach to research assumes that there are many ways to interpret the world and carry out a research study; reality and a mixture of varying approaches may enhance the understanding of the subject being investigated. It opposes the existing views of reality in positivism and interpretivism.

4.6 Study Area

4.6.1 Climate

Borno State is a state in the north-eastern region of Nigeria with a climate characterised by irregular and unstable rainfall patterns. The rains are brief, followed by a long dry spell. The climate is divided into two seasons: wet and dry. The wet season lasts four months (June to September), while the dry season lasts from October to May. Temperatures are normally high all year, with an annual average of 29°C. (Binbol, 2009). The warmest months are April and May, with average temperatures ranging from 29°C to 32°C. The harmattan month runs between November and March, and it is associated with large diurnal temperature changes (Carrol, 1974). The annual rainfall ranges from less than 600 mm in the north to more than 1500 mm in the south. Also, rainfall varies from year to year but has been decreasing over the last two decades (Amaza *et al*., 2007). The rainfall pattern is a single peak, beginning in late May with maximum rainfall in August and ending in late October. The months of November to March are dry, with only a few light rains in April and early May. Precipitation is often low, with 75-100 mm of rain per day being common with an annual average of 630 mm. Borno State has a high mean yearly sunshine hour count (10 hours) yet a low mean relative humidity (20 - 40%) (Binbol, 2009).

4.6.2 Vegetation

The vegetation consists primarily of shrubs and seasonal grasses, with only a few stunted trees. Millet, cowpea, and maize are the primary crops grown in the state (Idrisa *et al*., 2012). Other important crops grown are wheat (*Triticum*) and groundnuts (*Arachis hypogea*). Cabbage (*Brassica oleracea*), spinach (*Amarantus*), onions (*Allium cepa),* and tomatoes (*Lycopersicon esculentum*) are vegetables cultivated in the area. Borno is dominated by short grasses, shrubs, and small trees such as the Acacia tree (*Acacia albida*), desert date (*Balanites ficcus spp.*), neem tree (*Azadirachta indica*), and baobab tree (*Adansonia digitata*). The extent of shrub cover is influenced by the level of farming and the length of the rainy season (Buji *et al*., 2021).

4.6.3 Population

The state has a population of 4,151,193 (NPC, 2006) with a projected 2016 estimate of 5,860,183 based on a 3.2 population growth rate by the National Bureau of Statistics. For administration purposes, Nigeria is divided into administrative layers of states and local government areas (LGAs), and each LGA is subdivided into wards. These administrative sub-units are subdivided into EAs, or Census Enumeration Areas, following the National Population Bureau demarcation of 2006 (WFP, 2017). For this study, a survey was carried out in eight local governments of Borno State, shown in the following table:

Table 4.1: Local Government Areas Surveyed

Local Government	**Population**
Bayo	115,900
Biu	257,500
Mafa	151,800
Maiduguri	791,200
Kaga	131,900
Kawaya Kusa	83,100
Konduga	230,500
Jere	306,400

Source: NBS population projection (2022).

Each local government area consists of five Enumeration Areas (EAs) and samples were randomly drawn from all 40 (EAs), and 10 households were studied in each of the EAs. It is important to state here that these eight local governments were chosen as local government areas of interest based on security reports and clearance to work because of terrorist and insurgency activities (Fig. 4.1). These eight local government areas were referred to as insurgency-free local government areas as of the time this survey was carried out, according to security reports. This research is centred on current and emerging concepts and multidimensional food security thinking, studies, measurement, and policy measures. It combines the merits of the major food security indicators, viz., HFIAS and CSI (Appendices A5), to investigate the household food security situation in Borno State. A household food security survey was conducted between December 2021 and February 2022.

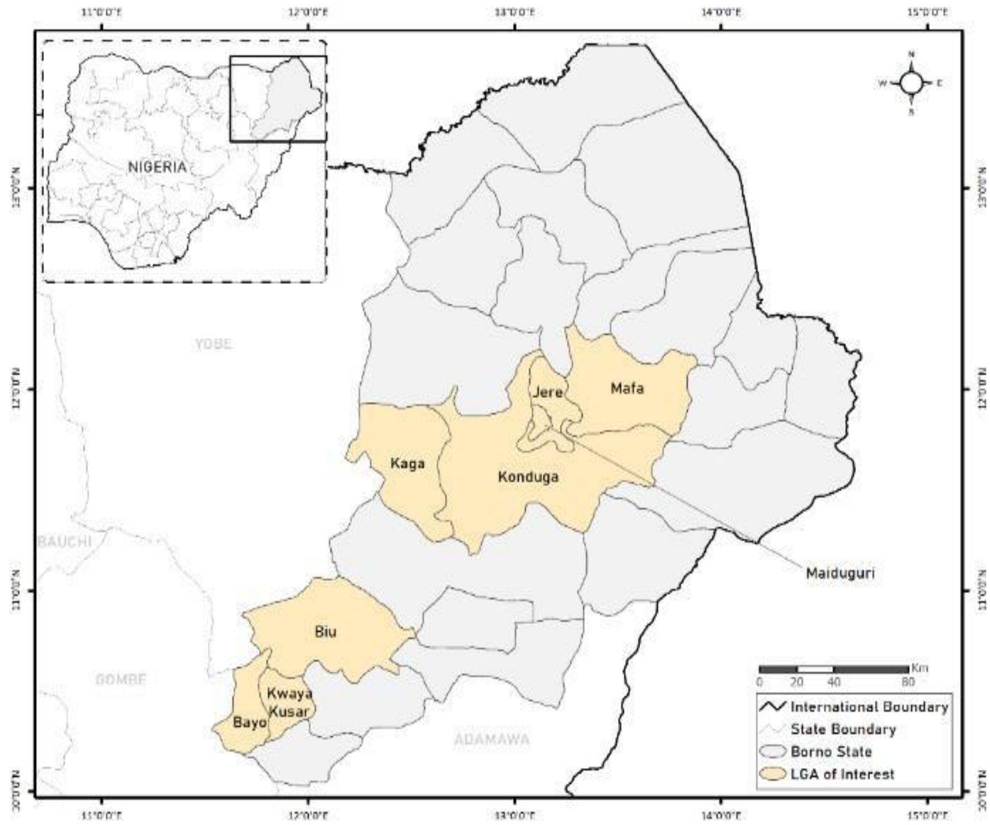


Figure 4.1: Map of local government of interest. Source: by author using ArcGIS

4.7 Importance of Measuring Household Food Insecurity

Studies reiterate that food security is difficult to measure (Clapp *et al.,* 2022; Ashley, 2016). The Food and Agricultural Organisation (FAO), advanced two important elements to measure food security, which include food availability or supply, and the use of budget and consumption data gathered from national surveys to calculate the mean calories of a population which is regarded as the demand side (Makombe, 2023). Food insecurity is a global issue that is common to every region of the world, although the severity of it varies from one region to another and place to place and differs among populations. The assessment of food insecurity necessitates an approach that can bring out the causes and symptoms of food deprivation identified as peculiar to a specific condition of population of a place, household, or region. Web *et al*. (2006) explain that measuring food insecurity and indeed any other phenomenon will aid the process of inquiry and enhance clarity and precision by standardisation. Having regard for the multi-dimensional nature of food security, capturing it must be an accurate measurement that guarantees that important components are not missed out on (Qureshi, 2017). Considering the severity of food insecurity and its potential implications, it becomes necessary to quantify the status of the food insecurity condition of the household in Borno State to have deeper knowledge of the situation and to arrive at a context-specific solution to address it.

4.8 Sampling Technique

Questionnaires for the quantitative survey for this study were administered among farmers' households in the study area. The probability or representative sampling method was used, with ten small farmers' households randomly selected in each of the eight local councils under consideration to answer the questions already detailed on the questionnaire administered, focusing on the four dimensions of food security viz.: availability, access, utilisation, and stability.

The target population for the focus groups are members of the public who are of adult age (18 years old and above) and residents in Borno State. Samples were purposively taken to ensure perspectives on the topic of climate change effects on the food security of individual households.

4.9 Data

4.9.1 Data Collection Preparation

This food security study combines qualitative and quantitative data acquisition, using focus group discussions and random sampling surveys using questionnaire (Table 4.2).

Table 4.2: Summary of Data and Sources

Data	**Category**	**Range**	**No. of observations**	**Source**
Household Survey	Questionnaire/ Focus group discussion	2021	398	Field survey
Conflict Incidence	Conflict	2011 – 2021	11	Global Terrorism Database
Temperature	Climate	1992 - 2021	30	WMO (http://climexp.knmi.nl/start.cgi)
Guinea Corn	Food Production	1993 2021	29	Borno State Ministry of Agriculture
Sorghum	Food Production	1997 - 2021	25	Borno State Ministry of Agriculture
Cassava	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Millet	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Maize	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Rice	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Groundnut	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Beans/Cowpea	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture

The focus group consists of smallholder farmers and Ministry of Agriculture extension officers. This allowed this study to explore experience of the effects of climate change/weather variability on individual farming household food security. The information collected from this source was used to complement the data collected from survey questionnaires. The focus group consisted of five groups in total, and each group consisted of 8 individuals. This group was limited to eight individuals for the convenience of managing the group during discussion, and a total of 5 interviews were conducted. Only the interviewer, interviewee and a translator were present, and sample questions are attached as **Appendix (4A6)**.

4.9.2 Sample Size Adequacy

A total of 398 households were surveyed in this study. This sample size is statistically adequate for generalisation to the wider population of Borno State. Using Cochran's formula (1977) for large populations at a 95% confidence level and a 5% margin of error, the minimum required sample is calculated as:

$$n_0 = \frac{Z^2 . p(1-p)}{e^2} \qquad \text{Eq. (4.1)}$$

Where:

Z =1.96 (standard normal deviate at 95% confidence),

p = 0.5 (proportion of population with attribute, giving maximum variability),

e = 0.05 (margin of error).

$$n_0 = \frac{1.96^2 . 0.5(1-0.5)}{0.05^2} = 384.16$$

Thus, a minimum of 385 households is required. The sample of 398 households therefore exceeds this threshold, ensuring sufficient statistical power and reliability of estimates.

Similarly, applying Yamane's (1967) simplified formula for large populations:

$$n = \frac{N}{1+N(e^2)} \qquad (4.2)$$

For large populations ($N > 50{,}000$), this approximates to:

$$n \sim \frac{1}{e^2} = \frac{1}{0.05^2} = 400$$

This further validates the adequacy of the 398 households sampled, as the number closely aligns with the required 400. Accordingly, the sample size is considered statistically sufficient to provide robust findings representative of the study population.

4.9.3 Training of Research Assistants

Training of research assistants for the fieldwork was conducted over two days in November 2021. Training included lectures on interviewing techniques and the contents of the questionnaires and mock interviews between trainees to gain practice in asking questions. Research assistants were drawn from among students from higher institutions from around the study area. Appropriate Personal Protection Equipment (PPE) was provided for research assistants, and social distancing measures were made mandatory during the survey process because of the COVID-19 pandemic.

4.9.4 Recruitment of Research Participants

The researcher was responsible for the recruitment of interview participants with the support of the field officer of the National Bureau of Statistics, Borno State, Nigeria, and an agriculture farm extension officer of the state ministry of agriculture. They were identified through their places of work or organisations they work for and from churches, mosques, and the community. They were recruited through emails and telephone numbers, depending on the preferred mode of contact. The researcher distributed an information sheet to each identified participant (Appendix 4A1), which provides an overview of this study and its objectives.

4.9.5 Focus Group Discussion.

The researcher was responsible for the recruitment of focus group participants. This was carried out by drawing on existing networks to reach as many people as possible. Participants for the focus group discussion were drawn from existing networks of communities, churches, mosques, market locations and volunteer groups. Through these networks, invitations were issued to participants (Appendix 4A2) to participate in an information session to provide details about the study.

Along with this invitation, a Participant Information Sheet (PIS), (appendix 4A3) that provides an overview of this study, and its objectives was circulated to participants so that they decide beforehand if they want to participate. Through contacts made with the key informants and focus group discussants, potential persons who met the recruitment criteria was identified and were invited to participate in the in a town hall meeting like that was arranged by the researcher. As a result of security concerns and logistics, it was decided this discussion would be held virtually, this information was circulated to individual selected participants and honorarium was provided for them to buy data on their phone to be able to join the meeting virtually. Participants were issued a recruitment letter electronically (Appendix 4A1) and Participant Information Sheet that provides an overview of this study and its objectives so that they decide beforehand to participate (Appendix 4A4)

4.9.6 Informed Consent

Consent was sought from each participant via signed consent forms which was issued electronically. Consent forms were included in information on the objectives of the study, the form of participation being requested of the participant, and the expected outcomes and benefits of the study. One copy of the informed consent form was made available to participants and a second copy was kept by the researcher. Participants were sought and were advised the process are being recorded only for data collection purposes**.** Participants were well informed of their right to withdraw from the study at any time regardless of their reasons, and their liberty to decline to answer questions for any reason they may have with no penalty. All interviews were conducted within one hour using the structured interview guide (Appendix 4A6). Interview transcription contains no information that can allow individuals to be linked to specific statements of opinion and recordings were later transcribed for analysis. All recordings securely stored till they are analysed, and outmost confidentiality of material and information were well preserved.

4.9.7 Ethical Consideration

Ethics approval for this research was asked for from London Metropolitan university and granted fully on 21/11/22. Full consent was sought from all participants, focus group discussion participants, key informants, and research assistants.

This was done using a consent form (Appendix 4A2), which details the objectives and purpose of this study, the type of participation required of them, the expected result of the study, and the potential advantages of the study. The identity of all participants was well protected by assigning to them pseudo-names, and all recordings and attendant data were secured through passwords and in accordance with the Data Protection Act (1998). Access to data will be limited to the researcher and any authorised persons' codes and passwords. Any aspects of other authors used in this work are properly acknowledged.

4.10 Limits of the Survey

This survey was limited to eight local governments of Borno state. Borno State has been challenged by banditry and terrorism. Survey activities were limited to the council areas where there were no security challenges and safety concerns. Second, nutrition, dietary health, water and sanitation, and components of food security were not included in this survey. This means the assessment of nutritional quality of households was not considered in these investigations to keep the focus of the investigation, i.e., weather variability and food security.

4.11 Data Cleaning, Quality Control and Homogenisation

The World Meteorological Organisation (WMO) describes climate data as the records of observed climate conditions recorded at specific places and times using instruments following a set of standard procedures. Climate data consists of climate information derived from the observation points and inclusive of other non-climatic factors such as the environment of the observation site, detailed information about the instrument used and the observation process. Methods and procedures used in observation and processing of data can also affect data collected from a site. There can be artificial alterations or changes to data which can affect the statistical properties of the observations abruptly or gradually over time, depending on the nature of the disturbance; this is referred to as data inhomogeneity. Some factors that can cause data inhomogeneity includes changes in instruments, changes in processing, changes in the environment around the shelter, changes in observing practices and changes in stations' locations (Peterson *et al.,* 1998).

It is important to correct this condition of a data set to guarantee its quality assurances and consistency. The procedure of bringing data into a common geospatial framework to guarantee consistency of data, integrity of analysis and validity of results is referred to as data homogenisation. With reference to climatic data, the reason for climate data homogenisation is to adjust climate records to eliminate non-climatic factors so that any temporal changes in the adjusted data will only reflect the changes due to the climate process.

4.12 Challenges Encountered in the Data Collection Process and How They Were Managed

Security concerns were a major challenge encountered during the study process. The ongoing insurgency issues happening in Borno state created fear which prevented the researcher from accessing all areas during the data collection process. The researcher managed this challenge by putting a specific focus on eight local government areas that were free from insecurity at the time. The researcher made use of a security report to single out the specific areas that were secure to conduct the research process. Although the areas were considered safer to engage in the research process, the researcher worked closely with local authorities to ensure safe access to the areas.

Another challenge was the logistics of conducting focus group discussions and interviews. The costs were expensive and impacted the overall increase in the cost of the research project. To mitigate this challenge, virtual platforms were used for discussions. Participants were also provided with honorariums to cover data costs for their phones. Regional remoteness also posed a major challenge to the recruitment process. To address this, the researcher collaborated with local networks such as community organisations to facilitate seamless recruitment.

4.13 Data Preparation

4.13.1 Climate Data

The software used to perform SPI analysis is a free software called the Meteorological Drought Monitor (MDM) is used to calculate rain-based drought indices (Nasrin

Salehnia *et al.,* 2017). It was accessed through https://agrimetsoft.com/mdm while the licence was requested and obtained through an email to the developers.

Data used for the analysis comprises of precipitation data from downloaded from the World Meteorological Organisation's Climate Explorer (http://climexp.knmi.nl/start.cgi) Monthly precipitation data for five weather stations covering five states of northeast Nigeria were obtained (Fig. 4.2, Table 4.3).

Missing values from the downloaded data were estimated using the nearest neighbour approach using the XLSTAT package in Excel. An average of 50 years of data was available and downloaded for the stations.

Table 4.3: Weather Stations

Weather Station	**State**	**Latitude**	**Longitude**	**Elevation (m)**	**Available Data**
Bauchi	Bauchi	10.30 N	9.80 E	609	1950-2019
Maiduguri	Borno	11.90 N	13.10 E	354	1950-2019
Nguru	Yobe	12.80 N	10.50 E	344	1950-2019
Potiskum	Yobe	11.60 N	11.00 E	414	1950-2019
Yola	Adamawa	9.20 N	12.50 E	174	1950-2019

Forecasting of the data to 2019 was performed using Excel's Forecast Function (the AAA version of the Exponential Smoothing (ETS) algorithm) given as:

$$Ft{+}1 = \alpha yt + (1 - \alpha)\, F1, \qquad \text{Eq. (4.3)}$$

Where,

$Ft{+}1$=Forecast for next period

α= Smoothing constant

yt=Observed value of series in period t

Ft= Old forecast for period t eq.

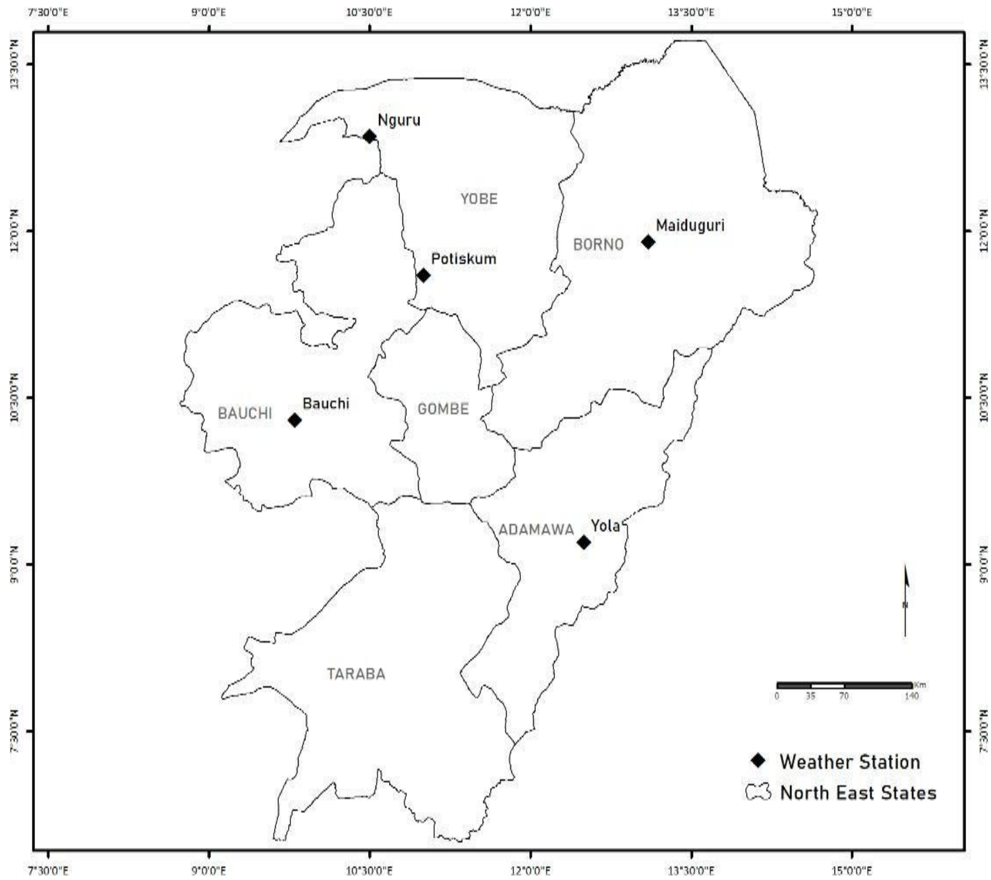


Figure 4.2: Map of weather stations

Negative values from forecast results were assigned a zero value (since precipitation cannot record a negative value) using the MAX function in Excel.

Following the above, monthly precipitation data from 1950 to 2019 were extracted from all five weather stations covering the northeast to ensure uniformity while calculating the drought indices. These data were structured in a two-column format in Excel and saved as an .xlsx file, as this is the acceptable input format for the MDM software.

4.13.2 Food Data

Food production data was sourced from the database of the Borno State Ministry of Agriculture. As a result of the shortages and irregularity of the food production data over the time series, and to cover the years under consideration, the food production data were smoothened and prepared using the ETS model for forecasting the data to date and backcasting the data to determine previous years. The ETS models are a family of time series models with an underlying state space model consisting of a level component, a trend component (T), a seasonal component (S), and an error term (E).

The ETS class of models was introduced in the late 1950s (Brown, 1959; Holt, 1957; Winters, 1960) to consider different combinations of trend and seasonal components. The basic ETS model consists of two main equations: a forecast equation and a smoothing equation. By integrating these two equations into an innovation state space model, which may correspond to the additive (A) or multiplicative (M) error assumption, it is possible to obtain an observation/measurement equation and a transition/state equation, respectively (Perone, 2022). The first equation describes the observed data, while the second equation describes the behaviour of the unobserved states. The states refer to the level, trend, and seasonality.

The simplest of the exponentially smoothing methods is naturally called simple exponential smoothing (SES) (Hyndman and Athanasopoulos 2018). This method is suitable for forecasting data with no clear trend or seasonal pattern. The food production data did not display any clear trending behaviour or any seasonality; hence, the choice of the model. That said, it is assumed that the food production season falls within the rainy season period that is climatically referred to as the single maxima period between June and October for this climatic zone under study.

We often want something between these two extremes. For example, it may be sensible to attach larger weights to more recent observations than to observations from the distant past. This is exactly the concept behind simple exponential smoothing. Forecasts are calculated using weighted averages, where the weights decrease exponentially as observations come from further in the past.

The SES model is given by:

$$y(t) = \beta(t) + \varepsilon(t) \qquad \text{(Eq. 4.4)}$$

where $\beta(t)$ takes a constant at the time t and may change slowly over time; $\varepsilon(t)$ is a random variable and is used to describe the effect of stochastic fluctuation.

4.13.2.1 Forecast (Downcast) Error

There are several indicators to evaluate the quality of a forecast. The overall model performance was evaluated using four statistical measures (Perone, 2022). They include the Mean absolute error (MAE), symmetric mean absolute percentage error (SMAPE), Root mean squared error (RMSE) and mean absolute scaled error (MASE). These are some of the common evaluation metrics for forecasting or backcasting. MAE is a measure of overall accuracy that gives an indication of the degree of spread, where all errors are assigned equal weights. If a method fits the past time series data very well, MAE is near zero, whereas if a method fits the past time series data poorly, MAE is large (Perone, 2022).

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |e_t| \qquad \text{(Eq. 4.5)}$$

SMAPE is a modification of the MAPE developed to overcome the disadvantages of MAPE, especially the inability to process zero values. SMAPE is defined as

$$SMAPE = \frac{1}{n}\sum_{i=1}^{n} \left(\frac{|x_i - \hat{x}_i|}{(x_i - \hat{x}_i)/2}\right) \times 100\% \qquad \text{(Eq. 4.6)}$$

Where x_i is the actual value, and $\hat{x}_i$ is the predicted value.

RSME

$$RMSE = \sqrt{MSE} \qquad \text{(Eq. 4.7)}$$

MASE

$$MASE = \frac{1}{n}\sum_{i=1}^{n} \left| \frac{x_i - \hat{x}_i}{\frac{1}{n-1}\sum_{i=1}^{n} |x_i - x_{i-1}|} \right| \qquad \text{(Eq. 4.8)}$$

Finally, MASE is a scale-free error metric and probably the most versatile and reliable measure of forecast accuracy (Hyndman and Koehler, 2006). A MASE lower than 1 indicates that the model performs better than the naive benchmark model. When MASE = 1, that means the model is exactly as good as just picking the last observation, while a 0.5 value for MASE means that the model has doubled the prediction accuracy. Generally, the lower, the better (Perlato, 2019).

4.14 Methods

This research applies mixed methods, or multiple methods, because of the complexity of the phenomenon being investigated**.** The first method made use of a structured questionnaire consisting of four modules that include household socio-economic characteristics, the Household Food Insecurity Access Scale (HFIAS), and Coping Strategy Index (CSI) module questions (Appendices A5) that were adopted as an interview guide to generate the primary data used. The purpose of the survey is to extract primary data to address food security issues, focusing majorly on four of the central food security dimensions: availability, access, utilisation, and stability. This was used to examine the household vulnerability to food insecurity in the study area.

The descriptive statistical analysis of household food security was carried out, and ordinal regression analysis was applied to estimate the food insecurity through the Household Food Insecurity Access Scales (HFIAS) of the household population in the study area.

To complement the above, qualitative data was also collected through focus group interviews using structured, closed-ended guides (Webb-Girard *et al*., 2012); the group interview examined i) the agricultural systems practised, ii) farmers' level of knowledge about climate variability and change, iii) the adaptation measures in use and iv) the security challenges they faced. The above was combined with a qualitative questionnaire designed to address the farmer’s experience of climate change and their coping strategies.

The second method, the Standardised Precipitation Index (SPI), applies historical precipitation data obtained from the World Metrological Organisation (WMO) in respect of the weather stations identified with the study area to examine the possible nexus between precipitation variability, climate change indicators and agricultural food production.

The third method, multiple regression (MR), examines the relationships between agricultural food production as related to major agricultural food products, weather variables and security challenges predominant in Borno state. This third analysis will give an overall picture of food security issues from production/supply perspectives since the inception of banditry, conflicts, and terrorism in the past twenty years or so, given that methodology one and two did not cover the entire state because of resources and security challenges.

Table 4.4: Framework of Methods/Objectives of the study

Objec-Tive	**Description**	**Data**	**Methods**	**Output**
1	Examines the household food security conditions in Borno state	Household survey	Descriptive Statistics; Ordinal Regression	Frequencies and percentages; Ordinal regression (Wald) coefficients; Model statistics
2	Determine the food security index in Borno State.	Household Survey, Focus group discussion	Descriptive Statistics: HFIAS	Frequencies and relative percentage distributions.
3	Examine the relationship between precipitation variability and food crop production in Borno State of northeast Nigeria.	Weather Data: Agricultural Food Production data	SPI – Deviation from long-term mean. Regression	Graphs, frequencies and percentages, SPI classification, precipitation food production anomalies, Regression coefficients, and correlation coefficients.
4	Explore the effects of security challenges on food security in Borno State.	Weather Data: Agricultural Food Production data. Conflict Incidence; IDP Population	MLR; Correlation	Descriptive distribution, correlation, Model Statistics
5	To provide policy recommendation for successful adaptation	Food policies in Nigeria	Desk review	Policy recommendations

	and coping strategy for sustainable food production by the farmers that may be introduced into the policy framework of the government both in Borno and the region-wide			

4.14.1 The Standardised Precipitation Index (SPI)

Generally, northern Nigeria has a long history of precipitation deficit and anomaly, and precipitation is an important natural resource which is highly variable, and any irregularity in its distribution and amount received will have profound consequences on the social and economic lives of the people, including agricultural productivity, food security, water quality, water resource management, land use, and human health, as well as ecological impacts such as biodiversity.

The application of the SPI to interpret and quantify the precipitation condition of the study area is important and useful in understanding the long-term climatic experience of north-eastern Nigeria over the series (1950-2019). Through the SPI algorithms, climate change indicators, i.e., precipitation, drought frequency and temperature, are used to assess variation in climatic conditions over time and its impacts on food security conditions in the study area. The above will help to answer the question of precipitation variability as a major contributory factor to sustainable food security (insecurity) in Borno State.

The Standardised Precipitation Index (SPI) is a method developed by McKee *et al. (1993)* for assessing climatic variability and is primarily useful for monitoring drought. It indicates the actual rainfall as a standard departure with respect to rainfall probability distribution function (Kumar *et al*., 2009); this method has in recent years gained popularity among scholars as a drought indicator that allows comparisons across space and time. It is especially useful for drought studies because of this feature, particularly when temperature data is ambiguous. Unlike other indices, such as the Palmer Drought Severity Index (PDSI), which only consider long-term periods, it enables short-term assessments of drought (Wang *et al*., 2017). It will allow researchers to determine the rarity of a drought event at a temporal resolution of any effect of climate variability on food security in the Sahel of northern Nigeria and can also give insight into possible constraints and adaptation to coping with weather variability and be useful to determine the period of anomalous rainfall. This method is based on statistical methodology capable of determining the degree of wetness by comparing 3, 6, 12 or 24 monthly rainfall totals with the historical rainfall period over a long period of time.

To calculate SPI, long-term data on precipitation is required to determine the probability distribution function to be transformed to a normal distribution with zero mean and standard deviation of one (Kumar *et al*., 2009). Edward and McKee (1997) pointed out that SPIs are expressed in standard deviations, with positive SPIs connoting greater than average precipitation and negative SPIs denoting less than average precipitation. SPI is calculated based on monthly precipitation aggregations where the values could be compared across various geographic and climatic areas.

The SPI expresses anomalies in absolute terms in millimetres. SPI was originally designed to be applied with station data but has been recently applied to gridded rainfall datasets; it is calculated for a range of periods accumulated, ranging from 3, 6, 12 and 24 months each, to assess drought duration, intensities and frequencies (Vardin *et al*., 2005**).** It allows the characterisation of drought conditions for a range of agricultural, meteorological and hydrological applications. Hayes *et al*. (1999) explain that the temporal versatility of the SPI allows the analysis of drought dynamics as related to the onset and cessation of the droughts. It also guarantees that the frequency of extreme events at any location through standardisation.

This method has proven to be a very useful application for drought and water resources monitoring and a useful application. The interpretation of the SPI may be different with the time scale, and the application may be used in varieties of meteorological, hydrological and agricultural fields.

The main factor controlling persistent drought conditions is precipitation, and it has been argued that the SPI index based only on precipitation data performs well when compared to hydrological indices (Oladipo, 1985).

SPI has been designed with the capability to detect drought at multiple time scales. Giddings *et al*. (2005) hence described SPI as analogous to Z-score and normalised.

$$z\_score = x - \frac{\Pi}{\sigma} \qquad \text{(eq. 4.7)}$$

Z - Score = (X-mean/standard deviation),

Where **Z**-score expresses the **X** score's distance from the mean (**μ**) in standard deviation (**δ**) units.

The calculation of SPI with the time series data, at a monthly scale, will be carried out using a two-parameter gamma distribution function. It involves the transformation of precipitation data into lognormal values followed by the calculation of U statistics and shape and scale parameters of the gamma distribution. The parameters that result from this are then used to derive the incomplete gamma cumulative probability of an observed precipitation event (Kumar *et al*., 2009).

The first step is the gamma distribution, whose probability density function is defined as

$$g(x) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{\frac{-1}{\beta}} \qquad \text{for } x > 0 \qquad (4.10)$$

Where $\alpha > 0$ is a shape parameter, $\beta > 0$ is a scale parameter, and $x > 0$ is the amount of precipitation. $\Gamma(\alpha)$ is the gamma function, which is defined as

$$\Gamma(\alpha) = \prod_{v=0}^{n-1} \frac{n!n^{y-1}}{y+v} \equiv \int_0^{\infty} y^{\alpha-1}e^{-y}dy \qquad (4.11)$$

Fitting the distribution to the data requires α and β to be estimated. Edwards & McKee (1997) suggest estimating these parameters using the approximation of Thom (1958) for maximum likelihood as follows.

$$\hat{\alpha} = \frac{1}{4A}(1 + \sqrt{1 + \frac{4A}{3}}) \qquad (4.12)$$

$$\hat{\beta} = \frac{\underline{x}}{\hat{\alpha}} \qquad (4.13)$$

Where for n observations

$$A = ln\, ln\, (\underline{x}) - \frac{\sum \quad lnln\,(x)}{n} \qquad (4.14)$$

This approach is refined using an iterative procedure suggested by Wilks (1995)

$$[\alpha^* \ \beta^* \ ] = [\hat{\alpha} \ \hat{\beta} \ ] - \left[\frac{\partial^2 L}{\partial \hat{\alpha}^2} \ \frac{\partial^2 L}{\partial \hat{\alpha} \partial \hat{\beta}} \ \frac{\partial^2 L}{\partial \hat{\alpha} \partial \hat{\beta}} \ \frac{\partial^2 L}{\partial \hat{\beta}^2}\right]^{-1} \left[\frac{\partial L}{\partial \hat{\alpha}} \ \frac{\partial L}{\partial \hat{\beta}}\right]$$

$$= [\hat{\alpha} \ \hat{\beta} \ ] - \left[-n\Gamma^n(\hat{\alpha}) \ \frac{-n}{\hat{\beta}} \ \frac{-n}{\hat{\beta}} \ \frac{n\hat{\alpha}}{\hat{\beta}^2} - \frac{2\sum \quad x}{\hat{\beta}^3}\right]^{-1} \left[\sum \qquad ln \, ln \, (x) \ - n \, ln \, ln \, (\hat{\beta}) - n\Gamma^1(\hat{\alpha}) \ \frac{\sum \quad x}{\hat{\beta}^2} - \frac{n\hat{\alpha}}{\hat{\beta}}\right] \qquad (4.15)$$

Where α^* and β^* are generally better estimates of α and β than $\hat{\alpha}$ and $\hat{\beta}$. The process is repeated until the algorithm converges. If no convergence is detected, Thom's estimate of α and β are used.

