IMPACT OF CLIMATE VARIABILITY ON CEREAL CROP PRODUCTION IN NORTH CENTRAL STATES, NIGERIA

BY

MUSA, Musa
PhD/SPS/2017/1016

DEPARTMENT OF GEOGRAPHY
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

OCTOBER, 2021

ABSTRACT

Climate variability, its impacts and the associated vulnerabilities is a growing concern across the globe. It is believed to be one of the greatest impediments for achieving food security and sustainable crop production globally. The study investigated the impact of climate variability on cereal crop production in the North Central States of Nigeria. The specific objectives were examination of the trend and spatio-temporal variability in climatic variables (rainfall, temperature and relative humidity); examination of the trend in yield of the selected crops (Rice, Maize and Guinea corn); examination of the relationship between climatic variables and yield of the selected crops; analysis of the effect of daily extreme climatic indices on yield of the selected crops and identification of the adaptation and mitigation strategies to climate variability on crop yield. The study utilized climatic and crop yield data from Climate Prediction Center, Merged Analysis of Precipitation (CMAP) and Agricultural Development Projects (ADPs) and personal interview and questionnaire administration. Non-parametric test, Mann-Kendall test and Theil-Sen slope estimator (β) approach was used to analyse the spatio-temporal trend in climatic variables (Rainfall, Maximum Temperature, Minimum Temperature and Relative Humidity) and crop yield (Rice, Maize and Guinea corn) during the study period (1989 – 2018). Pearson Product Moment Correlation and Multiple Regression analysis were utilized in the examination of the strength of association between climatic variables and crop yield. Standardised extreme climatic indicators developed by Expert Team on Climate Change Detection and Indices (ETCCDI) under the World Meteorological Organization (WMO) were used to assess the effect of extreme climatic indices on crop yield. Descriptive statistics was used to analyse the questionnaires administered and interview schedule data. The results indicated that a downward trend existed in the monthly rainfall distribution in the study area especially at the onset of the rain in the month of May and an upward trend towards the cessation period in the month of October. On annual basis, there existed downward trend in rainfall in all the study locations except in Lafia where significant upward trend at alpha value of 0.001 was detected. It is evident that maximum 1-day rainfall (R1D) and maximum 5-day rainfall (R5D) correlated insignificantly with the three crops across the study areas. The variation in rainfall is between 0.09 mm yr^{-1} and 6.06 mm yr^{-1} within the rainy season months of May to October. The result of the crop-climate relationship indicated that rice yield at Abuja and Lafia was strong at 56 % and 54 %, respectively, while it was weak at Minna, Lokoja and Ilorin at 23 %, 27 % and 10 % respectively. For Maize, the result indicated weak relationship in all the study locations except at Lafia which was strong at 57 %. Guinea corn yield response to climate variability was weak over the study locations, it indicated 37 %, 40 %, 27 %, 24 % and 47 % in Minna, Lokoja, Abuja, Ilorin and Lafi stations, respectively; this is attributable to the fact that it is more tolerant to climatic extremes with much longer growing period than other crops studied. Conclusively, it is established that susceptibility of the yield of the selected cereal crop to the impact of climate variability occurred in the study area and each of the climatic variables impacted on the yield of the crops at different scales and level. It is therefore recommended that smart climate technologies and innovative practices for sustainability of yield of cereal crop be adopted in the face of current challenges of climate variability in the study area.

TABLE OF CONTENTS

CHAPTER ONE

1.0. INTRODUCTION

1.1. Background to the Study

Climate is traditionally defined as the description in terms of the mean and variability of relevant atmospheric variables such as temperature, precipitation and wind. Climate can thus be viewed as a synthesis or aggregate of weather. This implies that the portrayal of the climate in a particular region must contain an analysis of mean conditions, of the seasonal cycle, of the probability of extremes such as severe frost and storms. The World Meteorological Organization (WMO), considered thirty (30) or thirty-five (35) years as the standard number of years for carrying out the statistics used to define climate (Goose *et al.,* 2010).

The radiation energy of the sun, and its distribution and temporal fluctuation ultimately determines the climate of a region. The long-term condition of the atmosphere is a function of a range of interrelating elements. This include; temperature, solar radiation, rainfall, air masses (wind and storms), ocean current, pressure system, humidity, topography, cloudiness and visibility (Babasubramanian, 2017).

In recent time climate variability and change have been considered to be one of the most prominent universal environmental issues. For the period 1885 to 2013, the mean temperature of the globe increased by 0.84 ^{0}C and it is predicted to also increase further by 1.5 – 5.9 ^{0}C towards the end of the twenty-first century (IPCC, 2014). Developing nations are more susceptible to such changes as they have inadequate means of adaptation to the disasters and agriculture plays central role in their national economy (Majumder *et al*., 2016).

Anthropogenic causes of climate variability emanating from the rise in the amount of Green House Gases (GHGs) sent to the atmosphere and inadequacy in food supply are the major threat to human existence in the twenty- first century. The Inter-governmental Panel on Climate Change (IPCC) reported that the continuous emissions of GHGs released into the atmosphere from 1970 and 2004 contributed to the amount of the gases available in the atmosphere by 70 % (Omojolaibi, 2011). The major GHGs released into the atmosphere are Methane, Carbon Dioxide, Nitrous Oxide, Hydrofluorocarbon, Perflorocarbon and Carbon hexafluoride. Overtime Carbon dioxide continuously increased and has really contributed to over 45 % of the entire Green House Gas emissions (Odingo, 2009).

The impact of climate variability, its related vulnerabilities are emergent global concern. Climatic variability and extreme events are predicted to be on the rise in several regions and thus having substantial effects on food productions beyond the effects of changes in climatic means. This reliance is mostly critical for both food and cash crops (Akinseye *et al*., 2012).

In Nigeria, Agricultural activities plays a major role in the economic growth. It employs about 75 % of rural population in different aspect of agricultural production. It is also the sector that solely contributed about 40.07 % to the Country GDP in 2009 and it has continued in that trajectory up till date (Aye & Ater, 2012). The agriculture sector also is a pivot to the national food security by providing the highest proportion of the total national food consumption requirement. Several processing industries in Nigeria rely on the agricultural sector for their raw materials need. Conversely, agricultural productivity growth has been below expectation (Aye & Ater, 2012).

Agriculture primarily provides means of employment for most Nigerians. The sector provides more than one third of the total GDP (Kolawole & Ojo, 2007). The sector employs more than 70 % of the adult population in direct or indirect basis. Inter- annual and Intra-annual climate variability have increased in occurrence, duration and amplitude for the past 35 years. In recent past, there has been risen occurrences of extreme weather events such as drought, flood, risen heat waves and strong wind which have caused extensive damage to National agricultural production. (Singh & Kalra, 2016).

Cereal crops is in the family of the monocot 'Gramineae or Poaceae' and they are often grown extensively to get the parts that are edible of their seeds. These fruits are botanically called '*Caryopsis*' and are made up of endorsperm, brain and sperm (Ukwuru *et al*., 2018). Cereal crops provide the main dietary energy need for body and also supply substantial quantity of protein, minerals (potassium and calcium) and vitamins (vitamin A and C) (Idem & Showemimo, 2004). Cereals are essential foods that provide a substantial amount of energy (calories) and protein in human diet worldwide. Availability of cereals in human diet makes the nutritional qualities of cereals more vital to human health (Henry *et al*., 2016).

Cereals are consumed in different forms which include pastes, noodles, cakes, breads, drinks etc. in Nigeria, the rate of consumption depends on ethnicity and religion. After processing, the husk, bran, plant parts are valuable as feed for animals and in the culture of micro-organism. Gum and wax syrup are obtained from cereal crop for industrial usage. Various tribal groups in Nigeria rely on residue of cereal crops for diverse purposes (Ismaila *et al*., 2010)

The common cereals consumed in Nigeria are maize, rice, guinea corn, millet, wheat, pearl, fonio millet and sugarcane. The commonest of the cereal based on the level of consumption is rice. It is grown and used as "Tuwo cinkafa, masa" and is also prepared according to the preference of individuals (Egwin *et al.*, 2013). Maize crop on the other hand is a major crop utilized in various forms such as “Ogi”, a porridge cooked from maize fermentation. It is a common meal in Nigeria that is often used for weaning infant or as breakfast for many adults (Ismaila *et al.*, 2010). Guinea corn is among the most widely cultivated cereal crops and accounts for 50 % of the total cereal crops produced in Nigeria. It is widely grown both for food and as a feed grain and it constitutes a major source of calories and protein for millions of people in Africa (Onogwu *et al.*, 2018).

Ayinde *et al*. (2011) reported that climatic variability is driving Nigeria’s agriculture into major hazard and stress. This means that food availability and rural livelihood is facing severe threat as production of crops takes major part of agricultural practices. It is on the backdrop of this that the present study assessed the impact of climate variability on yield of the selected crops in the study area.

1.2. Statement of the Research Problem

The inter-connectivity between change in climate and agriculture are; risen average temperature, variation in the amount of rainfall, fluctuating pattern and increased concentration of atmospheric $CO_{2,}$ increased pollution level and variability in climate and extreme events occurrence such as flood, drought and storm. All these affects agricultural activities negatively particularly in vulnerable communities (David, 2011).

The analysed climatic data of Nigerian Meteorological Agency (NiMet) revealed that the climate in Nigeria has significant variability over the past century. (Abiodun *et al*., 2013). Though there is major inter-annual variability in the climate, diverse decadal trends are evidently visible. For example, between early 1950s to the late 1960s, there was prolong wet period, followed by drought decades of the 1980s and 1970s, the obvious reoccurrence of the above normal wetly conditions in the 1990s. These fluctuating climatic conditions underline Nigeria's susceptibility to the impact of extreme climate occurrence (Hassan *et al*., 2013).

Food security and crop yield are often considered to be the major factors for defining whether an individual, a household or a particular region attained food security. These pillars are impacted by the variability in climate. It was estimated that Nigeria has about 190 million inhabitants in the year 2017, the highest in African continent, nearly accounting for 48% of the whole population in Western Africa (Amaka *et al*., 2016). The country's food requirement increases as the population increases, whereas the capacity to grow food declined due to the effect of desertification, flooding and climate variability and change that is already affecting the already vulnerable resources and threatening food production. (Amaka *et al*., 2016).

The risen food demand is caused by increased population and industrialization. Conversely, the increased rate of consumption of food per head is a correspondingly major contributor to growth in the demand of food. These factors combined with climate variability and change compound to cause the main hindrance to food security globally (Henry *et al*., 2016).

Several evaluation of the impact of climate variability on crop production both at the global and local scale have been published, notable among them is the works of Aye and Ater (2012), Akintunde *et al*. (2013), Nwaiwu *et al.* (2015), Chabala *et al.* (2015), Wang *et al*. (2016), Suleiman *et al*. (2016), Srivastava *et al*. (2017), Kalu and Mbanasor (2017), Okringbo *et al*. (2017), Kumar and Sidana (2017), and Byakatonda *et al*. (2018). Previous studies on rainfall and temperature patterns in Nigeria had utilised parametric methods for example, Akinsanola and Ogunjobi (2014), Igwenagu (2015), Ogunrayi *et al.* (2016). The parametric methods is known to have constraints for analysing agro-climatic data as they need normally distributed data which is not usually the case for agro-climatic variables.

Though similar studies exist, but no documented evidence on how the crop yield responds when the stages of temperature and rainfall changes. The current classification of standardized extreme temperature and rainfall indicators by Expert Team on Climate Change Detection and Indices (ETCCDI) under the World Meteorological Organization (WMO) has not been adopted in crops-climate variable relationship. Therefore based on the shortcoming of the earlier methods and for more efficient and effective analysis the ETCDDI method is adopted in this research work to fill this gap in knowledge.

1.3. Justification for the Study

Impacts of climatic variability on crop yield are predicted to increase in the coming century. For instance, much of the changes in climate that will ultimately result from previous human actions have not occurred and the recent trends in these activities signify likely high increase in global change (Steven & Stephen, 2013).

In recent time, international pressures and concern have increased on the possible impact of climate variability and change on agricultural production and the environment (BNRCC, 2008; Apata *et al*., 2009). Furthermore, it was projected that the Nigerian food distribution will be threatened by rainfall and temperature fluctuations, particularly if the uncertainties are severe. (NEST, 2004).

Knowing the current and future climate trends, and enabling information on the likely duration and dynamics of climate variability provides opportunity for expansion of scope of knowledge on climate variable crop relationship

Evidently, climatic variability has strong effect on agriculture in Nigeria, particularly, crop production. The various mitigation measures by the government have stimulated huge investment on human and material resources at Federal, State and Local levels. Despite the effort by government at all level, the impact still persists and new trend continues to manifest. The study investigated the impact of climate variability on selected cereal crops in parts of North Central States, Nigeria. It identified suitable adaptation and mitigation measured that will aid public policy and guarantee improve crop productivity in the face of changing climate.

1.4. Scope and Limitation of the Study

The study was delimited to parts of North Central States. The study area covered Four States namely; Niger, Kogi, Nasarawa, Kwara, and Federal Capital Territory (FCT), Abuja. The study area lies between Latitude 7^0 48^1 N and 9^0 36^1 N and Longitude 4^0 32^1 and 8^0 30^1 E. It examined the impact of climate variability on cereal crop production (rice, maize and guinea corn). The study used climatic data and yield record of the selected crops for the period of thirty (30) years (1989 to 2018). Questionnaire and interview schedule was conducted in six adopted villages of the Agricultural Research Institutes within the study area.

The limitation of the study were inadequate funding and logistic during the field survey, high illiterate respondents and their negative attitude to questionnaire. Lack of documented evidence on indices for Relative Humidity to determine the response rate of the crops at various stages of changes in Relative Humidity was also considered as a limiting factor for this study.

1.5. Aim and Objective of the Study

The study assessed the impact of climate variability on cereal crops production in North-Central States, Nigeria.

The objectives were:

i. examination of the trend and spatio-temporal variability in climatic variables (rainfall, temperature and relative humidity) 1989 to 2018;
ii. examination of the trend in yield of the selected crops (Rice, Maize and Guinea corn);
iii. examination of the relationship between climatic variables and yield of the selected crops;
iv. analysis of the effect of daily extreme climatic indices on yield of the selected crops; and
v. identification of the mitigation and adaptation strategies to climate variability on crop yield.

1.6. Research Questions

i. To what extent are the climatic variables (rainfall, temperature and relative humidity) distributed over space and time?
ii. What are the trends in yield of the selected crops (Rice, Maize and Guinea corn)
iii. What is the relationship between climatic variables and yield of the selected crops?
iv. What are the effects of daily extreme climatic indices on yield of the selected crops?
v. What are the available mitigation and adaptation measures to climate variability on crop production?

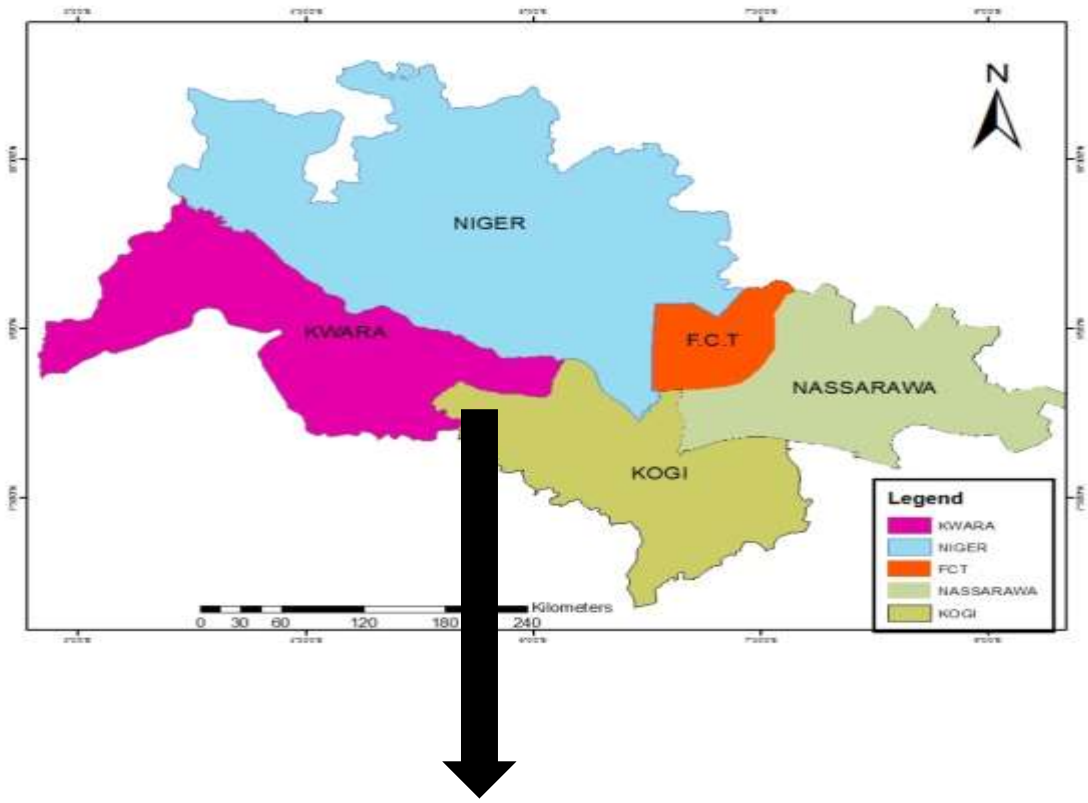
1.7. Study Area Description

The study area lies between Latitude 7^0 48^1 N and 9^0 36^1 N and Longitude 4^0 32^1 E and 8^0 30^1 E. It covered about seven States and the Federal capital territory.

1.7.1. Socio economic activities of the study area

The major socio-economic activities in the study area were fishing and farming. Due to viable land, agriculture is a common source of livelihood. Also, the river Benue and river Niger cuts through this zone, as a result, fishing is possible. Inhabitants also engage in mat making, hunting, dying, weaving and trading among others. Mineral resources are also found in the region such as columbite, tin, iron ore, and gold. As a result, mining activities are carried out regularly across the zone. The north central also has several dam which are source of hydroelectric power to Nigeria (Baten, 2016).

The study area map depicting the Five study locations is presented in Figure 1.1.



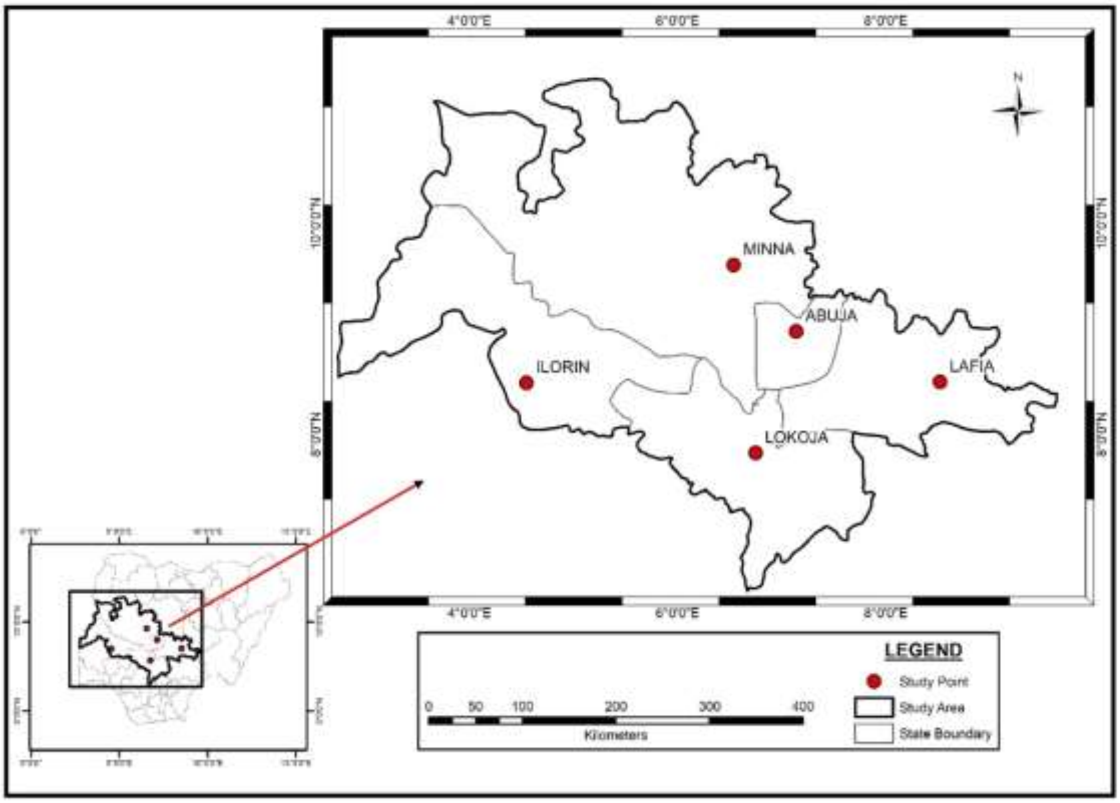


Figure 1.1. The Study Areas (Minna, Lokoja, Ilorin, Lafia and Abuja, Nigeria)

Source: Authors Work, 2018.

1.7.2. Climate of the study area

The study area belongs to the Guinea Savannah climatic zone of Nigeria. In this zone, the continental north wind and south west monsoon control the wet and dry period. More often the dry season is from December to March while the rainy season is between May to October. The two seasons are mostly divided by slightly transition periods in April and November. Although, the beginning of February to March represent the peak of the dry season while the rains usually climax in August. The month of November to January are characterized by cold and dry weather conditions (The harmattan) under the influence of the Northeast Trade Wind (Olayemi *et al.*, 2014). The study area experiences moderate rainfall in most location, the mean annual rainfall is in the range of 1000-1600 mm. the probabilistic dry spell forecast by the Nigerian Meteorological Agency (NiMet) shows that the study area experiences moderate dry spell that usually last between 7 and 16 days. The temperature prediction by NiMet shows obvious warmer than normal temperature over most places in the study area (NiMet, 2018).

1.7.3. Relief of the study area

The study area consists of seven States and is situated geographically in the middle belt region of the country, spanning from the west, around the confluence of the River Niger and the River Benue. The region itself is rich in natural land features, and boasts some of Nigeria's most exciting scenery. The region is also home to many historical and colonial relics. The Jos plateau (200-1500m) is found in the North Central Highland and it is a Hydrological centre or watershed with radial pattern of drainage in which rivers like Hadeija, Kaduna and Sokoto take their sources. The highest point of Jos plateau is the Shere Hills (1650m) (Melzian, 2012).

1.7.4. Vegetation of the study area

The research area is situated in middle belt of the country and shares the same vegetation characteristics with the Guinea Savanna. This is the widest vegetation belt in Nigeria, covering about half of the country. The Guinea Savanna belt extends from the South eastern axis particularly around Enugu to the Northern part specifically towards Zaria in Kaduna State. It usually receives 6 month of rainy season around the Northern part and 8 months in the Southern axis. There is an annual rainfall range of between 1000 and 1600 mm on the average. The vegetation is often affected by human anthropogenic activities. The trees grow long tap-roots to withstand the hard condition, also the grasses have sizeable roots to survive dry season fire. Elephant grasses are commonly found with a height of around 3.6 m. The plot of the Savanna changes with the Park Savanna and borders the river bank with gallery forest. The grasses usually grow to a height that both man and animals can hide. In the first half of the dry period, the Savanna appears lifeless, the trees become bare. In the middle of the season, there is a rise in smoke screen, burning of dry grasses, which occurs annually as land preparatory measure for crop production (Ekaete, 2017).

1.7.5. Soil type of the study area

The classification of soils by the United Nation Food and Agriculture Organization (FAO) simply puts the soil of the study area into two different zones. The zones include:

1. Interior zone of lateritic soils
2. Alluvial soils Zones

These zones occupy areas with long period of dry season with alternating wet season. They can be found in the interior part of Nigeria covering places like Niger, Kogi, Kwara, Nasarawa, Plateau, and FCT. These States specifically constitute the study area.

1.7.5.1. Interior zone of laterite soils

The laterite soil zone contains a combination of clay and sand. Because they are made up of grey clay and area poorly drained, they become liable to seasonal flooding. The soils are highly corroded, impermeable to water, compacted and have low fertility. When the un- tapped vegetation around them is cultivated it lowers the soil productivity, thereby reducing the agricultural value of the soil (FAO, 2016).

1.7.5.2. Alluvial soils

These are collections of fresh water soils of grey to white sand, grey clay and sandy clay with humid top soil. Different groups of this type of soil are composed of black saline mangrove to brownish soils, with mat of rootlets (FAO, 2016). This specific soil region extends from the coastal inland through the Niger and Benue valley, and covering the entire vegetation zone.

CHAPTER TWO

2.0. LITERATURE REVIEW

2.1. Conceptual Definitions

2.1.1. The climate system

To understand the climate of the earth and its variations and to understand and possibly predict the changes of the climate brought about by human activities, one cannot ignore any of these many factors and components that determine the climate. We must understand the climate system, the complicated system consisting of various components, including the dynamics and composition of the atmosphere, the ocean, the ice and snow cover, the land surface and its features, the many mutual interactions between them, and the large variety of physical, chemical and biological processes taking place in and among these components. Climate in a wider sense refers to the state of the climate system as a whole, including a statistical description of its variations (IPCC, 1990).

The climate system is an interactive system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere, forced or influenced by various external forcing mechanisms, the most important of which is the Sun. Also the direct effect of human activities on the climate system is considered an external forcing. We must also take into account the fact that the state of the atmosphere used in the definition of the climate given above is influenced by numerous processes involving not only the atmosphere but also the ocean, the sea ice, the vegetation, etc. Climate is thus now more and more frequently defined in a wider sense as the statistical description of the climate system. This includes the analysis of the behaviour of its five major components: the atmosphere (the gaseous envelope surrounding the Earth), the hydrosphere (liquid water, such as; ocean, lakes and underground water), the cryosphere (solid water, such as; sea ice, glaciers and ice sheets), the land surface and the biosphere (all the living organisms), and of the interactions between them (IPCC, 2007).

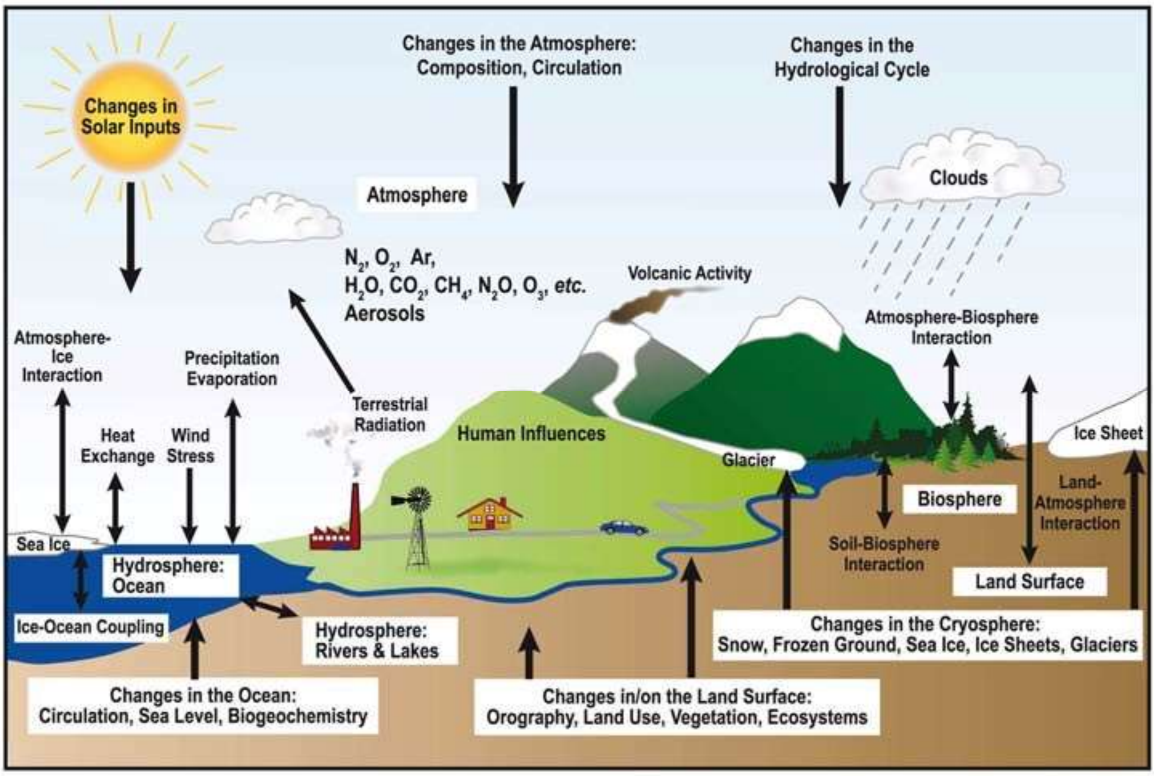


Figure 2.1. Schematic View of the Components of the Global Climate System

Adapted from IPCC (1990).

2.1.1.1. The atmosphere

The atmosphere is the most unstable and rapidly changing part of the system. Its composition, which has changed with the evolution of the Earth, is of central importance. The Earth's dry atmosphere is composed mainly of nitrogen (N_2, 78.1% volume mixing ratio), oxygen (O_2, 20.9% volume mixing ratio, and argon (Ar, 0.93% volume mixing ratio). These gases have only limited interaction with the incoming solar radiation and they do not interact with the infrared radiation emitted by the Earth. However, there are a number of trace gases, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3), which do absorb and emit infrared radiation. These so-called greenhouse gases, with a total volume mixing ratio in dry air of less than 0.1% by volume, play an essential role in the Earth's energy budget. Moreover, the atmosphere contains water vapour (H_2O), which is also a natural greenhouse gas. Its volume mixing ratio is highly variable, but it is typically in the order of 1%. Because these greenhouse gases absorb the infrared radiation emitted by the Earth and emit infrared radiation up- and downward, they tend to raise the temperature near the Earth's surface. Water vapour, CO_2 and O_3 also absorb solar short-wave radiation (IPCC, 2007).

2.1.1.2. Hydrosphere

The hydrosphere is the component comprising all liquid surface and subterranean water, both fresh water, including rivers, lakes and aquifers, and saline water of the oceans and seas. Fresh water runoff from the land returning to the oceans in rivers influences the ocean's composition and circulation. The oceans cover approximately 70% of the Earth's surface. They store and transport a large amount of energy and dissolve and store great quantities of carbon dioxide. Their circulation, driven by the wind and by density contrasts caused by salinity and thermal gradients (the so-called thermohaline circulation), is much slower than the atmospheric circulation. Mainly due to the large thermal inertia of the oceans, they damp vast and strong temperature changes and function as a regulator of the Earth's climate and as a source of natural climate variability, in particular on the longer time-scales. (IPCC, 2007b).

2.1.1.3. Cryosphere

The cryosphere, including the ice sheets of Greenland and Antarctica, continental glaciers and snow fields, sea ice and permafrost, derives its importance to the climate system from its high reflectivity (albedo) for solar radiation, its low thermal conductivity, its large thermal inertia and, especially, its critical role in driving deep ocean water circulation. Because the ice sheets store a large amount of water, variations in their volume are a potential source of sea level variations The ocean is an important part of the flows of carbon through the earth system as well. The ocean also holds (or supports) part of the cryosphere as sea ice (IPCC, 2007).

2.1.1.4. Biosphere (marine and terrestrial)

The marine and terrestrial biospheres have a major impact on the atmosphere's composition. The biota influences the uptake and release of greenhouse gases. Through the photosynthetic process, both marine and terrestrial plants (especially forests) store significant amounts of carbon from carbon dioxide. Thus, the biosphere plays a central role in the carbon cycle, as well as in the budgets of many other gases, such as methane and nitrous oxide. Other biospheric emissions are the so-called Volatile Organic Compounds (VOC) which may have important effects on atmospheric chemistry, on aerosol formation and therefore on climate. Because the storage of carbon and the exchange of trace gases are influenced by climate, feedbacks between climate change and atmospheric concentrations of trace gases can occur. The influence of climate on the biosphere is preserved as fossils, tree rings, pollen and other records, so that much of what is known of past climates comes from such biotic indicators (IPCC, 2007).

2.2.1. Climate change

Alteration of the earth's atmosphere that occurred for much longer duration, decades to millennia are referred to as "Climate change." The Intergovernmental Panel on Climate Change (IPCC) defines climate change as the change in climate which is attributed to changes in the mean state or variability of its properties and that persists for a longer time period, majorly for a decade or more. In another way, climate change is defined as any noticeable fluctuation in climate for a longer period, resulting from natural climatic variability or due to human induced causes (IPCC, 2007).

Natural processes such as volcanic activity, solar variation, plate tectonic, the ocean conveyor belt phenomenon, or shift in the earth orbit can cause climate change, but often time, the changes linked to human activities are considered when discussing climate change issue, such as risen greenhouse gases emission (IPCC, 2013)

2.2.2. Variability in climate

The variation in the mean state and other statistics of climate (for example, standard deviation and extreme occurrence) of the climate on all spatial and temporal scale beyond that of individual weather events is known as climate variability. Also, variability may be as a result of internal forcing (natural internal processes within the climate system) or external forcing (external variability) (IPCC, 2013).

In the year 2007, the IPCC reported that climate variability and change was becoming an emerging global problem impacting negatively on many sectors globally and was viewed to be the most severe threat to achieving the goals of Sustainable Development Goals (SDGs) with different effects on environment, agriculture, economic growth and natural resources.

2.2.3. Extreme variability in climate

Climate change leads to variation in the occurrence, spatial coverage, period, intensity, and timing of weather. Extreme climate (such as droughts and floods) could be due to a combination of weather and climate event which are, individually, not extreme particularly (but their accumulation is extreme). Extreme occurrence does not often translate to serious effect (Seneviratne & Nicholls, ND). Also, climate or weather event, even though not severe in a statistical consideration, is liable to result to extreme cases or impacts, either through happening continuously with other events passing or a critical threshold in a social, ecological or physical system.

Variation in extremes can also be directly linked to variations in the mean climate, because mean future conditions in certain variables are anticipated to lie within the extensions of current conditions. Climate and weather extreme events are the outcome of natural climate variability (together with El-Nino phenomena), and changes in climate on natural/multi decadal scale provide the background for human-induced changes in climate (Panda, 2013).

Drought, floods and risen heat waves which are extreme climate events have overtime affected human settlement, natural resources and the economy. The El Nino-Southern Oscillation and climate change resulting from human activities influence the extreme events. Describing the reason for the past extremes, trend and variability is key accurate prediction of the outlook of the future climate and extreme events occurrences (Panda, 2013).

2.2.4. Natural variability of climate

Variation in climate, whether in its statistics or mean state, such as extreme events occurrence, may be a result of internal interface between components of the climate system or from radiative forcing. A distinction can therefore be made between externally and internally induced natural climate variability and change (IPCC, 2013).

The response period of the various parts of the climate system varies with changes in extreme forces. Concerning the atmosphere, the troposphere response time is short, within few days or week, although, the stratosphere gets closer to equilibrium stage on a time-scale usually of few months. As a result of their large heat capacity, the oceans have high response period usually for decades, centuries or millennia. The surface troposphere response time is slow compared to that of stratosphere, and is determined majorly by oceans. Response period of biosphere to drought is faster but slower to cause change. Therefore, the system could respond to change in external forcing on a large range spatio-temporal scale. Solar variation effect on climate provides an instance of externally induced climate variation (IPCC, 2013).

2.3. Inter Tropical Discontinuity (ITD) and Climate Distribution in Nigeria

Nigeria receives rainfall from the south westerly which invades the country from the Gulf of Guinea coast, that is, the Tropical Atlantic. This moist airstream is overlain by the northeast trades which originate from above the Sahara and are thereby dry and dust laden. The zone of contact of the two air masses at the surface is a zone of moisture discontinuity and it is known as the Inter Tropical Discontinuity (ITD) zone. The ITD advances inland as far as 22 – 25^0N in August at the margin of the Sahara i.e. considerably beyond Nigeria‘s northern border (Adedokun, 2008) while it does not retreat equator ward beyond 4^0N latitude during the Harmattan dry season (Adefolalu, 2001).

Five weather zones are associated with the ITD Zone A to the north of the ITD is rainless as well as Zone B to the immediate south because they do not contain rain-producing clouds. Rainfall in the ITD occurs in Zone C and D where conditions favour the development of clouds of great vertical extent. Thunderstorms and squall lines are associated with Zones C weather and monsoon rains with Zone D weather. Therefore, rainfall is spatially discontinuous when Zone C weather prevails. On the other hand, the monsoon system gives continuous rains which may last 12 hours or more (Olaniran, 1995).

Generally, rainfall occurs at a distance of about 500 km south of the surface location of the ITD, 4–6 weeks behind it in its annual cycle. When the fifth weather type associated with the ITD that is Zone E, prevails over an area, light rainfall usually results because Zone E weather is dominated by layered stratiform clouds. The position of the ITD fluctuates seasonally and the different ITD zones affect different areas of the country at various times (Oguntoyinbo & Richards, 2007).

2.4. Crop Production and Climate Variability in Nigeria

The variation in climate has resulted to many devastating effects in most parts of Nigeria (Odjugo, 2010). These effects range from seasonal flooding, deforestation, prolonged drought, desertification, risen ocean level, erosion, risen heat waves, occurrence of pests and diseases, changing rainfall regime and degradation of arable lands. Specifically, the human induced deforestation and sea level rise is peculiar in the South-south regions; the South-eastern regions, flooding, soil erosion land degradation have become a re-occurring decimal; the North Central zone is ravaged by overgrazing and destruction of vegetal cover by the nomads while the North-east and North-west zones are increasing affected by desertification, heat stress and prolonged drought conditions (Ozor, 2009).

When temperature rises above the peak biological stage, crops will regularly response negatively with a declining growth and yield (Ayinde *et al.*, 2013). As reported by Khanal (2009), that increasing heat stress will likely threaten the physical development, maturation and further lower the yield of cultivated crop. Increased frequency of extreme weather events will negatively affect agricultural yield. Risen air temperatures will lower tillering and causes stunting.

2.4.1. Climate variability and rice production

Kuta (2011) reported that indigenous farmers are increasingly concerned about variations in weather due to its effect on food security. Also, that the variation in weather generally effects livestock, fisheries, forestry, reduces the species of aquatic plants and rice yield. Gumm (2010) stated that rice production which has become a significant crop for ensuring food security and tackling poverty will be affected as a result of increased temperature in rice growing area coupled with continued change in climate. Ramirez (2010) reported that unpredicted changes linked with global warming (risen temperature due to climate change) severely affects the physiology of rice crop which eventually reduces crop yield and quality of grain. Also, Gumm (2010) mentioned that until change occur in rice production methods or a variety of rice strain that can resist rise in temperatures, there is a likelihood of reduction in rice production over the next few decades due to increase hot days.

The major issue with rice cultivation are drought occurrence, flooding and extremes in temperature. All these factors are anticipated to increase with climate variability and change. Changes in rainfall pattern coupled with risen atmospheric temperature are likely to introduce unfriendly growing development of the crop. These fluctuations change cropping season which consequently decrease rice crop productivity (Ajetumobi *et al*., 2010).

As reported by Manneh *et al*. (2007), that rice crop is very sensitive to drought condition when compared to other crops and this can reduce stand establishment, tillering, height of plant, spikelet fertility as well as delay flowering. The rate of effect on drought depends on the period of the crop growth. Similarly, Ifeanyi-Obi *et al*. (2012) asserted that climate can affect the productivity of rice, starting from emergence to the final stage of harvest. Furthermore, they mentioned that fluctuation in climate such as continuous rise in night time temperature is likely to reduce the yield of rice. Also, that anomaly in rainfall notwithstanding its abundance is liable to affect rice yield negatively especially when the rain is not established at the critical growing stage of the crop. Lobell (2010) stated that increase rate of climate variability denotes a subtle balance amongst food security and agricultural production. The author recounted that the changes in climatic variables that are of importance to agriculture (rise in temperature and uneven rainfall distribution) are capable of reducing yield of cereal crops like maize and rice in the semi-arid regions of the world.

2.4.2. Maize production and climate variability

Available statistics revealed that climate variability and change is global, likewise its impacts but the most adverse effect is felt more by developing countries, particularly those in Africa, and this is as a result of their practice of weather dependent agriculture and their low level of coping capabilities (Ohajianya & Osuji, 2012). Consequently, in sub-Saharan Africa, climate models predicted increased evapo-transpiration and lower soil moisture levels. Previous studies have established that maize growing regions of sub-Saharan Africa will encounter increased growing season temperatures and frequency of droughts (IPCC, 2007b). This would result in some agricultural lands becoming unsuitable for cropping, and some tropical grassland becoming increasingly arid. It is projected that yield of many crops including maize in Africa may fall by 10-20 % by 2020 due to the effect of climate variability and change (Ajetumobi & Abiodun, 2010; Ajetumobi *et al*., 2010 and BNRCC, 2011).