Integrating the probability density function with respect to x and inserting the estimates of α and β yields an expression for the cumulative probability $G(x)$ of an observed amount of precipitation occurring for a given month and timescale.

$$G(x) = \int_0^x \quad g(x)dx = \frac{1}{\hat{\beta}^{\hat{\alpha}}\Gamma(\hat{\alpha})} \int_0^x \quad x^{\hat{\alpha}} e^{\frac{-x}{\hat{\beta}}} dx \qquad (4.16)$$

Substituting t for $\frac{x}{\beta}$ reduces Equation (7) to

$$G(x) = \frac{1}{\Gamma(\hat{\alpha}) \int_0^x \quad t^{\hat{\alpha}-1} e^{-1} dt} \qquad (4.17)$$

Which is the incomplete gamma function. Values of the incomplete gamma function are computed using an algorithm taken from Press *et al*. (1986). Since the gamma distribution is undefined for $(x) = 0$ and f or $q = P(x = 0) > 0$ where $P(x = 0)$ is a probability of zero precipitation, the cumulative probability becomes.

$$H(x) = q + (1 - q)G(x) \qquad (4.18)$$

$H(x)$ is then transformed into a normal variation Z by means of the following approximation provided by Abramowitz and Stegun (1965):

$$Z = SPI = -\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \text{ for } 0 < H(x) \leq 0.5 \qquad (4.19)$$

$$Z = SPI = +\left(t - \frac{c_0 + c_1 t + c_2 t^2}{1 + d_1 t + d_2 t^2 + d_3 t^3}\right) \text{ for } 0 < H(x) \leq 1 \qquad (4.20)$$

Hence, SPI represents a Z-Score variable and is normalised.

4.14.2 Comparison of SPI to Other Drought Indices

There are few other drought indices that exist that have been used globally to measure the severity and onset of drought and examine the spatial-temporal characteristics of drought. These indices include the Vegetation Drought Response Index (VegDRI), the Palmer Drought Severity Index (PDSI), the Quick Drought Response Index (QuickDRI), the Drought Amelioration Tool (EEDI), the moisture anomaly index (Z-index) (Palmer 1965), the aridity index (Gore and Sinha 2002) and Percent Normal, Deciles (Gibbs and Maher 1967).

Some of these indices have different levels of usefulness; for example, Guttman (1999) argues that the PDSI has only a nine-month timescale, which in effect will not allow the spotting of droughts that can impact agriculture, for example, agricultural drought because of a shortage of moisture and rainfall in the soil to support crop growth. And the primary economic impacts of drought are agricultural crop failure and pasture losses, decline in water availability and increasing cost of water availability**.**

SPI is preferred over other indices because it is more versatile and reliable. Other indices, such as the Palmer Drought Severity Index (PDSI) or the Vegetation Drought Response Index (VegDRI), are constrained within specific and fixed periods or factors, such as vegetation response (Guttman, 1999). On the other hand, SPI can be calculated in various periods (Oladipo, 1985). This allows the approach to capture different dynamics in precipitation variability as well as drought intensity levels in different seasons. The SPI approach has more flexibility compared to other methods, as it can detect drought conditions on both short-term and long-term scales.

The SPI also has the advantage of reflecting changes in water availability, as it has a foundation on precipitation data. This is unlike other indices which incorporate other variables such as soil moisture or vegetation health, which might not accurately represent precipitation deficits. SPI, through normal distribution, also allows easy comparison of different regions and climates (Kumar *et al*., 2009). This aspect makes it a universally applicable tool to assess drought and agricultural productivity.

4.14.2.1 Approach

SPI is one of the few drought assessment indices to assess 'ex post facto' the wet and dry condition of the study area over the period of 1950 to 2019, with the aim to explore if any links exist between precipitation variability, climate change and agricultural food productions. SPI has been described as one of the best methods for assessing climatic variability (McKee *et al*., 1993)**.** It is the number of standard deviations with which the precipitation recorded for any location differs from the average over a period. SPI is based on monthly aggregates of precipitation and has the advantage that its value can be compared over geographic regions with varying climatic conditions. This has made SPI a popular application for drought monitoring. The application of the SPI to interpret and quantify the precipitation condition of the study area is important and useful in understanding the long-term climatic experience of the region over the series (1950-2019).

4.14.3 Multiple Linear Regression

Borno State has witnessed one of the most dreaded and long-standing events of terrorism and armed insurgency in Nigeria. Borno State is regarded as the epicentre of the dreaded Boko Haram insurgency that started in the early 2000s, which eventually spread to other states of northern Nigeria. One of the many countries captured in the Global Hunger Index (GHI) early warning resources is Nigeria, with the highest level of concerns, where climate change, conflicts and economic downturns have been mentioned to be responsible for the dire conditions (GHI, 2023, WFP & FAO, 2023). Over time, it has been challenging for academics and policymakersto establish the linkages between climate change, violent conflicts and food insecurity.

Given the fact that the focus group interviews and survey conducted in this study were limited to eight local government areas of Borno State because of security challenges and resources. Here, this study assesses the state-wide relationship between security challenges, weather variables and food security (production) in Borno State using the Multiple Regression Analysis (MLR).

This analysis runs the multiple linear regression using precipitation, temperature and internally displaced persons (IDP) population as predictors. The IDP population was used as proxy data for conflicts and security challenges that ravaged the study area –

Borno State – over the last twenty years. The following food products, i.e., guinea corn, sorghum, cassava, maize, millet, rice, groundnut and beans/cowpea, were identified as staple food crops that feed the population of Borno State and indeed the entire northern Nigeria. It is hypothesised that climatic variables and conflicts affect food production in Borno State, which in turn affects food security. This analysis is expected to reveal the main pattern of association between these variables and the food production in Borno State and possibly arrive at a useful conclusion in respect of the variables/factors that will be useful in predicting food security conditions in Borno State. All analyses were conducted using SPSS (version 26; IBM Corporation, 2019). The independent variables are presented in Table 4.5.

Table 4.5: Independent Variables

Variable	**Description**	**Source**
IDP (conflict)	Internally Displaced Persons population figures	IOM, 2022
Temperature	Annual Mean Temperature	http://climexp.knmi.nl/start.cgi
Precipitation	Standardised Precipitation Index	Derived (WMO)

We used population forecasts from the National Population Commission records from 2006 (NPC, 2016). The number of people internally displaced due to conflict in the study area, obtained from the International Organisation of Migration (IOM, 2022), who have experienced food insecurity and whose food security has been significantly influenced by conflict, adds context to the MR analysis.

The food production data of Borno state were sourced from the state ministry of agriculture. Production data for six selected crops were used for the analysis, namely, Guinea corn, millet, maize, rice, groundnut, and cassava. These are grown in the northeastern part of Nigeria. Missing data within the dataset (2001 – 2019) were filled using the replace missing values functionality of SPSS. Conflict incidence data was obtained from the Global Terrorism Database (START, 2022), and data is available for Borno State from 2011 to 2020. The data was forecast using the Exponential Smoothing (ETS) method to derive the 2021 estimate. Food production and climate data were obtained from the Borno State Department of Agriculture and the World

Meteorological Organisation (WMO) Climate Explorer (Table 1). Across all categories, there are differences in the number of observations found in the available data. For example, there are thirty observational data sets for climate data, but only eleven for conflict data. All data were cross-referenced with the 11-year observation of conflict data to conduct additional analysis of the data. This ensured that all records were the same size.

Table 4.6: Summary of Data and Sources

Data	**Category**	**Range**	**No. of observations**	**Source**
Conflict Incidence	Conflict	2011 – 2021	11	Global Terrorism Database
Temperature	Climate	1992 - 2021	30	http://climexp.knmi.nl/start.cgi
SPI	Climate	1992 - 2021	30	Derived
Guinea Corn	Food Production	1993 - 2021	29	Borno State Ministry of Agriculture
Sorghum	Food Production	1997 - 2021	25	Borno State Ministry of Agriculture
Cassava	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Millet	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Maize	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Rice	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Groundnut	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture
Beans/Cowpea	Food Production	1992 - 2021	30	Borno State Ministry of Agriculture

To determine the relationship between a dependent variable and two or more independent variables, multiple linear regression (MLR) is an effective statistical technique. MLR can help identify variables such as conflict, crop yields, and climatic conditions that have a major impact on food security outcomes. A multiple linear regression equation was applied for the analysis, using the conflict data as the dependent variable and other factors as predictors. It is defined by the formula:

$$y = \beta_0 + \beta_1 S + \beta_2 P + \beta_3 T + \varepsilon \qquad (4.21)$$

where y = Conflict Incidence Data, β = coefficient, S = SPI, P = Food Production, T = Temperature, and ε = Error term.

The dataset used for this analysis consists of 11 observations of various food security predictors, including SPI, temperature, conflict, and crop yields (guinea corn, sorghum, cassava, millet, maize, rice, peanuts, and beans/cowpeas). Conflict is the dependent variable and is expected to be influenced by the other variables itemised above and investigates the cause-effect relationships between food production, weather variability, and insecurity conditions in Borno State. (MR) model is a linear statistical analysis to find the best relationship between a dependent variable and several other independent predictors using the least squares analysis (Mekanik *et al*., 2013). Nathan *et al*. (2012) explain that multiple regression creates an avenue for researchers to provide answers to questions that border on the roles that multiple independent variables play in accounting for variance in a single dependent variable. The MR method is adopted because it can determine the relative influence of one or more predictor variables on the criterion value and can identify outliers, or anomalies.

The MR method has the ability of better prediction from multiple predictions. It also avoids choosing and dependence on one prediction and circumvents non-optimal combinations of predictors. MR allows the examination of robust research hypotheses rather than simple correlation and creates the link between the ANOVA model and correlation (Hinton, 2004).

Chapter Summary

This chapter outlined the research methodology adopted to examine the impacts of rainfall variability on food security in Borno State, Nigeria. It began by restating the study's aim, objectives, and research questions, which focus on understanding the relationship between precipitation trends, agricultural production, household food security, and the influence of insecurity on livelihoods.

The research philosophy underpinning the study combined ontological and epistemological perspectives, recognising climate change both as a measurable phenomenon and as a human construction shaped by farmers lived experiences. A pragmatic paradigm was adopted, enabling the use of mixed methods—quantitative and qualitative approaches—to capture the multidimensional nature of food security.

The study area was described in terms of its climate, vegetation, and population distribution, highlighting Borno's reliance on rain-fed agriculture and its vulnerability to climate variability and insecurity. Data were collected from eight local government areas, selected for being relatively secure, using household surveys, focus group discussions, and secondary datasets. A total of 398 households were surveyed, complemented by interviews and official statistics.

The methodology employed three main analytical approaches:

- Descriptive statistics and ordinal logistic regression – to assess household food security conditions using indicators such as the Household Food Insecurity Access Scale (HFIAS) and the Coping Strategy Index (CSI).
- Standardised Precipitation Index (SPI) – to analyse long-term precipitation data (1950–2019) and detect rainfall variability and drought patterns.
- Multiple Linear Regression (MLR) – to explore relationships between rainfall, temperature, conflict (proxied by IDP population), and agricultural production of staple crops such as sorghum, maize, millet, and cassava.

The chapter also detailed the sampling techniques, ethical considerations, data cleaning and homogenisation procedures, and challenges encountered, particularly insecurity and logistical constraints. Security risks restricted fieldwork to specific areas, while focus group discussions were partly conducted virtually due to safety and cost concerns.

By integrating household-level data, historical precipitation records, and agricultural production trends, the chapter established a robust methodological framework for assessing the nexus between climate variability, conflict, and food insecurity in Borno State.

CHAPTER 5

Overview of This Chapter

This chapter provides a detailed discussion and interpretation of the qualitative and quantitative analysis conducted in this study. It begins with an analysis of descriptive statistics and then applies the regression analysis and Household Food Insecurity Access Scale (HFIAS) analysis to further interpret findings. To enhance the credibility of the findings, comparisons have been done with previous literature as discussed in the literature review. This section also includes socio-economic applications of the findings in the Sahel region as well as actionable recommendations that would improve food security in Borno state and entire Sahel region.

5.0 Data Analysis

5.1 Descriptive Statistical Analysis

5.1.1 Demographics of the Study

398 persons from 8 local government areas (LGAs) of Borno state, Nigeria, participated in the household food security assessment. The average household size of the respondents ranges from 1 to 35. An average of 7 persons comprises each household of the respondents; 88.9% of the households have dependants, while 11.1% do not have dependants. The gender distribution of the household heads reveals 89.2% male and 10.8% female. The age distribution of the household heads from the respondents reveals that the youngest is 18 while the oldest is 85. Only 10% of the household heads are either single, widowed or divorced, and 32% of the household heads do not have any experience of formal education. In all, the household heads have an average of 8.4 years of formal education experience, with the highest number of years spent for formal education being 24; 23.4% of the heads of females in the households completed their education at the O'Level, and only 1.3% got their formal education to the postgraduate level.

The common occupation of the household heads includes trading, farming and civil service, constituting 30.7%, 28.9% and 22.9%, respectively, while 61.3% of the household heads do not have a secondary occupation; meanwhile, the most common secondary occupation among the rest who have a secondary occupation is farming (24.4%); 72.4% of the household heads earn less than 50,000 naira monthly, and only 2% earn above 100,000 naira monthly. The average number of income earners among the households is 1.6, and more than half of the respondents have only 1 income earner in the household (53.3%). The findings align with data from the literature review on the main causes of food insecurity in the sub-Saharan region. Sub-Saharan Africa, particularly dry lands like the Sahel of northern Nigeria, is more prone to famine, starvation, and food insecurity. The discourse of food security has continued to take centre stage because of the impacts of famine, hunger, and starvation (Kregg-Byers & Schlenk, 2010).

The monthly income of the head of females in the household's ranges from 0 to 100,000 naira, with an average of 7,728 naira per person. About 31.9% of the households use up all their monthly income for their monthly expenses, while 39.9% spend 75% of their monthly income, and only 3.5% spend about 25% of their total monthly income.

An average of 32,626.4 naira is spent on food in the households in one month, while some households spend as low as 5,000 naira; others spend as high as 100,000 naira on food in a month. The class of foods consumed by most households are cereals, roots and tubers, and staple grains, which statistically constitute 75.6% of the households, and only 3.3% spend more on meat, fish, eggs and milk.

5.1.2 How Participants Responded to Food Insecurity in the Borno Region

Different interview questions were asked of the participants to assess how they responded to food insecurity issues within the region. Figure 5.1 below clearly illustrates questions and responses from the participants regarding the issue.

Food access experiences of the households on food insecurity within a month reveal that 56.5% of the households were not able to eat the kinds of foods they preferred because of a lack of resources. While 49.7% of the household heads worry that their households would not have enough food, 50.3% did not worry. Few household heads stated that any member of their household went a whole day and night without eating because of lack of enough food. Only 5.8% of the household heads stated that there was ever no food to eat in their households because of a lack of resources to get food.

45.5% of the households must eat limited/few varieties of foods due to lack of resources (Fig. 5.1).

About half of the household heads (49.7%) indicated that they worried that their household would not have enough food. However, only about 9.8% of them expressed their worries either often (more than ten times in the past four weeks) or sometimes (three to ten times in the past four weeks). More than half of the household heads (56.5%) indicated that their household members were not able to eat the kinds of foods they preferred because of lack of resources.

However, only about 11.6% of the sample experienced this either often (more than ten times in the past four weeks) or sometimes (three to ten times in the past four weeks). 27.9% of the household heads indicated that their household members had to skip meals because there was not enough food. However, only about 6% of them experienced this either often (more than ten times in the past four weeks) or sometimes (three to ten times in the past four weeks). A few of the household heads (5.8%) indicated that there was ever no food to eat of any kind because of a lack of resources. More than half of this group (3.5%) experienced this either often (more than ten times in the past four weeks) or sometimes (three to ten times in the past four weeks).

Few of the household heads (12.3%) indicated that there were times when their household members went to sleep at night hungry because there was not enough food. However, only about 2% of them experienced this either often (more than ten times in the past four weeks) or sometimes (three to ten times in the past four weeks).

In respect of household food insecurity coping strategies, twelve questions were used to assess the coping strategies of household food insecurity. Generally, many of the households favour the purchase of food on credit and reliance on less preferred and less expensive food. In sampled households, 53.3% identified the purchase of food on credit as their coping strategy, while 58.8% identified the reliance on less preferred and less expensive foods. The questions and responses are combined in Figure 5.2 below.

5.1.3 Food Insecurity Coping Strategies

In respect of household food insecurity coping strategies, twelve questions were used

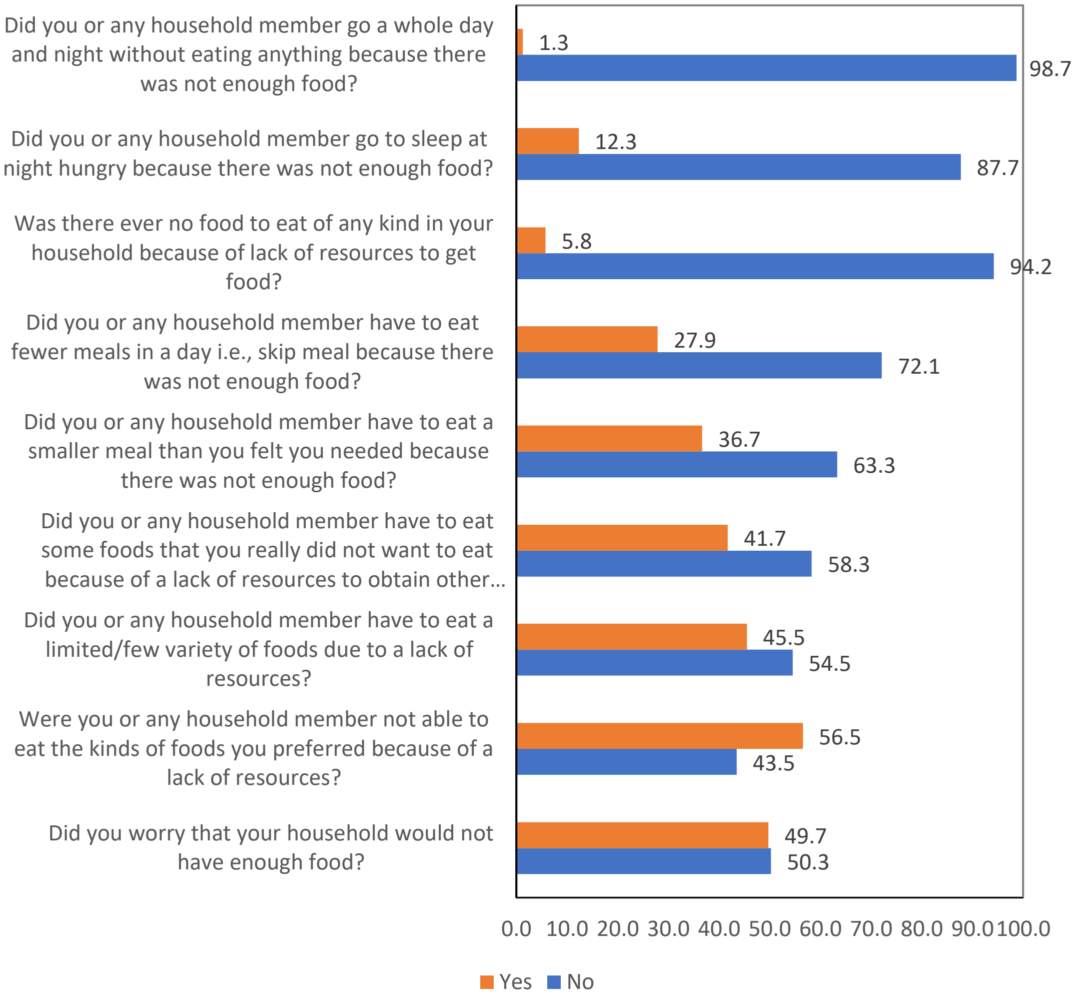


Figure 5.1: Response to household food insecurity access scale questions

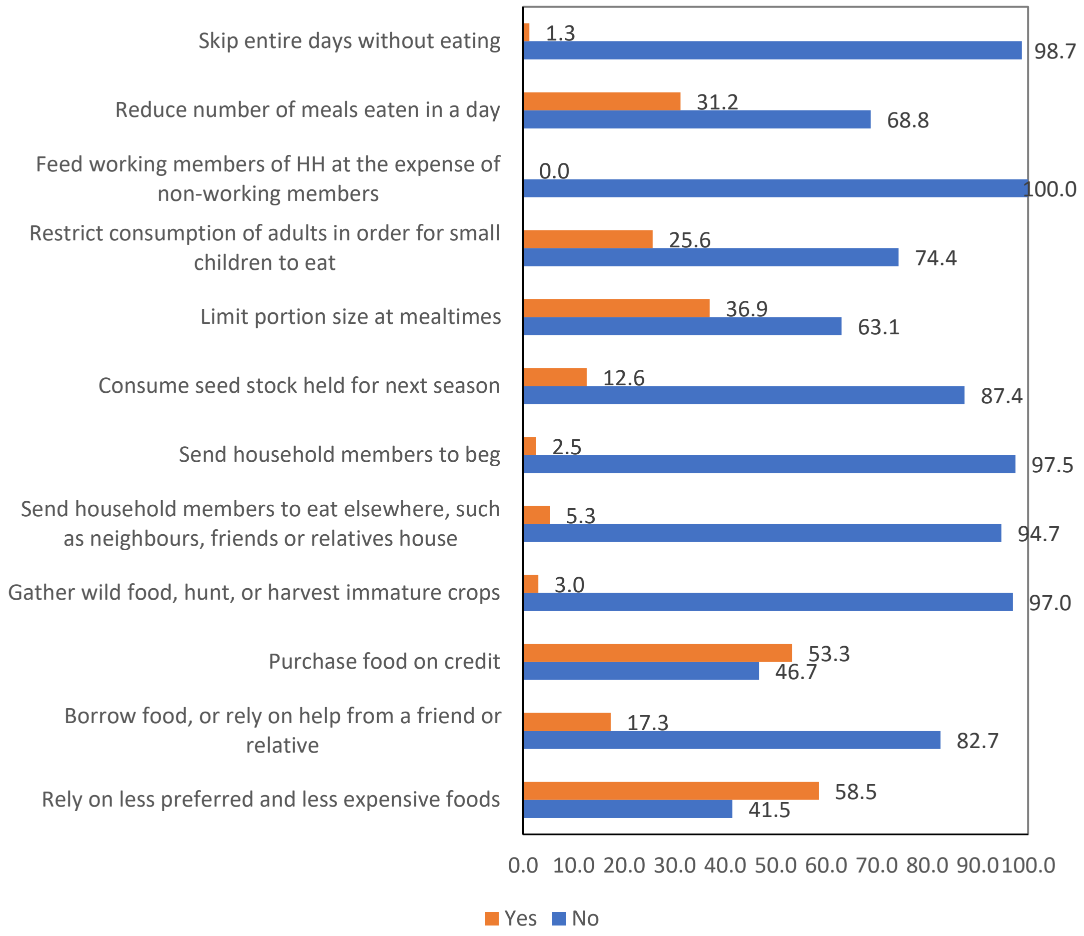


Figure 5.2 : Household food insecurity coping strategies

to assess the coping strategies of household food insecurity. Generally, many households favour the purchase of food on credit and rely less on preferred and less expensive food. In sampled households, 53.3% identified the purchase of food on credit as their coping strategy, while 58.8% identified the reliance on less preferred and less expensive foods.

58% of the households, which represents more than half, rely on less preferred and less expensive food to cope with food insecurity. And most households that experience this apply this coping strategy at least one day a week, which represents 43%. About 87% of the households do not consume their seed stocks to cope with food insecurity, but about 13% do. Among those who consume their seed stocks to cope with food insecurity, 8.5% practice this more than once in a week**.** Only 36.9% of the households limit their portion size at mealtimes, with the majority of those in this category (31.4%) practising it on more than one day of the week. A quarter of households (25%) restrict adult consumption for little children to eat; 20.4% of the households practice this as a coping strategy more than once in a week. A quarter of households (25%) restrict adult consumption for little children to eat. 20.4% of the households practice this as a coping strategy more than once in a week. Finally, 31.2% of the households adopt the reduction of the number of meals eaten in a day as a coping strategy for food insecurity, and 24.1% out of this number practise that more than once in a day.

Responses to climate change evidence, crises and shocks produced a polarity of experience, especially extreme weather events except for long periods of dry season/harmattan**.** A large percentage of the respondents indicated that they have not experienced drying of rivers and streams, erratic rainfall patterns, heat waves, heavy and long periods of rainfall, massive floods/storm surges and outbreaks of pests/diseases. However, 47.2% indicated that they have experienced long periods of dry season/harmattan, while the remaining 52.8% said they did not experience such in the past 12 months. Many of the households (98.5%) stated that they do not have an experience of conflict in any form, whether religious, ethnic or political, in their localities. The distribution of the ownership of land among the households follows an even pattern. About 51.3% of households own land, while 48.7% do not.

Many of the households indicated that they have access to credit, drinkable water, free drinking water from boreholes, information through phones, TV, radio or extension agents and markets. Evidence from the survey data shows that some of the households do not have access to electricity, farm technology, free medical care and paved roads. Among the households that have access to drinkable water, 27.6% live in more than 1 km away from the water source.

5.1.4 Response to shocks and climatic change events

A survey was also conducted to examine how populations in the Borno region responded to climatic changes and shocks. The survey examined the participant's experiences with the drying of rivers, erratic rainfall patterns, and heat waves. It also includes questions on long periods of rainfall and massive floods, as well as pests and diseases, as illustrated in figure 5.3 below.

In Figure 5.3, 87.4% of the households do not experience the effects of drying rivers and streams, and 12.6% did experience it; 33.9% of households in the study said they experienced the effects of erratic rainfall patterns, while 66.1% did not. In the experience of heat waves, 20.4% of the surveyed household population said they experienced heat waves, and 79.6% said they did not experience it. 1.8% of the households surveyed said they experienced heavy and long periods of rain, while 98.2% said they did not. 47.2% said they experienced a long dry season/Harmattan, while 58.8% said they did not. 29.4% said they experienced massive floods and storm surges, while 70.6% said they did not experience such. 39% of the surveyed households said they experienced outbreaks of pests and diseases, and 64.1% said they did not.

Items that fit into the Household food insecurity Access Scale (HFIAS), that is, the items that explain food security in the study area considering the above sections HFIAS includes the evidence of the outbreak of pests/disease, erratic rainfall patterns and long periods of dry season/harmattan, access to free drinking water from the borehole and the distance to the source of drinkable water.

5.1.5 Interpreting Findings from a Socioeconomic Perspective

The findings of this study explain and reflect the complex impact of the various socioeconomic factors and their role in food security in the Borno and Sahel region. Like the International research program of Global Environmental Change and food

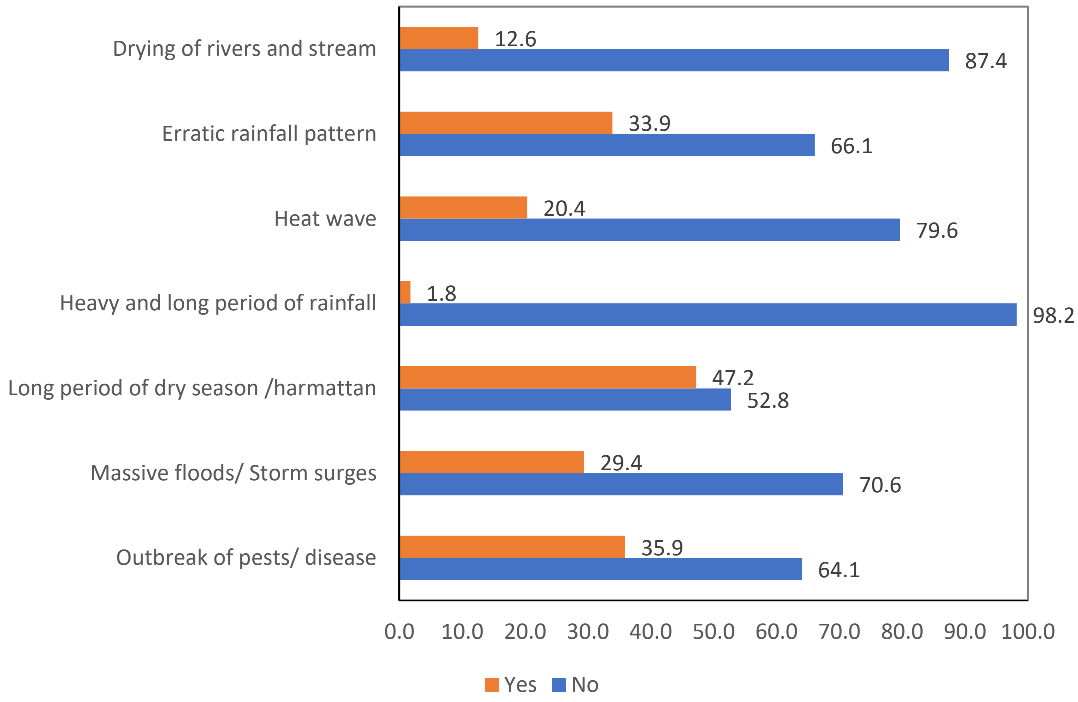


Figure 5.3: Response to Shocks and Climate Change Evidence/Events experienced in the last few years

Systems (GECAFS) (2006) suggests in the literature review that food insecurity in Borno and the Sahel region entails the unavailability of food, lack of adequate access to resources, and the coping mechanisms households adopt to manage the issue (Zakari *et al.*, 2022). According to GECAFS, food security is defined according to availability, focusing on production, distribution, and exchange, and according to access, focusing on affordability, allocation, and preference. Other considerations include the focus on nutritional value, social value and safety (GECAFS, 2006). Socio-economic issues such as regional conflicts and economic disparities have played major roles in defining food security in the region (Badewa, 2022).

A major contributor to food insecurity in the Borno region is ongoing conflicts in the northeast parts of Nigeria. The Boko Haram rebels have destroyed productive lands in the area and led to the major displacement of most small-scale farmers who depend on agriculture for survival (Adelaja & George, 2019). Between 2010 and 2015, the production of sorghum, rice, and millet declined by over 50% due to regional conflicts (Yobom & Le Gallo, 2022). As evidenced in this study, 49.7% of the households in the survey are worried that they would not have enough food. Conflicts and insecurity are major issues that cause the problem (Adelaja & George, 2019). Borno is a representation of the large Sahel region that is more often faced with insecurity challenges that lead to major food insecurity issues.

Economic hardships and limited access to infrastructure are also major contributors to food insecurity in the Borno region. Like in other Sahel regions such as Chad, Mali, and Niger, households in Borno rely on informal coping strategies which include the purchase of food on credit and the consumption of less preferred foods (Iocchi, 2020). Most people in the Sahel region have limited access to finances, which immerses them in major debts and perpetuates the cycle of poverty throughout their lives. The population also consumes undesired foods which are more often less nutritious or of lower quality (Adesoye & Adepoju, 2020). Such consumption contributes to poor health and the prevalence of food deficiency diseases in the region.

Regarding economic disparities, this study's findings show that over 70% of the Borno population earns less than 50,000 naira monthly, which further limits their ability to buy food. Many have to rely on credit to meet their basic needs, including food. Additionally, only 10% of the population had women as household heads, which suggested a high dependency on the male figure as household heads. The statistic also suggests limited female empowerment in food security. The finding effectively aligns with other economically disadvantaged regions in Nigeria and the Sahel region (Mayhew *et al*., 2022). In Niger, for example, poor neighbourhoods find it difficult to afford nutritious foods, which contributes to major deficiency diseases (Lentz *et al*., 2021). Others also depend on foreign aid and government support to provide food, more so in the dry seasons.

Concerning environmental shocks, aspects such as drought and unpredictable rainfall patterns further contribute to food insecurity. Like other Sahel regions, Borno people mainly depend on cereals and root tubers as stable foods (Reynolds *et al*., 2015). Most people have limited expenditure on nutritious food, which includes meat, fish, eggs, and milk, due to low incomes. Their high dependency on cereals and tubers poses a major threat to their food security, especially with the existing erratic rainfall patterns in the region (Reynolds *et al.*, 2015). It also implies limited dietary diversity, which further exacerbates food insecurity issues.

Access to resources which include land and drinkable water also plays a key role in food security. In this study's findings, 51.3% of households in Borno own land but have limited ability to use it due to insecurity issues and limited capital. The population also has limited access to clean water. Findings revealed that 27.6% of the population must travel over a kilometre to access drinkable water. In comparison, the Sahel regions have limited access to water and energy resources. Over 300 million people in the Sub-Sahel region have water scarcity or improved water sources around them (Liu *et al*., 2022). The lack of such basic services negatively affects the population's well-being and compounds food insecurity issues.

5.2 Household Food Insecurity Access Scale (HFIAS) Analysis

The Household Food Insecurity Access Scale (HFIAS) was used as the direct food insecurity measurement in this study. Developed by the USAID-funded Food and Nutrition Technical Assistance 11 project (FANTA), between 2001 and 2006, in partnership with other stakeholders like Cornell and Turft Universities, as an adaptation of the approach used to estimate the prevalence of food insecurity in the United States (U.S.) annually. The central idea of this method is that the experience of food insecurity (access) causes predictable reactions and responses that can be captured and quantified through a survey and summarised on a scale (Coates *et al.,* 2007).

The frequency and variability over time of household food insecurity of a population can be assessed from the information collated from the HFIAS. This method has been applauded for having the merits of population-level targeting, keeping and tracking, and evaluating food access-focused interests (IDEP, 2023). It has also been useful in various contexts of food insecurity, like the Household Hunger Scale (HHS), which is derived directly from the HFIAS, and the Food Insecurity Experience Scale (FIES). HFIAS has been adopted and used in the Bangladesh Integrated Household Survey and by the World Food Program (WFP, 2009) for rapid Emergency Food Assessments (IDEP, 2023).

Questions in the HFIAS module address nine conditions of household food insecurity under three domains, which are anxiety and uncertainty about household food supply, insufficient quality of food, and insufficient food intake (Table 5.1).

HFIAS has been used in several other nations and lends credibility to its ability to distinguish food-secure from food-insecure households. The HFIAS questions capture the HFI experience and can be used in categorising households and populations in the order of extremity (Obayelu *et al*., 2021; Nour and Abdalla, 2021; Obayelu and Oyekola, 2018; Samim *et al*., 2021; Farhadian *et al*., 2015; Otekurin *et al*., 2021). HFIAS information can be used to measure the prevalence of HFI and discover changes in a population's HFI situation over time.

Table 5.1: Household Food Insecurity Conditions

Domain	**Conditions (Questions)**
Anxiety and uncertainty about the household food supply	1. Did you worry that your household would not have enough food?
Insufficient Quality (includes variety and preferences of the type of food)	2. Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?
	3. Did you or any household member have to eat a limited variety of foods due to a lack of resources?

	4. Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?
Insufficient food intake and its physical consequences	5. Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?
	6. Did you or any household member have to eat fewer meals in a day because there was not enough food?
	7. Was there ever no food to eat of any kind in your household because of a lack of resources to get food?
	8. Did you or any household member go to sleep at night hungry because there was not enough food?
	9. Did you or any household member go a whole day and night without eating anything because there was not enough food?

The four levels of household food insecurity with increasing severity were characterised based on the nine items. They include food secure (FS), mildly food insecure (MiFI), moderately food insecure (MoFI) and severely food insecure (SFI).

A quick description of the categories of household food insecurity levels as determined by the HFIAS module is as follows (Coates *et al*., 2007):.

i. Food Secure (FS): The household had no experience with food insecurity or only had the experience of worrying about food on a rare basis ((Q1 = 0) + (Q1 = 1), Q1a = 1).

ii. Mildly Food Insecure (MiFI): The household is worried about not having food to eat occasionally or regularly ((Q1 = 1), Q1a = 2 or = 3)), and/or being unable to consume choice foods ((Q2 = 1), Q2a = 1 or = 2 or = 3)), and/or having little variety of food ((Q3 = 1), Q3a = 1)), and/or some food referred to as unpalatable only on rare occasions ((Q4 = 1), Q4a = 1)).

iii. Moderately Food Insecure (MoFI): The household consumes few varieties or unpalatable foods on occasion or frequently ((Q3 = 1), Q3a = 2 or = 3)), and/or has begun to reduce the size or number of meals on occasion or infrequently ((Q5 = 1), Q5a = 1 or = 2)), but did not experience any of the three extreme food insecurity situations (Q7a-9a).

iv. Severely Food Insecure (SFI): The household has moved gradually to reducing the quantity of meal or number of meals most frequently ((Q5 = 1), Q5a = 3)) + ((Q6 = 1), Q6a = 3)), and/or experiencing the three most extreme situations such as "not having any food to eat", "going to bed without eating any food" or "going a whole day hungry", even infrequently ((Q7 = 1), Q7a = 1 or = 2 or = 3)) + ((Q8 = 1), Q8a = 1 or = 2 or = 3)) + ((Q9 = 1), Q9a = 1 or = 2 or = 3)). However, if any household has experienced any of these three severe food deprivation situations in the last 30 days, only one is considered SFI (Otekunrin *et al*., 2021).

Where Q1, Q2, …, Q9 are the nine questions and Q1a, Q2a, …, Q9a are the corresponding frequency of occurrence.

The food insecurity levels of households can be determined by the HFIAS score, but not without caution. Table 5.2 revealed that households with a HFIAS score of ≥ 1 are FS; a HFIAS score of 2, 3, 4, 5, 6, 7, and 10 belonged to MiFI households; a HFIAS score of 8, 9, 11,12, 13, 14, 16, and 17 belonged to MoFI households; and households with a HFIAS score of 15, 18,19, 20, 21, 22, 23, 24, 25, 26, and 27 are SFI (Coates *et al*., 2007).

Table 5.2: Categories of food insecurity

Question	**Frequency**		
	Rarely (1)	Sometimes (2)	Often (3)
Q1a			
Q2a			
Q3a			
Q4a			

Q5a			
Q6a			
Q7a			
Q8a			
Q9a			

5.2.1 Ordinal Logistic Regression for Food Security

Since the criterion variable (food security) was a stratified ordinal variable, ordinal regression was employed. The ordinal regression that is based on the McCullagh methodology is known as the ordinal logistic regression (Yazdanpanah *et al*, 2021). The ordinal regression allows for modelling the dependence of an ordinal dependent variable on a series of independent variables (Christensen, 2015). One goal of ordinal regression is to optimise the response variable in different problems. This means that, with a change in the status of controlling variables, an optimal status is obtained from the response variable (Abreu *et al*., 2008). In this type of regression, the regression coefficients show how changes in the independent variables influence the dependent variable (Gutiérrez *et al*., 2015).

The ordinal logistic regression using SPSS can be defined as

$$log\ log\ it\left[\pi(Y \leq J|x_1, x_2' \ldots x_p\right] = ln\ ln\ \left(\frac{\pi(Y \leq f||x_1', x_2, \ldots x_p)}{\pi(Y > f||x_1', x_2, \ldots x_p)}\right) = \alpha_j + (-\beta_1 X_1 - \beta_2 X_2 - \ldots - \beta_p X_p) \quad (5.1)$$

where α_j's are the thresholds, and β_1, β_2,…, β_p are the logit coefficients; $j = 1,2, j - 1$.

The model was chosen because the response variable has more than two ordinal categories. These categories were treated against the potential variables, which are assumed to affect the risk of inadequate access to food. Household size, gender of household head, level of education, work status, and whether the household practices agriculture are all demographic characteristics that are routinely included in food security surveys. The influence of each predictor was determined by looking at both the coefficient value and the sign. A negative coefficient indicates that the factor reduces the likelihood of insufficient food security (Ndhleve *et al*., 2012).

5.2.2 Results

5.2.2.1 Food Security Prevalence

The Household Food Insecurity Access Scale (HFIAS) in the questionnaire is used to investigate the food security status of households in Borno State. Among the nine conditions of food insecurity, the incidence of inability to eat preferred food due to lack of resources is the highest food security problem in the area (Table 5.3). The literature review suggests different ways food insecurity would prevail. According to the USDA Economic Research Council (2014a), food insecurity occurs when there is (1) uncertainty about future food availability and access, (2) insufficiency in the amount and kind of food required for a healthy lifestyle, or (3) the need to use socially unacceptable ways to acquire food. As illustrated in Table 5.3, 56.5% of respondents reported lacking resources to cater to their food insecurity issues, while 45.5% claimed that they only eat a limited variety of foods. 41.7% had resource constraints which limited their access to the foods they ate. These findings suggest that households in the region struggle with access to food, the quality of the food, and the variety of the diet.

Further studies in this section suggest that 49.7% of households reported worrying about not having enough food, while 27.9% had to reduce their meals per day. The findings also indicated that only a limited population (1.3%) had major food insecurity issues such as going an entire day or night without food. Although the margin is small, these statistics indicate an ongoing struggle to maintain food security.

The results from the HFAIS provide a detailed picture of the current state of food security in the Borno region. Of all the 98 surveyed households, 37.7% were classified as food secure, while 22.1% were mildly food insecure, 24.6% were moderately food insecure, and 15.6% were severely food insecure (Fig. 5.4). From the study, a significant population percentage was food secure, though the larger part of the population had varying degrees of food security.

Table 5.3: Distribution based on the repetitiveness of food insecurity conditions.

		Rarely	Sometimes	Often	Total
	Incidence Question	**Freq (%)**	**Freq (%)**	**Freq (%)**	**N (%)**
1.	Did you worry that your household would not have enough food?	159 (39.9)	36 (9.0)	3 (0.8)	198 (49.7)
2.	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?	179 (45.0)	43 (10.8)	3 (0.8)	225 (56.5)
3.	Did you or any household member have to eat a limited variety of foods due to a lack of resources?	137 (34.4)	40 (10.1)	4 (1.0)	181 (45.5)
4.	Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?	132 (33.2)	30 (7.5)	4 (1.0)	166 (41.7)
5.	Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?	112 (28.1)	32 (8.0)	2 (0.5)	146 (36.7)
6.	Did you or any household member have to eat fewer meals in a day because there was not enough food?	87 (21.9)	22 (5.5)	2 (0.5)	111 (27.9)
7.	Was there ever no food to eat of any kind in your household because of a lack of resources to get food?	9 (2.3)	12 (3.0)	2 (0.5)	23 (5.8)
8.	Did you or any household member go to sleep at night hungry because there was not enough food?	41 (10.3)	6 (1.5)	2 (0.5)	49 (12.3)
9.	Did you or any household member go a whole day and night without eating anything because there was not enough food?	1 (0.3)	4 (1.0)	5 (1.3)	5 (1.3)

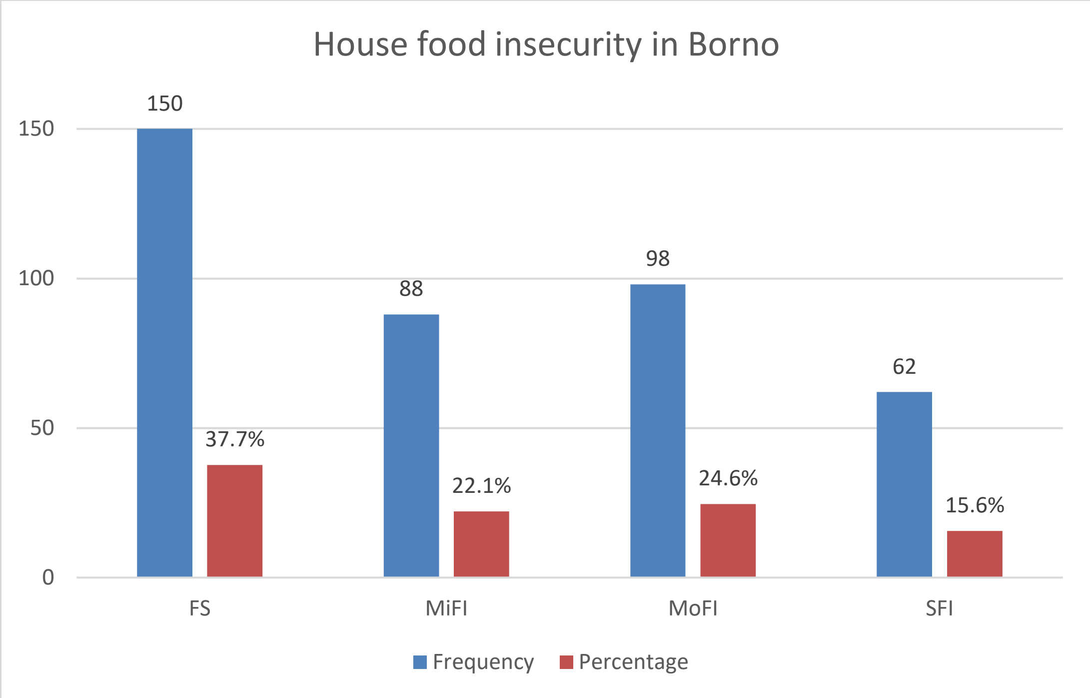


Figure 5.4: Household food insecurity

From a policy perspective, local and national governments in the Borno region have a crucial role to play in improving access to affordable food in poor neighbourhoods. Data from the literature review shows that some countries in the Sahel region have no access to modern equipment and new technology (Kregg-Byers & Schlenk, 2010; Hogson,2004). Therefore, more investments in technology are crucial. However, it is important to note that even with the advent of modern technology and equipment for improved and mass production,

food insecurity would still not be eliminated (Barret, 2002). This is because modern equipment and technology would still not produce a suitable supply of nutritious food for the population. The government must also consider boosting the current agricultural sector and enhancing the economic opportunities in vulnerable populations (Tomich *et al*., 2018). Based on specific research in the region, they can offer localised and targeted interventions that address the local challenges in the region.

5.2.3 Demographic & Socioeconomic Characteristics

Table (5.4) shows the demographic and socio-economic characteristics of the household based on their food security status. The percentage of food-secure households decreases with an additional member, so also does the food-unsecured household. The number of years of education shows a marked contrast in food-insecure households, 46.8% indicated no years of education. Households whose heads are primarily farmers are highest (41.9%) in the food-insecure category, while it is traders in the food-secure category.

Household heads aged 25–40 years were the household age group with the highest percentage of FS (47.3%), MiFI (45.5%), MoFI (48%), and SFI (58.1%) among all the age-group categories. About 48.9% and 40.3% of household heads that were above 40 years old were MoFI and SFI, respectively. This indicated that household heads that are older than 40 are more likely to be SFI because of limited resources owing to reduced energy to engage in farming activities leading to a reduction in productivity and income. Additionally, these groups are considered to have physical limitations to engage in farming or labour activities that bring income. In this case, government interventions should be in place to support older household heads, such as financial support and access to less physically demanding tasks with good income levels.

Table 5.4: Socio-demographic characteristics according to food insecurity category

	FS (n = 150)	MiFS (n = 88)	MoFS (n = 98)	SFI (n = 62)	Total (N=398)
Household size					
≤5	73 (48.7)	30 (34.1)	47 (48)	27 (43.5)	177 (44.5)
6 to 10	57 (38)	38 (43.2)	37 (37.8)	25 (40.3)	157 (39.4)
11 to 15	13 (8.7)	11 (12.5)	12 (12.2)	10 (16.1)	46 (11.6)
≥16	7 (4.7)	9 (10.2)	2 (2)	0 (0)	18 (4.5)
Household with dependant i.e., with children below 18 years old					
Yes	135 (90.0)	78 (88.6)	83 (84.7)	58 (93.5)	354 (88.9)
No	15 (10.0)	10 (11.4)	15 (15.3)	4 (6.5)	44 (11.1)
Age of household head					
15 to 24	0 (0)	4 (4.5)	3 (3.1)	1 (1.6)	8 (2.0)
25 to 40	71 (47.3)	40 (45.5)	47 (48)	36 (58.1)	194 (48.7)
41 to 55	56 (37.3)	28 (31.8)	35 (35.7)	23 (37.1)	142 (35.7)
56 to 64	14 (9.3)	10 (11.4)	11 (11.2)	2 (3.2)	37 (9.3)
65 above	9 (6)	6 (6.8)	2 (2)	0 (0)	17 (4.3)
Gender					
Male	137 (91.3)	84 (95.5)	85 (86.7)	49 (79.0)	355 (89.2)
Female	13 (8.7)	4 (4.5)	13 (13.3)	13 (21.0)	43 (10.8)
Marital Status					
Single	0 (0)	2 (2.3)	1 (1.0)	1 (1.6)	4 (1.0)
Married	137 (91.3)	82 (93.2)	87 (88.8)	52 (83.9)	358 (89.0)
Widowed/Divorced	13 (8.7)	4 (4.5)	10 (10.2)	9 (14.5)	36 (9.0)
Educational Years					
0	47 (31.3)	25 (28.4)	26 (26.5)	29 (46.8)	127 (31.9)
1 to 6	16 (10.7)	21 (23.9)	12 (12.2)	8 (12.9)	57 (14.3)
7 to 12	36 (24)	15 (20.3)	26 (26.5)	15 (24.2)	92 (23.1)
13 to 18	47 (31.3)	25 (28.4)	31 (31.6)	9 (14.5)	112 (28.1)
19 +	4 (2.7)	2 (2.3)	3 (3.1)	1 (1.6)	10 (2.5)
Education Qualification of Household Head					
No Education	47 (31.3)	25 (28.4)	26 (26.5)	29 (46.8)	127 (31.9)
FSLC	7 (15.5)	20 (22.7)	14 (14.3)	4 (6.5)	45 (11.3)
O'Level	39 (26)	15 (17)	22 (22.4)	17 (27.4)	93 (23.4)
NCE/OND	30 (20)	16 (18.2)	23 (23.5)	8 (12.9)	77 (19.3)
BSc/HND	25 (16.7)	10 (11.4)	13 (13.3)	3 (4.8)	51 (12.8)
PG Cert	2 (1.3)	2 (2.3)	0 (0)	1 (1.6)	5 (1.3)
Primary Occupation of Household Head					
Civil servant	35 (23.3)	23 (26.1)	26 (26.5)	7 (11.3)	91 (22.9)
Farmer	31 (20.7)	37 (42)	20 (20.4)	26 (41.9)	114 (28.6)
Private Sector employee	4 (2.7)	2 (2.3)	3 (3.1)	2 (3.2)	11 (2.8)
Artisan	8 (5.3)	1 (1.1)	8 (8.2)	2 (3.2)	19 (4.8)
Trader	52 (34.7)	19 (21.6)	33 (33.7)	19 (29)	122 (30.7)
Student	0 (0)	0 (0)	1 (1)	0 (0)	1 (0.3)
Unemployed	1 (0.7)	0 (0)	0 (0)	1 (1.6)	2 (0.5)
Secondary Occupation					
Yes	42 (28)	47 (53.4)	37 (37.8)	28 (45.2)	154 (38.7)
No	108 (72)	41 (46.6)	61 (62.2)	34 (54.8)	244 (61.3)
Monthly Household Income					
0 to #50,000	107 (71.3)	59 (67)	72 (73.5)	50 (80.6)	288 (72.4)
#50,001 to #100,000	37 (24.7)	28 (31.8)	26 (26.5)	11 (17.7)	102 (25.6)
Above #100,000	6 (4)	1 (1.1)	0 (0)	1 (1.6)	8 (2.0)
Number of Income Earners					

0	3 (2.0)	2 (2.3)	2 (2.0)	1 (1.6)	8 (2)
1	71 (47.3)	45 (51.1)	52 (53.1)	44 (71)	212 (53.3)
2	51 (34)	31 (35.2)	37 (37.8)	11 (17.7)	130 (32.7)
3	13 (8.7)	7 (8)	7 (7.1)	6 (9.7)	33 (8.3)
4	10 (6.7)	3 (3.4)	0 (0)	0 (0)	13 (3.3)
5	1 (0.7)	0 (0)	0 (0)	0 (0)	1 (0.3)
6	1 (0.7)	0 (0)	0 (0)	0 (0)	1 (0.3)
Female Head monthly Earning					
0	69 (46)	44 (50)	55 (56.1)	43 (69.4)	211 (53)
1,000 to 20,000	65 (43.3)	36 (40.9)	34 (34.7)	14 (22.6)	149 (37.4)
20,001 to 30,000	11 (7.3)	6 (6.8)	2 (2)	2 (3.2)	21 (5.3)
30,001 to 40,000	1 (0.7)	0 (0)	0 (0)	1 (1.6)	2 (0.5)
> 40,000	4 (2.7)	2 (2.3)	7 (7.1)	2 (3.2)	15 (3.8)
Amount spent on food in the last month					
≤10000	4 (2.7)	0 (0)	12 (12.2)	2 (3.2)	18 (4.5)
10000 to 50000	135 (90)	79 (89.8)	81 (82.7)	57 (91.9)	352 (88.4)
>50,000	11 (7.3)	9 (10.2)	5 (5.1)	3 (4.8)	28 (7)

Male-headed households are more FS than their female-headed counterparts. The same applies across all categories of food insecurity; female-headed households are less than 20% except for SFI, where they recorded 21%. This could be due to their heavy responsibilities at home, such as childcare and other responsibilities, which demanded their reduced involvement in farming operations, which could result in limited access to productive assets (Obayelu *et al*., 2021; Otekunrin *et al.,* 2021; Ahmed *et al.,* 2015). As the literature review suggests, women face challenges to get access to land, education, financial supports, livestock and equal wages with men (Valin *et al*., 2021). This limitation limits their food security levels compared to male-headed homes in the region.

Further findings in the Borno region reveal that 31.3% of food-secure (FS) households lack formal education, which is lower compared to the 46.8% of severely food-insecure households. The statistics suggest the significant role played by education in improving food security. Education can be associated with greater opportunities for employment and resources that effectively manage food security. Regarding household occupation, 34.7% of food-secure households are traders, which is higher than 20.7% of food-insecure households who are involved in farming. Additionally, 41.9% of food-insecure households have heads as farmers which suggests that farming alone may not provide sufficient income and resources for food security. It suggests the need to diversify income sources or improve agriculture to reduce food insecurity.

5.2.4 Crisis and Climate Change Event Experiences

Data from Table 5.5 below shows that MiFS (46.6%) and FS (40.7%) reported the highest experiences of floods and storm surges compared to 10.2% and 8.1% experienced by MoFS and SFI respectively. A total of 29.4% of the participants experienced massive floods and storm surges. Heatwaves were mainly experienced among SFI (41.9%) and MoFS (32.7%) groups compared to the FS (14%) and MiFS (2.3%). The statistic suggests that people who were more food insecure were vulnerable to heat waves. Overall, 20.4% of the participants had experienced heat waves. Drying rivers and streams were mainly experienced by mildly food insecure individuals (MiFS) which suggested the vulnerability to water by this population. The outbreak of pests and diseases was mainly visible among MiFS (69.3%). The FS group also had a large percentage of people (30.7%) who reported exposure to pests and diseases. 35.9% of the participants reported to have been exposed to pests and diseases. Regarding erratic rainfall patterns, MiFS (59.1%) reported the highest percentage, followed by FS (30%) and MoFS (31.6%). SFI (11.3%) reported to have fewer encounters with erratic rainfall.

Other important considerations in this section include long periods of dry season and long periods of rainfall. The FS group (32%) had fewer instances of long dry seasons compared to the MiFS (67%) group, SFI (61.3%), and MoFS (43.9%). Additionally, almost half of the participants (47.5%) had previous experiences of long dry seasons. On the other hand, long periods of rainfall were only experienced by 1.8% of the sample participants. Conflict experiences were also low in the population. Only MiFS (3.4%), MoFS (2%), and SFI (1.6%) report conflict experiences, with FS (0%) not experiencing any conflict.

From an overall view, various climatic factors impact food security in the Borno region. In the literature review, it was clear that in developing countries, food insecurity may be caused by the drop in agricultural production because of persistent drought and famine, an unexpected pest attack on agricultural produce which would lead to poverty and hunger. For a country to be food secure, there will be access to food in adequate and acceptable quantity and quality, consistent with decent existence always for most of the population (Davis, 2009). Some other drivers of chronic food insecurity include wars, conflicts, economic crises, and weather events like droughts that have the propensity to displace people from their homes (WFP, 2021). From the findings, MiSF seems to be the most vulnerable group to climatic crises and conflicts in the Borno region. They report having been exposed to erratic rainfall patterns, drying of rivers, and long dry seasons. MoFS and SFI groups are also highly exposed to heat waves and long dry seasons. Such exposure could be the main contributor to crop damage and water unavailability, which impacts food insecurity. The SFI does not appear to be affected by climatic problems as much as in the case of MiSF, which implies that other factors such as poverty and lack of resources could be contributing to the problems that make them food insecure. The food-secure people are less exposed to climatic crises in the region. Although they are exposed to a certain percentage, the impact is lower compared to other groups. The findings also show that conflicts are rare across all groups. In this case, the conclusion can be that other factors, such as environmental and climate events, impact food insecurity more than social or political instability.

Table 5.5: Experiences of Shocks, Crisis and Climate Change Events

	FS (n = 150)	**MiFS (n = 88)**	**MoFS (n = 98)**	**SFI (n = 62)**	**Total (N=398)**
Massive flood/Storm surge					
Yes	61 (40.7)	41 (46.6)	10 (10.2)	5 (8.1)	117 (29.4)
No	89 (59.3)	47 (53.4)	88 (89.8)	57 (91.9)	281 (70.6)
Heat wave					
Yes	21 (14)	2 (2.3)	32 (32.7)	26 (41.9)	81 (20.4)
No	129 (86)	86 (97.7)	66 (67.3)	36 (58.1)	317 (79.6)
Drying of rivers and stream					
Yes	12 (8)	31 (35.2)	5 (5.1)	2 (3.2)	50 (12.6)
No	138 (92)	57 (64.8)	93 (94.9)	60 (96.8)	348 (87.4)
Outbreak of pests/disease					
Yes	46 (30.7)	61 (69.3)	29 (29.6)	7 (11.3)	143 (35.9)
No	104 (69.3)	27 (30.7)	69 (70.4)	55 (88.7)	255 (64.1)
Erratic rainfall pattern					
Yes	45 (30)	52 (59.1)	31 (31.6)	7 (11.3)	135 (33.9)
No	105 (70)	36 (40.9)	67 (68.4)	55 (88.7)	263 (66.1)
Long period of dry season/harmattan					
Yes	48 (32)	59 (67)	43 (43.9)	38 (61.3)	188 (47.5)
No	102 (68)	29 (33)	55 (56.1)	24 (38.7)	210 (52.8)
Heavy and long period of rainfall					
Yes	2 (1.3)	1 (1.1)	3 (3.1)	1 (1.6)	7 (1.8)
No	148 (98.7)	87 (98.9)	95 (96.9)	61 (98.4)	391 (98.2)
Conflict Experience					

Yes	0 (0)	3 (3.4)	2 (2)	1 (1.6)	6 (1.5)
No	150 (100)	85 (96.6)	96 (98)	61 (98.4)	392 (98.5)

5.2.5 Access to Resources

There is a dichotomous distribution between households who have lands and those who do not (Table 5.6). Regarding resources, households with access to free drinking water from boreholes are more likely to be more food-secure (60% in FS compared to 24.2% in SFI). Similarly, access to credit is more common among food-secure households (72% in FS vs. 30.6% in SFI). The two factors point out the importance of improving infrastructure to enhance food security.

The analysis indicates that the gender of the household head plays a significant role in influencing food security in the region. A positive estimate of 1.517 ($p = 0.019$) indicates that male-headed households are more likely to experience low levels of food insecurity. Regarding marital status, married heads tend to have lower food insecurity issues ($p = 0.071$). The statistic supports the role played by a stable family in managing food insecurity. On the same note, the analysis shows that diverse household incomes enhance food security. An additional income earner in a family reduces food insecurity by 0.343. Other causes of food insecurity include heat waves and long dry seasons, which increase the likelihood of food insecurity by (1.124, $p = 0.003$) and (1.023, $p = 0.004$), respectively.

Access to farm/other technology (1.108, $p < 0.001$) plays a strong positive role in reducing food insecurity. This demonstrates the major role of technology in enhancing food security in the region. Additionally, access to credit ($p = 0.081$) marginally reduces insecurity, which highlights the need for improved credit access for farming households. Therefore, policy implications should focus on advancing farm technology and credit levels to make farming more profitable and more income-generating

Table 5.6: Access to Resources

	FS (n = 150)	**MiFS (n = 88)**	**MoFS (n = 98)**	**SFI (n = 62)**	**Total (N=398)**
Land ownership					
Yes	75 (50)	62 (70.5)	39 (39.8)	28 (45.2)	204 (51.3)
No	75 (50)	26 (29.5)	59 (60.2)	34 (54.8)	194 (48.7)

Plots of land owned					
0	10 (13.3)	3 (4.8)	5 (12.8)	7 (25)	25 (12.3)
1 to 10	50 (66.7)	21 (33.9)	27 (69.2)	20 (71.4)	118 (57.8)
11 to 20	12 (16)	29 (46.8)	6 (15.4)	0 (0)	47 (23)
>20	3 (4)	9 (14.5)	1 (2.6)	1 (3.6)	14 (6.9)
Farm and other productive technology					
Yes	25 (16.7)	32 (36.4)	28 (28.6)	40 (64.5)	125 (31.4)
No	125 (83.3)	56 (63.6)	70 (71.4)	22 (35.5)	273 (68.6)
Drinkable water					
Yes	132 (88)	83 (94.3)	88 (89.8)	55 (88.7)	358 (89.9)
No	18 (12)	5 (5.7)	10 (10.2)	7 (11.3)	40 (10.1)
Free drinking water from borehole					
Yes	90 (60)	70 (79.5)	62 (63.3)	15 (24.2)	237 (59.5)
No	60 (40)	18 (20.5)	36 (36.7)	47 (75.8)	161 (40.5)
Paved road					
Yes	37 (24.7)	21 (23.9)	45 (45.9)	32 (51.6)	135 (33.9)
No	113 (75.3)	67 (76.1)	53 (54.1)	30 (48.4)	263 (65.1)
Credit					
Yes	108 (72)	40 (45.5)	57 (58.2)	19 (30.6)	224 (56.3)
No	42 (28)	48 (54.5)	41 (41.8)	43 (69.4)	174 (43.7)
Information through phones, TV, radio or extension agents					
Yes	135 (90)	81 (92)	90 (91.8)	58 (93.5)	364 (91.5)
No	15 (10)	7 (8)	8 (8.2)	4 (6.5)	34 (8.5)
Markets					
Yes	148 (98.7)	85 (96.6)	97 (99)	61 (98.4)	391 (98.2)
No	2 (1.3)	3 (3.4)	1 (1)	1 (1.6)	7 (1.8)
Free medical care					
Yes	14 (9.3)	5 (5.7)	13 (13.3)	2 (3.2)	34 (8.5)
No	136 (90.7)	83 (94.3)	85 (86.7)	60 (96.8)	364 (91.5)
Electricity					
Yes	59 (39.3)	55 (62.5)	36 (36.7)	15 (24.2)	165 (41.5)
No	91 (60.7)	33 (37.5)	62 (63.3)	47 (75.8)	233 (58.5)

5.3 Regression Analysis

The factors influencing food insecurity among farming households are presented in Table 5.7. The indicators, including household characteristics, livelihood characteristics, experience of shocks and access to resources were the independent (explanatory) variables. The dependent variable is the food insecurity prevalence levels categorised into four outcomes (1 = FS, 2 = MiFI, 3 = MoFI, and 4 = SFI). The predicted probabilities of Y = 1 or the marginal effects were estimated, which measured changes in the probability of food insecurity (access) outcome with respect to a change in explanatory variables. Table 5.7 indicated that the results of the ordinal logistic regression of each of the explanatory variables on the food insecurity prevalence categories.

The result revealed that the gender and marital status of the household head are significant indicators of household food insecurity. With regards to the livelihood of the household, the number of income earners in a household is significant in determining food security. Furthermore, the experience of shocks such as massive floods, heat waves, outbreaks of pests or disease, long periods of dry seasons, and conflict are significant factors in determining food security in the area. Access to farm or productive technology and credit shows significance.