The most variable of the climatic element is the rainfall, it determines the cropping season in developing nations like Nigeria where rain-fed agriculture is the predominant practice. Most farmers are concerned with what the anticipated rainfall would likely be, more than other climatic elements because it controls the success or failure of crops (Ibrahim *et al.*, 2017). Regardless of the economic significance of maize crop, several elements influence it growth and production in Nigeria. Ojo (2013) enumerated the main threat facing the production of maize crop in Nigeria to include price fluctuation, capitalization, pest and diseases, poor storage facilities and inefficiency of resource utilization. Climate is also another major factor specifically rainfall. Climate reduces the productivity of maize crop in many ways, for example, prolonged period of break in rainfall (drought) or too much of rain too quickly (flood) can lead to complete (100 %) loss of maize crop. Also, it is estimated that the yield of many crops in African continent is likely to reduce by 10-20 % by the year 2020 because of climate variability and change (Ajetumobi *et al*., 2010). This is because agriculture production in African is majorly rain-fed and as such relying on the vagaries of weather.

The overall effect predicted by CERES-Maize (crop simulation model), for changes in temperature, rainfall and CO_2 levels on potential yields averaged for all Agro-Ecological Zones (AEZ) have been documented. The data revealed that increase in temperature at the current CO_2 level caused a general decline in yields. These effects were found to be more pronounced in the Humid Forest and Semi-arid AEZ with 18 % and 13 % yield reduction respectively while the least decline in yield was observed in the Derived and Southern Guinea Savannas (7 %). Similarly, Sowunmi and Akintola (2010) reported that maize cultivation output was highest in the Savanna when compared to the Rainforest, Mangrove Swamp and Montane Forest/Grassland zones for the period of 22 years examined in Nigeria. It was resolved that the Savannah zone (guinea, sudan and derived) are more productive for maize cultivation due to their suitable soil and favourable temperature.

Exposure to higher temperatures can significantly reduce grain yield. A doubling of CO_2 level will lead to yield gain only at low temperature increases (1 ^{0}C). At higher temperature, doubling CO_2 levels will result in gradual yield reduction with highest reduction at temperature of 4 ^{0}C, amidst drought situations, hundred percent (100 %) of areas cultivated are likely to witness losses in yield. Risen temperature will increase extent of agricultural pests and diseases by increasing the capability of the pests to withstand and attack crops thus affecting yield (Parry *et al*., 2007).

Rainfall is known to have direct relationship with agricultural crops, upward or downward amount of rainfall have effect on yield of crops (Walthall *et al*., 2012). The study of Kassie *et al*. (2014) showed that rainfall variability does not necessarily affect crop yields directly on water availability but indirectly affects crop yield by limiting the application of agricultural inputs (fertiliser). Hatfield and Prueger (2011) reported that maize crop is vulnerable to excess water in the early growth stages and can cause a reduction in growth, while a reduction in the amount of water in soil will lead to less growth and yield if the stress occurs during the grain filling period of growth.

2.4.3. Climate variability and guinea corn production

Overtime, there have been growing concerns on the risen temperature and rainfall variability throughout the seasons leading to increase variability of yield and therefore becoming an obvious factor on the output and adaptation of varieties of guinea corn. Although, guinea corn is a drought resistant crop, it is often negatively influenced by climate variability and change impact, management practice and socio-economic factors like any other crop. In the last three decades, unpredictability of seasonal climatic extremes resulted to heavy impact on guinea corn production globally (Traore *et al*., 2016).

Owusu-Sekyere *et al*. (2011a) reported that the yield of Guinea corn over Cape Coast zone of Ghana revealed a continuous decline over the past 16 years. The decrease was linked to dwindling amount of rainfall as well as variation in its onset. The drop in the yield of Guinea corn manifested in the Mfantseman Central Region. Decreasing amount of rainfall and increasing average temperature were seen as likely causes of the decline in Guinea corn yield (Owusu-Sekyere *et al*., 2011b).

2.4.4. Climate variability and rice insect pest

In general, there is an indirect impacts of CO_2 on rice insect pest, due to change in their host plant. Major plants especially those in the category of C3, such as grains (wheat and rice), root crops and legume react to risen CO_2 level through productivity increase (a quantitative reaction) such as the carbon fixation (Bazzaz, 2013). Due to climate change, risen temperature will be favourable for overwintering of pests in the presence of the host plant as well as the white backed, brown plant hopper and rice leaf folder may reduce the chances to inflict harm on crops (Kiritani, 2016). It is a statement of fact that the rate of natural control of rice pests by biological predators will rise under global warming condition (Kiritani, 2016). The risen temperature is majorly not suitable for the growth of certain insects in summer, whereas other insects can easily cope or lessen the harm by physiological or habitat accommodation (Hoffman, 2013).

2.4.5. Climate variability and maize insect pest

Adult maize stem rot, maize gray spot, P. polysora, leaf blight, leaf and sheath rot, leaf scotch and white blast are maize diseases that have over the years received research attention in Nigeria (Fakorede, 2010). The author observed further that within certain period, the diseases such as, streak virus which was rather insignificant during the 1970s now became the utmost shocking national disease. Downy mildew which was not known in the initial phases of maize breeding later came into existence in Nigeria during the early parts of 1970s.

Daramola (2013) classified maize insect pests in Nigeria into three main headings. These include; storage pests, field pests and field-to-store pests. The author further highlighted their potential damage and suggested existing technologies to be used to eliminate them. It was emphasized that the field pests which are mainly insects, cause severe damage to maize particularly during the field stage of development. The ear and stem borer complex, armyworms, leafhoppers and silkworms are categorized under this group. The ear and stem borers are grouped under Lepidoptera family and are vastly spread, most damaging and the commonest pests of maize in Nigeria. The borer complex includes *Eldana saccharina* (Walker), *Sesamia calamistis* Hampson, and *Busseola fusca* (Fuller) (Lep: Noctuidae) that bore their stem, and the ear borer *Mussidia nigrivenella* Ragonot (Lep: Pyralidae).

2.4.6. Climate variability and guinea corn insect pest

Guinea corn is tolerant to insect feeding and defoliation. Insects that cause direct damage to seed or prevent seed set can cause serious loss, because the crop may not have enough time to re-produce new floret and setting seed. The crop's tolerating ability to injury shows high treatment thresholds. Recently, strong commodity cost prices for the crop satisfy monitoring techniques for insect pests and use of insecticides when pest numbers go beyond treatment thresholds (Georgia Pest Management Handbook, 2018).

The major insects in the soil that attack guinea corn includes seedcorn maggots, lesser white fringed beetle larvae, cornstalk borer, wireworms, white grubs southern corn rootworm, and the leaf and stalk-boring pest of guinea corn includes spider mites, aphids and greenbug, grasshopper, stink bug among others. Ajeigbe *et al*. (2018)

enumerated the common guinea corn insect pests in Nigeria to include armyworm, black field ear wing, chinch bug, cutworms, sorghum head caterpillar, spider mites and stink bugs. With climate variability and change these insects pests have become very difficult to sample and predict. It is recommended that before planting, a careful inspection of soil is done when land is being prepared for planting (especially when ploughing land) for the presence of white fringed beetle larvae or white grubs, wireworm. These insect pests return to the soil in moments of time and make some inspections almost immediately after ploughing the soil.

Insects in the soil will cause serious destructions in seed gaps in the row stands. They also bore deep into seedling plants below the surface of the soil destroying the major stem, which destroy the leaf whorl causing a "dead heart" type injury (Georgia Pest Management Handbook, 2018). The conditions below increase the risk of destruction caused by soil insects of cereal crops:

i. No-till, strip-till and reduced system where viable crop residue is left on the surface of the soil. Wet and cool conditions favour cutworms, grub and wireworms.
ii. Following newly cultivated ground or planting into weedy or sod species.
iii. Planting late such as vegetables or double cropping behind winter crops.
iv. Double cropping behind winter cover crop or cereal grains. Cereal crops are grasses and are always hunted by the same insect pest.
v. Planting under conventional tillage on light soils during hot, drought conditions or planting into burnt cereal stubble. This favours minimal cornstalk borer infestations.

2.5. Challenges of Crop Production in Nigeria

Crop production in Nigeria is directly affected by many aspects of climate change stemming primarily from average increases in temperature, change in rainfall amount and duration, rising atmospheric concentration of carbon dioxide, sea water rise and change in climatic variability and extreme events such as flood and drought (Chijioke *et al*., 2011).

The production of major export crops in the country such as groundnut, rubber, coffee, cocoa and palm produce in the country has declined since the drought of 1972/73 which was the first real evidence of climate change in Nigeria. Though there is evidence of increase in food crop production generally in Nigeria, the nation is not self-sufficient in production of any food crop except cassava. The question remains therefore as to whether the production level will ever meet the demand given the rate of population growth in the country. Also, the proportion of change in production due to impact of climate variability will remain an important research focus as well as measures needed to improve the resilience of the farmers to enable them adapt to climate variability and change (Ajetomobi *et al*., 2010).

Crop production takes a significant aspect of agricultural production and exports in Nigeria. Generally, there are many factors influencing crop production and these include soil, relief, climate and diseases among others. In relation to climate, rainfall is one of the dominant controlling variables in tropical agriculture since it supplies soil moisture for crops. Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops (Tunde *et al*., 2011).

2.5.1. Rice production in Nigeria

Rice (*Oryza sativa)* is the most vital crop among the cereals consumed globally after maize and wheat. In Nigeria, rice is grown in almost all ecological belts available in the country for consumption and sales (Agronigeria, 2014). In specific areas, there is a long custom of growing rice, but for many, rice has been a luxury food for important occasions only. With the increase availability of rice, it has become an everyday diet of many Nigerians (Ukwuru *et al*., 2018).

There are many varieties of rice grown in Nigeria. Some of these are considered 'traditional' varieties; others have been introduced within the last twenty years. Rice is grown in paddies or on upland fields, depending on the requirements of the particular variety; there is limited mangrove cultivation. New varieties are produced and disseminated by research Institutes, or are imported from Asia. The spread of these strains is determined by their perceived success, and farmers multiply seed for their own plots when they see a variety doing well in someone else's field, or if a variety is fetching a good price in the market (agronigeria, 2014). With the recent agricultural policy of the Federal Government which aims to promote local rice production and eliminate importation, several initiatives have been developed both at the local and national scale. Among them is the development of Lake Rice which is the collaborative effort of Lagos and Kebbi State. This effort has increased rice production in the affected area and the nation at large.

2.5.1.1. Trend in rice production in Nigeria

The United State Agency for International Development (USAID) (2010) reported that rice sector in Nigeria is filled with insufficient and weak producers – market chain due to poor amenities and inefficient distribution network which has given birth to limited productivity and involvement of farmers in rice farming. To monitor the rate of importing rice, Saka *et al*. (2005) stated that distributing improved varieties and other modern inputs as a complete package to rice farmers is very paramount.

Onimawo *et al*. (2010) noted that Federal Agriculture Research Oryza (FARO) 44 and 52 are useful medically for dietary checks of diabetes due to their low amount of glycemic indices when it is compared with other varieties. Therefore, to step up the competitiveness of Nigerian rice producers, FARO 44 (sippi) was recommended to farmers as a result of its early growth and quality grain therein. In Nigeria, the improvement in rice production programme began during the colonial administration, with the coming onboard of the Federal Department of Agriculture, Moor Plantation, Ibadan in the 1920s (Ukwungwu *et al*., 2012). By 1939, many research Centres for rice crop development were established by the West Africa Commission. These Centres were to provide services to all the West African countries.

Damola, (2010) reported that the environments for rice production are categorized into five namely; rain-fed lowland (47 %), rainfed upland (30 %), lowland irrigated area (1 %), irrigation scheme of small-scale (16 %) while the deep water accounted for the remaining (6 %).

Rice production challenges in Nigeria include inadequate irrigation practices, inconsistent policies on rice developmental, low level of farming technologies, low level of disseminating improved seed variety, poor accessibility to institutional credence, weak agricultural extension programs and poor agricultural contributive supply system etc. However, processing challenges consist of use of arcade methods of processing, low awareness of the quality control system, improper strategies for parboiling, use of outdated milling machines, power failure resulting to inefficient milling etc. (Damola, 2010).

Alarima *et al*. (2011) asserted that land tenure system, information transfer, and training on mechanical and technical elements are the challenges facing rice production in Nigeria. In addition, the author revealed that the problems were interconnected and as such they can easily influence one another. As land tenure problem continues, farmers are faced with the challenges of farm input, production and technology. Inadequate information to the farmers was found to be linked to economic, input and production challenge.

2.5.1.2. Climatic and soil requirement for rice production

One of the most cogent weather parameters for successful rice farming is rainfall. Rainfall distribution in different region is greatly influenced by the natural features of the environment, the condition of the mountain and plateau. A monthly rain of 100-200 mm is expected during the vegetative period of rice. Temperature is also a major climatic element which has both favourable and unfavourable influences on the growth, yield and development of rice. Rice is sub-tropical and tropical plants which require a moderately high temperature of between 20 °C to 40 °C. Temperature of about 30 °C is needed during the day while 20 °C is required at night, and this seems to be far more conducive for growth of rice crops. Rice production is affected by factors of temperature at different stages of development. The mean temperature for fertilisation and vegetation ranges from 15 to 20 ^{0}C. However, during ripening period; it ranges from 17 to 32 ^{0}C. Temperature above 36 ^{0}C affects grain infilling. The production of rice is also affected by radiations from the sun especially during the last 34 to 44 days of its ripening. The influence of radiation from the sun is more evident where nitrogenous nutrients, water, temperature are not constraints. Sunshine with minimum temperature during ripening of rice assists in the growth of carbohydrates in the cereals. Rice germinates on soils like gravels, silt and loams. Specifically, clayed loam is best for rice cultivations (Agronigeria, 2014).

2.5.2. Maize production in Nigeria

Maize (*Zea mays*) is the commonest cereal around the globe after rice and wheat with regards to cultivation area and total production. Maize grain contains protein, carbohydrates, and some amount of vitamin (Rotimi, 2016). It is grown on 100 million hectares of land in developing nations, with 75 % of the total production coming from very low middle income nations (FAOSTAT, 2010). In recent time, maize crop is widely cultivated as an important domestic and commercial commodity within the Northern, Southern and Eastern regions of Nigeria. The crop can be cultivated on major soils across the savannah zones, but it produces optimally on a well-drained loamy soils. (IITA, 2012).

Maize cycle is relatively very short therefore making it the very first crop to be harvested for consumption in Nigeria. It is processed into many forms; preparations of the crop are lot easier than cassava. With the development of mechanized farming couple with the use of hybrid maize variety, production can measure up to 10.3 tonnes per hectare. With the traditional method of production in Africa; output is 2.2 tonnes per hectare. In Nigeria, the demand for maize crop is increasing daily. This is because the grain is widely used as poultry feed and also as a major food for human consumption (Ogunniyi, 2011).

2.5.2.1. Climatic and soil requirements for maize production in Nigeria

Approximately 10 to 16 kg of maize are produced for every millimeter of water used. Yield of 3152 kg/hectares requires between 350 and 450 mm of rain annually. When it finally matures, each strip of plant will have used up about 250 mm of water in the absence of moisture constrain. Maize is a warm weathered crop and should not be cultivated in regions where daily mean temperature is less than 20 ºC. The lowest required temperature for maize germination is 10 ºC. Germination is usually very fast and less variable at soil temperatures of 16 to 18 ºC. At 20 ºC, maize developed within five to six days. The critical temperature affecting maize yield is estimated to be 32 ºC. Frost can destroy maize at all stages of growth and about 120 to 140 frost free period is needed to avoid damage. While the point of growth is under the soil surface, new leaves develop and frost destruction is reduced. (Jean, 2009).

Maize crop requires favourable soil and climatic conditions for optimal growth. Although, it can be cultivated on different types of soil, it grows maximally in well-drained, deep, medium textured sandy loam or loamy, fertile and properly drained soil (Kelley & Boyhan, 2010).

The soil gives physical nutrients, support and water to maize. Meaning that, in the event of time, whenever there is a deficiency in the factors of production, it will result to a decrease in production. The provision of physical nutrients, support and water by soil to a large extent depends on the soil structure, topography, soil management practices and soil type. For massive production, there is a requirement for proper cultivation to ensure improved crop yield and proper soil management. Preparation of land should include adequate tillage to provide favourable soil condition for seedling and to ensure a better soil structure for root growth and development (Kelley & Boyhan, 2010).

2.5.3. Guinea corn production in Nigeria

Guinea corn (*Sorghum bicolar*) is a grain crop that is widely cultivated globally. It is a highly yielding cereal crop grown under rain fed condition. It is a very important component farming system that defines the cropping patterns of major peasant farmers. Guinea corn is also used as animal feed, for human consumption and industrial purposes (Ahmed, 2014).

2.5.3.1. Climatic and soil requirements for guinea corn production

Guinea corn is majorly a warm-weather crop which regularly requires high temperature for goof germination and growth. The minimum temperature range for germination is between 7 and 10 ^{0}C. At a temperature of 15 ^{0}C, 80 % of seed grows out within 10 to 12 days. It also grows under rainfall conditions of about 450 mm to 850 mm. The appropriate period of planting is when there is enough water in the soil and the soil temperature is 15 ^{0}C or higher at a depth of 10 cm. Temperature plays a significant role in the growth and development after germination. Temperature of about 27 to 30 ^{0}C is required for adequate growth. Lower temperature of about 21 ^{0}C, may not have any severe effect on the output of the crop. Exceptionally high temperatures can lead to yield reduction. Flower initiation is thwarted with increase in night and day time temperatures (Ahmed, 2014).

Plants with four to six mature leaves that are open to a cold treatment (temperatures lower than 18 ^{0}C) will form lateral shoots. Temperatures below freezing point are destructive to Guinea corn and may eventually destroy the plant. At the age of 1 to 3 weeks, plants may recover if exposed to a temperature of 5 ^{0}C below freezing point, but at 7 ^{0}C below freezing point, they are killed. Crop older than 3 weeks don't have much tolerance to low temperatures and may die off at 0 ^{0}C. Guinea corn is produced under changing rainfall condition of approximately 400 mm to about 800 mm (Agronigeria, 2014).

2.6. Empirical Studies

Awotoye and Matthew (2010) studied climate variability impact on crop production in South-West, Nigeria. Climatic and crop yield data were utilized for the study. The classes of food crops studied were grains, tubers, vegetables and legumes. Results showed that the selected crops varied in their responses to climatic variables. The study discovered that the output of food crops such as legumes, vegetables and grains was largely determined by inter-annual and seasonal changes in rainfall. Further results revealed that the combination of non-climatic and climatic elements accounted for the low coefficient of correlation ($r \leq 0.4$) between crop yield and rainfall. The study further showed that the 2012 climate projection of the study area would likely have negative impact on distribution of food, infrastructure production and livelihood assets.

Ayinde *et al*. (2013) conducted a research on the impact of climate variability and change on rice production in Niger State. Descriptive statistics, co-integration method and unit root test were used for the analysis. Findings from the study showed that only relative humidity and minimum temperature that were critical for rice production in the study area. Further result showed that an upshot in relative humidity of 2 % brought 18 % decrease in production of rice, while an increase in minimal temperature gave 52.4 % increase in rice production.

Aye and Ater (2012) investigated the impact of climate change on grain yield in Nigeria using Stochastic Model Approach. Data were obtained from 7 States of the Federation for the period of 18 years. The States cut across the six geopolitical zones. The simulation output revealed that there was an increment in rice production whereas its variations had increase. The study concluded that co-variances of rice and maize would decrease in the nearest future due to climatic change.

Kalu and Mbanasor (2016) used fully Modified Ordinary Least Square (FM-OLS) approach to assess climate variability impact on grain yields in Nigeria. Time series data from 1970 to 2012 for Millet and Sorghum were utilized. Results revealed that the expansion of land area exerted major impact on Sorghum yield at 5 % significant level during the study period. Further results showed that climate variable (mean annual temperature), CO_2 emissions and expansion of land area also affected millet yield significantly.

Kangalawe *et al*. (2017) studied the impact of climate variability and change on agricultural production and livelihood system in Western Tanzania. Structure and semi structured interviews, physical observations, focused group discussion and secondary data from reviewed literature were utilized. About 183 households were randomly selected with average age of 45 years. The analytical tools used were Inferential and Descriptive statistics methods. Result revealed that the mean maximum temperature in Kigoma since 1950s had risen by about 2 ^{0}C while the mean minimum temperature declined slightly from 1960 to 1980s, but had showed upward trend since the 1990. Further results showed that climatic change had resulted to total decline in the productivity of agricultural goods and variation in agro-diversity. The study also established that crop pests and diseases had increased, resulting in major hindrance to agriculture.

Akintunde *et al*. (2013) investigated the impact of agro-climatic variables on cash crop production in Nigeria. Climatic variable (rainfall, temperature, relative humidity, sunshine hour and radiation) as well as yield record of (Cocoa, Palm Kernel and Palm Oil) for the period 1970 to 2003 were used. Error-correction model (ECM) was used for the analysis. Result showed that the significant of the Error-correction terms for the crops affirm the presence of a symmetry relationship between the variables in all the cointegrating vectors. Though, temperature, price of producer and Gross Domestic Product were found to be the important features affecting cocoa yield, the rate of exchange rate was considered the major factor for the palm produce.

Nwaiwu *et al.* (2015) studied the impact of climate variability on food crop production in South-Eastern, Nigeria. Time series data of rainfall, temperature, relative humidity and sunshine as well as yield record of maize, yam and cassava were used. Both Co-integration analysis and Descriptive Statistics were used. Results revealed that all the climatic variables considered for the study showed fluctuating pattern of trend during the study period and thereby affecting the output of the crops. Further results showed that in 1985, the highest value of yam was detected with 23 thousand tonnes while the lowest was in 2011 with 9 thousand tonnes. The highest record for maize was in 1985 with 3.6 thousand tonnes and the lowest was in 2011 with 1.4 thousand tonnes and was detected in 2011. Cassava yield was highest in 1985 with 25 thousand tonnes while the lowest was in 2010 and 2011 with 10 thousand tonnes each.

Mathew *et al.* (2015) investigated climate variability impact on crop production using RegCM3-GLAM system performance level in Nigeria. Daily climatic data from Regional Climate Model (RegCM3) and 11 years crop yield record (1999–2009) were used. Result showed that RegCM3 had the actual simulation of climate variability in the country. The coefficient of correlation for the observed and simulated climatic variables showed a range of value of 0.72 and 0.96 at $p < 0.01$. During dry season period (March to November), the model over-estimated rainfall and maximum temperature while during the raining season (April to October) it under-estimated maximum temperature and rainfall. However, the model gave an accurate simulation of the spatial distribution and mean of crop productions across the study area. In the entire simulation, the root mean square errors were completely lower than 35 % of the observed productions. The model gave a different evaluation in the various geo-political zones. Cowpea simulation showed the worst performance while maize simulation gave the best performance across the savannah zones.

Abdul-rahaman and Owusu-Sekyere (2017) carried out a research to investigate the impact of climatic variability on sustainable production of food crops in North-eastern Ghana. Climatic data (rainfall and temperature) and crop (groundnut, maize, rice and millet) production data for the period 1987 to 2014 were used. Interviews with selected workers from related institutions were used to generate information. The study identified that opposite relationship existed between climatic variables and food crop production across the stations. The impacts were not homogenous, as climatic variables (temperature and rainfall) did not exert the same impact on all crops. This shows that the general interpretation of the relationship between food crop production and climatic variability should be taken with cautions and that each variable must be properly checked on its own merit.

Chabala *et al.* (2015) investigated the effect of climate variability on maize production in Zambia. Climatic data (Rainfall and temperature) and maize yield were utilized. Geographical Information System (GIS) approach was used to analyse the spatial pattern of maize production across the study region. Correlation and multiple regression method using least square regression models were used to investigate the strength of association between the variables of climate and crop yield. Results showed that in Nyimba region, a significant ($p = 0.05$) explanation of variations in maize production was linked to the levels of maximum temperature, minimum temperature and rainfall with 52% of the variations. The study revealed that variations in maize yield by temperature and rainfall was not significant for the rest of district considered for the study.

Osborne *et al.* (2013) investigated the impact of climate change on crop yield using climate model uncertainty and adaptation. Global Large Area Model (GLAM) was utilized for crop production simulation. The Li *et al* (2007) parameterization method was used to simulate the responses of spring wheat. It was further developed to simulate soya beans. Result showed that the relationship between the observed and stimulated time series of production for each country revealed more significant relationships ($p < 0.05$) for four Countries (USA, Argentina, Brazil and India), having assurance in the capacity of GLAM to stimulate response of climate change variation and soya bean yield whereas spring wheat correlation result showed more significant correlation ($p < 0.05$) for both the observed and stimulated for three countries (Australia, Hungary and Argentina). In the absence of adaptation, most GCMs produced regularly lower or higher yields when compared to other ensemble. The study concluded that under climate change scenario derived from NCAR PCM, both soya bean and spring wheat would result to higher yields in the nearest future, while MIROCH climate change simulation would leads to lower future yield.

Okringbo *et al.* (2017) carried out a research to investigate the effect of climatic variability on arable crop production in Bayelsa State, Nigeria. Purposive sampling technique was used in selection of climate change prone Local Government Areas (LGAs). Descriptive statistics such as frequency distribution, percentages and mean count was used for the anlysis. The null hypothesis was tested using paired z-test technique. Results showed that all the three arable crops selected for the study (cocoyam, yam and cassava) had low yield. Lodging of crops was observed in all parts of the study area which was responsible for exposing the crops to pests and disease attacks and the resultant reductions in production. The study affirmed the farmer's awareness of climate variability and its effect such as changes in rainfall regime and rise in sea level that constrained the farmers on the kind of agricultural activity to practice.

Mastachi-Loza *et al*. (2016) used GIS approach, Thiel-Sen test, Mann-Kendall test, Kendall's rank correlation and Seasonal Trend Analysis (STA) to investigate trend in climatic variables in the Upper Lerma River Basin, Mexico. Result of the Thiel-sen trend pattern showed a rise in average rainfall from 850 to 980 mm, in the past 50 years. The Mann-Kendall test result revealed that rainfall in the study area had increased significantly with an annual rate of change of 2.568 mm per year while the average minimum temperature showed increase with rate of change of 0.015 ^{0}C annually. Further, the average annual maximum temperature was lowest at 20 ^{0}C in 1976, while the highest was 22.6 ^{0}C in 2011. The study established that from 1980 a risen trend line was continuously noticed for all the three observed climate variables, which was also in tandem with the report of IPCC, (2014).

Srivastava *et al*. (2017) carried out an assessment of the effect of climatic variables on the spatio-temporal variability of crop production and biomass gap in Ghana. Time series climatic data as well as maize and biomass data (1992–2007) in 18 districts that constituted the study area. LITTUL5 crop simulation model was used for the analysis. Result showed that the temporal change in the simulated yield of biomass was significantly correlated with average temperature during the growing period of the crop and the energy from the sun (R2= 0.93; $p < 0.05$), assuming that energy from the sun and the mean temperature were considered as limiting factors of climate across the region. Results of the maize yield simulation and production of biomass amidst scarce water conditions differed in space and showed significant relationship with energy from the sun and rainfall in the growing period of the crop (R^2= 0.99; $p < 0.05$), though, related temporal change in maize yield simulation showed significant correlation with radiation during the growing period of the crop (R^2= 0.96; $p < 0.05$). The study revealed that under input intensity in the humid and tropical central, neither biomass yield, maize grain nor the potential water limited yields showed significant positive relationship with rainfall during the growing period.

Innocent *et al*. (2016) studied climate changes and status of the productions and diversities of sorghum in the arid zone of Benin. Participatory Research Appraisal were employed for the data collections. Focus Group Discussions, direct observation, individual interviews, and questionnaire were utilized to generate information from respondents. Descriptive statistics using Statistical Analysis System (SAS) software was used for the analyses. Results showed that climate variability effect on the production of Sorghum were viewed under five levels: loss or abandonment of landraces (22 %), reduction of productivity (30.7 %), Sorghum plants fast drying (18.9 %), increase in storage pests that caused major damage to stocks (19.2 %), underground seeds rot resulting from increase heat (9.2%). The study concluded that numerous agronomic challenges were limiting the production of Sorghum in the study region and these included striga spread, soil porosity and climate variability among others.

Byakatonda *et al*. (2018) carried out a research to investigate the effect of climate variability and length of growing season on crop production in Botswana. A combination of Aridity Index (AI), Standardized Precipitation Evapotranspiration Index (SPEI), Spearman's Rank Correlation and Southern Oscillation Index (SOI) signifying El Niño southern oscillation effect on local climate, and Artificial Neural Network (ANN) were used. Characteristic of the local rainfall was shown via the Length of Rainy Season (LRS). Finding revealed that the influence of ENSO was noticeable across the study area which accounted for 86 % and 79 % variation in Sorghum and Maize yields respectively. Though, both AI and SPEI were responsible for the 72 % and

66% variations in the yield of sorghum and maize. Length of Rainy Season (LRS) accounted for 55% and 64 %, of the yields, respectively. The projection using ANN showed the possibility of declining yields of sorghum and maize by 52 % and 70 %, respectively in five year period.

Wang *et al.* (2016) conducted a study to estimate the effect of climate variability on crop yield in the Mid-Western United State of America (USA). The study adopted the Soil and Water Assessment Tool (SWAT) for the analysis. Results showed non-significant correlation for aeration stress and crop yield across the study area. The simulation of yield showed that stress emanating from drought was the major determinant of yield as against aeration stress at short and long period of return.

Wang *et al*. (2017) conducted a research to assess the spatio-temporal changes and area variation of extreme precipitations events in the Coastal area of China. A combination of trend analyses, wavelet analysis, Pettitt test, Remote Sensing analysis, Accumulative anomaly and Mann-Kendall statistics was utilized. Results showed insignificant downward and upward trend of rainfall extreme events towards the southern and northern coastal regions. The study identified that trends in rainfall extreme events in the coastal areas of Huanghuai, Huabei and Jiangnan would continue in that direction whereas that of Jianghua and Dongbei coastal areas would exhibit frequent variation in the future. Out of all the extreme rainfall indices considered for the study, only Consecutive Dry Day (CDD) varied majorly within the coastal region.

Suleiman *et al.* (2016) studied the impact of rainfall variability on crop production planning in Bida Basin, Nigeria. Inferential and Descriptive statistics methods were utilized to analyse the 40 years rainfall data (1969 - 2009). Results revealed that the pattern of rainfall was in form of alternating dry and wet years and characterized by strong seasonality. Further, results showed that failure rates in terms of crop yields and moisture harvested was disastrous due to lack of the basic characteristics of rainfall such as cessation and onset dates and the length of rainy days.

Ibrahim *et al*. (2017) studied rainfall variability over Gusau and environs in Zamfara State, Nigeria. Monthly rainfall data from Gusau synoptic stations for 60 years (1953-2012) were analysed using Sen's T and Mann–Kendall tests. There was significant downward trend in April, June, July, August and September, while in May and October an upward trend was detected during the same period. Further, results showed that in the seven months considered for the study only the months of May and October showed upward trends at 0.028 mm and 0.182 mm, while the other months depicted downward trend at -4.492mm, -0.580 mm, -0.069 mm and 0.716 mm. The study concluded that the study area was experiencing some basic indices of climate change.

Itiowe *et al*. (2019) studied rainfall trends in Abuja, Nigeria. Daily rainfall data of 31 years (1986 to 2016) were used. Standardized Precipitation Index (SPI) and Coefficient of Variability methods were used for the analysis. The results obtained indicated that there was a downward trend in the rainfall amount received in the study area during the period under study. Also, that a gradual decadal decline in rainfall was observed when SPI was used to compare the three decades under review.

Akinbile *et al*. (2015) studied trend analysis in climatic variables and its impact on rice yield in Ibadan, Nigeria. The climatic parameters of temperature (T), rainfall (R), relative humidity (RH) and solar radiation (SR), and rice yield for the period (1980 to 2010) were used. Mann–Kendall test, Sen’s slope estimator as well as correlation, multiple regression and variability index (VI) were computed for the parameters. Results showed that temperature and relative humidity had significant ($P<0.001$) decreasing trend while rainfall and solar radiation showed statistically non-significant increasing trends during the study period. Further results showed that temperature, solar radiation and rainfall had the most significant effect on rice yield.

Fu *et al.* (2013) investigated the variability in rainfall extreme events in China for the period 1961 to 2009. Time series data of rainfall from 599 stations obtained from China Meteorological Administration were used. Extreme events were defined using duration and re-occurrence intervals. The period of extreme event of 1, 5, 10 and 30 days were selected for the study, while thresholds linked to interval of re-occurrence of 1, 5 and 10 years were also considered. The temporal variability of extreme rainfall index depicted inter-annual and inter-decadal changes. The time series anomalies of the nine regional extreme rainfall indices showed that the Northern, North-Eastern as well as Yellow River Basin witnessed declining extreme rainfall trend over the past 50 years, whereas the others regions experienced upward trend. The rainfall seasonal variability revealed that 95.6% 1-day, 1-year return period of rainfall extreme events occurred between the months of April to September. The study concluded that the possible cause of variability and trend in rainfall extreme events across the study area was due to wind circulation, magnitude of East Asian Monsoon, ENSO and global warming.

Akinsanola and Ogunjobi (2014) investigated rainfall and temperature variability in Nigeria using observations of air temperature and rainfall from 25 synoptic stations from 1971-2000. Statistical approach was deployed to determine the confidence levels, coefficients of kurtosis, skewness and coefficient of variation. Analysis of air temperature indicated that in the first decade of 1971- 1980 anomalies between -0.2 and -1.6 were predominant, in the second decade of 1981-1990, only five stations (Lokoja, Kaduna, Bida, Bauchi and Warri) showed positive anomaly while greater portion of the country were normal with evidence of warming in the third decade of 1991-2000. Results further indicated that there were statistically significant increases in precipitation and air temperature in vast majority of the country. Analyses of long time trends and decadal trends in the time series further suggested a sequence of alternately decreasing and increasing trends in mean annual precipitation and air temperature in Nigeria during the study period.

Klein-Tank and Konnen (2003) examined the trends in daily extreme rainfall and temperature indices in Europe. The study adopted the World Meteorological Organization Commission for Climatology (WMO-CCL) threshold for rainfall and temperature extreme indices. Results showed that average indices of rainfall extreme increased between 1946 and 1999. Further, results showed that for the period 1976 to 1999 number of annual extreme warm increased quicker than projected from the resultant degree in the number of extreme cold. Results also revealed decline in the spatial coherence of the trend. The study concluded that stations where the annual amount increased, the index that represented the fraction of the annual amount due to very wet days gave a signal of disproportionate large changes in the extremes, whereas the stations with a decreasing annual amount had low response of the extremes.

Ibrahim *et al.* (2018) investigated the distribution, temporal trend and rate of change in rainfall over the Savannah Zones of Nigeria. Rainfall records from 13 globally reference synoptic stations for the period 1970 to 2016 were used. Mann-Kendall test, Theil-Sen's slope estimator and Precipitation Concentration Index (PCI) were utilized for the analysis. The study showed that PCI fell within three categories of 11-15, 16-20 and >20 on annual scale. Further, results showed that the PCI depicted two distinct pattern, which are moderate, irregular and strong irregular concentration of rainfall in the Guinea Savannah zone. Conversely, the Sudano-Sahelian savannah zone revealed irregular and highly irregular concentration of rainfall. The study further showed that eight out of the thirteen stations studied recorded 62 % declining trend in rainfall. The study concluded that rainfall was gradually descending toward a moderate to uniform distribution across the stations.

Li *et al.* (2017) examined the impact of extreme precipitation indices on yield of rice in Tropical Island of China. Time series data from 1988 to 2013 were used. Mann-Kendall statistics and Spearman Rank Correlation methods were adopted for the analysis. Result showed increasing trend in the precipitation indices for most stations. Further, results depicted significant upward trends for R10 and R20 in Kaikou in the months of July and November. The critical cut-off value of the correlation between extreme precipitation indices and rice yield at Hainan Island provides the basis for vulnerability assessment and support to establish program for unforeseen conditions under future climate change scenario.

Gebrekros *et al.* (2016) carried out a research on climate variability and change impact on Sorghum Production in Ethiopia. Climatic and sorghum yield data for the period between 2006 and 2009 were used. The Calibration and Evaluation of Agricultural Production Simulation (APSIM) Model was utilized for the analysis. Root Mean Square Error (RMSE), Coefficient of Determination (R^2) and Index of Agreement were used to determine the model effectiveness. The combined monthly unit of heat increased throughout the period of the study which resulted to short maturity date for sorghum for a week when compared to historical record. The simulation of future sorghum yield showed a decreasing trend of about 5 % and 24 % using both the predicted and historical climate data, respectively.

Sufiyana *et al*. (2020) investigated the impact of climatic variables on guinea corn in Bakori Local Government Area, Katsina State, Nigeria. The climatic data of rainfall and temperature as well as Guinea corn yield were used. The data were analyzed using correlation and regression analysis in SPSS. Results revealed that the most important climatic variables influencing the yields of Guinea corn in the study area were temperature and rainfall.

Ragatoa *et al.* (2018), studied trend in temperature in Nigeria from 1981 to 2015. Daily observation data were used. Analysis was done using three different methods; Modified Mann Kendall (MMK), Pre- Whitening (PW) methods and normal Mann Kendall (MK) test. Results from the different methods showed variation in the trend from one station to another and for the minimum and maximum temperature. The general trend was found to be increasing. The study found that the variation in temperature increased the Diurnal Temperature Range (DTR) that impacted on human.

Ogunrayi *et al*. (2016), studied rainfall and temperature trends over Akure, Nigeria. The study utilized monthly rainfall and temperature data for 32-year (1980 to 2011). Descriptive and time series analyses were used to determine the rainfall and temperature regime of the study area. Results showed that rainfall in the study area was characterized by alternating wet and dry periods with a tendency towards a wetter condition, which implied increased length of rainy season and shorter dry season period. Temperature showed increasing trend during the study period; causing a warmer environment, with consequences on human health, amongst others.

The study of Ly *et al*. (2013) showed that during the period from 1960 to 2010 there was a negative trend in the number of cool nights, and more frequent warm days and warm spells in the West African Sahel region. The study also found mixed trend in the extreme rainfall indices. The cumulated rainfall of extremely wet days showed a positive trend in most locations. Moreover, the maximum number of consecutive wet days showed an overall decreasing trend from 1960 to the mid-1980s. However, starting from the late 1980s, an increasing trend was observed in several locations, signifying that extreme rainfall events have become more frequent in the West African Sahel during the last decade, compared to the 1961–1990 period.

Tahir (2014) studied trends in productivity of maize and sorghum in Nigeria. Annual yield record for the study period (1983 to 2008) was used. Productivity was evaluated through harvested area i.e. the amount of crop grown per unit area harvested. In order to determine variation over the period of production, trend analysis of the productivity of the crops was conducted. Graphical method was used to analyse trend of crop productivity. Productivity (yield) was measured using ratio and percentages. Results of trend analysis showed a declining growth rate for the crops whereas the projected trends of productivity of maize crop was at 0.678 and comparatively low for sorghum at 0.292. The study established that in order to achieve improved performance of the crops; productivity, pricing and marketability and expansion of cultivable land be adopted.

Ntat *et al*. (2017) carried out a study to assess the impact of rainfall variability on yield of crops in North Central States, Nigeria. Rainfall data from six referenced synoptic stations for the period 1987 to 2016, and crop yield record between 1994 to 2016 were used. Mann-Kendal test and Kriging method were used to analyse the spatio-temporal distribution in rainfall while multiple regression method was used to ascertain the relationship between rainfall and crop yield. The study established an annual rainfall amount of 1100 mm and 1700 mm. Abuja station depicted significant increasing trend while other stations showed no significant trend. The study also revealed that the distribution of rainfall was influenced by the Jos Plateau rather than latitudes or longitude. The study concluded that rainfall influenced maize and rice yield positively but at varying degree across the stations.