Table 5.7: Food security indicators

Variables	Estimate	Std. Error	Wald	Sig.
Household Characteristics				
Household Size	0.029	0.035	0.665	0.415
Household with dependants, i.e., with children below 18 years of age	0.182	0.352	0.265	0.606
Gender of the household head	1.517	0.648	5.472	0.019**
Age Group	-0.161	0.14	1.337	0.248
Marital status of the household head	-1.133	0.627	3.26	0.071*
Educational qualification of the head of the females in the household	-0.169	0.224	0.569	0.451
Educational Years	0.044	0.251	0.031	0.859
Livelihoods				
Primary/major occupation of the household head	-0.084	0.055	2.276	0.131
Secondary Occupation	0.004	0.253	0	0.988
Monthly income of the household	-0.355	0.278	1.627	0.202
Number of income earners in the household	-0.343	0.157	4.781	0.029**
Monthly expenditure of the household	-0.107	0.143	0.565	0.452
Amount spent on food for the household in the last one month	0.000	0.000	0.033	0.856
Female Head Income	0.128	0.141	0.835	0.361
Shocks				
Massive floods/storm surges	-0.714	0.281	6.45	0.011**
Heat wave	1.124	0.381	8.698	0.003***
Drying of rivers and stream	0.086	0.397	0.046	0.83
Outbreak of pests/ disease	-0.777	0.437	3.168	0.075*
Erratic rainfall pattern	-0.37	0.44	0.707	0.4
Long period of dry season/harmattan	1.023	0.351	8.466	0.004***
Heavy and long periods of rainfall	-0.643	0.766	0.704	0.401
Conflict (religious, ethnic or political) in the last 12 months	1.342	0.781	2.955	0.086*
Access				

Land ownership	-0.272	0.246	1.221	0.269
Farm/Other productive technology	1.108	0.289	14.684	0***
Drinkable water	-0.297	0.399	0.554	0.457
Free drinking water from the borehole, i.e., not bought	-0.303	0.258	1.381	0.24
Paved roads	0.342	0.244	1.967	0.161
Credit	-0.463	0.265	3.047	0.081*
Information through phones, TV, radio or extension agents	0.387	0.403	0.924	0.337
Markets	-0.866	0.74	1.372	0.242
Free medical care	0.185	0.374	0.244	0.621
Electricity	0.09	0.286	0.099	0.753
Model statistics				
-2 Log Likelihood	896.746			
Cox and Snell	0.342			
Nagelkerke	0.368			
McFadden	0.157			
Chi-square	1322.087			

5.3.1 Coping Strategies and Food Security

The main coping strategies employed by the households in the study area, as suggested by the data, include reliance on less preferred and less expensive foods, with 58.5% of the sampled households attesting to using this strategy to cope with food shortages, while 53% of the households relied on purchasing food on credit, 36.9% relied on limiting portion size at mealtimes, 31.2% depended on reduction of the number of meals eaten in a day, 25.6% coped by using restriction of consumption of adults for small children to eat, and 17.3% relied on borrowing food from a friend or relative. The less important coping strategies includes skipping entire days without eating; 1.3% of the sampled household said they used this method to cope with food shortages, 2.5% of the household population used sending household members to beg, while 5% relied on sending household members to eat elsewhere, such as at neighbours', friends' or relatives' houses, and 3% depended on gathering wild food, hunting, or harvesting immature crops (Table 5.8).

Table 5.8: Coping strategies for food insecurity in the study area

Coping Strategy	Frequency (N=398)	Percentage
Rely on less preferred and less expensive foods	233	58.5

Borrow food, or rely on help from a friend or relative	69	17.3
Purchase food on credit	212	53.3
Gather wild food, hunt, or harvest immature crops	12	3.0
Send household members to eat elsewhere, such as neighbours', friends' or relatives' houses.	21	5.3
Send household members to beg	10	2.5
Consume seed stock held for next season	50	12.6
Limit portion size at mealtimes	147	36.9
Restrict consumption of adults in order for small children to eat	102	25.6
Feed working members of HH at the expense of non-working members	0	0.0
Reduce number of meals eaten in a day	124	31.2
Skip entire days without eating	5	1.3

5.3.2 Summary Interpretation

The coping strategies employed by households to enhance food security in the Borno area reveal key strategic insights into the economic, cultural, and social context of food security in the Sahel region. The most employed strategies include increased reliance on less expensive foods, purchasing food on credit, and limited portion sizes at mealtimes. These strategies are mainly short-term strategies that may not be directly applicable in the long term. For example, the reliance on lower-quality alternatives that prioritises quantity over quality only solves short-term food security challenges (Gracia-Arnaiz, 2022). Consuming less nutritious foods contributes to malnutrition, particularly among children and elderly adults, which may affect their health in the long term (Troesch *et al*., 2015). Similarly, purchasing food products on credit provides the family with temporary relief and creates a cycle of debt that elevates the levels of poverty among the population (Seefeldt, 2015). Increased debts also reduce the probability of investing, which leads to further hardships, which leads to major financial distress that leads to economic constraints.

In reducing the number of meals and portions per meal, households attempt to make food last for longer. However, this may have major consequences for the household member's physical health and productivity. Long-term implications of these strategies may include stunted growth among children and malnutritional diseases in the population (Fraser *et al*., 2022). Other short-term strategies included in the findings include borrowing food from friends and restricting consumption for adults so that children can eat (Grunseit *et al*., 2019). These strategies reflect the larger Sahel region, which is more culturally inclined to collectivism. The strategies are, however, unsustainable in the long term, as the community may end up being food insecure if drought conditions persist for longer periods.

Overall, these strategies mainly suggest a more short-term coping strategy that provides limited solutions for the future. To address food security issues in the Sahel, a long-term approach to food security should be considered. In the literature review, the 2030 agenda for Sustainable Development aims to attain long-term food security by guaranteeing every citizen access to adequate food all year round through sustainable food systems, increasing smallholders' productivity and incomes, eradicating cases of stunting among children, and reducing food waste (Global Hunger Index, 2022). In recent years, there have been several international summits to promote the SDG goals of eradicating hunger and poverty; von Braun *et al*. (2021) highlighted a few that include the UN Food Systems Summit in September 2021, the UN Climate Change Conference (COP26) in November 2021, and the Nutrition for Growth Summit in December (2021). A major strategy would be to improve agriculture in the region.

To achieve long-term food security, the government and international community should ensure farmers have access to quality agricultural inputs and adequate water supply to increase production in the long term (Kang *et al*., 2017). Additionally, financial services and advice should be made more available to enhance the financial well-being of the population. Farmers should be made aware of how to access favourable loans and investments (Stolper & Walter, 2017). People should also be enlightened on the importance of proper nutrition. Such enlightenment would mitigate the negative impacts related to consuming less nutritious foods (Mayes & Thompson, 2015). The local and national governments could also focus on enhancing infrastructure and diversifying the economy to accommodate more creativity and people in economic growth (Anyaehie & Areji, 2015). As a result, the source of income would increase which could improve the overall food security levels in the region.

5.4 Qualitative Data Analysis

Borno state is in the heart of northeastern Nigeria. Like other states in the northern region, there are two main seasons: the rainy season and the dry season. The predominant production system is agropastoral farming systems. Some farmers only focus on crop cultivation, mainly beans, soybeans, millets, Bambara nuts, etc. The food security dynamics in the study areas are similar not only to surrounding districts in northeast Nigeria but also to smallholder farming communities elsewhere in the northern part of the country (Ojoko *et al*., 2017).

Five communities, Mafa, Konduga, Kaga, Maiduguri and Bayo, were purposively selected based on the relative ease of access and mobility for the researchers and the community participants, locality and distance between the communities to ensure that they are not adjacent to one another and have predominantly agricultural households. The participants were selected from the households which were smallholder farmers. From this sample of households, 12 women and 28 men took part in a total of five group interviews (Brownhill & Hickey, 2012). Due to the cultural characteristics in each of the communities, three group interviews with men, one group interview with women and one group interview with men and women together were conducted.

Using structured, closed-ended guides (Webb-Girard *et al*., 2012), the group interview examined i) the agricultural systems practiced, ii) farmers' level of knowledge about climate variability and change, iii) the adaptation measures taken and iv) the security challenges they faced. The group interviews were conducted by trained moderators in the local language. A digital data collection tool was used to record the number of participants who agreed with each answer. Notes were also taken when participants provided insight into a question. Before each group interview began, verbal informed consent to participate was obtained from each participant. Ethics approval was obtained from the University Ethics Approval Board before beginning the research.

Each group interview was led by a moderator and conducted in the local language. At the end of each session, materials (i.e., digital responses, field notes, and photographs of the sessions) were collected. These were uploaded to the Kobo Toolbox server in the researcher's password-protected account (Poloju *et al*., 2022). Responses were downloaded in a tabular format and analysed using descriptive statistics in Microsoft Excel (Appendix A7). The analysis began with an overall summary of responses from all sessions. The percentage of individual responses to each question was then derived.

5.4.1 Agricultural Systems and Climate Variability

The informants engaged in both rain-fed and irrigation farming practices and combined crop farming with pastoralism to diversify their income sources. Multiple cropping systems were utilised, where multiple types of crops were planted. Approximately 40% of the informants utilised fertilisers to enhance productivity, while others used animal dung as manure to increase agricultural yields. Maize, millet, beans, rice, soybeans, groundnuts, and Bambara nuts were preferred crops over sorghums. In the agro-pastoral system, farmers reared sheep, goats, and cows. Over the past 30 years, farmers have observed a change in crop production, with approximately 25% indicating an increase, while the majority reported a decrease. Farmers attributed the decline in crop production to factors such as climate change, lack of financing to sustain their activities, and extreme weather events, including droughts and floods.

According to the findings from this study, approximately 57.5% of the respondents reported resorting to or attempting to adopt strategies to cope with the current climate fluctuations. The adaptation measures cited by these individuals included altering crop varieties, utilising water conservation techniques, refraining from using chemical fertilisers, pesticides, and insecticides, relying on religious beliefs or prayers, relocating to other areas, implementing soil conservation practices, using irrigation, adjusting planting schedules, and expanding the amount of land under cultivation. It was revealed that poverty emerged as the most significant obstacle impeding farmers' ability to adapt to climate variability and change. Other obstacles identified by the farmers included limited awareness and information regarding climate change, inadequate access to water, insufficient land for cultivation, poor soil quality, and insufficient levels of technological development.

As climatic conditions continue to change, in terms of increased sunshine and unpredictable rainfall patterns, it calls for agricultural systems to adapt to new realities. As described in detail in the literature review, climatic change affects four major pillars of food security, which include availability, access, utilisation and stability (FAO *et al*., 2018). Climate projections confirm that food security will be affected by climate change in the future of socio-economic streams, and cereal crop prices will increase between 1-29% by 2050. It is projected that consumers with low income are particularly vulnerable, with more people at risk of hunger; an increase in carbon dioxide will benefit crop production at reduced temperatures, and nutrition quality will be reduced, as stated in the model projection (Mbow *et al*., 2020). A key approach to managing climatic change is more farming of drought-resistant crops (Fan *et al*., 2023). Farmers in the Borno region should consider shifting to climate-resilient crops, such as millet and Bambara nuts, to be assured of food security in the long term (Shokunbi *et al*., 2021). Millet, for example, has a deep-rooted system that allows it to access water in deeper soil layers. Similarly, Bambara nuts can thrive in areas with low rainfall, which makes it suitable to exist in semi-arid environments (Shokunbi *et al*., 2021). The two crops would assure the population food security within the region throughout the year.

Farmers should also consider more effective water management techniques, for example, irrigation and water harvesting. To farm crops such as maize, beans, and rice, a heavy supply of moisture is important during their growing season. Overdependence on rainfall could lead to major frustrations as the plants may not reach full maturity (Zongoma, 2015). The broader decrease in crop yields, more so among rain-dependent crops, is mainly due to limited investment in technology solutions in the region. Governments and related stakeholders should invest in providing farmers with financing and advancing their technology through smart solutions to enhance production in the region (Wolfert *et al*., 2017). It is, however, important to note that technology advancements come with major risks. In the literature review, Korthals (2014) discussed the risk inherent in food safety that is derived from technological advancement. Apart from the problem of possible contamination and pollution that surrounds food production and consumption, the production of genetically modified food through technology and its consumption among populations, especially in developing countries, has been a subject of debate and ethical concerns. Therefore, careful implementation of technology should be considered to ensure it benefits communities through improved food security.

5.4.2 Security challenges

All individuals encountered challenges in accessing the farm due to security concerns. Furthermore, they were subjected to assaults by bandits, resulting in the devastation of their farmlands. To mitigate these security issues, participants recommended reporting incidents to the village chief and law enforcement agencies, as well as arming themselves for self-protection. To address the issue of insecurity, participants emphasised the responsibility of the authorities in guaranteeing a secure environment for the purpose of engaging in farming activities.

The security challenges faced by communities in Borno have had major impacts on climatic variability, agricultural productivity, and local economic conditions. Most notably, insecure environments have restricted farmers' access to their lands, which has resulted in delayed planting and harvesting of crops (Momale, 2024). In the literature, it is also clear that war and conflicts are prominent drivers of food insecurity and crises, especially in developing regions (FAO, 2017). Economic activities tied to farming are therefore delayed, which has increased food shortages and long-term food insecurity. Additionally, climatic change already poses a major threat to agriculture due to erratic weather patterns, floods, and drought. Combining climatic challenges and security issues makes it difficult for farmers to effectively plan and adapt to changing weather conditions (Amaza, 2018). For example, farmers may find it difficult to implement adaptive agricultural systems such as water conservation due to potential security risks that prevent them from accessing their land more frequently. Also, in times of drought when there is a need for a rapid response, humanitarian and local organisations may find it difficult to help local populations due to the disorderliness caused by bandits and criminal gangs.

Major economic implications include the loss of investments and shifts in agricultural practices. Continuous bandit attacks lead to significant financial losses which may wipe away all personal savings and external investments when farmyards are destroyed (Amaza, 2018). Such losses exacerbate the cycle of poverty, as there is an absence of income from agricultural activities. Additionally, farmers may opt to change their farm crop choices to those that are less profitable and easier to manage (Momale, 2024). They could also consider abandoning farming altogether to depend on government and humanitarian support, which would reduce food availability and increase overdependence on external aid.

To comprehensively address farming challenges in the Borno region, policy interventions that prioritise both immediate and long-term strategies should be considered. One significant strategy is improving the local security infrastructure. The local authorities should prioritise investing in community policing strategies to develop a secure environment for the farmers (Ifeanyi, 2023). The programme can be successful if the law enforcement officers are trained and equipped to handle local security issues in rural areas. Additionally, the region should establish village- and community-level security committees to increase awareness of local security issues and enhance faster response to banditry actions (Onuoha *et al*., 2023). Self-defence training for farmers is also key to helping them reduce the risks of attacks. Local authorities should call farmers for workshops to train them to protect themselves from bandits and how to report insecurity incidents effectively (Onuoha *et al*., 2023). Authorities could also consider providing firearms to farmers, upon extensive training. Such provisions should, however, be done with high levels of regulation.

Rural development in terms of infrastructure could also play a significant role in managing security in the region. The government could invest in irrigation systems, good roads, and communication networks to keep communities busy throughout (Hertzog *et al*., 2017). Such developments reduce the potential of local populations being recruited into terrorist groups that delay economic activities. The government could also put efforts into educating farmers about climate change and conflict resolution strategies (Läderach *et al*., 2021). Such awareness improves cooperation between communities and law enforcement agencies in the region.

5.4.3 Discussion

The revelation that informants engage in both rainfed and irrigation farming, combining crop cultivation with pastoralism, demonstrates a diversified approach to agriculture. This strategy is one of the risk-reduction measures employed by farmers in the area. Consequently, farmers who do not diversify their livelihoods are taking on more risk and are less food secure. A study conducted by Welderufael (2014) emphasised the importance of household livelihood diversification in achieving food security. Additionally, Echebiri *et al*. (2017) found that there is a major and beneficial connection between income diversification and a household's food security status. Improving farmer income and livelihoods is an essential goal of both global and national strategies, which promote increasing on- and off-farm income and boosting its use among smallholder farmers (FAO, 2014; Wiggens & Keats, 2012). Meanwhile, the adoption of multiple cropping systems and the use of fertilisers or animal dung as manure underscore the complexity of their agricultural practices. Interestingly, the preference for certain crops like maize, millet, beans, and soybeans over sorghum suggests a nuanced understanding of crop choices influenced by various factors such as market demands and environmental considerations.

The observed change in crop production over the past 30 years, with climate change, financing challenges, and extreme weather events identified as contributing factors, raises concerns about food security in the area. This necessitates a closer examination of policies and interventions that could support farmers in adapting to these challenges (Fagariba *et al*., 2018).

The participants' recognition of temperature changes, an increase in hot days, and alterations in precipitation patterns align with broader concerns about global climate change. The dichotomous agreement on the change in the number of precipitation days reflects the complexity of climate-related observations. The dual attribution of rainfall changes to both natural forces and climate change highlights the need for a nuanced understanding of local perceptions and scientific evidence. This suggests climate education for rural farmers, as well as access to climate predictions and information, to improve understanding and preparedness, both of which are critical to resilience. The acknowledgement by farmers that climate change impacts crop production, with extreme temperatures, poor rainfall, and shifts in the rainy season cited as indicators, emphasises the urgency of climate-smart agricultural practices.

The findings reveal that over half of the informants have attempted to adapt to climate fluctuations, employing diverse strategies. The emphasis on changing crop varieties, water conservation techniques, altered fertiliser and pesticide use, and the role of religious beliefs in adaptation points towards a multi-faceted approach. However, the identification of poverty as a significant barrier to adaptation is a crucial insight. This calls for targeted interventions that address socio-economic disparities and empower farmers with the resources needed for sustainable adaptation.

The security challenges faced by participants, including attacks by bandits and damage to farmland, present a significant obstacle to agricultural activities. The reliance on reporting to village chiefs and police, as well as arming themselves, underscores the critical role of local authorities in ensuring a secure environment for farmers to avert severe food insecurity across the nation due to the inability of farmers to practise. To address security concerns, a comprehensive approach involving community engagement, law enforcement, and possibly regional development initiatives could contribute to creating a safer environment for agricultural practices.

5.4.4 Conclusion and Future Directions

The results from this study provide a rich foundation for future research and policy interventions. The intertwined nature of agricultural systems, climate variability, adaptation measures, and security concerns necessitates a holistic approach. Policymakers and researchers can build on these findings to formulate context-specific strategies that support sustainable agriculture, enhance resilience to climate change, and ensure the security of farming communities. Additionally, fostering awareness and knowledge dissemination about climate change and security measures will empower farmers to make informed decisions, contributing to the overall resilience of the agricultural sector in the region.

5.5 Analysis of Standardised Precipitation Index (SPI)

5.5.1 Drought Index Analysis

The yearly indices were generated from 1950 to 2019 across the weather stations. Appendix 4.1 represents the output SPI for the entire series (1950 to 2019). Table 5.9 below shows the colour classification for drought categories as derived from the SPI calculations, and Figure 5.5 shows the actual figures relative to the level of drought that was experienced year to year over the time series (1950-2019). The navy-blue colour code represents extremely wet conditions and green for moderately wet; the brown colour stands for extremely dry conditions, while the tan colour represents severely dry, and yellow represents a moderately dry condition.

Table 5.9: SPI Classification Description

Classification	**Value**	**Colour Code**
Extremely Dry	<-2	
Severely Dry	-1.5 to -1.99	
Moderately Dry	-1.0 to -1.49	
Near Normal	-0.99 to 0.99	
Moderately Wet	1.0 to 1.49	
Very Wet	1.5 to 1.99	
Extremely Wet	>2	

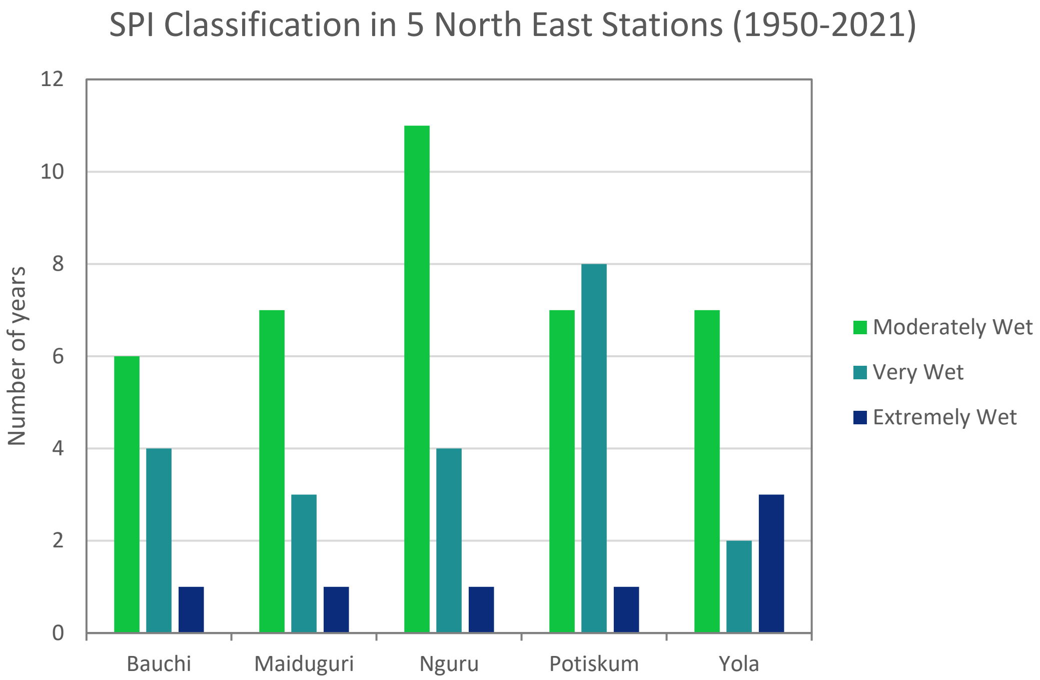


Figure 5.5: Number of wet years for each SPI class across the five weather stations

During the 69 years' time series, Bauchi station experienced 55 years of near normal SPI precipitation, 7 years of moderately wet, 2 years of extremely wet and 6years of very wet SPIs. Maiduguri station experienced 50years of SPI normal precipitation, 8 years of SPI moderate precipitation, 4 years of very wet SPI precipitation and 2years of extremely wet SPI (precipitation). Nguru station experienced 48 years of near normal SPI precipitation, 12 years of moderately wet SPI, 2 years of very wet, and 4 years of extremely wet SPI precipitation receipt over the 69 years period. Potiskum weather station experienced a total SPI of 51 years of near normal precipitation, 7 years of moderately wet, 8 years of very wet, and two years of extremely wet SPI precipitation over the series. Yola station experienced 48 years of near normal precipitation, 8 years of moderately wet, 3 years of very wet, and four years of extremely wet precipitation (Fig. 5.6).

5.5.2 SPI Dry Years Classification

Figure 5.6 expresses the comparison of SPI dry years in the weather stations in northeast Nigeria. Over the series (1950-2019), Bauchi station experienced four years of extremely dry spell over the period, one year of severely dry spell and 3 years of moderately dry spell over the series under consideration. Maiduguri station experienced a total of 4 years of extremely dry spells, 1year of severely dry and 6 years of moderately dry over the time series. While Nguru station experienced a total of 5 years of severely dry and 6 years of moderately dry spells over the time series in consideration. Potiskum station experienced a total of 2 years of extremely dry and 3 years of severely dry spells while Yola experienced 1 year of extremely dry SPI, 1 year of severely dry and 12 years of moderately dry SPIs. Of significant note here is the similarity of patterns of dryness in the five weather stations during the period of 24 years of 1995 to 2019.

Bauchi station experienced near normal dry SPI index consistently over the 24-year period, Maiduguri station experienced same except for year 2000 which experienced very wet index. Nguru experienced near normal index dryness SPI indexes over the same period dotted with few years of moderate dry indexes. Potiskum had normal dry indexes over the same 24 years period dotted with few years of moderate SPI indices.

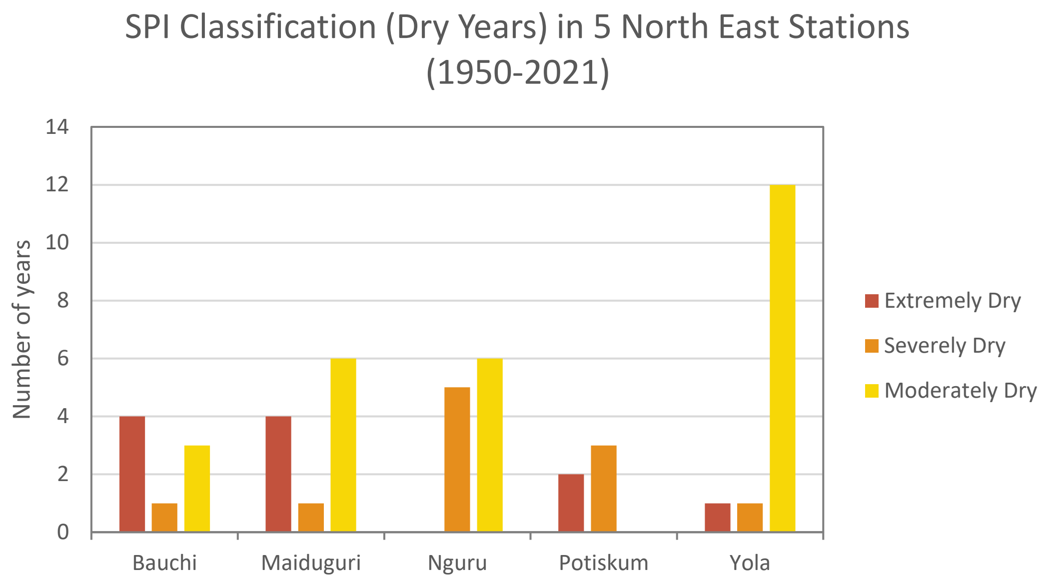


Figure 5.6mber of years for each dry SPI classes across the five weather stations

5.5.3 Maiduguri Station

The SPI for all stations was calculated over the period of 1950 to 2019. And for the reason of this analysis, the time series were segregated into decades, i.e., 1950-1959, 1960-1969, 1970-1979, 1980-1989, 1990-1999, 2000-2009, and 2010-2019.

The decade of 1950 to 1959 was relatively wet, as only one year (1951) was recorded as a dry year, and the rest of the years of the decade were all wet, as the SPI indexes recorded above the long-term mean and wet by classification. In the second decade of the time series (1961-1970), also recorded as a wet decade, only the year 1964 came across as dry in the series, with an index of -1.09. The third decade (1971-1980), years 1971, 1972 and 1973 were all dry with SPI indices of -0.64, -1.23 and -1.28, respectively, and years 1974 to 1980 were all wet with positive SPI indices. In the fourth decade (1981-1990), it was recorded as dry, with the year 1988; 1989 was recorded as wet years with the SPI indices of 0.32 and 0.22, and in the fifth decade (1991-2000), the years 1991, 1993, 1994 and 1997 were recorded as dry with SPI indices of -0.79, -0.75, -2.04 and -0.31, respectively, while the rest of the years recorded wet or positive SPI indices. In the decade of 2001 to 2010, the years 2001 to 2004 had positive indices or recorded wetness, and the rest of the decade was dry with negative indices of SPIs. And finally, in the decade of 2011 to 2020, the entire decade came across as dry with negative SPI indices (Fig. 5.7).

5.5.4 Climate Change Indicators

The central purpose of climate change indicators is to give information regarding climatic conditions and be utilised as an early warning system by providing observational data that may reveal an environmental problem before it cascades to a bigger dilemma (Donnelly *et al*., 2004). An indicator therefore connotes a parameter, a value derived from a parameter that indicates or gives information that describes the condition of a phenomenon, place or area with the importance not only directly associated with the parameter value but extending beyond it (OECD, 1993).

The United States Global Change Research Program (USGCRP, 2019) identifies several indicators of climate change, which include temperature, heavy precipitation, heat waves, Arctic ice extent, Hawaii ocean acidity, drought conditions, and growing season length. USGCRP, (2017), projected the temperature of the earth will continue

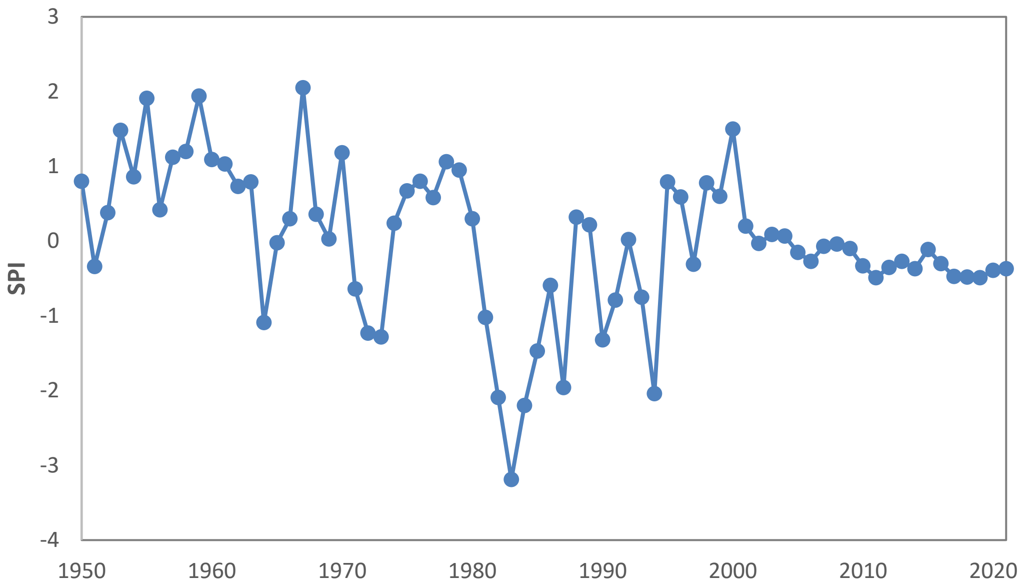


Figure 5.7: SPI derived from Maiduguri station at an annual timescale

to rise and this will continue to bring more evaporation which will induce more overall precipitation in many areas of the world. The dynamic of climate change leads to shifts in wind patterns and ocean currents that propel the world's climate system; some areas are warming more than others, some have experienced cooling, and precipitation patterns fluctuate around the world.

With the increase in temperatures, there will be an increase in evaporation, and this also leads to increased precipitation but will not necessarily lead to an increase in the amount of water available for drinking, irrigation, and industry. The surge in evaporation can lead to more intense precipitation events; in the instance of heavier rain and snowstorms, it can consequently lead to damaging of crops and increase flood risk, even if the total precipitation receipt in an area does not increase (USGCRP, 2019).

5.5.5 Precipitation and Temperature Anomalies in North-Eastern Nigeria

For climate change detection and attributions, this study focuses on three major components: precipitation, temperature and drought frequency throughout (1950-2019) using the five geographically contiguous weather stations around the study area. This was carried out by comparing annual temperature and precipitation over the series to the long-term mean. An anomaly was calculated for each of the five weather stations. The daily temperature measurements of each station were used to deduce monthly anomalies, and the mean was used to find the annual temperature anomaly for each year.

Precipitation anomalies were derived from total annual precipitation for each station, in inches, while the drought frequency is derived from the frequency of occurrence of drought using the SPI.

5.5.6 Precipitation Anomaly

The mean across the five weather stations, Bauchi station (Lat. 10.30^0 N, long. 9.80^{0}E), has the highest mean annual precipitation of 1011.01 mm followed by Yola (lat.9. 20^{0}N, long.12.50^{0}E), with mean annual precipitation of 837.21 mm; Potiskum (Lat. 11.60^{0}N, long. 11.00^{0}E) with 669.81mm mean annual precipitation; Maiduguri (Lat. 11.90^{0}N, long. 13.10^{0}E), with a mean annual precipitation of 590.92 mm over the series and Nguru weather station (Lat. 12.80^0N, long. 10.50^0E) has the lowest annual mean precipitation of 422.08 mm over the series (Table 5.10).

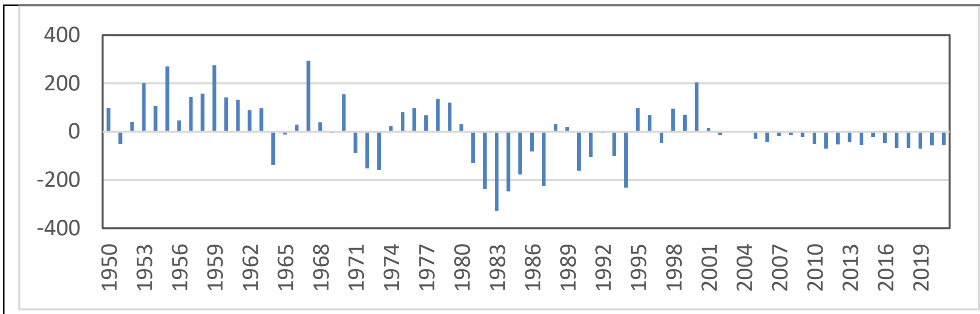
Table 5.10: Annual Mean Precipitation for the five Weather Station

Station	Annual Mean Precipitation (1950-2010)
Maiduguri	590.92
Yola	837.21
Bauchi	1011.01
Potiskum	669.81
Nguru	422.08

5.5.7 Decadal Fluctuations

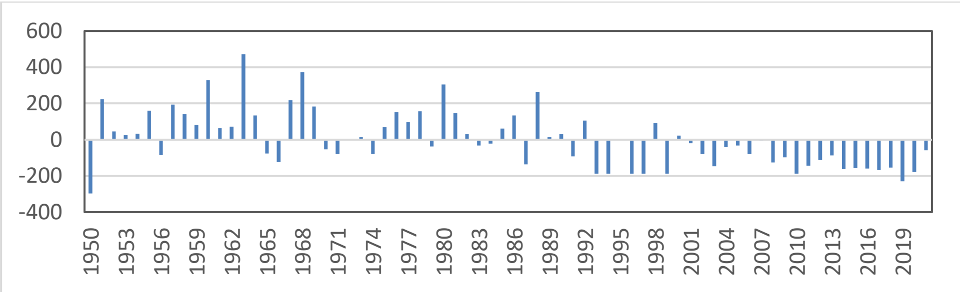
An examination of the decadal fluctuations of precipitation mean deviations was carried out for the five weather stations as shown in the figure (5.2). The first two decades of the seventy-year series (1950-1969) show that all five stations under consideration recorded substantial wet or high precipitation as shown; all five stations recorded mean precipitation above the long-term mean (figure 5.2). The third decade exhibits a mixture of deviations above and below the long-term mean for all weather stations. Remarkably, from 1980 onwards, all five stations experienced continuous below long-term mean precipitation. For example, Maiduguri experienced below-mean precipitation from 1980 to 1995. Yola station experienced a below-the-mean deviation over the long term, i.e., from the year 2000 to 2019; Nguru and Potiskum weather stations consistently experienced below the long-term mean precipitation, as shown in Figure 5.8, starting from 1996 till the year 2019.