2.7. Summary of Empirical Studies Reviewed

The general observation and experience derived from the review of related studies confirmed that many of the specific studies in various regions across the globe are in tandem with global trend of continuous changes in climatic variables. However, the magnitude of changes in the trend varies from one location to another. Studies have shown that the trend has been responsible for the reduction in food production particularly cereal crops in various regions of the world. Hence, the present situation underscores the need for continuous investigation in this field so as to unravel the potential effects that climate variability would have on food crop production. This will help in advancing timely adaptation and mitigation strategy and policy formulation to tackle climate variability and change impact.

CHAPTER THREE

3.0. MATERIALS AND METHODS

3.1. Types and Sources of Data Used

The two sources of data used for this study were; primary and secondary.

3.1.1. Primary data used

The primary data used were obtained from reconnaissance survey, questionnaire administration and interview schedule.

3.1.1.1. Reconnaissance survey

The survey was conducted to examine the nature of farmlands, types of agricultural practices, susceptibility of the farmlands to extreme climatic events (flood and drought) and to identify the adaptation and mitigation measured use by the farmers. This was used to ascertain the validity of the responses provided by the target population.

3.1.1.2. Method of questionnaire administration

Structured questionnaire was issued to crop based farmers in the six adopted villages designated by the National Agricultural Research Institutes within the study area. The farmers surveyed were those residing in the community and have spent at least ten years. Another set of questionnaire was administered to the National Cereal Research Institute (NCRI) Badegi, Niger State to elicit information on available climate resilience agricultural technologies developed and dissemination by the Institution. This was done because the NCRI represents the coordinating Research Institute for the North Central Zone and has a national mandate on technology development and dissemination on cereal crops.

3.1.1.3. Interview method

Interview schedule was conducted simultaneously with the questionnaire administration. This was done on the field with crop farmers who provided detailed information on the subject matter particularly from illiterate population.

3.1.2. Secondary data used

Climatic and crop yield data were the two main secondary data used for this study.

3.1.2.1. Climatic data

Daily rainfall, temperature (maximum and minimum) and relative humidity for the period 1989 to 2018 were the climatic variables used. The thirty (30) years data was sufficient to justify the variation in climatic parameters of the study area.

3.1.2.2. Crop yield data

Annual yield data per hectares for the selected crops (Rice, Maize and Guinea corn) for the period 1989 to 2018 were used. These crops were the staple crops cultivated in the study area.

3.2. Data Sources

The primary data were obtained through reconnaissance survey, questionnaire administration and interview schedule.

The secondary climatic data were sourced from Climatic Prediction Center Merged Analysis of Precipitation (CMAP) from National Oceanic and Atmospheric Administration (NOAA). The CMAP provides very useful data for climate analysis, validation of numerical model, research on hydrology and other significant applications. It also has comprehensive global coverage, improved data quality and extended period (Xie & Arkin, 1997).

Crop yield data were sourced from the Agricultural Development Project (ADP) Offices of the respective States in the zone.

3.3. Method of Data Collection

Table 3.1 presents the locational attributes of the study location; these included stations for climatic data collection, coordinates of the study area (Longitude and Latitude) and number of years of data generated.

Table 3.1. Study Location, Coordinate and Number of Years of Data Generated

S/N	**Weather Station**	**Coordinate**	**Number of Years of Data Generated**
1	Minna	Lat 9^0 36^1 Long 6^0 32^1	(1989-2018) 30 Years
2	Lokoja	Lat 7^0 48^1 Long 6^0 44^1	(1989-2018) 30 Years
3	Ilorin	Lat 8^0 30^1 Long 4^0 32^1	(1989-2018) 30 Years
4	Lafia	Lat 8^0 29^1 Long 8^0 30^1	(1989-2018) 30 Years
5	Abuja	Lat 9^0 31^1 Long 7^0 29^1	(1989-2018) 30 Years

Source: Authors Work, 2018

The questionnaire was administered to major cereal crop farmers within the study area. Two Adopted Villages from each of the three Agricultural Research Institutions located within the study area were covered for the exercise. The adopted villages were designated by the National Agricultural Research Institutes to represent technology trial and dissemination centres and they are located within ten kilometer radius to the host Institutions. The Research Institutes, host States and Adopted Villages are presented in Table 3.2.

Table 3.2. Locational Attributes of Communities for Field Survey (Reconnaissance Survey, Questionnaire Administration and Interview)

SN	Name of Institution	Location	State	Local Government Area	Community Surveyed
1	National Cereal Research Institute (NCRI)	Badeggi	Niger	Bida	Ndagbachi and Emitsu Ndanda
2	Nigeria Store Product Research Institute (NSPRI)	Ilorin	Kwara	Ilorin West/Asa	Aliara and Laduba
3	Agricultural Research Council of Nigeria (ARCN)	Abuja	FCT	AMAC/Kuje	Karshi and Kiyi

Source: Authors Work, 2019

Sixty registered cereal crop farmers from each of the Adopted Village were selected for the exercise. The respondents were chosen from the list of registered farmers available in the communities. Three hundred and fourty two (342) completed copies of questionnaire were returned out of the three hundred and sixty (360) that were administered. This represented 95 % returned rate. The respondents were those that were cultivating at list one out of the selected crops and had stayed in the community for about ten years or more. This was because of their knowledge of the environment and experience on crop production.

3.4. Method of Data Analysis

3.4.1. Objectives and analytical method used

3.4.1.1. Objective one; examination of the trend and spatio-temporal variability in climate variables (Rainfall, Temperature and Relative Humidity).

The Mann-Kendall test was used for the analysis. The equation is given as:

$$S = \sum_{k=1}^{n-1} \sum_{i=k+1}^{n-1} \mathrm{sgn}(\mathrm{x_j} - \mathrm{x_k}) \tag{3.1}$$

Where

$$\mathrm{sgn}\,(\mathrm{x_j} - \mathrm{x_k}) = \begin{cases} 1 \text{ if } (\mathrm{x_j} - \mathrm{x_k}) > 0 \\ 0 \text{ if } (\mathrm{x_j} - \mathrm{x_k}) = 0 \\ -1 \text{ if } (\mathrm{x_j} - \mathrm{x_k}) < 0 \end{cases} \tag{3.2}$$

The probability linked to S and size of sample n was computed in order to qualify the significance of the trend statistically.

The probability associated with the Mann-Kendal test was calculated using a normal-approximation statistics developed by Kendall. This was used for dataset with more than ten (10) value in as far as there were not many tied within the dataset.

To calculate variance of S. VAR(S) the equation was used as follows;

$$\mathrm{VAR(S)} = \frac{\mathrm{n(n-1)(2n-5)} - \sum_{\mathrm{i=1}}^{\mathrm{m}} \mathrm{t_i}\,(\mathrm{t_i}-1)\,(2\mathrm{t_i}+5)}{18} \tag{3.3}$$

Where

n = Number of data point

t_i = Tie of the sample time series and

m = Number of tied value

To calculate the test statistics Z, equation 3.2 and 3.3 were utilised.

The computation for normalized test statistics Z was given as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & \text{if } S < 0 \end{cases} \quad (3.4)$$

When a positive Z value was detected it indicated increasing trend whereas a decreasing trend symbolizes a negative value of Z, and a zero value shows no trend.

3.4.1.1.1. Magnitude of Trend Change

To establish the magnitude of trend change in climatic parameters, the Theil-Sen slope estimator approach was used. This method provides an elaborate evaluation of the trend magnitude (Yue *et al*., 2002; Li *et al*., 2017; Ibrahim *et al*., 2018). The equation was given as:

$$\beta = \left(\frac{x_{j-} x_k}{j-k}\right) \forall k < j \quad (3.5)$$

Where

β = is slope between data points x_j *and* x_k

x_{j-} x_k = Data value at time j and k. j>k respectively.

The analysis was done using MAKESENS 1.0 software developed by the Finish Meteorological Institute.

3.4.1.1.2. Spatial interpolation of derived climatic parameters

To understand the changes in climatic event, this study considered how that event varied spatially and temporally using Inverse Distance Weighted (IDW) method. It is an exact technique of interpolation that apply the condition that the predicted point value is influenced more by points that are closer than those farther away.

The importance of the IDW method is that the values projected falls within the range of minimum and maximum values of the identified points. The equation is given as:

$$Z_0 = \frac{\sum_{i=1}^{s} Zi \frac{1}{di^k}}{\sum_{i=1}^{s} \frac{1}{di^k}} \qquad (3.6)$$

Where

Z_0 = is predictable value at point *0*,

Z_i = is value of Z at identified point *i*,

d_i = is distance between point *I* and *0*,

s = is number of identified point used in the estimation, and

k = is specified power.

3.4.2.1. Objective two; examination of the trend in yield of the selected crops (Rice, Maize and Guinea corn). The Mann-Kendall test was also used. See equation (3.1).

3.4.3.1. Objective three; examination of the relationship between climatic variables and yield of the selected crops.

Correlation and Regression analysis were utilized to assess the strength of association between the climatic variables and crop yield.

3.4.3.2. Correlation analysis

Mansfield, 1994 concluded that in order to examine the linear relationship between two or more variables, the Pearson Product Moment Correlation method is best used. This study therefore adopted the methods to establish the strength of relationship between the climatic variable and crop yield. The equation was given as:

$$R = \frac{n\sum xy-(\sum x)(\sum y)}{\sqrt{n(\sum x^2)-(\sum x)^2}\sqrt{n(\sum y^2)-(\sum y)^2}} \qquad (3.7)$$

Where

R = coefficient of linear correlation

n = number of data

$\sum x$ = sum of all x

$\sum y$ = sum of all y

$\sum x^2$ = individual x score and the combine squares

$\sum xy$ = sum of the product of each x score and its residual score

$(\sum x)^2$ = square of all total x score

3.4.3.3. Regression analysis

Stepwise predictor selection method in Statistical Packages for Social Science (SPSS) version 23 was used for the multiple regression analysis. This was done for the reason that there were more than one independent variable (rainfall, temperature and relative humidity). According to Mansfield (1994), there are two advantages that multiple regression has over simple linear regression. The former can predict the dependent variable more accurately when more than one variable is used unlike the latter. Secondly, when there is more than one independent variable, then a simple linear regression of the dependent variable may give a biased estimate of the effect of this variable on the dependent variable.

The equation for multiple linear regression was given as:

$$y = a + b_1X_1 + b_2X_2 \dots . b_nX_n \qquad (3.8)$$

Where

y = is the predictor

a = is the constant

$X_1 \ldots\ldots X_n$ = is independent variable

$b_1 \ldots b_n$ = is the coefficient of regression

In multiple regression, b1 stands for variation in y in relation to a unit change in X1, holding constant the other independent variables. Also, statistical test is often conducted in order to determine if every coefficient of regression significantly varies from zero.

3.4.4.1. Objective four; analysis of the effect of extreme climatic indices on yield of the selected crops. The World Meteorological Organization standardized indicators contain in CCL/CLIVAR/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) was utilized. To improve a constant perspective on observed climate change and weather extremes, ETCCDI has defined a core set of descriptive indices of extreme. The indices describe special characteristics of extremes including amplitude, frequency and persistence (Li *et al*., 2017; Wang *et al.*, 2017; Azizzadeh and Jovan, 2018; Ibrahim *et al*., 2018).

For rainfall, a total of nine extreme indices were adapted for this study (Table 3.3), which are endorsed by CCL/CLIVAR/JCOMM Expert Team on Climate Change to be the core indices. The indices ranged from Consecutive Dry Days (CDD), Consecutive

Wet Days (CWD), Simple Daily Intensity Index (SDII) to Number of Heavy Rainfall Days (R10), Number of Heavier Rainfall Days (R20) and Number of Rainstorm Days (R50) among others. The indices were extracted using R software. The software is widely used for statistical computing and graphics.

Table 3.3. Rainfall Extreme Indices Used

Index	Description	Definition	Unit
CDD	Consecutive Dry Days	Maximum Number of Consecutive Dry Days	day
CWD	Consecutive Wet Days	Maximum Rainfall on Wet Days	may
SDII	Simple Daily Intensity Index	Average Rainfall on Wet Days	mm/day
R1D	Maximum 1-day Rainfall	Annual Maximum 1-day Rainfall	mm
R5D	Maximum 5-day Rainfall	Annual Maximum Consecutive 5-day Rainfall	mm
R95T	Very Wet Day Rainfall	Fraction of Annual Rainfall due to events ≥95th percentile	%
R10	Number of Heavy Rainfall Days	Number of Rainfall days ≥10mm/day	day
R20	Number of Heavier Rainfall Days	Number of Rainfall days ≥20mm/day	day
R50	Number of Rainstorm Days	Number of days Rainfall ≥50mm/day	day

Adapted from Li *et al*. (2017)

For temperature (Minimum and Maximum), a total of Five extreme indices were adopted (Table 3.4). These indices are also endorsed by CCL/CLIVAR/JCOMM Expert Team on Climate Change to be the core indices. The indices were Monthly Minimum Value of Daily Maximum Temperature (TXn), Monthly Maximum Value of Daily Maximum Temperature (TXx), Monthly Minimum Value of Daily Minimum Temperature (TNn), Monthly Maximum Value of Daily Minimum Temperature (TNx) and Monthly Mean Difference between TX and TN (DTR).

Table 3.4. Extreme Temperature Indices Used

ID	Descriptive	Definition	Unit
TXn	Min Tmax	Monthly minimum value of daily maximum temperature	Oc
TXx	Max Tmax	Monthly maximum value of daily maximum temperature	
TNn	Min Tmin	Monthly minimum value of daily minimum temperature	
TNx	Max Tmin	Monthly maximum value of daily minimum temperature	
DTR	Diurnal Temperature Range	Monthly mean difference between TX and TN	days

Adapted from Azizzadeh and Jovan (2018)

The extreme rainfall and temperature indices were computed based on the crop growing season between 1989 and 2018. To measure the trend in rainfall and temperature indices, the linear trend method was used.

Spearman Rank correlation method was utilized to examine the strength of association between the climatic variables and yield of the selected crops. The equation is given as:

$$r = 1 - \left(\frac{6\Sigma d^2}{n\,(n^2 - 1)}\right) \qquad 3.8$$

Where

d = Variance between the two numbers in all pair of ranks

n = Number of pairs of data

3.4.5.1. Objective five; Identification of the adaptation and mitigation strategies to climate variability on crop production. Descriptive statistics was used for the analysis.

CHAPTER FOUR

4.0. RESULTS AND DISCUSSIONS

4.1. Trend in Climate Variables (Rainfall, Temperature and Relative Humidity)

The analysis was segmented into monthly and annual distribution patterns for each of the variables studied.

4.1.1. Trend in monthly rainfall in the study area

Table 4.1 depicts the trend of monthly rainfall in the study area. May to October were primarily considered since they represent the crop growing season in the study area. The result showed downward monthly rainfall trend at the onset of rains in May but gradually increased towards the cessation period in October. The Minna station depicted a non-significant downward trend in May, June, July, and August on a station-by-station basis. In contrast, September and October show a non-significant upward trend. The result for the Lokoja station showed a significant downward trend in May, June and July at 0.05, 0.01 and 0.1 alpha values. August and September showed a non-significant downward trend, while a significant upward trend at alpha value of 0.05 occurred in October.

Further, the result for Abuja station showed a significant downward trend at an alpha value of 0.1 in May and a non-significant downward trend in June, July and August, while October showed a non-significant upward trend. For the Ilorin station, a non-significant downward trend was detected in May, June, July, and August, respectively. In contrast, September and October depicted a non-significant upward trend. Finally, the result for Lafia station shows a significant downward trend in June, July, and August at alpha values of 0.05, 0.05, and 0.1, while in September and October, a significant upward trend was depicted at alpha values of 0.1 and 0.05, respectively. Given the identified findings, there is a gradual decrease in rainfall amount received across the stations during the period under study. The decrease in rainfall is potential evidence of climate change, and the change would negatively impact the general water availability for agricultural production systems across the Guinea savanna ecological zone of Nigeria. The finding is in line with the study of (Akinsanola and Ogunjobi 2014; Umar 2016).

Table 4.1. Monthly Trend in Rainfall in the Study Area

Station	May	June	July	August	September	October
Minna	-0.04	-1.07	-0.76	-0.86	0.89	0.71
Lokoja	-2.07*	-3.07**	-1.71+	-0.39	-0.04	2.46*
Abuja	-1.82+	-1.26	-1.36	-0.64	1.25	0.64
Ilorin	-0.75	-1.29	-1.25	-1.49	0.71	0.25
Lafia	0.52	-2.43*	-2.36*	-2.21*	1.91+	2.50*

***Trend is significant at α = 0.001 = 99.9%, **Trend is significant at α = 0.01 = 99%, *Trend is significant at α = 0.05 = 95%, +Trend is significant at α = 0.1 = 90% confidence levels.

4.1.1.1. Magnitude in change (β) in monthly rainfall in the study area

Table 4.2 depicts the magnitude of change in monthly rainfall across the stations. The result showed the decreasing rate of change at 0.09 mm yr^{-1}, 1.03 mm yr^{-1}, 1.61 mm $yr^{-1,}$ and 1.41 mm yr^{-1} in May, June, July, and August, respectively at the Minna station. At the same time, September and October showed an increasing rate of change at 1.43 mm yr^{-1} and 0.64 mm yr^{-1} in the same station. On the other hand, the Lokoja station depicts decreasing rate of change at 2.15 mm yr^{-1}, 6.12 mm yr^{-1}, 3.09 mm yr^{-1}, 0.74 mm $yr^{-1,}$ and 1.53 mm yr^{-1} in May, June, July, August, and September, respectively. In contrast, the month of October showed an increasing rate of change at 3.72 mm yr^{-1}.

Further, the Abuja station depicts a decreasing rate of change at 1.67 mm yr^{-1}, 3.71 mm yr^{-1} and 1.43 mm yr^{-1} in the months of June, July and August respectively. In comparison, an increasing rate of change at 2.02 mm yr^{-1}, 1.88 mm yr^{-1}, and 0.59 mm yr^{-1} was detected for May, September, and October, respectively. The Ilorin station showed a decreasing rate of change at 0.44 mm yr^{-1}, 1.19 mm yr^{-1}, 2.34 mm yr^{-1}, and 2.18 mm yr^{-1} in May, June, July, and August, respectively. Similarly, September and October showed an increasing rate of change at 1.06 mm yr^{-1} and 0.28 mm yr^{-1}, respectively. Lafia station showed decreasing rate of change at 4.03 mm yr^{-1}, 4.86 mm yr^{-1}, and 4.59 mm yr^{-1} in June, July, and August. While the increasing rate of change at 2.52 mm yr^{-1}, 4.56 mm yr^{-1}, and 6.06 mm yr^{-1} was detected in May, September, and October, respectively.

This result is significant as the stations where the analysed monthly distribution showed negative magnitude of change, it replicates the Mann-Kendall trend analysis (see Table 4.1). Generally, the finding showed a decreasing magnitude of change in the monthly rainfall distribution across the study area except in October, which showed a constant increase across the stations. The finding implies that the fluctuating pattern of the Inter-Tropical Discontinuity (ITD) has affected the rainfall distribution in the study area. The finding is in line with Ibrahim *et al*. (2017) study, which found an upward trend in rainfall at 0.182mm in October in Gusau and Environs, Nigeria.

Table 4.2. Magnitude in Change (β) in Monthly Rainfall in the Study Area

Station	May	June	July	August	September	October
Minna	-0.09	-1.03	-1.61	-1.41	1.43	0.64
Lokoja	-2.15	-6.12	-3.09	-0.74	-1.53	3.72
Abuja	2.02	-1.67	-3.71	-1.43	1.88	0.59
Ilorin	-0.44	-1.19	-2.34	-2.18	1.06	0.28
Lafia	2.52	-4.03	-4.86	-4.59	4.56	6.06

4.1.1.2 Trend in annual rainfall

Table 4.3 represents the trend in annual rainfall in the study area. The result showed a non-significant decreasing trend at Minna, Abuja, and Ilorin stations, respectively. On the other hand, Lokoja station depicted a significant downward trend at 0.01 alpha value. At the same time, Lafia station shows a significant increasing trend at 0.001 alpha value. Generally, the study showed a decreasing trend in most stations across the study area except in Lafia, where a significant increasing trend was detected. The finding indicates that although regional weather-producing features influence rainfall regimes, stations' local factors are also at play. Thus, findings from this study agree with Itiowe *et al*. (2019), which found a downward trend in the annual rainfall received in parts of the study areas over the past thirty-one (31) years. The finding also conforms to that of Tiamiyu *et al.* (2015).

Table 4.3. Trend in Annual Rainfall in the Study Area

Station	Range of Years	Total Number of Years used	Test-Z
Minna	1989 - 2018	30	-0.75
Lokoja	1989 - 2018	30	-3.14**
Abuja	1989 - 2018	30	-0.86
Ilorin	1989 – 2018	30	-0.86
Lafia	1989 - 2018	30	3.68***

4.1.1.3 Seasonal and annual variability in rainfall in the study area

The distribution of seasonal and annual rainfall variability is depicted in Table 4.4. The result showed that the lowest coefficient of variation in seasonal rainfall occurred in the Ilorin station at 20.36 %, and Lafia had the highest at 37.79 %. The further result shows that the Ilorin station had the lowest annual variation with 17 %, and the highest was found in Lafia with 37.7 %. Generally, the seasonal and annual variability in rainfall depicts a decreasing trend towards the western axis of the study area, which implies that the variation in climatic parameters increased with increasing longitude.

Table 4.4 Seasonal and Annual Variation in Rainfall (%) in the Study Area

Stations	Seasonal	Annual	Difference between Seasonal and Annual (CV)
Minna	24.75	22.84	1.91
Lokoja	29.84	27.69	2.15
Abuja	31.97	31.08	0.89
Ilorin	20.36	17.82	2.54
Lafia	37.79	37.70	0.09

4.1.1.4 Interpolation of coefficient of variability in rainfall at the seasonal and annual time scale

Figures 4.1a and b, depicts the coefficient of variability in seasonal and annual rainfall distribution interpolation. The result showed that Ilorin and Minna stations had the lowest variability in seasonal rainfall at 20.36 % and 24.75 %, and the highest was found in Lafia at 37.79 %. Result for the annual variation showed that Ilorin and Minna had the lowest values at 17.82 % and 22.84 % and the highest variation was found in Lafia at 37.7 %. The finding implies that the seasonal and annual rainfall distribution increased toward the South Eastern axis of the study area. According to Recha *et al.* (2012), a CV > 30% indicates large rainfall variability. Therefore, overall, a high variation in season and annual rainfall in Abuja and Lafia suggest that those stations are more susceptible to floods and droughts. Consequently, the finding should encourage the adaptation of short-season crops and the development of drought mitigation strategies such as supplementary irrigation and rainwater harvesting to mitigate any climate shocks among climate-dependent farmers.

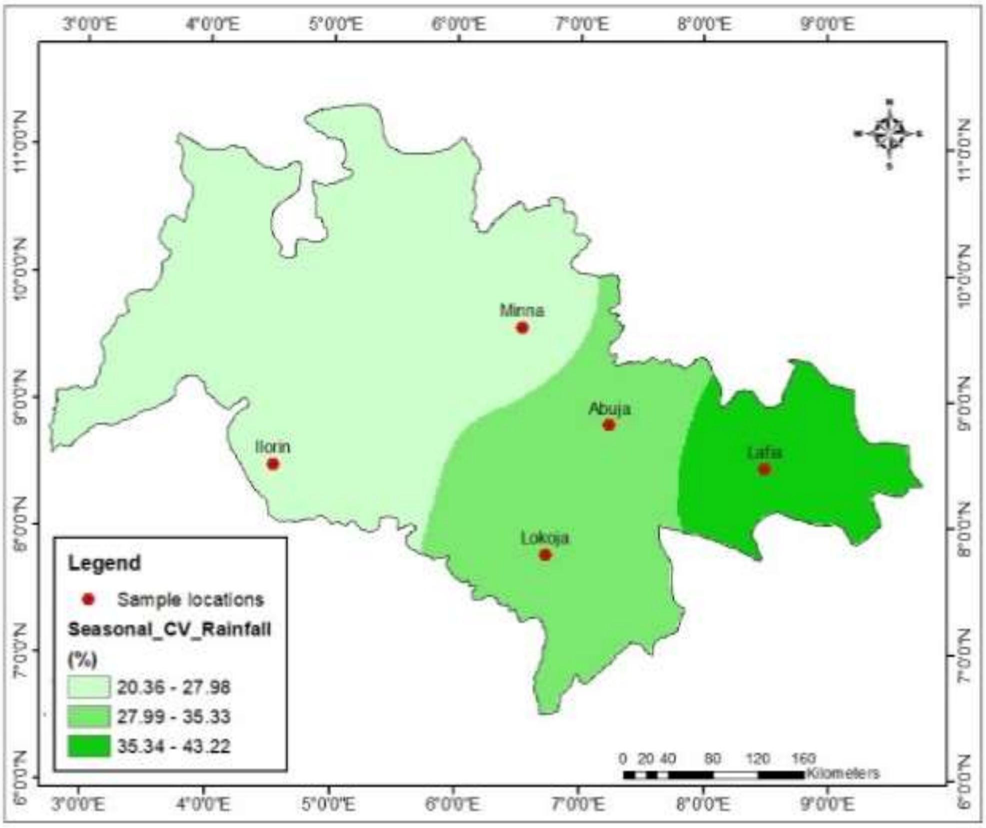


Figure 4.1a. Coefficient of Variation in Seasonal Rainfall

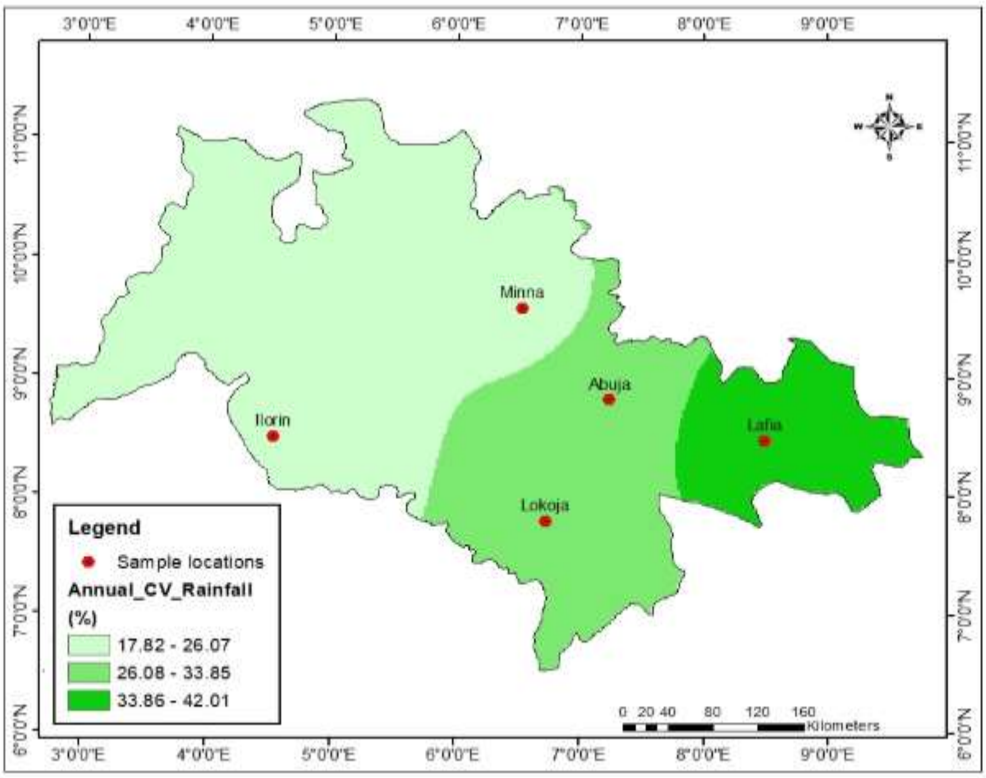


Figure 4.1b. Coefficient of Variation in Annual Rainfall

4.1.2. Trend in monthly maximum temperature in the study area

Table 4.5 depicts the trend of monthly maximum temperature in the study area. Results showed an upward trend in the bulk of the stations. On a station-by-station basis, the Minna station showed a non-significant upward trend in May, June, September, and October, respectively. At the same time, a significant upward trend at 0.01 and 0.05 alpha values were detected in July and August in the same station. The result for the Lokoja station showed a significant downward trend at 0.01 and 0.001 alpha values in August and September. The month of October showed a non-significant downward trend while May, June and July had a significant upward trend at alpha values of 0.05, 0.001, and 0.1.

Further, the result for Abuja station showed a non-significant downward trend in May and October, while in July, it showed a non-significant upward trend. The month of September showed a significant downward trend at 0.05 alpha value, while June and August showed a significant upward trend at 0.1 alpha value each. The Ilorin station depicted a non-significant upward trend in all the months except August, where a non-significant downward trend was detected. The result for Lafia station showed a significant downward trend at 0.001 and 0.01 alpha values in September and October and a non-significant downward trend in July. The months of May, June, and August depicts a significant upward trend at 0.05, 0.05, and 0.1 alpha values, respectively.

Table 4.5. Trend in Monthly Maximum Temperature in the Study Area

Station	May	June	July	August	September	October
Minna	0.49	0.71	2.89**	2.07*	0.76	0.04
Lokoja	2.14*	3.39***	1.82+	-2.78**	-3.99***	-3.96
Abuja	-1.32	1.77+	0.32	1.82+	-2.39*	-1.99
Ilorin	1.46	1.53	0.14	-0.86	0.36	0.96
Lafia	2.07*	2.49*	-1. 39	2.86**	-3.59***	-3.09**

***Trend is significant at $\alpha = 0.001$ **Trend is significant at $\alpha = 0.01$ *Trend is significant at $\alpha = 0.05$ +Trend is significant at $\alpha = 0.1$ confidence levels.

4.1.2.1. Magnitude of change (β) in monthly maximum temperature in the study area

Table 4.6 depicts the result of the magnitude of change in monthly maximum temperature in the study area. On a station-by-station basis, the Minna station showed increasing rate of change in May, June, July, August, September, and October at 0.56 ^{0}C, 0.19 ^{0}C, 1.45 ^{0}C, 1.10 ^{0}C, 0.33 ^{0}C, and 0.09^{0}C, respectively. On the other hand, the result for the Lokoja station showed decreasing rate of change in August, September, and October at 1.31 ^{0}C, 1.75 ^{0}C, and 2.29 ^{0}C, respectively, while the months of May, June, and July showed increasing rate of change at 1.38 ^{0}C, 1.64 ^{0}C, and 1.32 ^{0}C.

Further, the Abuja station depicted a decreasing rate of change in May, September, and October at 1.19 ^{0}C, 1.38 ^{0}C, and 1.77 ^{0}C, respectively, while June, July, and August showed an increasing rate of change at 0.97 ^{0}C, 0.19 ^{0}C, and 0.79 ^{0}C. The result for the Ilorin station showed increasing rate of change in May, June, July, September, and October at 0.71 ^{0}C, 0.59 ^{0}C, 0.07 ^{0}C, 0.20 ^{0}C, and 0.36 ^{0}C, respectively. At the same time, the month of August shows a decreasing rate of change at 0.49 ^{0}C. Lafia stations depicted a decreasing rate of change in July, September, and October at 1.15 ^{0}C, 2.82 ^{0}C, and 3.13 ^{0}C, respectively, while May, June and August showed increasing rate of change at 2.06, 2.16 ^{0}C, 2.29 ^{0}C, respectively.

The finding of the study is in agreement with that of Umar (2016), which revealed that there was an incremental rise in the amount of maximum temperature received in parts of the study area from 1986 to 2015. Similarly, the study of Ragatoa *et al.* (2018) found an increasing trend in the amount of maximum temperature received between 1981 to 2015 in selected stations in Nigeria.

Table 4.6. Magnitude of Change (β) in Monthly Maximum Temperature

Station	May	June	July	August	September	October
Minna	0.56	0.19	1.45	1.10	0.33	0.09
Lokoja	1.38	1.64	1.32	-1.31	-1.75	- 2.29
Abuja	-1.19	0.97	0.19	0.79	-1.38	-1.77
Ilorin	0.71	0.59	0.07	-0.49	0.20	0.36
Lafia	2.06	2.16	-1.15	2.29	-2.82	-3.13

4.1.2.2. Trend in annual maximum temperature in the study area

Table 4.7 showed analysis of the trend in annual maximum temperature in the study area. Result depicts a non-significant upward trend in all the stations during the period under study. The finding is an affirmation of the increasing trend in global temperature. The result is in tandem with the study of Umar (2016).

Table 4.7. Trend in Annual Maximum Temperature in the Study Area

Station	Range of Years	Total Number of Years used	Test-Z
Minna	1989 - 2018	30	1.29
Lokoja	1989 - 2018	30	3.46
Abuja	1989 - 2018	30	2.75
Ilorin	1989 - 2018	30	0.32
Lafia	1989 - 2018	30	2.82

***Trend is significant at α = 0.001 = 99.9%, **Trend is significant at α = 0.01 = 99%, *Trend is significant at α = 0.05 = 95%, +Trend is significant at α = 0.1 = 90% confidence levels.

4.1.2.3. Annual and seasonal variability in maximum temperature in the study area

The seasonal and annual variability in maximum temperature is depicted in Table 4.8. The result showed that the lowest seasonal coefficient of variation occurred in the Ilorin station with 1.41 %, and Lafia had the highest with 3.88 %. On an annual scale, the lowest variability occurred in the Ilorin station with 1.22 %, while Lafia station recorded the highest with 3.68 %.

Table 4.8. Annual and Seasonal Coefficient of Variation in Maximum Temperature

Stations	Seasonal	Annual	Difference between Seasonal and Annual CV
Minna	2.31	1.81	0.50
Lokoja	2.85	2.43	0.42
Abuja	2.62	2.43	0.19
Ilorin	1.41	1.22	0.19
Lafia	3.88	3.68	0.2

4.1.2.4. Interpolation of coefficient of variation in seasonal and annual maximum temperature in the study area

The result of interpolation of annual and seasonal variability in maximum temperature is presented in Figures 4.2a and b. The result showed that Ilorin and Minna stations had the lowest coefficient of variation in maximum seasonal temperature with 1.41 %, and the highest was found in Lafia with 37.79 %. The finding implies that the coefficient of variation in seasonal and annual maximum temperature increased towards the eastern axis of the study area; this could be a result of relief of the study area.

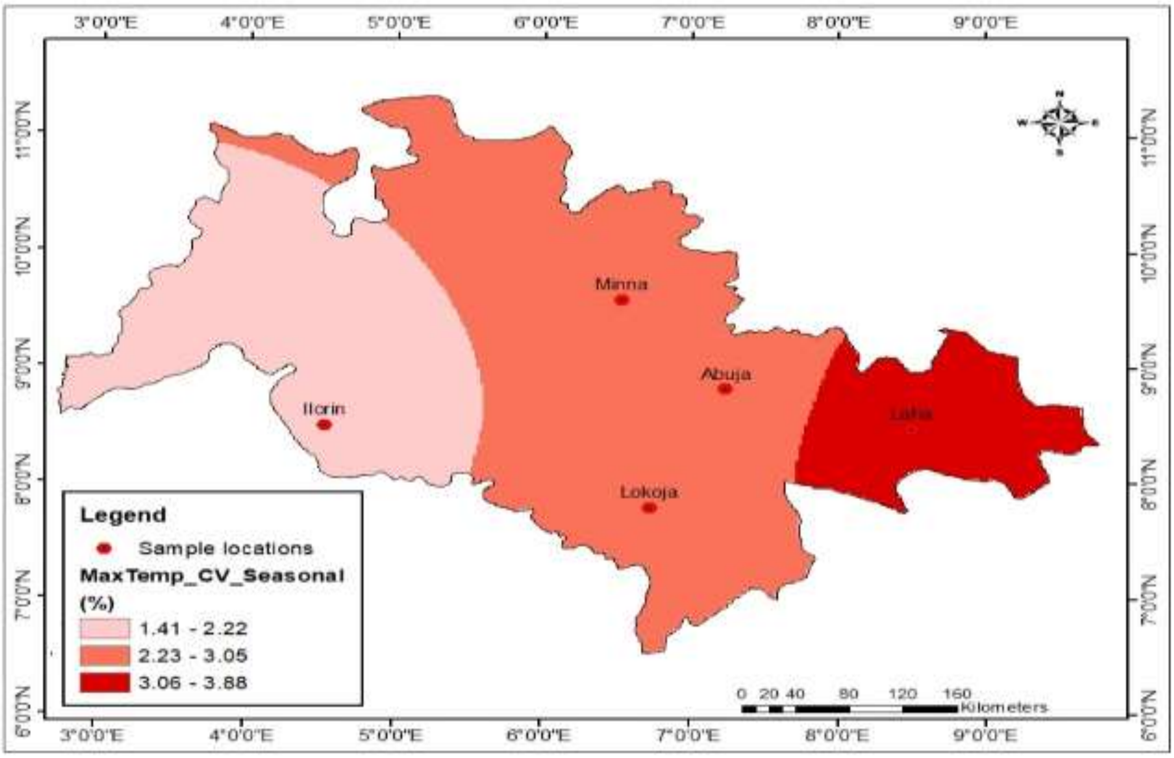


Figure 4.2a. Coefficient of Variation in Seasonal Maximum Temperature

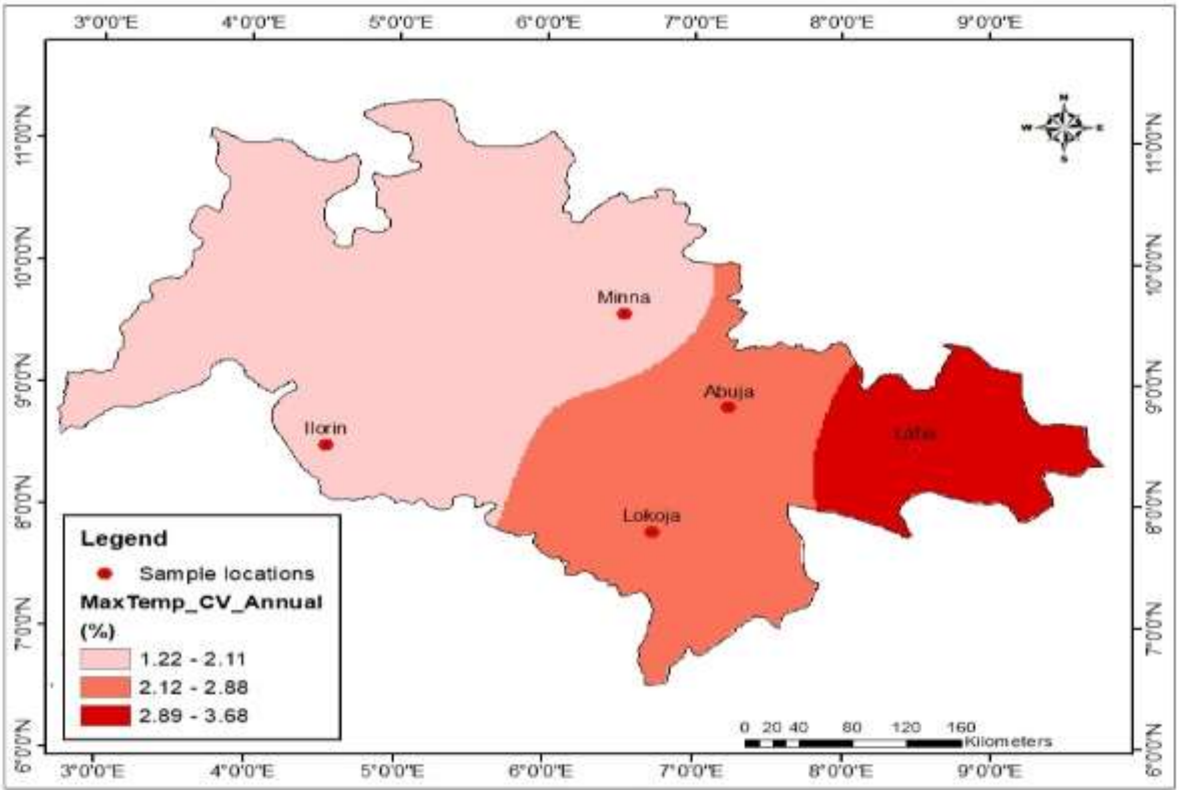


Figure 4.2b. Coefficient of Variation in Annual Maximum Temperature

4.1.3. Trend in monthly minimum temperature in the study area

Table 4.9 depicts the analysis of the trend in monthly minimum temperature in the study area. Results showed an upward trend in the bulk of the stations. On a station-by-station basis, the Minna station showed a significant upward trend in July, August, September, and October at 0.05, 0.05, 0.01, and 0.001 alpha values, respectively, and a non-significant upward trend in May and June. The result for Lokoja station showed a significant upward trend in May and June at 0.01 and 0.05 alpha values and a non-significant downward trend in August, September, and October. The month of July showed a non-significant upward trend.