Variability of precipitation as experienced in the above results has been explained in some earlier studies carried out in some locations around the same latitudes – the Sahelian region between latitude 10^0 and 20^0 degrees north in West Africa. The fluctuations in the interannual and decadal timescale in this region have been attributed to different global and regional sea surface temperature anomaly patterns, which include the anomalies in the Tropical Atlantic explained by Hastenrath (1990), the East Pacific mode by Folland *et al.* (1991), inter-hemispheric contrast of sea surface temperature (Folland *et al*., 1986), the Indian Ocean influence (Palmer, 1986) and the Mediterranean effects (Ward, 1994).



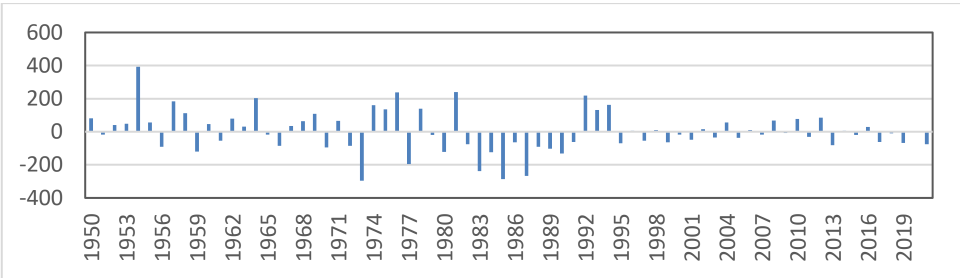
(a)

Maiduguri



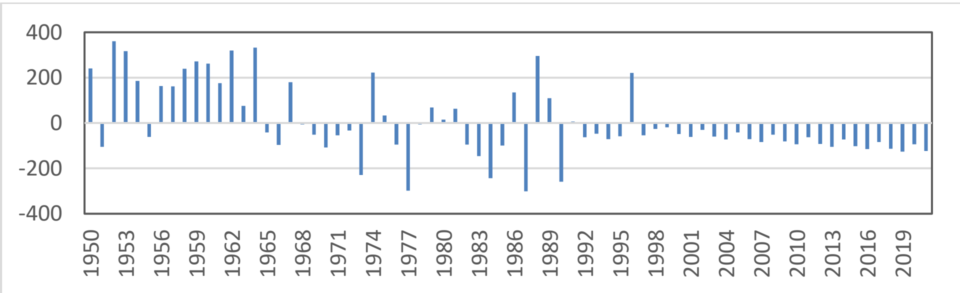
(b)

Yola



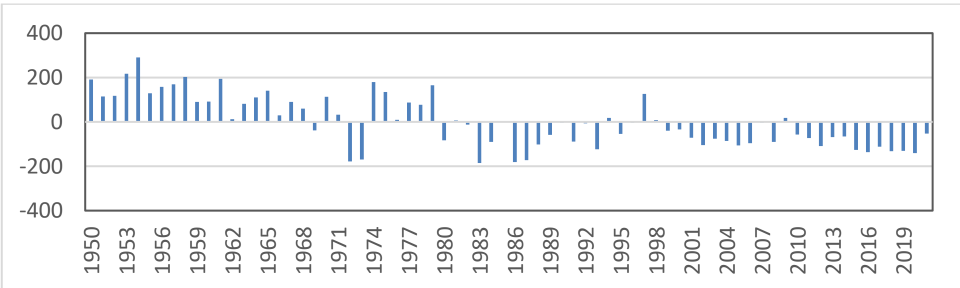
(c)

Bauchi



(d)

Potiskum



(e)

Nguru

Figure 5.8: Precipitation Deviation from Long-term Annual Mean (in mm) (1950-2019), five weather stations

Charney *et al*. (1977) argue that the cause of droughts in this region was a result of intensive anthropogenic land use in the form of overgrazing and deforestation, which inevitably rendered the surface of the land bare without vegetation. The land surface albedo/reflectivity of the surface tends to increase because of the effects of human activities, which in turn reduces the warming of the ground and consequently reduces the heating of the atmosphere from the surface. This process led to a reduction in convection necessary for the formation of rain-bearing clouds (Brook, 2004). The argument was criticised by Mortimore (1998) on the strength that the magnitude of the hypothetical changes is unrealistic, as the assumption of land cover changes due to the removal of vegetation by humans and animals could not be widespread enough to cause changes in the atmospheric heat and moisture budgets.

5.5.8 Drought Frequency

Drought is a condition of moisture shortage that results from precipitation deficit over a period (McKee *et al*., 1993). Drought has been described as a phenomenon that has one of the most severe impacts on society when compared with other extreme weather sorts and is a significant economic hazard for many countries with agriculture, livestock, forestry, energy, industry, and water sectors all particularly at risk. And any changes in the hydrology because of drought will cause serious risk to the society (Jenkins & Warren 2015).

White and Glantz (1985) identify six types of droughts, which include meteorological, hydrological, atmospheric, climatic, and water management. Zeng (2003) explains that droughts have inflicted wide-ranging effects on the society and the environment, and pervasive droughts have resulted in desertification, land degradation, and serious humanitarian disasters, as witnessed in the Sahel from the late 1960s to the 1970s.

Drought can also have severe impacts on power generations, including solar thermal, geothermal and hydropower generations (Tarroja *et al*., 2018) and has been known to increase the risks to wildlife by influencing the occurrences of heat waves (Fischer *et al*., 2007). The IPCC (2007) climate projections suggest there will be increases in drought frequency in Africa and the Global Precipitation Climatology Centre (GPCC) observations suggests positive trends of meteorological droughts frequency. duration and intensity in West Africa. The multiple nature of droughts leads to the various characterisations it attracts, and its complexity involves its other attributes, such as duration, severity and intensity. None of the characterisations are good enough to be used as a general criterion for drought (Gonzalez and Valdes, 2006). In general, specific objectives mostly dictate the methodology and the characterisation of drought types. However, one advantage of the application of the SPI here is that it provides the method for exploring and analysing the frequency, duration and intensity of drought events.

Following the above synthesis, the SPI is used here as a drought indicator, defined as a functional and quantitative event for a timescale when the SPI has a continuous negative value, with a value of -1.0 or less (McKee *et al*., 1993). The drought event comes to an end when the SPI becomes positive (Table 5.11).

Table 5.11: SPI drought classification values and event probabilities

SPI Value	**Category**	**Probability %**
0 to -0.99	Mild drought	34.1
-1.00 to -1.99	Moderate drought	9.2
-1.50 to -1.99	Severe drought	4.4
-2 or less	Extreme drought	2.3

Source: McKee *et al*., 1993

The SPI has a special relationship with probability and follows a normal distribution pattern and therefore can be applied for both wet and dry periods. It can be used for the current percentage of average precipitation for a period of *j* month. SPI is normalised so that wet and dry climates can be represented similarly (McKee *et al*., 1993).

5.5.9 Drought Frequency Graph

Here, the drought frequency of Borno State is explored using the SPI analysis. The number of months within six months (SPI-6) with an SPI value lower than -2. The six-month period in this graph started from January to June 1950 and continued over the series to 2019 (Fig. 5.9).

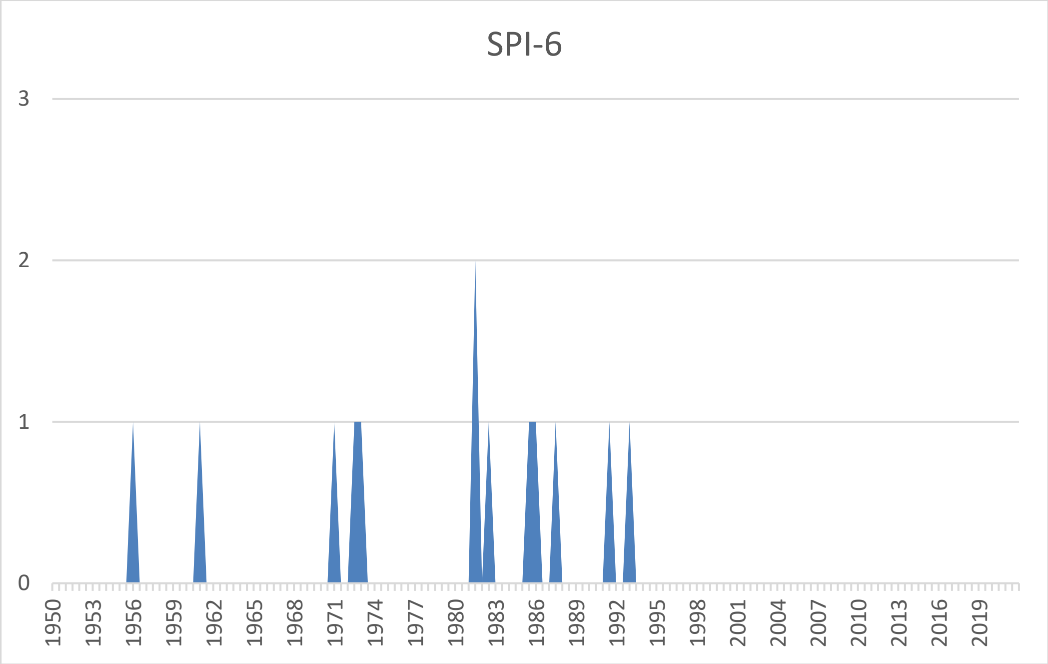


Figure 5.9: Drought Frequency – SPI-6

The general characteristics of the droughts derived from SPI-6 over the series appear anomalous as it occurred in 1956, 1963, 1971, 1973, 1982, 1983 1986, 1988, 1992 and 1993. As shown in the graph (fig.5.9), the year 1982 has the highest frequency of drought with -2 SPI-6 cumulative. Significantly, the drought frequency over the series 1950- 2019 coincided with the great drought years in the Sahel latitudes. The characteristic anomalous shown in the drought years (Fig. 5.4), occurred in 1956 and followed by 1963 with 7 years recurrence, and recurred again in 1971, 1973, 1982, and in 1983. The drought trends continue after 3 years in 1986, 2 years after in 1988, 4 years after in 1992 and finally 1 year after in 1993. The highest frequency of drought was recorded in the second six-month of 1982. There has not been any significant incident of drought from 1993 to 2019.

This significant occurrence has been linked to the sudden increase in Sahelian rainfall since the 90s and the greening of the Sahel as explained by Giannini and Kaplan, (2018), who used the multi-model ensembled model, the Inter Comparison Project (CMIP5), to explain the role of external forcing of the Sahel variability in the past and future from the point of view of oceanic forcing. The output of this model succeeded in predicting the twentieth century pattern of Sahel rainfall including the decline in the 60s and 70s and the driest in the early 80s with the partial recovery since the 90s. Giannini and Kaplan (2018), linked anthropogenic emissions to change in temperature in the subtropical north Atlantic Ocean as an indirect attribution to the tail end of the 20th century drought in the Sahel and the eventual increases in precipitation as shown in the figure (5.4). Held *et al*., (2005), applied an ensembled model to simulate the Sahelian rainfall and attributed the pattern of the Sahelian rainfall to anthropogenic forcing because of aerosol loading and an increase in greenhouse gases. Their model projects that greenhouse gases will be the main driver of drier Sahel in the future.

Shinoda, (1990) held that the Sahel period of desiccation appears to have persisted through the period of large-scale atmospheric changes and the dry decadal episode in the Sahel in recent years because of pattern changes in the global circulation which in turn induced changes in sea surface temperature pattern.

Some studies using modelling suggest that the inter-hemispheric temperature gradient that occurs globally, for example, the tropical oceans is directly linked to rainfall in the Sahel region bringing drought in the Sahel when the oceans are relatively cold in the

Northern Hemisphere in relative to the southern hemisphere oceans (Kang *et al*., 2007). In the early part of the 20th century, the northern Hemisphere exhibited a warm trend substantially more than the Southern Hemisphere, from the middle of the century to 1980s, the Northern Hemisphere got cooler on the average and the Southern Hemisphere continued to warm. However, since 1980, the Northern Hemisphere has started to warm again faster than it happened in the early 20th century (Kang *et al*., 2007). This indirectly responsible for the absence of drought in the Sahel and by extension Borno state since 1993.

5.5.10 Standardised Food Production Anomaly.

The relationships between precipitation and food production were explored through Figure 5.10, by relating aggregate food production over the series (1992- 2020) to precipitation over the same period. This suggests that there was dramatic low production of food identified with below average precipitation between 1992 and 1994, and food production shortage continued even through above average precipitation between 1995 and 2002 when food production started rising through precipitation deficit There was a sharp increase in food production between year 2004 and 2006. Surprisingly, through low precipitation even below the mean precipitation. The explanation for this surge is not unconnected to aid delivery and other food supplies from international organisations because of the special focus on this region because of the insurgency.

From the year 2007 onward, food production continues to decline till the year 2021 because of the precipitation deficit and the advent of COVID-19 in the year 2020 made it worse than it already was. The relationships were further explored by applying correlation statistics to explore the relationships between the two variables, the correlation coefficient between the two variables was one (1) which suggests a strong connection between precipitation and food production in Borno state.

5.5.11 The Correlation Between SPI and Specific Crops Production in Borno

The overall correlation between SPI and agricultural production as indicated in Table 5.12 is 0.053, which suggests a weak correlation. The correlation data in Table 5.13 can be used to compare the precipitation findings with crop production, particularly between 1992 and 2021. Regarding the specific crops, millet shows a positive

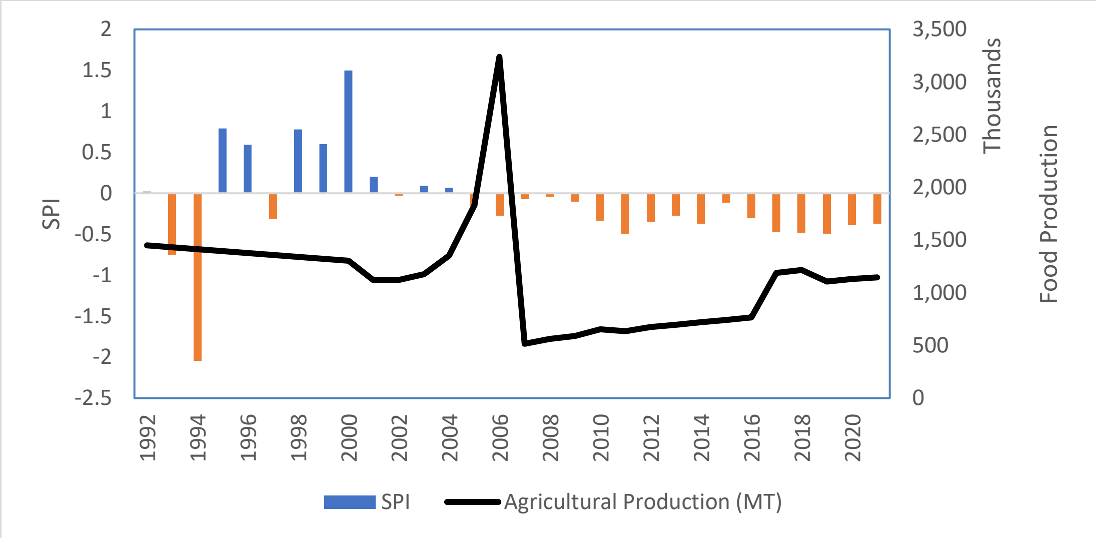


Figure 5.10: Comparison of time series of the standardised precipitation index (SPI) and standardised agricultural production anomaly over the 30-year period between 1992 and 2019. Borno SPI on an annual scale is represented in the coloured bars, while agricultural production is represented with the line. It is the sum of millet, maize, rice, groundnut and beans/cowpea

correlation of 0.14374 with SPI, which suggests a slight but positive correlation. The finding suggests that millet was well adapted to the dry conditions of the area but still benefited from the wet periods experienced over the years. On the other hand, maize shows a negative correlation of -0.1117 with SPI, which implies that it is more susceptible to variations in precipitation in the Borno area. Maize is more likely to have reduced production in drought periods, as it is moisture sensitive. Like maize, rice shows a negative correlation of -0.1495 with SPI, which indicates that it is also sensitive to precipitation anomalies. Rice requires consistent rainfall to thrive.

Groundnuts showed a negative correlation of -0.1212 with SPI, which indicated that production decreased slightly in years when there was below-normal rainfall. However, the finding shows that the crop is not as drought sensitive as maize and rice. Beans and cowpeas had a positive correlation of 0.17962, which suggests that they seem to benefit slightly from higher precipitation levels.

As observed in the findings and literature review, a change in climate is predicted to have profound negative effects on food security and consequently reduce economic growth, exaggerate poverty, diminish species composition and ecosystems, and impact livestock livelihoods and crop productivity (World Bank, 2013). Studies affirm that families, especially in rural and vulnerable communities, have been adopting negative coping methods such as skipping meals and reducing quality and quantity, most especially among children. This inevitably provokes the risks of malnutrition (United Nations (UN), 2010)

5.5.12 Integrating Local Perceptions of Climate Variability

Integrating local perceptions of climate variability in these objective measures offers a holistic understanding of how communities experience these changes. The study participants reported a shift in the average temperature over the past 30 years, with a noted increase in hot days during the same period. This change was attributed to climate change and the early onset of the dry season. Most of the respondents also indicated that the average precipitation has altered over the past 30 years; however, there was no consensus regarding the number of precipitation days. Approximately 60% of the informants reported a decrease in precipitation days, while others

Table 5.12: Correlation between SPI and agricultural production in Borno (1992-2021)

	Agricultural Production (MT)	SPI
Agricultural Production (MT)	1	
SPI	0.05301	1

Table 5.13: Correlation between SPI and Individual crop production in Borno (1992-2021)

	SPI
SPI	1
Millet Prod. (MT)	0.14374
Maize Prod. (MT)	-0.1117
Rice Prod. (MT)	-0.1495
Groundnut Prod. (MT)	-0.1212
Beans/Cowpea Prod. (MT)	0.17962
Agricultural Production (MT)	0.05301

believed that the number of such days had increased. Some participants attributed the variation in precipitation days to natural forces and God's creations, while others linked it to climate change. The impact of climate change on crop production has been recognised by farmers, who have observed a range of factors, including extreme temperatures, fluctuations in rainfall, changes in the start of the rainy season, and poor rainfall.

5.6 Results of Regression Analysis

5.6.1 Descriptive Statistics

The Standardised Precipitation Index (SPI) values range from -0.49 to -0.11 with a mean of -0.3718. This suggests that rainfall is not high in the region. The temperature is quite constant for this period and shows hardly any fluctuations. Among the crop yield data, the values for beans/cowpeas are more consistent and show less variability compared to other crops (Table 5.14). The SPI ranges and mean imply below-average rainfall. The SPI standard deviation was 0.11583 during the period, meaning rainfall was consistent. The temperature values range between 28.12°C to 28.58°C, and the mean temperature is 28.30°C. Temperature values show a small standard deviation of 0.17, which implies that temperature remained relatively constant throughout the period, with limited fluctuations. Conflict data is also an important consideration in this study. Conflict incidences range from 91 to 283, while the average number of conflict incidents is 200.73. A standard deviation of 57.703 indicates that the number of conflicts varies to some extent with fluctuations year after year.

Cowpeas and beans suggest greater consistencies in their production compared to other crops. The production ranges between 117,200 and 153,100 and has a mean of 131,912.18. The standard deviation was relatively low (12,012.05), indicating stable yields throughout the period. Guinea corn yield ranges between 7,598.09 and 922,337.20 and has an average yield of 9,223.37. A standard deviation of 9,223.37 implies high variability, which implies that some years had higher yields than others. Sorghum production ranged between 192,613 and 402,300 and had an average yield of 261,440.73. A standard deviation of 70,574.71 implies moderate fluctuations in the production of sorghum from year to year. Cassava yield varies between 4,163.02 and 528,098.00, with a mean yield of 9,223.37. A standard deviation of 9,223.37 indicates a high level of variability in the yield, like Guinea Corn.

High variabilities are also observable in crops such as millet, maize, groundnuts, and rice. The yields for millet range from 75,000 to 261,296 and show an average mean of 175,426.45. A high standard deviation of 77,588.42 shows significant deviations in the production of millet in the region. Maize yields range from 199,884 to 627,200 and have an average yield of 175,426.45. The Standard deviation is 77,588.42, which can be interpreted as significant variations in production over the years. Maize production ranges between 199,884 and 627,200 and has an average yield of 378,105.45. The production has a high variability (standard deviation of 182,190.11). That data shows unpredictable production that fluctuates year after year. Rice also shows moderate variability. Its yields range between 41,512 and 186,600 and have a standard deviation of 67,180.808, which implies significant fluctuations in production over time. For groundnuts, the production ranges from 60,335 to 201,500, while the standard deviation is 64,830.704. This implies that production fluctuates but does not experience extreme variability.

5.6.2 Assumption Checking

Statistical tests were performed on the dataset to diagnose potential issues that could affect the validity and reliability of the multiple linear regression model (Ngongi and Urassa, 2014). These tests included:

Table 5.14: Descriptive Statistics for Variables (2011-2021)

	N	Minimum	Maximum	Mean	Std. Deviation
SPI	11	-0.49	-.11	-0.3718	.11583
GuineCorn (MT)	11	7598.09	922337.20	9223.37	9223.37
Sorghum (MT)	11	192613	402300	261440.73	70574.71
Cassava (MT)	11	4163.02	528098.00	9223.37	9223.37
Temperature (ºC)	11	28.12	28.58	28.30	0.17
Millet (MT)	11	75000	261296	175426.45	77588.42
Maize (MT)	11	199884	627200	378105.45	182190.11
Rice (MT)	11	41512	186600	103428.82	67180.808
Groundnut (MT)	11	60335	201500	122706.73	64830.704
Beans/Cowpea (MT)	11	117200	153100	131912.18	12012.05
Conflict (No of Incidence)	11	91	283	200.73	57.703
Valid N (listwise)	11				

5.6.2.1 Multicollinearity Test

A multicollinearity test was performed on the data set using a correlation matrix. The test assessed whether the independent variables were highly correlated with each other. High multicollinearity can increase the standard errors of the coefficients (Kahsay *et al*., 2020). It was observed that only SPI, temperature and bean yield data do not have a high correlation. Other independent variables have a correlation coefficient greater than 0.8 when compared with at least one other variable (Table 5.15). On the higher end, SPI shows a moderate positive correlation with Guinea Corn (0.626) and millet (0.677) at 0.05 significance levels. On the lower end, SPI shows a moderate negative correlation with maize (-0.565) and rice (-0.569). Temperature shows very low correlations with most of the other variables, as most values are below 0.3, which implies low multicollinearity. Beans/cowpeas are also weakly correlated, with the highest correlation being 0.376 with SPI. The weak correlation makes the variable highly independent of other variables. Conflict incidents also have limited correlations with other variables. The highest correlation with other variables is 0.246 with groundnut. The correlation suggests that conflicts do not strongly or directly influence agricultural production.

Guinea corn shows a high degree of correlation with many other variables, which include sorghum (0.759**), cassava (0.865**), millet (0.939**), maize (0.916**), rice (0.933**), and groundnut (0.941**). The high correlation implies that the variable might be a highly redundant predictor if included in a regression analysis against other variables. Additionally, sorghum, cassava, millet, maize, rice, and groundnut are highly correlated with each other. The correlation of sorghum with cassava (0.865**), millet (0.700**), and maize (0.806**). Cassava also has high correlations with millet (0.660*), maize (0.628*), rice (0.674*), and groundnut (0.685*). Millet is highly correlated with maize (0.976**), rice (0.977**), and groundnut (0.953**).

5.6.2.2 Normality Test

The normality test was performed to ensure that the residuals (errors) of the model are normally distributed. This was checked using normal probability plots (Q-Q plots) (Appendix A9) and the Shapiro-Wilk test. For normally distributed data, the residuals in the Q-Q diagram follow a straight line. Deviations from the straight line indicate deviations from normality. In addition, in the Shapiro-Wilk test, a p-value > 0.05 indicates that the residuals are normally distributed; otherwise, there is a potential problem (Jurečková & Picek, 2007).

The Shapiro-Wilk test shows that SPI, temperature, beans, and conflict data are normally distributed. SPI has a p-value of 0.128, which is greater than 0.05. Additionally, cowpeas/beans and temperatures have p-values of 0.578, 0.065, and 0.805, which are greater than 0.05. In this case, we accept the null hypothesis that the variables are normally distributed. All the other variables are not normally distributed, as their p-values are lower than 0.05. This confirms the result of the previous collinearity test (Table 5.16).

Table 5.15: Correlation Matrix

	SPI	**GuineCorn**	**Sorghum**	**cassava**	**Temperature**	**Millet**	**Maize**	**rice**	**groundnut**	**beanscowpea**	**Conflict**
SPI	1	.626*	-0.259	0.429	0.292	.677*	-0.565	-0.569	-0.522	0.376	0.285
GuineCorn	.626*	1	-.759**	.865**	-0.003	.939**	-.916**	-.933**	-.941**	-0.194	-0.006
Sorghum	-0.259	-.759**	1	-.627*	-0.140	-.656*	.700*	.693*	.806**	0.314	0.203
cassava	0.429	.865**	-.627*	1	-0.066	.660*	-.628*	-.674*	-.685*	-0.362	0.107
Temperature	0.292	-0.003	-0.140	-0.066	1	-0.027	0.077	0.001	0.040	0.130	0.051
Millet	.677*	.939**	-.656*	.660*	-0.027	1	-.976**	-.977**	-.953**	0.002	-0.119
Maize	-0.565	-.916**	.700*	-.628*	0.077	-.976**	1	.987**	.981**	0.143	0.202
rice	-0.569	-.933**	.693*	-.674*	0.001	-.977**	.987**	1	.970**	0.152	0.197
groundnut	-0.522	-.941**	.806**	-.685*	0.040	-.953**	.981**	.970**	1	0.246	0.179
beanscowpea	0.376	-0.194	0.314	-0.362	0.130	0.002	0.143	0.152	0.246	1	0.068
Conflict	0.285	-0.006	0.203	0.107	0.051	-0.119	0.202	0.197	0.179	0.068	1

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

Table 5.16: Normality test table

Variable	**Statistic**	**df**	**Sig.**
SPI	0.887	11	0.128
GuineCorn	0.817	11	0.016
Sorghum	0.826	11	0.021
Cassava	0.833	11	0.025
Temperature	0.864	11	0.065

Millet	0.826	11	0.021
Maize	0.779	11	0.005
Rice	0.733	11	0.001
groundnut	0.739	11	0.001
beanscowpea	0.945	11	0.578
Conflict	0.963	11	0.805

5.6.2.3 Homoscedasticity

Homoscedasticity tests whether the residuals have constant variance across all levels of the independent variables. This can be assessed through residual plots or tests such as the Breusch-Pagan test (Greene, 2003; Klein *et al*., 2016).

The p-value for the Breusch-Pagan test is 0.485 (Appendix A10). Since the p-value is not less than 0.05, we cannot reject the null hypothesis of the test. This means that we do not have sufficient evidence to say that heteroskedasticity is present in the regression model.

5.6.2.4 Independence

Since the dataset is time series data, the independence of the residuals is checked using the Durbin-Watson test. The Durbin-Watson test shows the presence of autocorrelation in the data. If $d \approx 2$: Indicates no autocorrelation. If $d < 1.5$ or $d > 2.5$, this indicates possible autocorrelation. Values close to 0 indicate positive autocorrelation; values close to 4 indicate negative autocorrelation (Ariyadi, 2021; Akter, 2014). The result of the test puts the d value at 2.37. This indicates that there is no autocorrelation in the data set (Appendix A10).

In summary, the multiple linear regression diagnostic test performed on the data set shows the presence of collinearity, and some residuals are not normally distributed among some of the variables, while other potential problems such as heteroskedasticity and autocorrelation may be missing. To address these issues, the highly correlated variables are excluded from the model to avoid inflated standard errors. However, the interpretation of the model must be cautious due to the smaller number of predictors and the sample size.

5.6.2.5 Model Outputs

The output of the model uses conflict as the dependent variable and SPI, temperature and bean yield as independent variables. The R value of 0.29 indicates a weak correlation between the observed and predicted values of the dependent variable (conflict) (Table 5.17). It shows low interrelationships between the independent variables and conflicts. R-squared was found to be 0.084, which implies an 8.4% variance in conflict that is explained by the independent variables. The model, therefore, fails to account for the significant variation in conflict incidents. Most of the factors influencing conflicts are not captured by independent variables. The adjusted R-squared is similarly low, which further supports the limited explanation by the model. The Durbin-Watson statistic (-0.308) is also problematic, considering the values should range between 0 and 4, with 2 being ideal. The negative value implies that there may be patterns in the residuals that violate assumptions in the regression model. This reduces the validity of the model predictions.

Table 5.17: Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.290[a]	0.084	-0.308	65.997	2.078

From the ANOVA table, the F-statistic is used to test the overall significance of the regression model. The F-value of 0.215 is very low and further suggests that the model does not effectively support the variance of the conflict. The p-value is 0.883 which suggests that there is no significant relationship between the independent variables and conflict (Table 5.18). To further examine the relationship between the variables, Bayesian statistics were performed on the data.

Table 5.18: ANOVA Table

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	2806.871	3	935.624	0.215	.883
Residual	30489.31	7	4355.616		
Total	33296.18	10			

Bayesian regression statistics have been shown to explain relationships between small sample size data, particularly in clinical studies. As a quick review, in Bayesian statistics, the posterior distribution (which is summarised to yield the Bayesian equivalents of frequentist point estimates and standard errors) is a combination of the prior distribution (determined by the researcher) and the likelihood (determined by the data). The contribution of these two quantities to the posterior distribution is not equal. When the data contain many observations, the likelihood is given much more relative weight in calculating the posterior distribution than when the data have fewer observations. By similar logic, with small sample data, the prior distribution is given more weight in calculating the posterior distribution, relative to whether the data came from a larger sample (Van de Schoot *et al*., 2014).

The Bayesian outputs (Table 5.19) suggest that the average (mean) impact of SPI on conflict is 155.66, with a 95% credible range between -321.14 and 632.45. This interval shows that, given the available data and priors, there is a high probability that the actual effect falls within this range. However, the range is too wide to definitively determine the impact of SPI on conflict. The same applies to the other analysis variables, such as temperature and bean yield. Temperature shows a negative effect on conflict with a mean of -11.885. However, the credible interval is between -8065.329 and 9312.746, which is too large. The large credible interval suggests a substantial uncertainty on the exact impact of temperature on conflict. For the bean/cowpea mean, the mean is -316.767. The credible interval is narrow (almost zero), which implies negligible or almost zero impact on conflict.

Table 5.19: Bayesian Statistics Outputs

Bayesian Estimates of Coefficients[a,b,c]					
Parameter	Posterior			95% Credible Interval	
	Mode	Mean	Variance	Lower Bound	Upper Bound
(Intercept)	623.708	623.708	18903712.174	-8065.329	9312.746
SPI	155.656	155.656	56920.409	-321.139	632.452
Temperature	-11.885	-11.885	23273.808	-316.767	292.997
beanscowpea	.000	.000	.000	-.005	.004
a. Dependent Variable: Conflict					
b. Model: (Intercept), SPI, Temperature, beanscowpea					
c. Assume standard reference priors.					

5.6.2.6 Actionable Recommendations on the Models Used

Following the weak predictive power of the previously discussed model, alternative modelling approaches should be considered. Modelling approaches such as time series and machine learning approaches such as random forest could be more effective in capturing relationships in the data (Cheng *et al*., 2019). Additionally, factors such as social and political events as well as economic variables could be considered to enhance the ability of the models to explain dependent variables.

5.7 Summary and Discussion

In summary, the analysis presented above examines the relationship between conflict, SPI, temperature and bean yield in the Borno region using both conventional regression and Bayesian statistical techniques. The main conclusion is that there is no statistically significant correlation between conflict and these variables. The F-test, p-value, and credibility intervals all show that there is no significant correlation between the overall model and the coefficients of each variable, although the R-value of 0.29 suggests a weak correlation, emphasising the complexity of conflict etiology (Collier, & Hoeffler, 2004). Although environmental factors such as resource scarcity and climate can increase tensions, they are rarely the primary or exclusive causes of conflict (Bernauer et *al*., 2012). This study emphasises that to develop a comprehensive understanding of conflict dynamics, a broader range of factors such as socioeconomic, political and institutional variables must be considered.

Given the small sample size, the use of Bayesian statistics in this analysis provides an insightful viewpoint. Although the results did not differ significantly from conventional methodology, Bayesian techniques have the advantage of integrating prior information and allowing probabilistic interpretations (Zyphur & Oswald, 2015). However, in this case, the inclusion of previous information did not significantly change the conclusions.