Further, the Abuja stations showed a significant upward trend in June and August at 0.01 and 0.05 alpha values and a significant downward trend at 0.05 alpha values in May and October. The result for the Ilorin station showed a significant upward trend in May, June, and July at 0.01, 0.05, and 0.1 alpha values, respectively and a non-significant trend in August and October, while September showed no trend. The result for Lafia station showed a significant upward trend in May at 0.001 alpha value and a significant downward trend in June at 0.05 alpha value while July, September, and October show a non-significant trend.

Table 4.9. Trend in Monthly Minimum Temperature in the Study Area

Station	May	June	July	August	September	October
Minna	0.29	1.18	2.07*	2.39*	2.71**	3.53***
Lokoja	2.64**	2.25*	1.57	-0.82	-1.04	-0.36
Abuja	-2.03*	2.75**	0.36	2.14*	-1.29	-2.25*
Ilorin	3.25**	2.00*	1.86+	-1.11	0.00	0.43
Lafia	4.35***	-2.46*	-1.00	0.21	-1.64	-0.25

***Trend is significant at $\alpha = 0.001$ **Trend is significant at $\alpha = 0.01$ *Trend is significant at $\alpha = 0.05$ +Trend is significant at $\alpha = 0.1$ confidence levels.

4.1.3.1. Magnitude of change (β) in monthly minimum temperature in the study area

The magnitude of change in monthly minimum temperature is shown in Table 4.10. The result for the Minna station depicts an increasing magnitude of change in May, June, July, August, September, and October at 0.07 ^{0}C, 0.26 ^{0}C, 0.52 ^{0}C, 0.64 ^{0}C, 0.57 ^{0}C, and 1.27 ^{0}C, respectively. On the other hand, Lokoja station showed decreasing rate of change in August, September and October at 0.32 ^{0}C, 0.35 ^{0}C and 0.09 ^{0}C, respectively, while May, June, and July showed an increased rate of change at 0.94 ^{0}C, 0.59 ^{0}C, and 0.56 ^{0}C, respectively.

Further, the result for Abuja station showed an increasing rate of change in June, July, and August at 0.91 ^{0}C, 0.02 ^{0}C, and 0.64 ^{0}C, respectively, and a decreasing rate of change in May, September, and October at 0.72 ^{0}C, 0.30 ^{0}C and 0.87 ^{0}C respectively. The Ilorin station depicted increasing rate of change in May, June, July, and October at 0.76 ^{0}C, 0.42 ^{0}C, 0.65 ^{0}C, and 0.12 ^{0}C, respectively, and decreasing rate of change in August at 0.40 ^{0}C while September showed no change. Lafia station showed an increasing rate of change in May and August at 1.53 0C and 0.05 0C and a decreasing rate of change in June, July, September and October at 0.85 0C, 0.28 0C 0.69 ^{0}C, and 0.09 ^{0}C, respectively. The finding from this study is in agreement with that of Ragatoa *et al.* (2018), which established that there was an upward trend in the amount of minimum temperature received in selected stations in Nigeria between 1981 and 2015. Similarly, the study of Ogunrayi *et al*. (2016) discovered an increasing trend in the amount of minimum temperature between 1980 to 2011 over Akure, Nigeria.

Table 4.10. Magnitude of Change (β) in Minimum Temperature in the Study Area

Station	May	June	July	August	September	October
Minna	0.07	0.26	0.52	0.64	0.57	1.27
Lokoja	0.94	0.59	0.56	-0.32	-0.35	-0.09
Abuja	-0.71	0.91	0.20	0.64	-0.30	-0.87
Ilorin	0.76	0.42	0.65	-0.40	0.00	0.12
Lafia	1.53	-0.85	-0.28	0.05	-0.69	-0.09

4.1.3.2. Trend in annual minimum temperature in the study area

Table 4.11 depicts the analysis of the trend in annual minimum temperature in the study area. The result showed a significant upward trend at 0.01 alpha value in the Minna station, while the other stations show a non-significant upward trend. Generally, the study revealed a rise in the amount of minimum temperature received across the study area during the period under study.

Table 4.11. Trend in Annual Minimum Temperature in the Study Area

Station	Range of Years	Total Number of Years Used	Test-Z
Minna	1989 - 2018	30	2.71**
Lokoja	1989 - 2018	30	0.18
Abuja	1989 - 2018	30	1.50
Ilorin	1989 - 2018	30	0.54
Lafia	1989 - 2018	30	1.50

***Trend is significant at α = 0.001 = 99.9%, **Trend is significant at α = 0.01 = 99%, *Trend is significant at α = 0.05 = 95%, +Trend is significant at α = 0.1 = 90% confidence levels.

4.1.3.3. Seasonal and annual variability in minimum temperature in the study area

Table 4.12 depicts the annual and seasonal variation of minimum temperature across the study area. The result revealed that the lowest coefficient of variation occurred in the Ilorin station with 1.06 %, and Lafia has the highest with 1.88 %. On annual, the lowest coefficient of variation occurred in Ilorin station with 1.6% and the highest was in Abuja station with 2.35 %.

Table 4.12. Seasonal and Annual Coefficient of Variation in Minimum Temperature

Stations	Seasonal	Annual	Difference between Seasonal and Annual CV
Minna	1.55	1.71	-0.16
Lokoja	1.54	1.43	0.11
Abuja	1.69	2.35	-0.66
Ilorin	1.06	1.16	-0.10
Lafia	1.88	1.55	0.33

4.1.3.4. Interpolation of seasonal and annual coefficient of variability in minimum temperature in the study area.

Figures 4.3a and b, depicts the result of interpolation of coefficient of variation in seasonal and annual minimum temperature. On seasonal basis, the Ilorin station had the lowest variation with 1.06 % while Abuja and Lafia falls within the highest range with 1.69 % and 1.88 % respectively. On annual scale the Ilorin station had the lowest value with 1.16 % while the highest was detected in Abuja station with 2.35 %.

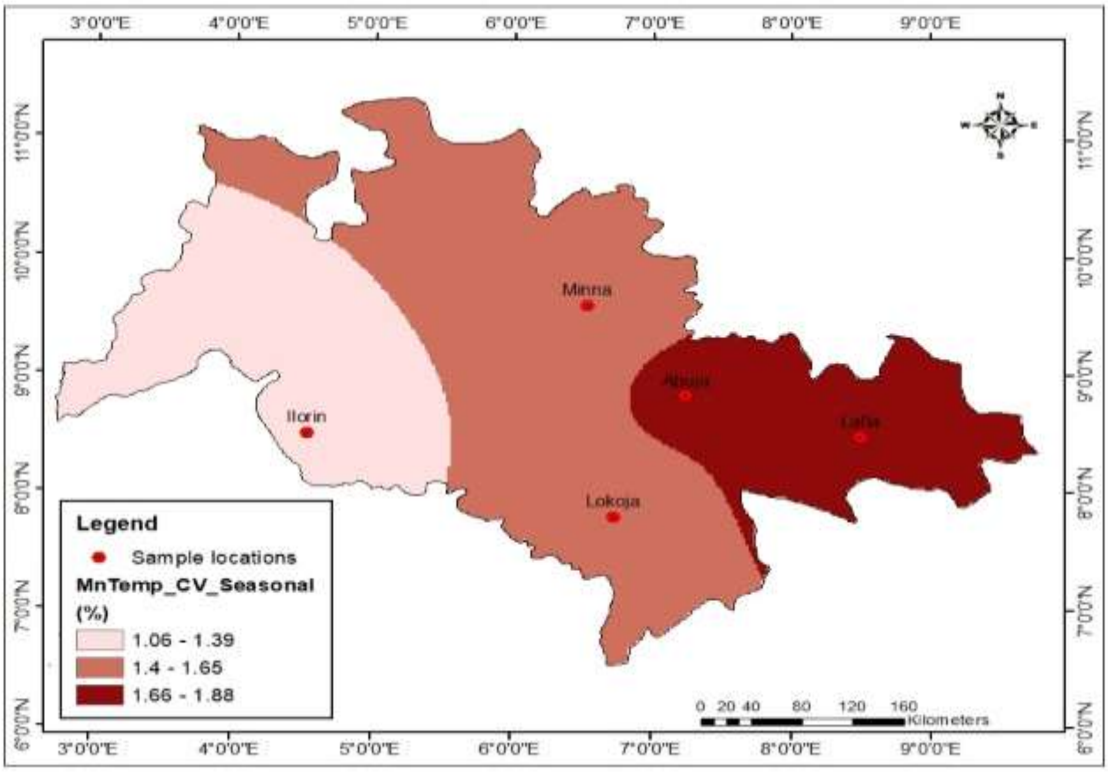


Figure 4.3a. Seasonal Coefficient of Variation in Minimum Temperature

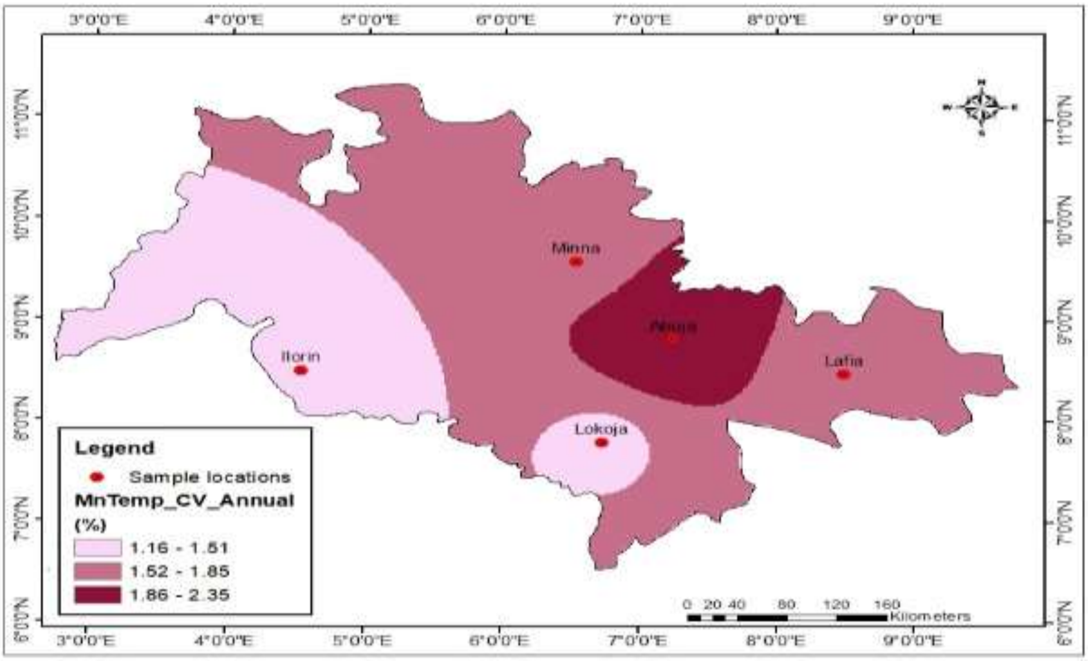


Figure 4.3b. Annual Coefficient of Variation in Minimum Temperature

4.1.4. Trend in monthly relative humidity in the study area

The analysis of trend in monthly relative humidity in the study area is depicted in Table 4.13. On a station by station basis, the Minna station showed a significant upward trend in May, June, July and October at 0.05, 0.05, 0.1 and 0.05 alpha values, respectively, and a significant downward trend in August and September at 0.05 and 0.001 alpha values, respectively. The result for Lokoja station showed a significant upward trend in August and September, while the other months were not significant.

Further, the Abuja station depicted a significant upward trend in May, June and October at alpha values of 0.1, 0.05 and 0.05, respectively and a significant downward trend in August and September at 0.01 and 0.001, respectively. The Ilorin station depicted a significant upward trend in June, August, September, and October at 0.05, 0.001, 0.001, and 0.1 alpha values, respectively. The months of May and July showed non-significance. The result for the Lafia station showed a significant upward trend in August and September at an alpha value of 0.001 each, while the other months showed a non-significant upward trend. Generally, the finding implies that relative humidity increased at the start of rain in May and slightly decreased towards the cessation period in October.

Table 4.13. Trend in Monthly Relative Humidity in the Study Area

Station	May	June	July	August	September	October
Minna	1.96*	2.14*	1.71+	-2.39*	-3.73***	2.39*
Lokoja	0.14	0.77	1.12	4.43***	3.82***	0.59
Abuja	1.82+	2.21*	0.99	-2.71**	-3.69***	2.49*
Ilorin	-1.29	1.99*	0.14	3.94***	3.59***	1.71+
Lafia	0.14	0.77	1.13	4.43***	3.82***	0.59

4.1.4.1. Magnitude of change (β) in monthly relative humidity in the study area

The magnitude of change in monthly relative humidity is depicted in Table 4.14. The Minna station showed the increasing magnitude of change in May, June, July, and October at 24 %, 19 %, 9 %, and 35 %, respectively. On the other hand, the months of August and September showed a decreasing rate of change at 6 % and 9 %, respectively. The result for the Lokoja station showed increasing rate of change in all the months considered in this study. May, June, July, August, September, and October depicted an increasing rate of change at 1 %, 3 %, 2 %, 9 %, 9 % and 2 %, respectively.

Further, the Abuja station showed an increasing rate of change in May, June, July, August, and October at 24 %, 17 %, 7 %, 6 % and 36 %, respectively. The month of September showed a decreasing rate of change at 10 %. The result for the Ilorin station showed increasing rate of change in June, August, September, and October at 8 %, 8 %, 9 %, and 4 %, respectively. The month of May showed decreasing rate of change at 4 % while July showed no change. The result for Lafia station showed increasing rate of change in May, June, July, August, September, and October at 1 %, 3 %, 2 %, 9 %, 9 %, and 2 %, respectively.

Table 4.14. Magnitude of Change (β) in Monthly Relative Humidity in the Study Area

Station	May	June	July	August	September	October
Minna	0.24	0.19	0.09	-0.06	-0.09	0.35
Lokoja	0.01	0.03	0.02	0.09	0.09	0.02
Abuja	0.24	0.17	0.07	0.06	-0.10	0.36
Ilorin	-0.04	0.08	0.00	0.08	0.09	0.04
Lafia	0.01	0.03	0.02	0.09	0.09	0.02

4.1.4.2. Trend in annual relative humidity in the study area

Table 4.15 depicts the trend in annual relative humidity in the study area. The result showed an increasing trend across the study area, with a significant value of 0.01 each for Minna and Abuja stations. The finding agrees with that of Ayinde *et al.* (2013), which showed that there was an incremental rise in the amount of relative humidity received in parts of the study area.

Table 4.15. Trend in Annual Relative Humidity

Station	Range of Years	Total Number of Years Used	Test-Z
Minna	1989 - 2018	30	2.926**
Lokoja	1989 - 2018	30	0.714
Abuja	1989 - 2018	30	2.962**
Ilorin	1989 - 2018	30	1.534
Lafia	1989 - 2018	30	0.713

***Trend is significant at α = 0.001 = 99.9%, **Trend is significant at α = 0.01 = 99%, *Trend is significant at α = 0.05 = 95%, +Trend is significant at α = 0.1 = 90% confidence levels.

4.1.4.3. Seasonal and annual variability in relative humidity in the study area

Table 4.16 depicts the analysis of seasonal and annual variability in relative humidity. On a seasonal basis, the result showed that the lowest coefficient of variation occurred in Lokoja and Lafia stations with 1.2 % for each station, while the highest was in Minna with 2.14 %. On an annual scale, the result showed that the lowest coefficient of variation occurred in the Ilorin station with 3.25%, and the highest was detected in the Minna station with 5.22%.

Table 4.16. Seasonal and Annual Variability in Relative Humidity (%)

Station	Seasonal	Annual	Difference between Seasonal and Annual CV
Minna	2.14	5.22	-3.08
Lokoja	1.2	3.52	-2.32
Abuja	2.09	4.51	-2.42
Ilorin	1.34	3.25	-1.91
Lafia	1.2	3.52	-2.32

4.1.4.4. Interpolation of coefficient of variability in seasonal and annual relative humidity in the study area.

The interpolation of coefficient of variability in seasonal and annual relative humidity is presented in Figure 4.4a and b. On seasonal basis, result showed that Ilorin, Lokoja and Lafia stations had a lower coefficient of variation while Minna and Abuja stations had the highest variation. The result showed a similar pattern with seasonal variation on an annual scale, with Ilorin, Lokoja and Lafia having a lower coefficient of variation while Abuja and Minna stations had the highest variation.

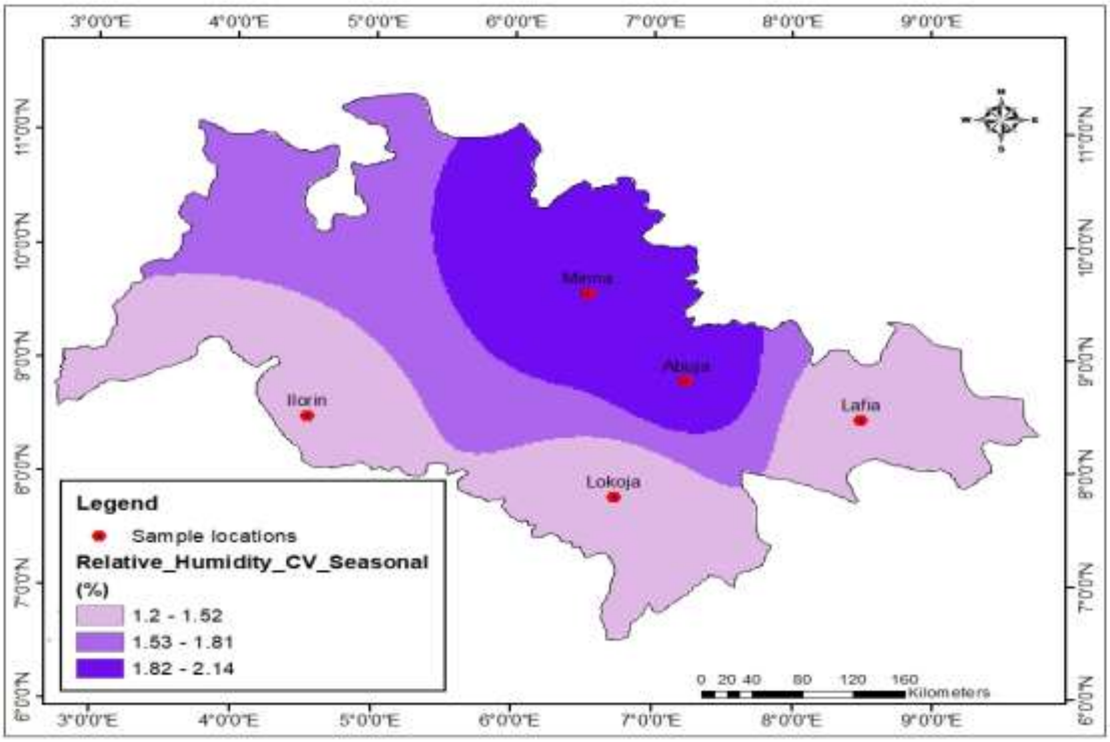


Figure 4.4a. Interpolation of Coefficient of Variation in Seasonal Relative Humidity

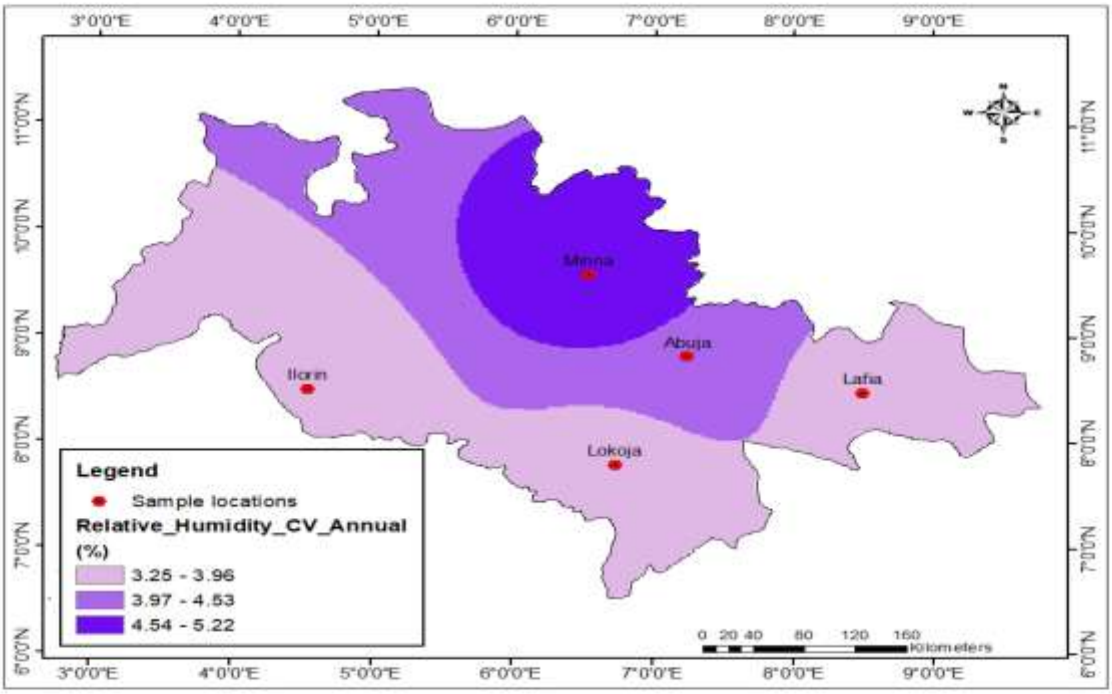


Figure 4.4b. Interpolation of Coefficient of Variation in Annual Relative Humidity

4.2. Trend in Annual Crop Yield in the Study Area

Yield records of the three selected crops studied - rice, maize, and guinea corn are presented in Tables 4.17, 4.18, 4.19, 4.20, and 4.21.