The causal links between climate variability, conflicts, and food security have been studied and have attracted mixed outcomes. Eze (2018) in the study of drought occurrences and its implications on households in Yobe, northeast Nigeria, where it was found that agriculture in Yobe is substantially constrained by the frequent occurrence of droughts.

Jelilov *et al*. (2018) modelled the relationship between insurgency-related killings and the amount of crop production in Borno State and found that there were significant relationships between insurgency and the amount of crop produced in Borno State.

Miguel *et al*. (2004) applied economic indicators of economic growth, agricultural output, and food prices as auxiliary factors to relate the economic impacts of factors to conflict and violence. The basic assumption is that climatic changes are not associated with any other variable that covaries with conflict/violence variables (Martin-Shields, Stojetz, 2019). The above assumption becomes increasingly contested with the realisation that climate variability tends to affect a wide range of economic variables (Sarsons, 2015).

Burke *et al.* (2009), in their study, find that conflict onset and duration are associated with above-mean temperatures and below-mean precipitation during civil war incidences. This conclusion was contested because of the possibility of being fraught with measurement error, methodological strategies and data choices (Sutton *et al*., 2010). Recently, the association between climate variables and conflicts has been established through meta-analyses of some previous studies that reported the correlation between temperature increases and the possibility of conflicts between groups (Burke & Miguel, 2013).

Interesting, most of the research around this subject matter were conducted in the sub-Saharan and Sahelian regions of West Africa, where there is continuous debate about the nature of the link between climate variability and conflicts via local economic situations (Fig. 5.11). This reasoning is motivated by the interest in finding the correlation between economic conditions and conflicts, and by following the order of cause and effect, through local economic conditions, high temperatures and low

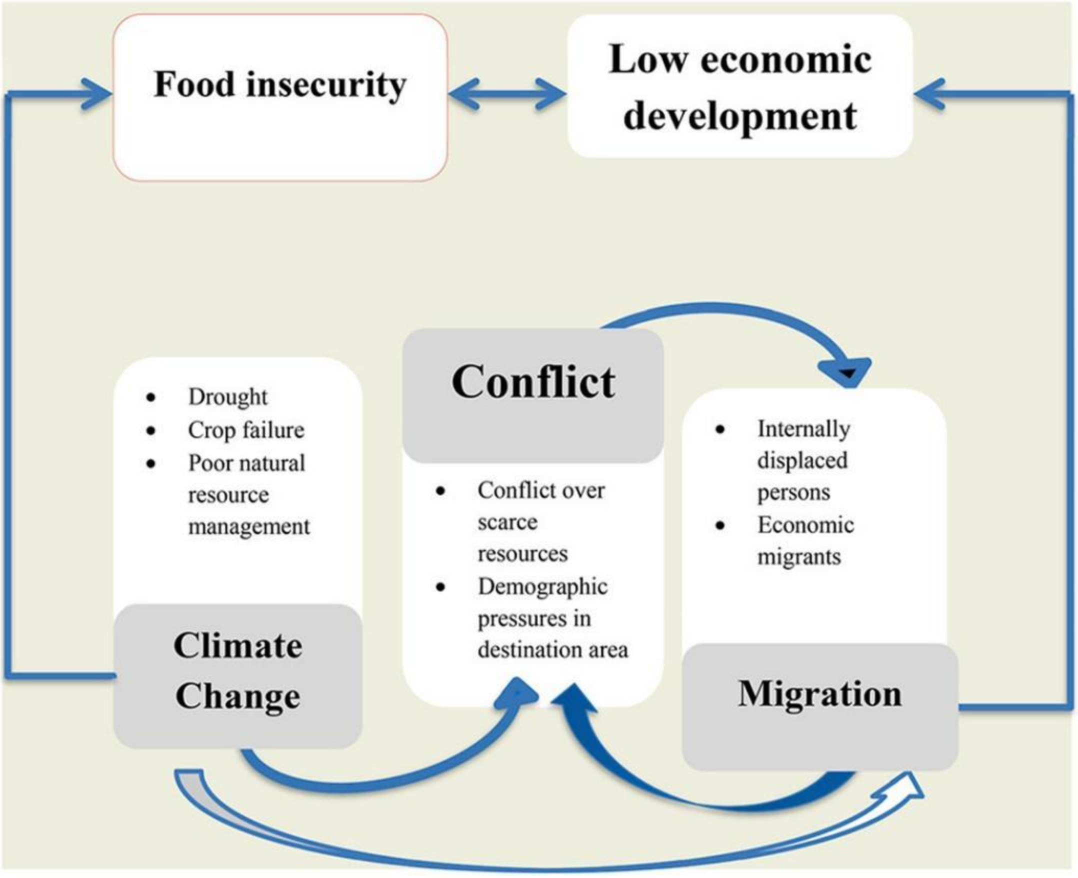


Figure 5.11: The conceptual model of climate, conflict and migration (Abel *et al*., 2019)

rainfall have negative effects on agricultural production (Martin-Shields, Stojetz, 2019). While this has not been disputed in Africa, a study in Ethiopia however reported negative impacts of climate change (Demeke, *et al*., 2011).

Another argument is that declined agricultural production and incomes has been postulated to be drivers of conflicts through fewer employment opportunities, grievances and prices but the process it takes remains elusive as it has not been empirically verified (Martin-Shields, Stojetz, 2019), because the relationship is complex and hard to untangle (Raleigh, *et al*., 2015). Studies have suggested a possible connection between temperature anomalies and conflicts. Agricultural yields variation that is caused by temperature variability has the possibility of altering migrations with the possibility of inducing violence and conflict.

High temperatures can induce shortages in crop supply and cascade to high food prices and depress economic output and lead to conflicts (Carleton & Solomon, 2016**,** Hsiang *et al*., 2011). Burke *et al*. (2015) provided a point of view through empirical psychological research that individuals have a propensity to behave violently because of high temperature. Research by Bollfrass & Shaver (2015), finds that there is a universal presence of the mechanisms of high temperature-induced conflicts with or without agricultural food production.

5.8 Policy review

Nigeria's National Development Plan (2021-2025) was examined to find potential areas for improvement to clarify the necessity of reorienting policy toward enhancing the adaptive capacities of the most vulnerable groups, particularly in Borno state. In the north-eastern region of Nigeria, many government initiatives are focused on security, preventing desertification, or providing humanitarian aid. Building the adaptive capacities of the most vulnerable individuals and smallholder farmers, who are disproportionately affected by the region's security and climate change issues, has received little attention. Furthermore, since agriculture is on the federal government's concurrent list, there are national policies and policy initiatives pertaining to it. However, to have a real impact on food security and the vulnerable, particularly in regions like Borno, it is more important to emphasise a clear policy direction and implementation framework at the subnational and local levels. Such and other policy interventions were recommended.

5.9 Limitations and Challenges

The analysis has some limitations that should be considered:

5.9.1 Geographical Coverage

The household survey was conducted in eight LGAs classified as conflict-free at the time of research. This excluded many high-risk areas severely affected by insurgency, meaning the findings may not fully capture the most vulnerable populations.

5.9.2 Reliance on Self-reported Data

Much of the analysis, especially household coping strategies and food consumption patterns, relied on respondents' recall and self-reporting. This introduces the possibility of recall bias or under/over-reporting.

5.9.3 Temporal Scope

The data represents a snapshot in time, which may not fully capture seasonal variations in food security or long-term livelihood dynamics shaped by fluctuating climate and conflict events.

5.9.4 Measurement Limitations

First, the explanatory power of the model is limited by the number of independent variables. While SPI, temperature and bean yield are significant factors, they do not encompass all potential conflict triggers. Including additional variables related to food security, such as socioeconomic indicators, political instability and ethnic diversity, could provide a more comprehensive insight. Also, while the Household Food Insecurity Access Scale (HFIAS) was effective in categorising households, it does not capture nutritional quality, dietary diversity in detail, or intra-household food allocation beyond what was reported.

5.9.5 Resource and Security Constraints

Data collection was shaped by logistical, financial, and security constraints, which restricted the breadth of sample size and the ability to conduct longitudinal studies across seasons and years. The inaccessibility challenge due to security faced in this research was mitigated using locally based research assistants and the use of a digital data collection tool that transmits data as soon as it is collected.

CHAPTER 6

6.0 Summary, Conclusions from Overall Findings, and Recommendations

6.1 Introduction

Climatic conditions and trends in the Sahel and indeed northeast Nigeria have been associated with high-impact events derived from climate change, affecting the important and sensitive sectors of the economy of this region. This research examines the relationships between climate variability, food security, and security challenges in Borno State, northeast Nigeria. The main source of food for the household population in Borno State is from agricultural food production, which is mainly rainfed, just like most regions in Africa south of the Sahara Desert. Food insecurity issues have been a prominent challenge in Borno State over the years, which is mostly associated with famine that emanates most times from weather variability with specific reference to precipitation deficit. The food insecurity condition over the years has been aggravated by worsening security challenges that followed the Boko Haram invasion of the northeast, which started from Maiduguri, the Borno state capital, in 2001. Given the fact that precipitation is a natural occurrence of an event and the availability or otherwise of it can hardly be modulated by human efforts. There is still the need to characterise the mode and effects on the population to advance both mitigative and adaptation methods to enhance the adaptive capacity of the population and manage the effects of climate variability.

6.2 Summary Findings

6.2.1 Household Food Security Survey

In this study, most households are vulnerable to food insecurity because of different combinations of challenges. Results from a survey carried out imply that, in Borno State, access to food was difficult for the majority of the household population, as implied in the data captured by the survey; 56.5% of the sample were not able to eat the type of foods of their choice because of scarce resources.

However, about 11.6% out of the sample experienced this frequently and 27.9% of the household heads indicated that their household members had to skip meals because there was not enough food. Accordingly, research indicates that reliance on less preferred and less expensive food is a food insecurity coping strategy, as more than half of the population (58%) of the households indicated in the survey. Again, about 87% of the households do not consume their seed stocks to cope with food insecurity, but about 13% do. Some households limit the portion of their meal to cope with food insecurity, and some households limit adult consumption and cede to children.

6.2.2 Household Food Insecurity Access Scale (HFIAS)

The use of the HFIAS in this study to group households based on their food security yields the following results: that 37.7% of the studied households were food secure, 22.1% were mildly food insecure, 24.6% were moderately food insecure, and 15.6% were severely food insecure, as shown in (figure 5.4).

Another significant revelation in this study is that 99% of the household heads confirmed that they have not been affected by conflicts, as shown in Table 5.6. This is in total agreement with the fact that the eight local governments where the household survey was carried out were referred to as conflict- and terrorism-free areas as cleared by security forces at the inception of the survey project. As regards weather and climate issues, this study reveals that food insecurity is more prominent among households that have experienced long periods of dry seasons and heat waves.

6.2.2.1 Availability of resources

Food security conditions for ownership of land/resources in the study are mixed and dichotomous in nature. Households who have access to free drinking water from boreholes are food secure, while the lack of it shows the food insecure category. This same explanation also applies to access to credit, with households that have access to credit tending to be food secure, while it is the opposite for households in the food insecure category.

6.2.2.2 Coping Strategies

This study reveals the main coping strategies employed for food insecurity by the households in the study area, which include reliance on less preferred and less expensive foods with (58.5%) of the sampled households attested to using this strategy to cope with food shortages, while 53% of the households relied on purchasing food on credit, 36.9% relied on limiting portion size at mealtimes, 31.2% depended on reduction of the number of meals eaten in a day, 25.6% coped by using restriction of consumption of adults for small children to eat, and 17.3% relied on borrowing food from a friend or relative. The less important coping strategies include skipping entire days without eating, with 1.3% of the sampled households saying they used this method to cope with food shortages; 2.5% of the household population used sending household members to beg, while 5% relied on sending household members to eat elsewhere, such as neighbours', friends' or relatives' houses; and 3% depended on gathering wild food, hunting, or harvesting immature crops.

6.2.2.3 Agricultural Practices

Findings from the qualitative interviews reveal that farmers combine rain-fed agriculture and irrigation farming, and farmers utilise crop and pastoral farming to diversify incomes. Mixed cropping systems were utilised with multiple types of crops planted. Approximately 40% of the informants utilised fertilisers to enhance productivity, while others used animal dung as manure to increase agricultural yields.

6.2.2.4 Climate Change

Through the qualitative focus interviews, participants reported a shift in the average temperature over the past 30 years, with a noted increase in hot days during the same period. This change was attributed to climate change and the early onset of the dry season. Respondents agreed that the average precipitation has dwindled over the past 30 years; however, there was no consensus about the number of precipitation days. Approximately 60% of the informants reported a decrease in precipitation days, while others believed that the number of such days had increased.

6.2.2.5 Adaptation measures

Again, findings from the study show approximately 57.5% of the respondents reported they used strategies to cope with the current climate fluctuations. Measures adopted included altering crop varieties, utilising water conservation techniques, refraining from using chemical fertilisers, pesticides, and insecticides, relying on religious beliefs or prayers, relocating to other areas, implementing soil conservation practices, using irrigation, adjusting planting schedules, and expanding the amount of land under cultivation. The study revealed poverty as the main obstacle for a farmer's capacity to adapt to climate variability and change.

6.2.2.6 Security challenges

Most participants mentioned they encountered challenges in accessing their farms due to security concerns. Furthermore, they were subjected to assaults by bandits, resulting in the devastation of their farmlands. Participants recommended reporting incidents to the village chief and law enforcement agencies, as well as arming themselves for self-protection. To address the issue of insecurity, participants emphasised the responsibility of the state and local authorities in protecting the citizens.

6.2.3 Precipitation Anomalies

The Standardised Precipitation Index (SPI) for the Maiduguri weather station is more important and of interest to this investigation. The precipitation anomaly is one piece of evidence of climate change detection attributions, and the Maiduguri weather station has a 590.2 mean precipitation over the series of the seventy-year period (1950-2019). There was a dry spell during the first decade of the series (1950-1959) and it became more pronounced in the years 1971, 1972 and 1973, which is attributed to climate variability induced by large-scale atmospheric modes that includes, El Niño Southern Oscillation, Atlantic Meridional overturning, Inter-hemispheric teleconnections, and the Sea Surface temperature in the tropical Atlantic. This dry spell is in concordant with the earlier findings of the drought spells that affected the entire region of the Sahel latitudes (10^0- 20^0 N). There was 50 years of normal precipitation, 8 years of moderate and 2 years of extremely dry precipitation based on the SPI classification and precipitation anomaly.

6.2.4 Decadal Mean Fluctuations

The first two decades of the seventy-year series, i.e., (1950-1969), show that all five stations under consideration recorded substantial wet or high precipitation, as shown in the analysis carried out. Five stations recorded mean precipitation above the long-term mean (figure 5.9). The third decade exhibits a mixture of deviations above and below the long-term mean for all weather stations. Of remarkable interest was from

1980 onwards; all five stations experienced a continuous below long-term mean precipitation. This is quite pronounced in Maiduguri, with below-mean precipitations from 1980 to 1995, and in Yola station, below the mean deviation over the long term, i.e., the years 2000 to 2019, Nguru and Potiskum weather stations consistently experienced below the long-term mean precipitation, as shown in figure 5.9, starting from 1996 till the year 2019.

Relationships between aggregate food production and precipitation explored over the series (1992 to 2020) suggest that there was dramatic low production of food identified with below-average precipitation between 1992 and 1994, and food production shortages continued even though above-average precipitation between 1995 and 2002 when food production started rising through precipitation deficit. There was a sharp increase in food production between the years 2004 and 2006, surprisingly, through low precipitation even below the mean precipitation. This surge may possibly be connected to an increase in aid delivery and other food supplies from international organisations because of the concerted focus on this region following Internally Displaced Persons (IDP) that resulted from insurgency strikes.

From the year 2007 onwards, food production continues to decline till the year 2021 because of the precipitation deficit, and the advent of covid-19 in the year 2020 made it worse than it already was. The relationships were further explored by applying the correlation statistics to explore the relationships between the two variables. The correlation coefficient between the two variables is 1, which suggests a strong connection between precipitation and food production in Borno State.

6.2.5 Results of Regression Analysis

The multiple regression MLR results revealed SPI values range from -0.49 to -0.11 with a mean of -0.3718. This suggests that rainfall is not high in Borno state and temperature less variable over the same period. Among the crop yield data, the values for beans/cowpeas are more consistent and show less variability compared to other crops.

The assessment for multicollinearity performed on the data showed only SPI, temperature and bean yield data do not have high correlation. High multicollinearity can increase the standard errors of the coefficients (Kahsay *et al*. 2020). Other independent variables have a correlation coefficient greater than 0.8 when compared with at least one other variable (refer to table 5.16).

Test of normality for the residual's errors showed the data was normally distributed i.e. Q-Q plot followed a straight line (**Appendix A9**). And the Shapiro-Wilk test showed a p-value > 0.05, which indicates that the residuals are normally distributed. The residuals of corn, rice and peanuts show a significant deviation from the normal probability line. In addition to this, the Shapiro-Wilk test shows that SPI, temperature, beans, and conflict data are normally distributed. This confirms the result of the previous collinearity test (Table 5.14).

Homoscedasticity tests whether the residuals have constant variance across all levels of the independent variables. The Breusch-Pagan test indicated a P-value of 0.485 (**Appendix A10**), and with the p-value of less than 0.05, we cannot reject the null hypothesis of the test. Therefore, there is no sufficient evidence to say that heteroskedasticity is present in the regression model. The test of independence of the residuals was carried out using the Durbin-Watson test. The result of the test puts the d value at 2.37. This value indicates the absence of autocorrelation in the data set (**Appendix A11**).

6.3 Overall Conclusions

This study is an attempt to enhance the understanding of the relationship between climate variability and food security through empirical research to contribute to the debate of food security and its importance to human societies. The challenges of food insecurity in Borno state, and indeed, Nigeria at large are very chronic and has affected the livelihood of the population for long because of weather variability that manifests itself in precipitation deficit and drought. This problem in the last twenty years has been compounded by terrorism, banditry and other related problems associated with resource control. These problems aroused the attention of some international development agencies and aid organisation especially because of the humanitarian issues attendant to these problems.

Nigeria government in partnership with some international aids organisations and development agencies have made several attempts to combat desertification and effects of rainfall deficits that has affected the livelihoods of the inhabitants of the Sahelian zone of northern Nigeria and more specifically the northeast. Efforts by successive government and international development agencies has been towards desertification and desert encroachments as solely responsible for livelihood vulnerability in Borno state. Little or no effort at all has been directed towards empowering the population to adapt to climate change. The federal government of Nigeria has not taken seriously the issues of climate change as a national policy imperative. Several efforts by Nigeria government have not yielded any results to alleviate the suffering of the people of Borno state especially the rural population. This study is an attempt to contribute to scholarship in the debate, come up with realistic policy suggestions that can strengthen the capacity of both rural and population to cope with the preponderance of food insecurity linked to precipitation variability.

The central aim of this research is to examine the relationships between rainfall variability and food security. Implicit from the results of the analysis carried out from the data obtained from the study area, the following conclusion could be affirmed. Derived from the standardised food production anomaly (figure 5.11), the precipitation anomaly and decadal mean precipitation fluctuations shows relationships with food production and thus availability. In the series (1992-1920), low food production identified with below standard mean precipitation, for example in 1992 to 1994, 1995 to 2002. Other studies have suggested that major agricultural food crops in this study area, for example, rice, maize, sorghum and groundnut are extremely sensitive to rainfall variability, on many occasions resulted in low food production, and thus food insecurity (ANACIM, WFP, IRI, 2012). Prevalence of low food production continued from year 2007 onward, till the end of the series because of rainfall deficit, till year 2021, and possibly compounded by the outbreak of covid-19 pandemic in the year 2020. Anywhere there is contrary result may be explained to be a result of aid supply following international attention because of drought and terrorism or intermittent flooding resulting from few months of rainfall, that usually destroy agricultural production.

Study examines the food security condition of the household population in the rural communities in eight local governments of Borno State as a case study. Results from the household survey show that the food security situation among the rural population was characterised into three main categories: high, medium and low.

The Standard Precipitation Index (SPI) was applied to examine precipitation variability over the time series (1950-2019). Through the time series, it was possible to understand the variability of precipitation as related to climate change. Anomalous precipitation over the time series points to the fact of climate change in the region, both in annual and decadal fluctuations.

Evidence from qualitative respondents in the study area suggests that the average precipitation has reduced over the past 30 years; however, there was no agreement in respect of the number of precipitation days. Approximately 60% of the informants reported a decrease in precipitation days, while others believed that the number of such days had increased.

The multiple regression equation was applied to examine the relationships between crop production and climate and security challenges prevalent in the study area to further understand how weather, security challenges and population factors individually or combined aggravate the food insecurity conditions of the study area. This, in a way, throws more light on the overall food security condition of Borno State. It helps to understand how these factors affected individual staple crop production and shed more light on the food availability condition of the population.

Within the context of this study, it is difficult to vouchsafe that only one factor or set of variables is responsible for the food insecurity status of Borno State and indeed northeast Nigeria. Results from the combination of three methods adopted for this study suggest that the food insecurity situation in the study area is dependent on a combination of factors that include natural variations in weather and climate in terms of deficits in precipitation to cultivate food crops and flooding that can obliterate farmland when there is excessive precipitation; high temperature; and human-induced factors like farming methods, conflicts and terrorism, migration, and overgrazing.

6.4 Future Direction

The nexus between climate variability and food security is an ongoing area of research, especially in semi-arid areas like Borno State and northern Nigeria as a whole. First, barring improvement in security problems that persisted in Borno State and indeed northern Nigeria, there will be future needs to carry out a household food security survey in every local government area of the states of northern Nigeria; this is currently impossible because of scarce resources and security challenges.

This study has not explored the direct effects of excess precipitation in terms of flooding on food security in Borno State; it will be worth examining to see how flooding has affected food production and availability in future studies.

One positive step towards ensuring food security in Nigeria is mainstreaming food security by creating the federal ministry of agriculture and food security. This is highly likely to enhance food security at the national level, and each state and local government area that are the arms of government closer to the rural population should follow this step taken by the federal government to mainstream food security by creating ministries for food security so that close attention could be focused on food security.

6.5 Significance of this Study

Borno State is in the Sahel latitude in the semi-arid land of north-eastern Nigeria and has been impacted by climate variability just like any other countries in the Sahel latitude. The adverse climate condition has been compounded by other associated problems like banditry, terrorism and conflicts to adversely affect the food security condition of the inhabitants of this land, especially the rural population.

This research has contributed to the body of knowledge on food security by dissecting the various dimensions of food security in Borno State, broadly studying the household food security conditions, determining the food security index, exposing the causes of food insecurity, and determining the food insecurity coping mechanisms of the rural household.

This study shows that in Borno state, households whose heads are educated have more capacity to be food secure. This can be helpful to the policy makers to pay more attention to promoting education in the rural areas and among farmers. This could also be useful in other parts of Nigeria and the Sahel latitude. The study revealed that lack of resources is responsible largely for food insecurity as evident in 50% of the survey respondent. This is vital for policy framing. Government can enhance the adaptive capacity of rural population through provision of resources to fortify them against food insecurity.

This study has created awareness of the fact that there is the need to shift policy attention from the traditional focus on mitigating desert encroachment and desertification in northern Nigeria.

Policy direction should be towards reducing the vulnerability of the rural population to climate variability, by the empowerment of the population to increase their adaptive capacity giving the fact that climate and weather variability is a massive nature control and humans can only do little to mitigate it.

This research shows the evidence of climate variability in northern Nigeria through the application of the SPI, evident in the series explored are precipitation anomalies especially pronounced in the first three decades of the series considered (1950-2019), with evidence of droughts, adjudged to be the worst witnessed in observation records. This research attested to the importance of local knowledge as 60% informants reported decrease in precipitation in the last 30 years.

This study reveals that precipitation is significantly associated with some food crop production while some are less significant. This in a way can help farmers plan their season and the research revealed that diversification of crops is an effective way of coping with climate variability.

Finally, though the role of conflicts in food insecurity is still being debated but this study adds to the body of knowledge on the role of conflicts in food insecurity in conflict ridden regions. There is no doubt that conflicts added to the vulnerability of populations, and this information can be used as evidence-based policy framework to plan the empowerment of vulnerable populations.

Table 6.1: Framework for Key Findings

Objective	Description	Data	Methods	Key Findings
1	Examines the household food security conditions in Borno state	Household survey	Descriptive Statistics; Ordinal Regression	Economic limitations cause food insecurity in most Borno State households, with 56.5 percent unable to purchase their favourite foods. 58% of respondents used less preferred, less expensive food as a coping mechanism, while 27% of respondents reported skipping meals. Furthermore, 13% of households consumed seed stocks, whereas other households prioritised the consumption of their children or limited portions.
2	Determine the food security index in Borno state.	Household Survey, Focus group discussion	Descriptive Statistics; HFIAS	While 62.3 percent of households experienced varying degrees of food insecurity (22.1 percent mildly, 24.6 percent moderately, and 15.6 percent severely), 37.7 percent of households were found to be food secure. Interestingly, 99 percent of household heads said that conflicts had no effect on their lives, which is consistent with the survey's location in a conflict-free area. Households impacted by extended dry seasons and heat waves were more likely to experience food insecurity.
3	Examine the relationship between precipitation variability and food crops production in Borno state of northeast Nigeria.	Weather Data; Agricultural Food Production data	SPI-Deviation from long term mean. Regression	According to the study, the Maiduguri weather station recorded 590.2 mm of precipitation on average over 70 years (1950–2019), with notable dry spells in the 1970s brought on by climatic variability. Borno State had generally little rainfall, as indicated by the Standardised Precipitation Index (SPI) values, which ranged from -0.49 to -0.11. All five weather stations studied saw below-average precipitation starting in 1980, which was highly correlated (r = 1) with declines in food production, especially from 2007 to 2021, which were made worse by COVID-19 in 2020. Long-term trends indicate that precipitation deficits have a detrimental effect on food security, even though there was a brief spike in food production (2004–2006) during low precipitation, probably because of international aid.
		Weather Data; Agricul		Conflict and the other variables examined (climate and food production) showed a weak correlation (R = 0.29), accounting for only 8.4

4	Explore the effects of security challenges on food security in Borno state.	tural Food Production data. Conflict Incidence; IDP Population	MLR; Correlation	% of the variance in conflict. These variables do not significantly predict the incidence of conflict in Borno State, according to the model's low overall significance (F-test = 0.215, p = 0.883). It is challenging to draw firm conclusions about how conflict affects food security because of the wide credible range (-321.14 to 632.45), which indicates high uncertainty, according to Bayesian regression analysis, even though SPI had a mean impact of 155.66 on conflict.
5	Identify proposal and actions that may help support the design and implementation of food security policies for sustainable food production, adaptation to climate change and coping strategies in the present and future, in Borno state and region wide.	Food policies in Nigeria	Desk review	In Borno State, smallholder farmers face significant challenges in obtaining necessary inputs, necessitating immediate assistance for agricultural production through loans, subsidies, and private sector investment to address food security and climate change adaptation. Climate resilience and environmental preservation must be given top priority in sustainable agriculture to counteract declining crop yields. Effective policies that support Nigeria's National Development Plan and Agenda 2050 require solid collaborations with private industry, civil society, and international organisations. It is imperative that policies pertaining to food security incorporate climate change adaptation, supporting Climate Smart Agriculture, social protection initiatives, and participatory policymaking. Enhancing farmer resilience will require regular Climate Change Vulnerability Assessments and making sure real-time data is accessible. Enhanced agricultural extension services, hybrid crop research, and local language instruction will all help to increase adaptive capacity. Since agriculture employs 70% of Borno's workforce and accounts for 65% of its GDP, bolstering the seed system, increasing financial incentives, and enabling direct payments to farmers will increase stability and productivity. The implementation of these measures is expected to improve agricultural resilience, increase food security, and align Borno's policies with both national and international development goals.

6.6 Contributions of the Study

This thesis makes important contributions to the understanding of food security under conditions of climate variability and conflict in Borno State, Nigeria. These contributions are delineated along four axes: practice, policy, theory, and methodology.

6.6.1 Contribution to Practice

i. Provides empirical evidence on the coping strategies households adopt (credit purchases, reliance on less preferred foods, portion reduction, migration, and aid dependence).

ii. Highlights the short-term effectiveness but long-term unsustainability of these practices, guiding NGOs, humanitarian agencies, and community organisations in designing interventions that support resilient livelihoods rather than temporary relief.

iii. Offers context-specific insights that practitioners can apply in other Sahelian communities experiencing similar shocks.

6.6.2 Contribution to Policy

i. Demonstrates the interplay between rainfall variability, conflict, and food insecurity, supporting the design of integrated food security policies that combine climate adaptation, agricultural development, and conflict mitigation.

ii. Provides a strong case for rights-based approaches to food security, positioning access to adequate food as a policy obligation rather than a charitable option.

iii. Offers state and federal authorities the evidence to target interventions more effectively (e.g., improving access to farm technology, credit, and clean water).

6.6.3 Contribution to Theory

i. Extends theoretical debates by applying and integrating Food Availability Decline (FAD) theory, Entitlement theory, Sustainable Livelihoods theory, and the Rights-Based Approach.

ii. Demonstrates that no single theory is sufficient to explain food insecurity in fragile contexts; instead, an integrated pluralist framework provides a more comprehensive explanation.

iii. Contributes to scholarship by positioning conflict as a cross-cutting factor that modifies how entitlements, livelihoods, and rights are realised in practice.

6.6.4 Contribution to Methodology

i. Illustrates the value of a pragmatic mixed-methods approach in fragile, conflict-affected settings.

ii. Provides justification for statistically adequate sampling (398 households) using both Cochran (1977) and Yamane (1967), while managing access challenges in insecure zones.

iii. Demonstrates how issues of bias, validity, and saturation were addressed through careful design (e.g., stratified random sampling, triangulation, member checking).

iv. Acknowledges and reflects on researcher positionality and axiology, contributing to methodological debates on conducting ethically sound, reflexive research in conflict-affected environments.

6.7 Recommendations

The main aim of this research is to produce a testable knowledge about the relationships between rainfall variability and agricultural food production and food security/insecurity in Borno state, in the arid lands of northern Nigeria. To help develop policy recommendations for policy makers that can possibly improve and enhance agricultural production and food security. A combination of primary and secondary data was explored with the following methodologies: Inferential statistics, Ordinal logistic regression, Standardised Precipitation Index (SPI), and Multiple Regression (MR). Survey was carried out in eight local governments of Borno State, which include Jere, Mafa, Konduga, Kaga, Maiduguri, Biu, Kawaya Kusa and Bayo local government areas. Each local government area consists of five Enumeration Areas (EAs), and samples were randomly drawn from all 40 EAs, and 10 households were studied in each of the EAs, with a total of 400 samples.

These samples were complemented with secondary data that covers the rest of the inaccessible local government areas of Borno state. Based on the results of the quantitative and qualitative data explored and literature reviews in respect of the effects of rainfall variability on the food security situation in Borno State, the recommendations below are provided.

6.7.1 Support Production with Affordable Agricultural Inputs.

There is no doubt that one very important need in Borno State is to interrupt the downward trend in agricultural production and enhance food security by producing more food while confronting precipitation variability by improving storage and provision of agricultural products. Borno State's population has increased in recent years and will continue to do so, so meeting the food security demand of this population requires a plan to increase agricultural production in a sustainable way. This means the old methods of tree clearing for agricultural use need to be abandoned for better methods to forestall deforestation and soil erosion. Smallholder farmers are challenged with low purchasing power to obtain fertilisers and pesticides needed to support their production. State government through the ministry of agriculture should support the smallholder farmers to finance the provision of this support either by subsidy or loans.

It is very important to promote food production to address the current food insecurity issues in Borno State, essentially because the main source of food for a typical household is from peasant agriculture. The constraints in agricultural production should be tackled head-on by supporting the farmers with high-yielding crop varieties and fertiliser support to enhance their production through improved soil fertility, security of farmlands and water. The policy framework enacted by both federal and state governments must encourage private sector investment in the agricultural sector to enhance production and distribution of agricultural inputs to farmers even in the remotest areas of the state. Part of the investment in this key sector is infrastructure like rail, roads, and electricity supply; this is a long-term investment with huge capital inputs. The regulatory framework must favour investors from the private sector supported by the rule of law to create functional relationships between the private and public sectors. There must be conscious effort towards financing, strengthening, and developing infrastructural networks that connect farmers to other states of the country to facilitate trades, boost the economy and guarantee food security. This will foster sustainable agricultural value chains that enhance food production and create more jobs in the agroeconomic sector.

6.7.2 Sustainable Agriculture

One of the primary shifts in policy direction should be to focus on sustainable agricultural methods to ensure Borno State's long-term food security by protecting nature's given natural capital, i.e., clean water, healthy soil, and healthy ecosystems/biodiversity. Food security should not rely mainly on maximisation of domestic food production driven by market forces but on making the best use of the land resources regardless of its quality. Food production should be balanced with the sustainable use of the environment and efficient use of land resources without harming the environment or lowering the standard of production. Rosenzweig *et al*. (2014) submitted that expanding agricultural productivity is central to managing the impacts of climate change that is projected to increase over the coming years and expected to significantly reduce crop yields. Climate change is expected to affect other areas' agricultural productivity and thus food security, for example, by reducing irrigation capacity as proposed by Schewe *et al.* (2013)*,* labour productivity by de Lima *et al.* (2021)*,* and micronutrient availability by Beach *et al*. (2019).

6.7.3 Partnership

Already, food insecurity in Borno state and indeed northeast Nigeria has gained some international attentions over the last few years especially since the advent of terrorists. activity in the northeast and the humanitarian disasters that follow. Some international organisations, including the United Nations' Food and Agricultural Organisations (FAO), World Food Program (WFP) and some charity organisations, and the British Department of International Affairs, all have their footprints in northeast Nigeria. These organisations have complemented the efforts of the federal government and state governments, making their presence felt among the population to reduce the shocks of food insecurity that emanated both from natural causes resulting from weather vagaries and human-induced challenges of conflicts and terrorism. Effective partnership with these organisations in terms of enabling support and policy integration from the state, local, and federal governments will translate to providing reprieve to obviate food insecurity among the rural population. Community development associations, civil society organisations and private businesses that are interested in playing any role should be supported with an enabling environment to function; this should be embedded in the policy framework and institutionalised through bilateral and multilateral commitments.

6.7.4 Climate Change

From the point of view of science, climate change has come to stay; therefore, climate policy must be enhanced by coordinating the local and international institutional framework to the benefit of the local population. No doubt, the inhabitants of Borno State have been affected by weather variability and climate change, which have severely affected their livelihood, cultural activities, socioeconomic lives and consequently food insecurity in the state. Drought, for example, has been attributed to the falling of the Gross Domestic Product (GDP) of the region, causing the population to consume because of the migration of people for better lives where the weather can support their livelihoods, especially cattle farmers, and some to urban centres (FMEnv, 2018).

First, the government should consider mainstreaming climate change adaptation and food security instead of leaving food security under the ministry of agriculture. This will situate well with the federal government of Nigeria's strategy that led to the creation of the National Council on Climate Change and the Ministry of Agriculture and Food Security and is consistent with Nigeria's Agenda 2050. Again, experience has shown that policy implementation has always been a major issue in the country. there should be a strategy to monitor the proper implementation of the policy. The bureaucratic issues surrounding the implementation of governmental policies should be eliminated.

Further, adaptation to climate change is recommended by the IPCC (2007), and the adaptive capacity of farmers should be enhanced because the question of climate change and weather variability is of nature's determination, and humans have little or no control over it. That said, the challenges of adaptation to climate change by the local farmers in Borno State are quite enormous. Experience from various policy strategies in the past shows a lack of real consultation and coordination among stakeholders; the government and its agency just throw at the farmers what they think or believe will be right for them without due consultations – a top-down approach. By this approach, many farmers practising farming in the rural areas are schemed out of the process of development because they have no say in the decisions that affect them. This is not always in conformity with the needs of the rural farmers and common people; this implicitly increases the level of their exposure to climate change/weather variability risks (FMEnv, 2001).

It is very important to keep policy enactment relevant, especially adaptation; it must not be done in isolation. Climate change policy must be inked with other sets of policies, especially as they are interconnected. There should be linkages between climate, economics, social issues, droughts, sustainable development, natural resources, foster governance and political rights, and protect human and animal rights. The promotion of 'autonomous adaptation' and Climate Smart Agriculture (CSA) methods by governments through the leveraging of social protection policies, such as social transfers and public work programmes.

OECD & FAO (2024) propose cash transfers through social protection to easily diminish the problem of budget constraints on the part of the farmers. This will invariably enhance their ability to implement the CSA practices and other technological innovations. Going by the submission of Rosenzweig *et al.* (2014), for example, expanding agricultural productivity is central to managing the impacts of climate change that is projected to increase over the coming years and expected to significantly reduce crop yields. Climate change is also expected to affect other areas' agricultural productivity and thus food security by reducing irrigation capacity as explain by Schewe *et al*. (2013), labour productivity by de Lima *et al*. (2021), and micronutrient availability by Beach *et al*. (2019). As a result, confronting the impact of climate change on food production will require a multidimensional policy approach to get the best outcome.

6.7.5 Vulnerability Assessment

To manage climate change risk, there must be proactive action to develop a Climate Change Vulnerability Assessment framework (CCVA) that is fitting to the specific exposure present in the study area. In the context of this study, it is suggested that a comprehensive CCVA be carried out from time to time. This study will involve population exposure and sensitivity to precipitation, temperature, population growth and size, adaptive capacity and demographic parameters. This will provide an understanding of the actual and potential root causes of exposure and vulnerability and formulate a testable hypothesis to produce up-to-date knowledge that guarantees suitable responses to climate change risks (Rowland *et al*., 2011; Small-Lorenz *et al*., 2013).

Vulnerability assessment of this geographical area needs to be done to date based on real-time data through public, private and agency collaboration. This will enhance the adaptive capacity of this vulnerable population if they have access to location-specific data and information. A function of exposure to physical occurrences like droughts and floods, sensitivity to factors influencing social environment and the capacity to adapt to the changing environment is referred to as 'climate change vulnerability' (Banita *et al*., 2015). Finding appropriate adaptation techniques is one important usefulness of a CCVA, but one of the major challenges of climate change adaptation is that it is an expensive venture, and without integrative and institutional-level support for rural farmers, they will not be able to cope sufficiently with the effects of weather variation. Policy direction and strategies should be towards eradication of the fundamental cause of food insecurity and poverty.

Farmers should have the capacity to respond to weather variability whenever it occurs at variance with their seasonal planting and harvesting schedule. This can only be possible with specific policy interventions that enhance the farmer's capacity to cope.

Confront the menace of climate change. There must be conscious efforts to increase investment in research and technologies that are climate smart**.** Climate-smart agriculture could be adopted using sensors on farms connected to a private network across fields, support farmers to monitor nutrients and water levels in their farm's soils. This will help farmers to avoid unnecessary spending on fertilisers and chemicals which will only be used if it becomes necessary to boost yields. This has been used in other climes; Climate Smart Agriculture service has been used successfully in India to improve the livelihood of over 50,000 farmers in the states of Madhya Pradesh and Maharashtra. Climate and conflict relations must be tackled head-on. Climate and conflict relations must be tackled head-on by creating opportunity for resolution. Raleigh *et al*. (2015), in their study in Africa, finds that the effects of climate change on conflict can be reduced through interventions by creating a conducive environment where food prices are stable and reliable with safe and accessible markets; this can invariably reduce the impacts of conflicts and climate change. Climate education and awareness and information services to be imbedded in the policy framework, and long-term anticipatory planning is to be introduced through multiscale institutional coordination.

6.7.6 Research and Education

The federal government of Nigeria and the Borno state government have invested a lot in education programmes to combat climate change and desertification in the Sahel part of Nigeria. It is high time for the government to change tactics in terms of policy focus especially in terms of research and education. Research should be very specific to the targeting the vulnerable population- the rural and peasant farmers in the rural remote areas who has the highest population in the state. Hybrids crop varieties that can withstand droughts and nocturnal radiation and have a short gestation period should be made available to the farmers even at subsidised prices to meet the challenges of weather variability. Again, education of the local farmers in modern technologies such as Multi- hazard Early Warning Systems, a support system that will prepare farmers for possible incidents of droughts, floods and other disasters, modern irrigation techniques, information about funding and information about the concept of climate change that could be useful for them to organise their farming.

6.7.7 Agricultural Extension Services

Information about adaptation methods should be well disseminated in a clear and concise manner to the farmers and circulated in local languages depending on localities and catchment criteria. The wide gap between the farmers and government officials should be closed so that farmers can connect to the policy directions of the government. Information should be given to the farmers in the rural enclaves at real time to help them make informed decisions about their planting season and at no cost to them. This will get them involved to play their roles in the policy of adaption and mitigation as proposed by the authorities.

6.7.8 Agricultural Revolution

Agriculture is the mainstay of the economy of Borno state, it constitutes 65% of the GDP, more than 70 per cent of the population depends on agriculture directly or indirectly for the means of livelihood, (FAO, 2019). Giving these facts, addressing the challenges of food insecurity by enhancing the capacity of the rural farmers to withstand the challenges of doing farming and thus food production will be important.

The federal and state governments should support the smallholder's farmer with good seed system that delivers all classes of seeds available and meet the demand of the farmers wherever they may be in the state. The seeds should also be affordable for the farmers even if it's at subsidised prices, and the quality of the seeds should meet the farmers expectations, regulated standards and labelled specifications. These resilient seeds must have the quality to resist, recover and can adapt to natural and man-induced shocks like variable weather patterns, like droughts, floods, pest and diseases. The above may not tackle the problem completely but will mitigate it to some degree.

6.7.9 Access to Funding and Financial Incentives

Government and international organisations should make a deliberate effort to inject funding into the farming system by creating a good financial institution that gives opportunities to peasant farmers to access funds without bureaucratic bottle necks. This will enhance the capacity of the farmers to adapt to climate change both in short and long-term measures. Evidence from this empirical study revealed that poverty is one factors that is barrier to farmers to cope with the problem of climatic fluctuations. Financial support for the farmers becomes integral to any policy decisions.

It may be worthwhile for the government to buy into borrowing the European Commission (EU) idea of Direct Payments Framework Instrument (DPFI) to guarantee farmers income in the face of climate adversity. These payments are made according to the sizes of the farmers cultivated land and it represents economic buffer to reduce farmers vulnerability to variable climatic condition and unpredictable market prices (EU, 2016).

6.8 Policy Implication

6.8.1 Policy Reviews

Borno State is predominantly rural, and food insecurity poses a critical threat to its population and to Nigeria more broadly. To strengthen food production, both federal and state governments must support rural communities through livelihood-enhancing activities that rebuild assets depleted by precipitation deficits, banditry, and terrorism. National food policy should prioritise sufficiency for all citizens, with implementation cascading down to the state and local levels. A nation's capacity to meet the food needs of its people underpins stability and development; dependence on imports risks what Sugeng & Fitria (2023) describe as "food imperialism."

Policies must address the impact of climate change, which has amplified natural disasters, economic risks, and social vulnerabilities. High levels of poverty and food scarcity have historically triggered crises in parts of sub-Saharan Africa, underscoring the urgency of resilient food systems. In Borno, the absence of integrated and sustained food and agricultural policies involving federal, state, local, and international stakeholders has hindered progress. Past interventions have been piecemeal, reactive, and largely ineffective, with the COVID-19 pandemic, hyperinflation, renewed conflict, and restricted access to farming areas further worsening conditions.

Recognising these gaps, Borno State has introduced the Food Security Strategy (FSS) 2024–2026, aligned with the National Development Plan (NDP) 2021–2025 and Nigeria's Agenda 2050. If effectively implemented, this framework could strengthen agricultural livelihoods, integrate emergency assistance with long-term resilience, and improve access to federal resources and technologies. Recent institutional reforms, including the establishment of the Federal Ministry of Agriculture and Food Security and the Federal Ministry of Livestock Development in 2024, signal growing national attention to food security and climate change. Borno must leverage this momentum by aligning state-level strategies with federal frameworks.

Diversification is equally crucial. Farmers should be encouraged to cultivate a mix of rice, beans, sorghum, maize, and potatoes, given their comparable nutritional value. Policies must promote crop diversity, blending scientific expertise with local knowledge systems, and integrating customary rules and inclusive governance with international best practice. A pluralistic, participatory approach will improve alignment between community realities and policy objectives, avoiding the pitfalls of purely technocratic reforms.

6.8.2 Policy Critique and Lesson Learned

Despite the proliferation of frameworks and interventions, government responses to food insecurity in Borno State have been largely ineffective. A central limitation lies in the narrow conceptual framing of food insecurity as primarily an environmental issue, with policy attention concentrated on desertification control and anti-encroachment measures. This reductionist perspective obscures the multidimensional drivers of food insecurity, which include poverty, conflict, market failures, and governance deficits.

Interventions have further been characterised by short-termism and donor dependency. Emergency food aid and externally funded relief dominate the response architecture, offering temporary reprieve but failing to transition into durable livelihood support or systemic reform. The absence of a structured pathway from humanitarian assistance to development-oriented resilience has entrenched dependency and undermined self-sufficiency.

Policymaking has also remained top-down and exclusionary, marginalising rural farmers, pastoralists, and community organisations who bear the brunt of climate shocks and insecurity. Their exclusion from agenda-setting and policy design has resulted in strategies that lack legitimacy, disregard indigenous knowledge, and fail to resonate with community realities, thereby weakening adoption and sustainability.

Institutional weaknesses compound these deficiencies. Fragmented governance structures, overlapping mandates, and weak inter-ministerial coordination have created duplication and inefficiency. Chronic underfunding, inconsistent political commitment, and entrenched corruption further constrain policy implementation. Many policies remain aspirational blueprints stalled at the execution stage due to limited financing, weak accountability, and bureaucratic inertia.

From these shortcomings emerge important lessons. First, sustainable food security cannot be achieved through emergency-driven, donor-dependent interventions. While necessary in times of acute crisis, such measures must be systematically linked to development-oriented strategies that build resilience and reduce chronic vulnerability. Second, the persistence of exclusionary policymaking highlights the necessity of institutionalising participatory frameworks that integrate the voices of farmers and local communities while drawing on indigenous knowledge systems. Third, fragmented and siloed responses reveal the importance of policy integration and coherence, recognising the interconnectedness of climate variability, conflict, agricultural productivity, and socioeconomic inequalities. Finally, recurrent implementation failures demonstrate that institutional capacity and governance reform are preconditions for success; without adequate financing, robust accountability mechanisms, and political consistency, even well-designed policies remain symbolic.

In sum, the Borno experience underscores that food security requires a paradigm shift: from reactive, fragmented, and exclusionary measures towards inclusive, integrated, and resilience-oriented frameworks. This shift entails empowering smallholder farmers, strengthening governance systems, mainstreaming climate-smart agriculture, and embedding food security within a broader socioeconomic development agenda. Only through such transformation can policies move from aspirational rhetoric to substantive change.

6.8.3 Aligning Policies with SDGs 2 and 13

The study's findings and recommendations align closely with SDG 2 (Zero Hunger) and SDG 13 (Climate Action). Ending hunger and ensuring sustainable production require accessible inputs, resilient seed systems, and high-yield varieties, complemented by financial incentives, subsidies, and extension services. Promoting Climate Smart Agriculture (CSA) and embedding adaptation into food security strategies are essential to reducing vulnerability to climate shocks.

To meet the SDG targets, Borno must integrate climate adaptation with agricultural development, strengthen infrastructure, and institutionalise coordination at federal, state, and local levels. Climate Change Vulnerability Assessments, investment in drought-resistant crops, and partnerships with international organisations will be central to building resilience. Beyond production, attention must also focus on diets, nutrition, health, and hygiene to address undernutrition and achieve long-term sustainable food systems and prioritising children in order to meet the SDG target of halving the number of children experiencing hunger and chronic undernutrition by 2030 (UNESC, 2024).

Chapter Summary

Chapter 6 synthesises the overall findings of the study, drawing conclusions on the nexus between climate variability, food security, and insecurity challenges in Borno State, Nigeria. The chapter highlights that households remain highly vulnerable to food insecurity due to low income, limited access to resources, and exposure to climatic shocks such as prolonged dry seasons and heat waves. Survey data show that 56.5% of households could not afford their preferred foods, 27.9% reported skipping meals, and 58% coped by relying on less preferred and cheaper foods. The Household Food Insecurity Access Scale (HFIAS) results classified 37.7% of households as food secure, while the remainder experienced varying levels of food insecurity. Access to credit and water resources emerged as critical determinants of food security. Coping mechanisms included meal reduction, borrowing food, and restricting adult consumption to prioritise children.

Qualitative findings revealed that households practice both rain-fed and irrigation farming, crop diversification, and mixed pastoral systems, yet climate change has reduced precipitation and increased heat stress over the past 30 years. Adaptation strategies—such as water conservation, crop variety adjustment, and soil management—are constrained by poverty, insecurity, and poor infrastructure. Security challenges, especially terrorism and banditry, further hinder farm access and threaten livelihoods. Climatic analysis using the Standardised Precipitation Index (SPI) confirmed significant precipitation anomalies and persistent below-average rainfall since the 1980s, strongly correlated with declining food production. Regression analysis confirmed that precipitation variability and temperature shift significantly influence crop yields, particularly for rice, maize, sorghum, and groundnut.

The chapter concludes that food insecurity in Borno State is shaped by a complex interaction of climatic variability, environmental shocks, socioeconomic inequalities, and human-induced challenges such as conflict and poor farming practices. The study emphasises that while humanitarian aid and short-term coping strategies have provided temporary relief, long-term solutions require structural interventions. Policy recommendations include: improving access to affordable agricultural inputs, supporting smallholder farmers with resilient seeds and fertilisers, strengthening irrigation systems, and promoting sustainable agricultural practices. Partnerships with international organisations, NGOs, and the private sector are critical to building resilience. The study further calls for regular Climate Change Vulnerability Assessments, enhanced agricultural extension services in local languages, and research into drought-resistant crop varieties. Policy frameworks should integrate climate-smart agriculture, social protection mechanisms, and participatory approaches that combine local and scientific knowledge.

Finally, the chapter aligns its recommendations with the Sustainable Development Goals (SDGs) 2 (Zero Hunger) and 13 (Climate Action), stressing that addressing food insecurity in Borno requires coordinated federal, state, and local policy frameworks. Building resilience through investment in sustainable infrastructure, empowering smallholder farmers, and integrating climate change adaptation into food security strategies are presented as key steps towards achieving long-term sustainable development in the region.

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APPENDICES

Appendix A1: Informed Consent Form (Key Informants) (Climate change and food security)

Project Title: Effects of Rainfall Variability on Sustainable Food Security in the Sahel (Borno state) in Northern Nigeria

By signing this consent form, I understand that I am not waiving my legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by Sunday Olusanya Fayanju, a PhD Candidate, School of Business and Law, London Metropolitan University, London United Kingdom. I have had the opportunity to ask any questions about this study, to receive satisfactory answers to my questions, and to receive any additional details I wanted.

I have been informed orally and in writing about the aims and the procedures of the study, the potential benefits, as well as potential risks. I am aware that this interview is being audio-recorded to ensure an accurate recording of my responses. I am aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous. **I was informed that I may withdraw my consent at any time before publications are submitted without penalty by advising the researcher.**

This study has been reviewed and received ethics clearance through a London Metropolitan University Research Ethics Committee. I understand that if I have any comments or concerns resulting from my participation in this study, I may contact the Research Ethics and Approval Office at …….

With my signature, I certify that I will fulfil the requirements for the study participation and I understand that my participation is voluntary and I can withdraw at any point without any negative consequences. I will inform the investigators about my perceptions and experiences with climate change and food security especially rainfall deficit (current and future concerns) and provide my insight into the awareness and consideration of the linkages between climate change and food security.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.
YES NO
☐ ☐

I agree to the use of anonymous quotations in any thesis, publication or presentation that comes of this research.
YES NO
☐ ☐

Participant Name: _____________________________ (Please print)
Participant Signature: _____________________________
Witness Name: _________________________________ (Please print)
Witness Signature: _______________________________
Date: _______________________________

Appendix A2: Invitation letter to an Information session for focus group discussions (Climate change and Food security: Effects of Rainfall Variability on Sustainable Food Security in Sahel of Northern Nigeria)

To potential participant: ……………………………………………………………….

Project Title: Effects of Rainfall Variability on Sustainable Food Security in the Sahel (Borno) in Northern Nigeria

You are hereby invited to an information session for the above-mentioned project, which shall take place on **(insert date)** at **(insert the venue)** as from **(insert the time)**. In this meeting the details of the proposed research that shall be conducted in your community shall be discussed. Effects of Rainfall Variability on Sustainable Food Security in the Sahel (Borno state) of Northern Nigeria is a study that aims to explore the determinants that you perceive to contribute to food shortages and how you think rainfall variability affect these determinants. You have been identified as a potential participant in this study and are hereby invited to attend the forth coming meeting. In this meeting, more details on the study shall be discussed. This letter is also accompanied by the information sheet summarising the study objectives and methodologies. Your attendance is highly appreciated.

Yours sincerely,

Sunday Olusanya Fayanju (Student Investigator)

PhD Candidate,

London Metropolitan University, United Kingdom.

Appendix A3: Telephone recruitment script for Key Informant Interviews

P = Potential Participant; I = Interviewer

I - May I please speak to [name of potential participant]?

P - Hello, [name of potential participant] speaking. How may I help you?

I - My name is Sunday Olusanya Fayanju and I am a PhD candidate in the School of Business and Law at the London Metropolitan University, London. I am currently conducting research under the supervision of Professor Samuel Idowu and Dr. Eyob Weldermel on the relationship between climate change and food security in the Sahel (Borno state, northern Nigeria).

As part of my thesis research, I am conducting interviews with (public officers in Borno state department of agriculture) to explore their knowledge of the relationship between climate change and food security. As your department role put you in the position to understand what challenges are for farmers and individuals to cope with the effects of climate change on food production and government role in helping famers adapt to the effects of weather anomaly.

Your knowledge and experiences will allow me to explore the association between climate stresses and food security within the broader societal structures. It will also aid in the understanding of the policy context and (public) discourse surrounding climate change and food security and assess the suitability/appropriateness of governmental interventions as an entry point for the implementation of climate change adaptation strategies. Is this a convenient time to give you further information about the interviews?

P - No, could you call back later? (Agree on a more convenient time to call person back).

OR

P - Yes, could you provide me with some more information regarding the interviews you will be conducting?

I - Background Information:

- I will be undertaking interviews starting in **[insert date]**.
- The interview would last about approximately 45-60 minutes in length to take place in a mutually agreed upon location or via telephone.
- Involvement in this interview is entirely voluntary and there are no known or anticipated risks to participation in this study.
- You may decline to answer any of the interview questions if you so wish. Further, you may decide to withdraw from this study at any time without any negative consequences by advising the researcher.
- With your permission, the interview will be audio-recorded to facilitate collection of information and the accurate record of your responses. The transcripts will be later transcribed for analysis. To ensure complete data collection, only those individuals who agree to be audio recorded will be invited to participate in the study.
- All information you provide will be considered confidential.
- The data collected during this study will be retained for a minimum of seven years in a locked cabinet in my supervisor's office.
- After the data have been analysed, you will be invited to a feedback meeting to heat a summary of the research findings or you may request a summary of the research findings.
- If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please feel free to contact. The final decision to participate is yours.

With your permission, I would like to email/mail/fax you an information letter which has these details along with contact names and numbers on it to help assist you in making a decision about your participation in this study.

P - No thank you.

OR

P - Sure (get contact information from potential participant i.e., email address)

I - Thank you very much for your time. May I call you in 2 or 3 days to see if you are interested in being interviewed? Once again, if you have any questions or concerns, please do not hesitate to contact me [Sunday Olusanya Fayanju] at (44) 07588776024

P - Good-bye.

I - Good-bye.

Appendix A4: E-Consent Form (addressed to participant)

Study Name: Climate change and food security: Effect of Rainfall Variability on Sustainable Food Security in the Sahel of Northern Nigeria.

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

I have read the information presented in the information letter about a study being conducted by Sunday Olusanya Fayanju at the School of Business and Law, London Metropolitan University. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted. **I was informed that participation in the study is voluntary and that I can withdraw this consent at any time before publications are submitted without any penalty by advising the researcher.**

I am aware that I have the option of allowing my interviews and participation in the focus group session to be audio recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous.

Please note that this study has been reviewed and approved by the London Metropolitan University Research Ethics Board. If you have concerns or questions about your rights as a research participant, please contact the Ethics Approval Board at …………

I agree, of my own free will to participate in this study.

☐ YES

☐ NO

I agree to be audio recorded during this study.

☐ YES

☐ NO

I agree to the use of anonymous quotations from me in any thesis, presentation or publication that comes of this research.

☐ YES

☐ NO

Participant's Name:

Participant's Signature: Date:

Participant's Contact Information:

Witness Signature: Date:

When this study is completed, we will write a summary of the results. Would you be interested in receiving a copy?

☐ YES, please e-mail me a summary of the results. My e-mail address is:

☐ YES, please mail me a summary of the results. My mailing address is:

☐ NO, I do not wish to receive a summary of the results.

Appendix A5: Questionnaire and Adapted Food Security Modules

1. Household's food security status assessment questionnaire on household

Introduction

Good day/Sannu. My name is Sunday Olusanya Fayanju, a PhD candidate carrying out a study on Effects of Rainfall Variability on Sustainable Food Security in the Sahel (Borno State) of Northern, Nigeria. This study is for PhD research in Sustainable Food Security, School of Business and Law, London Metropolitan University, United Kingdom. I am asking households for detailed information on their food security status. Your responses to the questions are purely for academic purposes and will be treated confidentially and anonymous too. You may choose not to answer or stop at any point in the discussion. Declining to participate will not in any way affect you or any member of your family. We intend to get honest answers from you.

Thanks for your kind cooperation.

MODULE 1: Household characteristics

1) Date and time of interview -----------------
2) Local government ………………
3) Household size i.e. the number of people in the house ………………...
4) Household with dependant i.e. with children below 18years of age [ ],household without dependant [ ]
5) Gender of the household head (a) male [ ] (b) female [ ]
6) Age of the household head …………
7) Marital status of the household head (a) single [ ] (b) married [ ] (c) widowed/divorced [ ]
8) Number of years spent in formal education (school) by the household head ………….
9) The educational qualification of the head of the females in the household (a) no education [ ] (b) first school leaving [ ] (c) O level [ ] (d) NCE/OND [ ] (e) first degree/HND (f) post graduate certificate [ ]
10) Primary/major occupation of the household head (tick against the correct answer)

Civil Servant	Farmer	Private Sector Employed	Artisan	Trader	Student	Unemployed	Others Specify

11) Does the household head have another (secondary) occupation (a) yes [ ] (b) no [ ] If yes tick against the correct answer.

Civil Servant	Farmer	Private Sector Employed	Artisan	Trader	Student	Unemployed	Others Specify

12. The total monthly income of the household (a) 0 - N50,000 [ ] (b) N50,000 - N100,000 [ ]
(c) Above N100,000 [ ].
12a. The number of income earners in the household (a) 0 - #50,000 [ ] (b) N50,000 - N100,000 [ ] (c) Above N100,000 [ ]
12b. How much does the head of the females in the house earn/month..............................
12c. The total monthly expenditure of the household (a) 25% [ ] (b) 50%[ ] (c) 75%[ ] (d) 100%[ ]
13. The amount spent on food for the household in the last one month ………….
14. On which class of food does the household spend the most (a) Cereal, root and tubers, and staple grains [ ] (b) processed food [ ] (c) meat, fish, egg and milk [ ] (d) fresh fruit and vegetables [ ] (e) others, specify..................

Section 1: Shocks; Crisis and Climate Change Evidences/Events experienced in the last 12 months
15. Identify the weather extreme event experienced by your household by ticking P

Extreme Events	Yes
1. Massive floods/ Storm surges	
2. Heat wave	
3. Drying of rivers and stream	
4. Outbreak of pests/ disease	
5. Erratic rainfall pattern	

6. Long period of dry season /harmattan	
7. Heavy and long period of rainfall	
8. Other specify	

Has your household experienced any conflict either religious, ethnic conflict or political in the last 12 months (a) yes [ ] (b) No [ ]

16. Section Two: Resource

a. Does your household own Land (a) yes [ ] (b) no [ ]. If yes how many plots …….

b. Does the household have access to:

- farm/ other productive technology (a) yes [ ] (b) no [ ]
- Drinkable water (a) yes [ ] (b) no [ ]. If yes, is the distance from the house less than 1 km
  (a) yes [ ] (b) no [ ].
- Free drinking water from the borehole i.e. not bought (a) yes [ ] (b) no [ ]
- Paved roads (a) yes [ ] (b) no [ ]
- Credit (a) yes [ ] (b) no [ ]
- Information through phones, TV, radio or extension agents (a) yes [ ] (b) no [ ]
- Markets (a) yes [ ] (b) no [ ]
- Free medical care yes [ ] (b) no [ ]
- Electricity (a) yes [ ] (b) no [ ]

Module 2: Household Food Insecurity Access scale questions

In the last 1 months, that is about 4 weeks (did (I/ we)) because of lack of resources (money to purchase, food from garden or farm, from store or any other household usual means). If yes, how often did it happen?

No	Occurrence Questions	Tick if yes	How often does it happen	How many days

1.	Did you worry that your household would not have enough food?			
2.	Were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?			
3.	Did you or any household member have to eat a limited/few varieties of foods due to a lack of resources?			
4.	Did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?			
5.	Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?			
6.	Did you or any household member have to eat fewer meals in a day i.e., skip meal because there was not enough food?			
7.	Was there ever no food to eat of any kind in your household because of lack of resources to get food?			
8.	Did you or any household member go to sleep at night hungry because there was not enough food?			
9.	Did you or any household member go a whole day and night without eating anything because there was not enough food?			

Input, 1, or, 2, or 3 under the frequency of occurrence.

1 = rarely (once or twice in the past four weeks), 2 = Sometimes (three to ten times in the past four weeks), 3 = Often (more than ten times in the past four weeks). Days: ½ to 28 days

Module 3: Household Food Insecurity Coping Strategies

Identify the food insecurity coping strategies of your household in the last 7 days. Tick against it.

Food insecurity coping strategies	Tick	No of days/week
a. Rely on less preferred and less expensive foods		
b. Borrow food, or rely on help from a friend or relative		
c. Purchase food on credit		
d. Gather wild food, hunt, or harvest immature crops		
e. Send household members to eat elsewhere, such as neighbours, friends or relatives house		
f. Send household members to beg		
g. Consume seed stock held for next season		
h. Limit portion size at mealtimes		
i. Restrict consumption of adults in order for small children to eat		
j. Feed working members of HH at the expense of non-working members		
k. Ration the money you had and buy prepared food		
l. Reduce number of meals eaten in a day		
m. Skip entire days without eating		

Module 4: DDS questions

In the last 24 hours what did your household eat for:

Breakfast	Snack	Lunch	Snack	Dinner	Snack

Question Number	Food group	Examples	Yes = 1 No = 0
1	Cereals	corn/maize, rice, wheat, sorghum, millet or any other grains or foods made from these (e.g. bread, noodles, porridge or other grain products)	
2	White roots and tubers	white potatoes, yam, cassava, or other foods made from these roots (e.g. *alibo, garri, fufu, tuwo*)	
3	Vitamins A rich Vegetables and tubers	pumpkin, carrot, squash, or sweet potato that are orange in colour inside + other locally available vitamin A rich vegetables (e.g. red/ yellow sweet pepper,	
4	Dark green leafy vegetables	dark green leafy vegetables, including wild forms + locally available vitamin A rich leaves such as Amaranth, cassava leaves, *yakwa/zogole* (Moringa), fluted pumpkin, pumpkin leave, garden egg leave , utazi, okazi, bitter leave, oziza, spinach, Ayoyo, oha, Uturukpa.	
5	Other Vegetables	other vegetables (e.g. tomato, onion, eggplant, garlic) + other locally available vegetables	
6	Vitamin A rich Fruits	ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya (pawpaw), dried peach, and 100% fruit juice made from these + other locally available vitamin A rich fruits, palm fruit, palm oil.	
7	Other Fruits	other fruits, e.g. *debino, gingiya*, including wild fruits and 100% fruit juice made from these	
8	Organ meat	liver, kidney, Intestine, heart or other organ meats or blood-based foods	

9	Flesh meats	Beef, pork, lamb, goat, rabbit, game, turkey, guinea fowl, chicken, duck, other birds, and. insects (termites, locust, crickets).	
10	Eggs	Eggs from chicken, quail, duck, guinea	
11	Fish and seafood	Fresh or dried fish or shellfish, crayfish, prawns, lobster, crab, shellfish and other sea foods	
12	Legumes, nuts and seeds	Dried beans, dried peas, palm kernel nut, beniseed, lentils (pigeon pea), nuts, walnut, Ukwa, Barbara nut, groundnut, Aya seed, seeds or foods made from these (e.g. *moi-moi, akara, Kunu gida*, peanut butter)	
13	Milk and milk products	Milk, cheese, yogurt or other milk products like nunu or fresh milk	
14	Oil and fat	Margarine, butter, vegetable oil, bleached palm oil, beniseed oil groundnut oil, olive oil, sunflower oil etc.	
15	Sweets	Sweets Sugar cane, sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes	
16	Spices condiments, Beverages	Black pepper, salt, condiments (soy sauce, Maggi cube, Royco cube, Knor, Jumbo, Ajino moto, hot sauce, Uda, and other local spices etc.), coffee, tea, alcoholic beverages.	

Did you or anyone in your household eat any food OUTSIDE the home yesterday? yes [ ], no [ ] ,

if yes where did the person eat from (a) street food [ ] (b) Restaurant [ ] (c) local food kiosk [ ] (d) food relief/ aid project [ ] (e) others ....

Item Number	Item	Tick
A	Rely on less preferred and less expensive foods (less exp)	
B	Borrow food, or rely on help from a friend or relative (borrow)	
C	Purchase food on credit (credit)	
D	Working (house chore, farm) in exchange for meal	
E	Attending uninvited occasions e.g., wedding, burial, naming ceremony etc. to eat food	
F	Wild food hunt (wild)	
G	Consume seed stock held for next season (stock)	
H	Send household members to eat elsewhere, Such as neighbours, friends or relatives house (elsewhere)	
I	Send household members to beg (beg)	
J	Limit portion size at mealtimes (limit)	
K	Restrict consumption of adults in order for small children to eat (restrict)	
L	Feed working members of household at the expense of non-working members working	
M	Ration the money you had and buy prepared food (ration)	
N	Reduce number of meals eaten in a day (reduce)	
O	Skip entire days without eating (skip)	
P	Stealing food	
Q	Prostitution to get money for food or food stuff in exchange	
R	Selling of assets e.g. jewelling, cloths, phones, land, or other productive assets	

What is the primary source of your food?

1= Own production, gathering, hunting, fishing [ ],

2= Purchased [ ],

3= Borrowed, bartered, exchanged for labour, gift from friends or relatives [ ],

4= Food aid [ ],

5= other ………..

2. Questions adaptation tables

(I) Identified Food Coping Strategies in Borno State

(ii) CSI ranking by focus groups

	Food insecurity coping strategies	Focus group ($f_{1..7}$) ranking of each strategy								
		F1	F2	F3	F4	F5	F6	F7	Av.	Rank
A	Rely on less preferred and less expensive	1	1	1	1	1	1	1	1	1
B	Borrow food, or rely on help from a friend (borrow)	3	2	2	2	2	2	2	2.1	2
C	Purchase food on credit (credit)	2	1	2	2	2	2	2	1.9	2
D	Working (house chore, farm) in exchange for meal or money to buy food	4	3	3	3	4	4	4	3.6	4
E	Attending uninvited occasions e.g. wedding, burial, naming ceremony etc. to eat food	1	1	2	2	2	2	1	1.6	2
F	Wild food hunt (wild)	3	3	3	4	3	2	3	3	3
G	Consume seed stock held for next season (stock)	3	3	3	3	3	3	3	3	3
H	Send household members to eat elsewhere, e.g. neighbours, friends, or relatives house	3	2	2	3	4	3	3	2.9	3
I	Send household members to beg for food (beg)	4	4	4	4	4	4	4	4	4
J	Limit portion size at mealtimes (limit)	1	1	1	1	1	1	1	1	1
K	Restrict consumption of adults in order for small children to eat (restrict)	2	1	2	2	1	1	2	1.6	2
L	Feed working members of household at the expense of non-working members (working)	2	3	3	3	3	3	2	2.7	3
M	Ration the money you had and buy prepared food (ration)	1	1	1	2	1	1	1	1.1	1

N	Reduce number of meals eaten in a day	1	2	1	1	1	1	1	1.1	1
O	Skip entire days without eating (skip)	3	4	4	4	3	4	4	3.7	4

(iii) Adaptation of HFIAS Keywords

Keyword	Interpretation
Lack of Resources	No food or money to get the food
Household	People living and eating together for at least 4 days a week, and having a sense of belonging together. May live in different roof but the same vicinity and under a household head.
Worry	Anxiety and uncertainty about not having enough food. Having fear or anxiety on how you will manage the household feeding.
Less Preferred Food	The food that household would not have chosen if the choice is open and affordable. To Borno that could be: eating very low grade, almost spoiling or dried but cheap vegetable and fruits like broken fresh tomatoes which the well to-do people do not buy; eating without meat or fish; taking tea without milk, not out of choice or medical advice but lack.
Limited/Few Varieties	Eating monotonous diet. For Borno, it is like eating *tuwo masara* (corn food) or drinking *Kunu* (drink made from corn) morning, afternoon and may be night because you have little or no choice, even when you know it is an unbalance diet.
Smaller meal	Eating less quantity of food than satisfies you. (when you no chop belle full) i.e. when you did not eat to your satisfaction, because the food or money to buy food was not enough
Fewer meals	Skipping meals. Instead of the 3 good (square meals) meals/day that is common to Nigerians, you ate once or twice/day, not during fasting as a religious activity, but due to lack of food and money to buy food
No food in the household	This needed no explanation
Sleep without food	Going to bed at night hungry, without supper or dinner and not even a snack. But you may have eaten in the morning or afternoon, but could not afford to eat night food and you went to bed hungry.
Whole day & night without food	Did not eat food from morning as you woke up till night when you went to bed Whole day

Appendix A6: FDG Questionnaire

Socio-Economic and demographic Information

Name of Interviewer: ____

Date of FGD: ____

Location (Community/LGA): ____

Number of participants: Male ______ Female _______ Total ________

Household Number: <1☐ 1-5☐ 6-10☐ 11+☐

Do you have any other source of income other than agriculture? Yes☐ No☐

If yes, please specify

.____

____

____

Agricultural Systems

Agricultural type practiced. Rainfed☐ Irrigation☐

Farming Types

Crop Farming ☐

Pastoral Farming ☐

Mixed Farming (Agro pastoral Farming)☐

Nomadic pastoralism ☐

Other, please specify.

____

____

____

Farming Systems Used

Multiple cropping ☐

Irrigation ☐

Monoculture ☐

Fertilizer use ☐

Others, please specify.

____

____

____

Crops/Cattle Types

Millet ☐

Sorghum ☐

Maize ☐

Groundnut ☐

Cattle Types: Sheep ☐ Goats ☐ Cows ☐ Horses ☐ Donkey ☐

Others, please specify

____

____

____

Have there been changes in crop production over the past 30 years?

Increase ☐ Decrease ☐ No change ☐

Please specify reasons for the above response.

Increases: ____

Decreases: ____

No changes: ____

State of Knowledge of Farmers on Climatic Variability and Change:

Temperature

Have you noticed any long-term changes in the mean temperature over the past 30 years? Yes ☐ No ☐

Has the number of hot days changed?

Increased ☐ Decreased ☐ No changes ☐

Please specify reasons for the above responses.

Increased: ____

Decreased: ____

No changes: ____

Rainfall

Have you noticed any long-term changes in the mean rainfall over the past 30 years?

Yes No ☐ ☐

Has the number of rainfall days changed?

Increased ☐ Decreased ☐ No changes ☐

Please specify reasons for the above responses.

Increased: ____

Decreased: ____

No changes: ____

What could account for the changes in crop production over the past year?

Climatic changes ☐ Other factors ☐ Don't know ☐

What is climatic variable that strongly affects your agricultural production? (depending on 3.3)

Extreme temperature ☐

Weak rainfall ☐

Variation in rainfall ☐

Change in the start of the rainy season ☐

Others, please specify.

____

____

Adaptation Measures

Have you adapted to or try to adapt to current climatic variation?

Yes ☐ No ☐

If "Yes", what are some of the adaptation strategies you have so far adopted?

A. Change of planting dates ☐
B. Change crop varieties ☐
C. Movement to different sites ☐
D. Switching from crops to livestock ☐
E. Switching from livestock to crops ☐
F. Reduction in number of livestock ☐
G. Reduction in cultivated land ☐
H. Increase in land area cultivated ☐
I. Use of water conservation techniques ☐
J. Implementation of soil conservation techniques ☐
K. Use of irrigation ☐

L. Use of shades and shelters ☐
M. Rural urban migration ☐
N. Use of insurance ☐
O. Search for off farming jobs ☐
P. Religious beliefs or prayers ☐
Q. Change use of chemical fertilizers, pesticides and insecticides ☐
R. Other adaptation techniques ☐

____

____

____

What are some of the constraints in adapting to climatic variability and change?

A. Limited awareness or information ☐
B. Poverty ☐
C. Low level of technology ☐
D. Shortages of labour inputs ☐
E. Poor soils ☐
F. Lack of water ☐
G. Shortages of land for cultivation ☐
H. Mention others ☐

____

____

____

What other adaptation options could you recommend for policy implications?

A. ____
B. ____
C. ____
D. ____
E. ____
F. ____

Security challenges questions

Have you experienced any challenges going to farm because of security issues?

Yes No ☐ ☐

Have you ever suffered any attack or wanton destruction of your farmland from bandits?

Yes No ☐ ☐

How do you circumvent the challenges if any?

If you wish to be informed of the results of this research, please indicate either your email address, telephone number or postal address below:

Appendix A7: FDG Data from KoboToolbox

	Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8
	start	13:52:58	14:55:35	15:35:52	13:28:17	15:57:30		
	end	14:34:43	15:10:46	15:50:34	15:57:30	16:32:20		
	Duration	00:41:46	00:15:12	00:14:42	02:29:12	00:34:51	00:51:08	
	today	2023-10-31	2023-10-31	2023-10-31	2023-10-31	2023-10-31		
	Good day/Sannu. My name is Sunday	OK	OK	OK	OK			
	Name of Interviewer	Aisha Bello	Abubakar Sadiq Ahmad	Abubakar Sadiq Ahmad	Abubakar Sadiq Ahmad	Sandra		
	Date of FGD	2023-10-31	2023-10-31	2023-10-31	2023-10-31	2023-10-31		
	Location |Community/LGA|	Laide Bubakari/Girie	Laide Fulani/Girie	laide Gari/Girie	Bajabure/Girie LGA	Vulnoklang/Girie local government		
	Coordinate			9.311624 12.461097 181	9.311592 12.460987 181.3098168693336 10.1627126633822562			
	_Coordinate_latitude			9.311624	9.311592			
	_Coordinate_longitude			12.461097	12.460987			
	_Coordinate_altitude			181.416995 2	181.3098169			
	_Coordinate_precision			29.92578387	10.1627 1266		TOTAL RESPONSE	PERCENTAGE
	Number of Female Participants	8	4			0	12	30
	Number of Male Participants	0	4	8	8	8	28	70
Demographics	""1.1 Household Number""						0	0
	""Number of response""						0	0
	##### c1						0	0
	<span style="display:none">row-Nur	0	0	0	0	8	0	0
	##### 1-5						0	0
	<span style="display:none">row_1-N	0	0	0	0	0	0	0
	##### 6-10						0	0
	<span style="display:none">row_2-N	5	8	8	8	0	0	0
	##### 11+						0	0
	<span style="display:none">row_3-N	3	0	0	0	0	0	0
	""1.2 Do you have any other source of income other than agriculture?""						0	0
	""No of response""						0	0
	##### Yes						0	0
	<span style="display:none">row-No	8	5	6	1	2	22	55
	##### No						0	0
	<span style="display:none">row_1-N	0	4	2	7	6	19	47.5
	If Yes, please specify		Business	Business	Student	Business	0	0
Agricultural Systems	""2.1 Agriculture type practiced""						0	0
	""Number of response""						0	0
	##### Rainfed						0	0
	<span style="display:none">row-Nur	8	8	8	8	8	40	100
	##### Irrigation						0	0
	<span style="display:none">row_1-N	8	8	8	8	8	40	100
	""2.2 Farming types""						0	0
	""Number of response""						0	0
	##### Crop farming						0	0
	<span style="display:none">Crop_fa	8	0	0	0	8	16	40
	##### Pastoral Farming						0	0
	<span style="display:none">row-Nur	8	0	0	0	0	8	20
	##### Mixed farming (agro-pastoral)						0	0
	<span style="display:none">row_1-N	8	8	8	8	8	40	100
	##### Nomadic pastoralism						0	0
	<span style="display:none">row_2-N	0	0	0	0	0	0	0
	""2.3 Farming Systems Used""						0	0
	""Number of response""						0	0
	##### Multiple cropping						0	0
	<span style="display:none">row-Nur	8	8	8	8	8	40	100
	##### Irrigation						0	0
	<span style="display:none">row_1-N	8	0	0	0	0	8	20
	##### Monoculture						0	0
	<span style="display:none">row_2-N	8	0	0	0	0	8	20
	##### Fertilizer Use						0	0
	<span style="display:none">row_3-N	8	0	0	0	8	16	40
	Others, please specify	Animal dung				0	0	0
	""2.3.1 Crops Types""						0	0
	""Number of response""						0	0
	##### Millet						0	0
	<span style="display:none">row-Nur	0	8	8	8	8	32	80
	##### Sorghum						0	0
	<span style="display:none">row_1-N	2	0	0	0	0	2	5
	##### Maize						0	0
	<span style="display:none">row_2-N	8	8	8	8	8	40	100
	##### Groundnut						0	0
	<span style="display:none">row_3-N	8	0	0	0	2	10	25
	Others, please specify	Beans, soya beans, E	Rice 8	Rice 5		8	0	0
	""2.3.2 Cattle type""						0	0
	""Number of response""						0	0
	##### Sheep						0	0
	<span style="display:none">row-Nur	2	4	8	1	5	20	50
	##### Goats						0	0
	<span style="display:none">row_1-N	8	3	6	3	5	25	62.5
	##### Cows						0	0
	<span style="display:none">row_2-N	2	2	2	3	2	11	27.5
	##### Horses						0	0
	<span style="display:none">row_3-N	0	0	2	0	0	2	5
	##### Donkey						0	0
	<span style="display:none">row_4-N	0	0	0	0	0	0	0
	Others, please specify	Duck,chicken,turkey			Chicken2	0	0	0
	""2.4 Have there been changes in crop production over the past 30 years?""						0	0
	""Number of response""						0	0
	##### Increase						0	0
	<span style="display:none">row-Nur	2	0	8	0	0	10	25
	##### Decrease						0	0
	<span style="display:none">row_1-N	6	8	0	8	8	30	75
	##### No change						0	0
	<span style="display:none">row_2-N	0	0	0	0	8	8	20
	""Specify reasons if""						0	0
	""Reason""						0	0
	##### Increase						0	0
	<span style="display:none">row-Rea	Rainfall for early planters		Climate		0	0	0
	##### Decrease						0	0
	<span style="display:none">row_1-R	Drought, floods, hik	Drought		Lack of finance	Climate change, lack o	0	0
	##### No change						0	0
	<span style="display:none">row_2-R	0				0	0	0

Climatic variability	""3.1.1 Have you noticed any long-term changes in the mean temperature over the past 30 years?""						0	0
	"" Number of response ""						0	0
	###### Yes						0	0
	<span style="display:none">row-Nur	8	8	8	8	8	40	100
	###### No						0	0
	<span style="display:none">row_1-N	0	0	0	0	0	0	0
	""3.1.2 Has the number of hot days changed?""						0	0
	"" Number of response ""						0	0
	###### Increased						0	0
	<span style="display:none">row-Nur	8	8	0	8	8	32	80
	###### Decreased						0	0
	<span style="display:none">row_1-N	0	0	8	0	0	8	20
	###### No changes						0	0
	<span style="display:none">row_2-N	0	0	0	0	0	0	0
	"" Please specify reasons for the above responses ""						0	0
	"" Reason ""						0	0
	###### Increased						0	0
	<span style="display:none">row-Rea	Raining seasons sto	Climate change		Climate change		0	0
	###### Decreased						0	0
	<span style="display:none">row_1-R	0	No	Climate change			0	0
	###### No changes						0	0
	<span style="display:none">row_2-R	0					0	0
	""3.2.1. Have you noticed any long-term changes in the mean rainfall over the past 30 years?""						0	0
	"" Number of response ""						0	0
	###### Yes						0	0
	<span style="display:none">row-Nur	6	8	8	8	8	38	95
	###### No						0	0
	<span style="display:none">row_1-N	2	0	0	0	0	2	5
	""3.2.2 Has the number of rainfall days changed?""						0	0
	"" Number of response ""						0	0
	###### Increased						0	0
	<span style="display:none">row-Nur	0	8	0	0	8	16	40
	###### Decreased						0	0
	<span style="display:none">row_1-N	8	0	8	8	0	24	60
	###### No changes						0	0
	<span style="display:none">row_2-N	0	0	0	0	0	0	0
	"" Please specify reasons for the above question""						0	0
	"" Reason ""						0	0
	###### Increased						0	0
	<span style="display:none">row-Rea	Nature, God's creation, deforestation					0	0
	###### Decreased						0	0
	<span style="display:none">row_1-R	0	Climate change	Climate change	Climate change	Climate change	0	0
	###### No changes						0	0
	<span style="display:none">row_2-R	0					0	0
	""3.3 What could account for the changes in crop production over the past year?""						0	0
	"" Number of response ""						0	0
	######Climatic changes						0	0
	<span style="display:none">row-Nur	5	8	8	8	8	37	92.5
	######Other factors						0	0
	<span style="display:none">row_1-N	3	0	0	0	0	3	7.5
	###### Don't know						0	0
	<span style="display:none">row_2-N	0	0	0	0	0	0	0
	""3.4 What is climatic variable that strongly affects your agricultural production? (depending on 3.3)""						0	0
	"" Number of response ""						0	0
	###### Extreme temperature						0	0
	<span style="display:none">row-Nur	3	0	8	0	8	19	47.5
	######Weak rainfall						0	0
	<span style="display:none">row_1-N	6	8	8	8	8	38	95
	###### Variation in rainfall						0	0
	<span style="display:none">row_2-N	8	0	0	0	0	8	20
	######Change in the start of the rainy season						0	0
	<span style="display:none">row_3-N	7	8	0	0	0	15	37.5
	Others, please specify						0	0
Adaptation	""4.1 Have you adapted to or try to adapt to current climatic variation?""						0	0
	"" Number of response ""						0	0
	###### Yes						0	0
	<span style="display:none">row-Nur	7	8	0	0	8	23	57.5
	###### No						0	0
	<span style="display:none">row_1-N	1	0	8	8	0	17	42.5
	""4.1.1 If "Yes", what are some of the adaptation strategies you have so far adopted?""						0	0
	"" Number of response ""						0	0
	###### B. Change crop varieties						0	0
	<span style="display:none">row_1-N	6	8				14	35
	######O.Search for off farming jobs						0	0
	<span style="display:none">row_14-	0					0	0
	###### I.Use of water conservation techniques						0	0
	<span style="display:none">row_8-N	5					5	12.5
	###### L.Use of shades and shelters						0	0
	<span style="display:none">row_11-	0					0	0
	######G.Reduction in cultivated land						0	0
	<span style="display:none">row_6-N	0					0	0
	######Q.Change use of chemical fertilizers, pesticides and insecticides						0	0
	<span style="display:none">row_16-	2					2	5
	###### P.Religious beliefs or prayers						0	0
	<span style="display:none">row_15-	9					9	22.5
	######C. Movement to different sites						0	0
	<span style="display:none">row_2-N	8					8	20
	###### D. Switching from crops to livestock						0	0
	<span style="display:none">row_3-N	0					0	0
	###### F.Reduction in number of livestock						0	0
	<span style="display:none">row_5-N	0					0	0
	######J.Implementation of soil conservation techniques						0	0
	<span style="display:none">row_9-N	8					8	20
	###### E. Switching from livestock to crops						0	0
	<span style="display:none">row_4-N	0					0	0
	###### M. Rural urban migration						0	0
	<span style="display:none">row_12-	0					0	0
	###### N.Use of insurance						0	0
	<span style="display:none">row_13-	0					0	0
	###### K.Use of irrigation						0	0
	<span style="display:none">row_10-	8					8	20
	###### A. Change of planting dates						0	0
	<span style="display:none">row-Nur	8					8	20
	###### H.Increase in land area cultivated						0	0
	<span style="display:none">row_7-N	8					8	20
	Other Adaptation techniques	0					0	0
	""4.2 What are some of the constraints in adapting to climatic variability and change?""						0	0
	"" Number of response ""						0	0
	######A.Limited awareness or information						0	0
	<span style="display:none">row-Nur	8	0	8	8	3	27	67.5
	###### B.Poverty						0	0
	<span style="display:none">row_1-N	8	8	8	8	5	37	92.5
	######C.Low level of technology						0	0
	<span style="display:none">row_2-N	7	0	0	0	0	7	17.5
	###### D.Shortages of labour inputs						0	0
	<span style="display:none">row_3-N	0	0	0	0	0	0	0
	###### E.Poor soils						0	0
	<span style="display:none">row_4-N	8	8	0	0	0	16	40
	###### F.Lack of water						0	0
	<span style="display:none">row_5-N	7	8	8	0	0	23	57.5
	######G. Shortages of land for cultivation						0	0
	<span style="display:none">row_6-N	8	0	8	0	0	16	40
	Mention others	0					0	0
	4.3 What other adaptation options could you recommend for policy implications?				Tree planting		0	0

Security	**5.1 Have you experienced any challenges going to farm because of security issues?**						0	**0**
	Number of response						0	**0**
	##### Yes						0	**0**
	<span style="display:none">row-Nur	8	8	8	8	8	40	**100**
	##### No						0	**0**
	<span style="display:none">row 1-N	0	0	0	0	0	0	**0**
	**5.2 Have you ever suffered any attack or wanton destruction of your farmland from bandits? **						0	**0**
	Number of response						0	**0**
	##### Yes						0	**0**
	<span style="display:none">row-Nur	8	8	8	8	8	40	**100**
	##### No						0	**0**
	<span style="display:none">row_1-N	0	0	0	0	0	0	**0**
	5.3 How do you circumvent the chall	Report to village he	Non		Safeguarding the farms my themselves			
	If you wish to be informed of the results of this research, please indicate either your email address, telephone number or postal address below:							
	Use the camera to take a photo of th	image-14_33_4.jpg	image-15_8_12.jpg	IMG_5732-15_50_3.jpeg	image-14_10_14.jpg	IMG_5738-16_32_10.jpeg		
	Use the camera to take a photo of th	https://kc.kobotool	https://kc.kobotoolbox.or	https://kc.kobotoolbox.c	https://kc.kobotoolbox.o	https://kc.kobotoolbox.org/media/original?media_file=avatund%2Fa		
	Point and shoot! Use the camera to take a photo of the FGD Session							
	Point and shoot! Use the camera to take a photo of the FGD Session_URL							
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	_validation_status							
	_notes							
	_status	submitted_via_web	submitted_via_web	submitted_via_web	submitted_via_web	submitted_via_web		
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	__version__	vB47AXBJtuTvaFyzi	vB47AXBJtuTvaFyziqYMFJ	vB47AXBJtuTvaFyziqYMF	vB47AXBJtuTvaFyziqYMFJ	vB47AXBJtuTvaFyziqYMFJ		
	_tags							
	_index	1	2	4	5	6		

Appendix A8: Food security analysis

	DESCRIPTIVE STATISTICS		
	foodsecurityirt.MOD1HH		
	February 22, 2022 23:40:27		
	hhsize		
==============================			
	Statistic	Value	

N	398		
Valid N	398		
Min	1		
Max	35		
Mean	7.0653		
Std. Dev.	4.3046		
Skewness	1.8206		
Kurtosis	5.7939		
First Quart	4		
Median	6		
Third Quar	9		
IQR	5		
==============================			
	m1q6		
==============================			
	Statistic	Value	

N	398		
Valid N	398		
Min	18		
Max	85		
Mean	42.3744		
Std. Dev.	11.9203		
Skewness	0.6005		
Kurtosis	0.2053		
First Quart	32		
Median	40		
Third Quar	50		
IQR	18		
==============================			
	m1q8		
==============================			
	Statistic	Value	

N	398		
Valid N	398		
Min	0		
Max	24		
Mean	8.3995		
Std. Dev.	6.6831		
Skewness	-0.0721		
Kurtosis	-1.4374		
First Quart	0		
Median	10		
Third Quar	15		
IQR	15		
==============================			

	m1q12a		
==============================			
	Statistic	Value	

N	398		
Valid N	398		
Min	0		
Max	6		
Mean	1.593		
Std. Dev.	0.8518		
Skewness	1.3541		
Kurtosis	2.6066		
First Quart	1		
Median	1		
Third Quar	2		
IQR	1		
==============================			
	m1q12b		
==============================			
	Statistic	Value	

N	398		
Valid N	398		
Min	0		
Max	100000		
Mean	7727.638		
Std. Dev.	13576.2		
Skewness	3.0968		
Kurtosis	12.2272		
First Quart	0		
Median	0		
Third Quar	10000		
IQR	10000		
==============================			

	m1q13		
==============================			
	Statistic	Value	

N	398		
Valid N	398		
Min	5000		
Max	100000		
Mean	32626.4		
Std. Dev.	15081.13		
Skewness	0.9417		
Kurtosis	1.8104		
First Quart	20000		
Median	30000		
Third Quar	40000		
IQR	20000		
==============================			

FREQUENCY ANALYSIS

foodsecurityirt.MOD1HH

February 2 23:34:09

m1q4 Household with dependant i.e. with children below 18years of age

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq	Cum. Pct.
1	Yes	354	88.9447	88.9447	354	88.9447
2	No	44	11.0553	11.0553	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

m1q5 Gender of the household head

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq	Cum. Pct.
1	Male	355	89.196	89.196	355	89.196
2	Female	43	10.804	10.804	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

m1q7 Marital status of the household head

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq	Cum. Pct.
1	Single	4	1.005	1.005	4	1.005
2	Married	358	89.9497	89.9497	362	90.9548
3	Widowed/	36	9.0452	9.0452	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

m1q9 The educational qualification of the head of the females in the household

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq	Cum. Pct.
1	No educat	127	31.9095	31.9095	127	31.9095
2	FSLC	45	11.3065	11.3065	172	43.2161
3	O' Level	93	23.3668	23.3668	265	66.5829
4	NCE/OND	77	19.3467	19.3467	342	85.9296
5	BSC/HND	51	12.8141	12.8141	393	98.7437
6	PG Cert	5	1.2563	1.2563	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

			m1q10	Primary/major occupation of the household head			
==							
Value	Descriptioi	Frequency	Percent	Valid Pct.	Cum. Freq.	Cum. Pct.	
--							
1	Civil Servai	91	22.8643	22.8643	91	22.8643	
2	Farmer	114	28.6432	28.6432	205	51.5075	
3	Private Sec	11	2.7638	2.7638	216	54.2714	
4	Artisan	19	4.7739	4.7739	235	59.0452	
5	Trader	122	30.6533	30.6533	357	89.6985	
6	Student	1	0.2513	0.2513	358	89.9497	
7	Unemploy	2	0.5025	0.5025	360	90.4523	
8	Other	38	9.5477	9.5477	398	100	
Valid Total		398	100	100			
Missing		0	0				
Grand Total		398	100				
==							

			m1q10_ot	Please specify			
==							
Value	Descriptioi	Frequency	Percent	Valid Pct.	Cum. Freq.	Cum. Pct.	
--							
Almajiri teacher		1	0.2513	2.6316	1	2.6316	
blacksmith		1	0.2513	2.6316	2	5.2632	
builders		2	0.5025	5.2632	4	10.5263	
business man		1	0.2513	2.6316	5	13.1579	
businessman		1	0.2513	2.6316	6	15.7895	
bussines		11	2.7638	28.9474	17	44.7368	
cement saler		1	0.2513	2.6316	18	47.3684	
deriving		1	0.2513	2.6316	19	50	
driver		2	0.5025	5.2632	21	55.2632	
driving		1	0.2513	2.6316	22	57.8947	
electrician		1	0.2513	2.6316	23	60.5263	
house maid		1	0.2513	2.6316	24	63.1579	
labour		4	1.005	10.5263	28	73.6842	
labourer		1	0.2513	2.6316	29	76.3158	
macanic		1	0.2513	2.6316	30	78.9474	
meat sellar		1	0.2513	2.6316	31	81.5789	
pastor		1	0.2513	2.6316	32	84.2105	
petty trader		1	0.2513	2.6316	33	86.8421	
qua'ranic teacher		1	0.2513	2.6316	34	89.4737	
tailoring		1	0.2513	2.6316	35	92.1053	
teacher		1	0.2513	2.6316	36	94.7368	
tricycle driver		1	0.2513	2.6316	37	97.3684	
tricycle rider		1	0.2513	2.6316	38	100	
Valid Total		38	9.5477	100			
Missing		360	90.4523				
Grand Total		398	100				
==							

m1q12 The total monthly income of the household

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq.	Cum. Pct.
1	NGN 0 - 5(	288	72.3618	72.3618	288	72.3618
2	NGN 50,0(	102	25.6281	25.6281	390	97.9899
3	Above NGI	8	2.0101	2.0101	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

m1q12a The number of income earners in the household

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq.	Cum. Pct.
0	None	8	2.0101	2.0101	8	2.0101
1	One	212	53.2663	53.2663	220	55.2764
2	Two	130	32.6633	32.6633	350	87.9397
3	Three	33	8.2915	8.2915	383	96.2312
4	Four	13	3.2663	3.2663	396	99.4975
5	Five	1	0.2513	0.2513	397	99.7487
6	Six	1	0.2513	0.2513	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

m1q12c The total monthly expenditure of the household

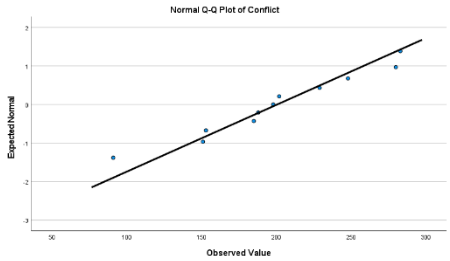
Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq.	Cum. Pct.
1	25%	14	3.5176	3.5176	14	3.5176
2	50%	98	24.6231	24.6231	112	28.1407
3	75%	159	39.9497	39.9497	271	68.0905
4	100%	127	31.9095	31.9095	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

m1q14 On which class of food does the household spend the most

Value	Descriptio	Frequency	Percent	Valid Pct.	Cum. Freq.	Cum. Pct.
1	Cereal, roc	301	75.6281	75.6281	301	75.6281
2	Processed	64	16.0804	16.0804	365	91.7085
3	Meat, fish,	13	3.2663	3.2663	378	94.9749
4	Fresh fruit	1	0.2513	0.2513	379	95.2261
5	Others, sp	19	4.7739	4.7739	398	100
Valid Total		398	100	100		
Missing		0	0			
Grand Total		398	100			

QID	QID Identification
STATE	State
LGA	LGA
EA	EA CODE
EAVERIFY	IS THE EA SELECTED COOREСТ (VERIFY IF THE EA SELECTED IS CORRECT)
HHNO	Household Serial No
SECTOR	SECTOR
PERM	MAY I BEGIN
NAME_HH	NAME OF HEAD OF HH
PHONENO	PHONE NUMBER OF HEAD
TEAM	TEAM NUMBER
INTNAME	INTERVIEWER NAME
HHSIZE	Household Size
M1Q4	Household with dependant i.e. with children below 18years of age
M1Q5	Gender of the household head
M1Q6	Age of the household head
M1Q7	Marital status of the household head
M1Q8	Number of years spent in formal education (school) by the household head
M1Q9	The educational qualification of the head of the females in the household
M1Q10	Primary/major occupation of the household head
M1Q10_O	Please specify
M1Q11	Does the household head have another (secondary) occupation
M1Q11B	If YES in Q11, what is the secondary occupation?
M1Q11_O	Please specify
M1Q12	The total monthly income of the household
M1Q12A	The number of income earners in the household
M1Q12B	How much does the head of the females in the house earn/month
M1Q12C	The total monthly expenditure of the household
M1Q13	The amount spent on food for the household in the last one month
M1Q14	On which class of food does the household spend the most
M1Q14_O	Please specify
M1Q15A	Identify the weather extreme event experienced by your household by ticking - Massive floods/ Storm surges
M1Q15B	Heat wave
M1Q15C	Drying of rivers and stream
M1Q15D	Outbreak of pests/ disease
M1Q15E	Erratic rainfall pattern
M1Q15F	Long period of dry season /harmattan
M1Q15G	Heavy and long period of rainfall
M1Q15H	Other specify
M1Q15HO	Please Specify
M1Q15I	Has your household experienced any conflict either religious, ethnic conflict or political in the last 12 months
M1Q16A	Does your household own Land
M1Q16A2	If YES, how many plots?
M1Q16B1	Does the household have access to: farm/ other productive technology
M1Q16B2	Drinkable water
M1Q16B2I	If YES, ?is the distance from the house less than 1 km?
M1Q16B3	Free drinking water from the borehole i.e. not bought
M1Q16B4	Paved roads
M1Q16B5	Credit
M1Q16B6	Information through phones, TV, radio or extension agents
M1Q16B7	Markets
M1Q16B8	Free medical care
M1Q16B9	Electricity
AgeNew	Age Group
EDUCYR	Educational Years
FMINC	Female Income

Appendix A9: Regression Analysis-Normality Test



Appendix A12: Regression Analysis- Coefficient Table

Coefficients

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	Collinearity Statistics Tolerance	VIF
1	(Constant)	623.708	3674.595		.170	.870		
	SPI	155.656	201.637	.312	.772	.465	.798	1.252
	Temperature	-11.885	128.935	-.035	-.092	.929	.914	1.094
	beanscowpea	.000	.002	-.045	-.116	.911	.858	1.165

a. Dependent Variable: Conflict

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	179.60	238.77	200.73	16.754	11
Residual	-96.162	81.505	.000	55.217	11
Std. Predicted Value	-1.261	2.271	.000	1.000	11
Std. Residual	-1.457	1.235	.000	.837	11

a. Dependent Variable: Conflict

Appendix A13: Bayesian Estimates

Bayesian Estimates of Coefficients[a,b,c]

Posterior				95% Credible Interval	
Parameter	Mode	Mean	Variance	Lower Bound	Upper Bound
(Intercept)	623.708	623.708	18903712.174	-8065.329	9312.746
SPI	155.656	155.656	56920.409	-321.139	632.452
Temperature	-11.885	-11.885	23273.808	-316.767	292.997
beanscowpea	.000	.000	.000	-.005	.004

a. Dependent Variable: Conflict

b. Model: (Intercept), SPI, Temperature, beanscowpea

c. Assume standard reference priors.