4.2.1. Trend in annual rice yield in the study area

The trend of annual rice yield is presented in Table 4.17. On a station by station basis, the Lokoja, Abuja and Ilorin stations depicted a significant upward trend at 0.001 alpha value for each station. The result for the Lafia station showed a significant downward trend at 0.001 alpha value while the Minna station showed a non-significant upward trend. The study revealed that the lower the coefficient of variation in climatic variables, the higher the yield of rice crops in the study area. Therefore, three stations – Ilorin, Lokoja, and Abuja, which showed a lower coefficient of variation in the identified climatic variables enhanced higher rice yield during the study period. This implies that rice yield increased with decreasing coefficient of variation in climatic variables. The study of Ayinde *et al*. (2013) found an increase in rice output from 1981 to 2010 in parts of the study area.

Table 4.17. Trend in Annual Rice Yield

Station	Range of Years	Total Number of Years Used	Test-Z
Minna	1989 - 2018	30	0.52
Lokoja	1989 - 2018	30	3.89***
Abuja	1989 - 2018	30	5.35***
Ilorin	1989 - 2018	30	4.89***
Lafia	1989 - 2018	30	-5.55***

***Trend is significant at $\alpha = 0.001 = 99.9\%$, **Trend is significant at $\alpha = 0.01 = 99\%$, *Trend is significant at $\alpha = 0.05 = 95\%$, +Trend is significant at $\alpha = 0.1 = 90\%$ confidence levels.

4.2.2. Trend in annual maize yield in the study area

Table 4.18 depicts the trend of annual maize yield in the study area. The result showed a significant increasing trend in Lokoja, Abuja, and Ilorin stations at 0.001 alpha value for each station and a significantly decreasing trend at 0.01 alpha value in Lafia station while the Minna station showed a non-significant decreasing trend. The study established that maize yield increased with decreasing coefficient of variation in climatic variables in the study area. The study of Chabala *et al.* (2015) found an increasing trend in maize yield in five stations out of the six stations investigated in Zambia which have similar climate with Nigeria and the study area in particular.

Table 4.18. Trend in Annual Maize Yield in the Study Area

Station	Range of Years	Total Number of Years Used	Test-Z
Minna	1989 - 2018	30	-0.23
Lokoja	1989 - 2018	30	4.61***
Abuja	1989 - 2018	30	3.59***
Ilorin	1989 - 2018	30	3.80***
Lafia	1989 - 2018	30	-3.23**

***Trend is significant at α = 0.001 = 99.9%, **Trend is significant at α = 0.01 = 99%, *Trend is significant at α = 0.05 = 95%, +Trend is significant at α = 0.1 = 90% confidence levels.

4.2.3. Trend in annual guinea corn yield in the study area

Analysis of trends in guinea corn yield is presented in Table 4 19. The result showed a significant increasing trend in Lokoja, Ilorin, and Lafia stations at 0.001, 0.001, and 0.05, respectively. On the other hand, the result for Minna station showed a significantly decreasing trend at 0.05 alpha value, while Abuja station showed a non-significant decreasing trend. The finding is similar to that of Innocent *et al*. (2016), which found an increasing trend in annual guinea corn yield in Northwestern Benin.

Table 4.19. Trend in Annual Guinea Corn Yield in the Study Area

Station	Range of Years	Total Number of Years Used	Test-Z
Minna	1989 - 2018	30	-2.52*
Lokoja	1989 - 2018	30	5.77***
Abuja	1989 - 2018	30	-1.53
Ilorin	1989 - 2018	30	3.68***
Lafia	1989 - 2018	30	2.02*

***Trend is significant at α = 0.001 = 99.9%, **Trend is significant at α = 0.01 = 99%, *Trend is significant at α = 0.05 = 95%, +Trend is significant at α = 0.1 = 90% confidence levels.

4.2.5. Magnitude of change in annual crop yield

Table 4.20 depicts the magnitude of change in annual crop yield (rice, maize and guinea corn) in the study area. On a station-by-station basis. The Minna station showed no change in rice and maize yield during the study period, while Guinea corn yield showed a decreasing rate of change at 0.02 tone. The result for the Lokoja station showed an increasing rate of change for rice, maize, and guinea corn yield at 0.05, 0.04, and 0.02 tone, respectively. The Abuja station showed increasing rate of change for rice and maize yield at 0.06 and 0.04 tone, respectively while guinea corn yield showed a decreasing rate of change at 0.04 tone.

Further, the result of Ilorin station showed an increasing rate of change for rice, maize, and guinea corn yield at 0.07, 0.02, and 0.03 tone, respectively. On the other hand, the result for Lafia station showed a decreasing rate of change for rice and maize yield at 0.15 and 0.11 tone, respectively while guinea corn yield showed an increasing rate of change at 0.01 tone. Generally, the study revealed that despite the fluctuating climatic parameters observed in the study area, the yield record of the selected crops showed incremental rise during the study period. This implies that the crops may be influenced by factors other than climate.

Table 4.20 Magnitude of Change (β) in Annual Crop Yield in the Study Area

Station	Rice	Maize	Guinea corn
Minna	0.00	-0.00	- 0.02
Lokoja	0.05	0.04	0.02
Abuja	0.06	0.04	-0.04
Ilorin	0.07	0.02	0.03
Lafia	-0.15	-0.11	0.01

4.2.6 Coefficient of variation in annual crop yield

The coefficient of variability in the annual yield of the selected crops (rice, maize and guinea corn) is presented in Table 4.21. The result showed that the lowest variation for rice yield occurred in Minna station with 22.32 %, and the highest was in Lafia with 66.96 %. The lowest variation in maize yield occurred in the Ilorin station with 14.26 %, while the highest was in the Lafia station with 48.84 %. The highest variation in guinea corn yield occurred in Abuja station with 63.80 %, while the lowest was detected in Lokoja station with 28.22 % variation.

Table 4.21. Annual Coefficient of Variation in Crop Yield

Station	Rice	Maize	Guinea corn
Minna	22.32	34.79	56.42
Lokoja	38.52	35.47	28.22
Abuja	33.85	20.01	63.80
Ilorin	30.75	14.26	38.21
Lafia	66.96	48.84	33.66

4.3 Relationship between Climatic Variables and Crop Yield in the Study Area

Tables 4.22, 4.23 and 4.24 depicts the results of the correlation analysis between climatic variables (Rainfall, Temperature and Relative Humidity) and crop yield (Rice, Maize and Guinea corn). The Tables summarise the outcome of the Pearson correlation between climatic variables and yields of the selected crops during the study period (1989 to 2018) and showed that it was significant at 0.01 and 0.05 (2 tailed).

Table 4.22 shows the result of the correlation analysis between the climatic variables and Rice yield in the study area. On a station-by-station basis, the Minna station showed a significant positive correlation for rice yield and rainfall at 0.05 alpha value, while the other parameters showed a non-significant positive correlation in the same station. The result for the Lokoja station showed a significant negative correlation between rice yield and maximum temperature at 0.05 alpha value and a significant positive correlation for relative humidity and rice yield at 0.05 alpha value, while rainfall and the minimum temperature showed a non-significant positive correlation in the same station.

Further results showed that the Abuja station detected a non-significant positive correlation between the climate variables of rainfall, minimum temperature and relative humidity with rice yield, while maximum temperature showed a non-significant negative correlation. Ilorin station showed a non-significant positive correlation between all the identified climatic variables and rice yield. The result for the Lafia station showed a significant negative correlation between rice yield and maximum temperature at 0.01 alpha value while the other parameters were not significant. Generally, the findings revealed a positive relationship between the climatic variables of rainfall, minimum temperature, and relative humidity with rice yield compared to maximum temperature. This implies that an increasing amount of rice yield was associated with increasing rainfall, minimum temperature,, and relative humidity in most parts of the study area. Findings from this study are similar to that of Ayinde *et al.* (2013), which found that minimum temperature and relative humidity exert more influence on rice yield compared to rainfall and maximum temperature in parts of the study area. Also, Akinbile *et al*. (2015) found that temperature and rainfall exerted more effect on rice yield than other climatic variables.

Table 4.22. Correlation Coefficient between Rice Yield and Climatic Variables

		Rice Yield	Rainfall	Max Temperature	Min Temperature	Relative Humidity
Minna Rice Yield	Pearson Correlation	1	**.394***	.152	.266	.140
	Sig (2 tailed)		.031	.424	.155	.462
Lokoja Rice Yield	Pearson Correlation	1	.348	**-.370***	.169	**.427***
	Sig (2-tailed)		.059	.044	.371	.019
Abuja Rice Yield	Pearson Correlation	1	.340	-.541	.220	.348
	Sig (2-tailed)		.066	.002	.242	.059
Ilorin Rice Yield	Pearson Correlation	1	.216	.134	.165	.040
	Sig (2-tailed)		.251	.480	.382	.833
Lafia Rice Yield	Pearson Correlation	1	.273	**-.693****	- .303	-.341
	Sig (2-tailed)		.145	.000	.103	.065

*Correlation is significant at the 0.05 level (2 tailed)
**Correlation is significant at the 0.01 level (2 tailed)

Figure 4.5 depicts the Pearson correlation coefficient distribution pattern between rice yield and climatic variables in the study area. The Figure showed a positive correlation between rice yield and the climatic variables of rainfall, minimum temperature, and relative humidity in all the stations except in Lafia, where a negative correlation was detected for minimum temperature and relative humidity. In contrast, rice yield negatively correlates with maximum temperature in all the stations except Minna and Ilorin stations. The finding revealed that the correlation between the climatic variables and rice yield was not homogeneous within the study area. This implies that the climatic variables did not exert the same influence on rice yield across the study area.

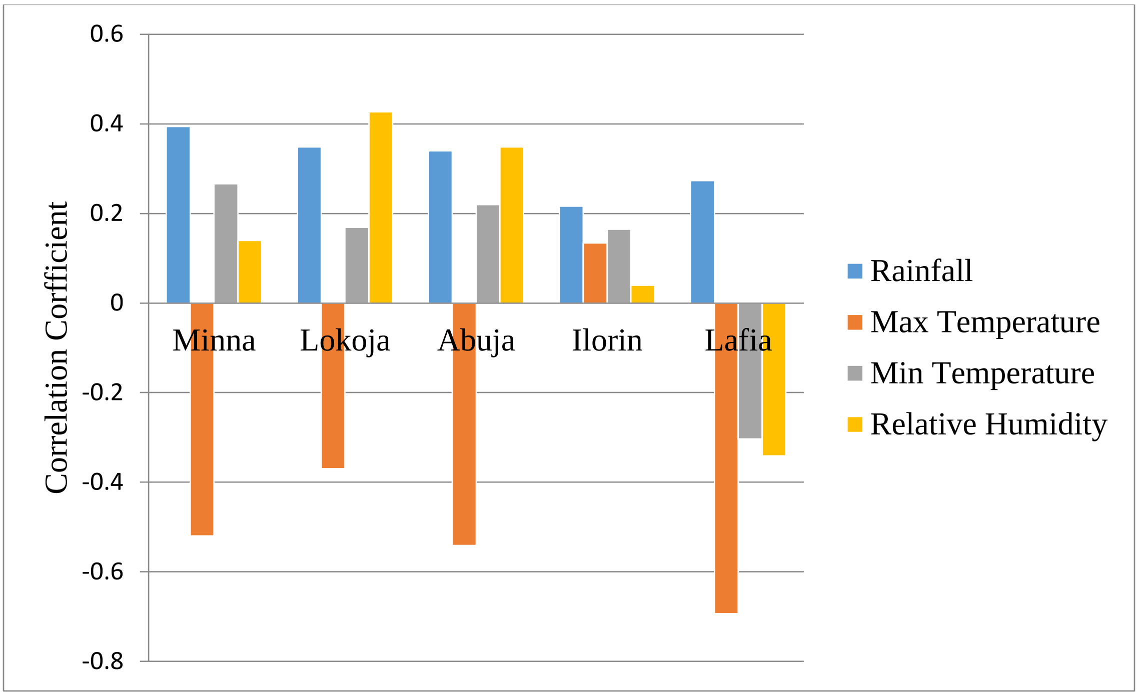


Figure 4.5. Pattern of Correlation Coefficient for Climatic Variables and Rice Yield

Table 4.23 depicts the result of the correlation analysis between maize yield and climatic variables. On a station by station basis, the Minna station showed a significant positive correlation for maize yield and the climatic variables of rainfall and maximum temperature at 0.05 alpha values each, and a non-significant positive correlation for relative humidity. However, minimum temperature showed a non-significant negative relationship with maize yield in the same station. On the other hand, the result for Lokoja station showed a significant negative correlation for maize yield and the climatic variables of rainfall and maximum temperature at 0.05 alpha value each, while minimum temperature and relative humidity showed a non-significant relationship.

Further results showed that the Abuja station depicted a non-significant positive correlation for maize yield and all the climatic variables except maximum temperature, which showed a non-significant negative correlation. In contrast, the Ilorin station depicted a non-significant negative correlation for maize yield and all the climatic variables except rainfall which showed a non-significant positive relationship. Finally, the result for the Lafia station showed a significant positive correlation for maize yield and maximum temperature at 0.01 alpha value, while the other parameters were not significant.

Generally, the study showed a weaker relationship between maize yield and the identified climatic variables as most stations detected a non-significant relationship between the variables.

Table 4.23. Correlation Coefficient between Maize Yield and Climatic Variable

Station		Maize Yield	Rainfall	Max Temperature	Minimum Temperature	Relative Humidity
Minna						
Maize Yield	Pearson correlation	1	**.389***	.141	-.195	.244
	Sig (2 tailed)		.034	.458	.301	.193
Lokoja						
Maize Yield	Pearson Correlation	1	**-.450***	**-.422***	.206	.264
	Sig (2 tailed)		.013	.020	.274	.158
Abuja						
Maize Yield	Pearson Correlation	1	.029	-.275	.003	.263
	Sig (2-tailed)		.879	.141	.987	.161
Ilorin						
Maize Yield	Pearson Correlation	1	.009	-.231	-.147	-.105
	Sig (2-tailed)		.962	.219	.438	.581
Lafia						
Maize Yield	Pearson Correlation	1	.230	**.705****	-.300	-.329
	Sig (2-tailed)		.220	.000	.107	.076

*Correlation is significant at the 0.05 level (2 tailed)
**Correlation is significant at the 0.01 level (2 tailed)

Figure 4.6 depicts the distribution pattern of the result of Pearson correlation coefficient between maize yield and climatic variables in the study area. The Figure showed a more positive relationship between maize yield and the climatic variables of rainfall and relative humidity compared to maximum and minimum temperature. This implies that maize yield in the study area was influenced more by rainfall and relative humidity than maximum and minimum temperature.

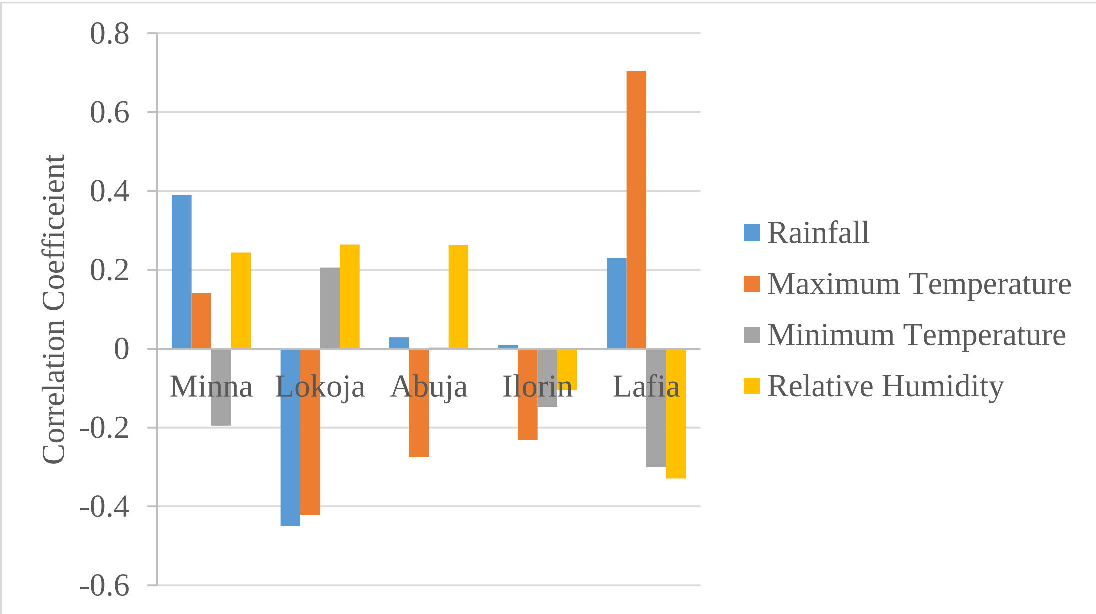


Figure 4.6. Pattern of Correlation Coefficient for Maize Yield and Climatic Variables.

Table 4.24 depicts the result of the correlation analysis between guinea corn yield and climatic variables. Generally, the result showed a negative relationship between guinea corn yield and climatic variables in the bulk of the stations. On a station-by-station basis, Minna station showed a significant negative correlation for Guinea corn yield and relative humidity at 0.05 alpha value, while the other climatic variables were insignificant. The result for the Lokoja station showed a significant negative correlation for Guinea corn yield and rainfall at 0.05 alpha value while the other climatic variables showed a non-significant positive and negative relationship.

Further, the Abuja station showed a significant negative correlation for guinea corn yield and maximum temperature at 0.01 alpha value while the other climatic variables showed a non-significant negative and positive correlation. The result for the Ilorin station depicted a negative correlation for guinea corn yield and all the climatic variables except relative humidity, which showed a non-significant positive correlation. Lafia station depicted a significant positive correlation for guinea corn yield and the climatic variables of minimum temperature and relative humidity at 0.05 alpha value each. There is a significant negative correlation for the maximum temperature at 0.01 alpha value while rainfall showed a non-significant negative relationship. Findings from the study was at variance with that of Sufiyana *et al*. (2020), which found that rainfall and temperature had a significant relationship with guinea corn yield in the Bakori Local Government Area of Kastina State.

Table 4.24. Correlation Coefficient between Guinea corn Yield and Climatic Variables

Station		Guinea corn Yield	Rainfall	Maximum Temperature	Minimum Temperature	Relative humidity
Minna Guinea corn Yield	Pearson Correlation	1	.343	-.006	-.055	**-.448***
	Sig (2 tailed)		.064	.974	.774	.013
Lokoja Guinea corn Yield	Pearson Correlation	1	**-.450***	**-.422***	.206	.264
	Sig (2 tailed)		.013	.020	.274	.158
Abuja Guinea corn Yield	Pearson Correlation	1	-.280	**-.587****	.299	.404
	Sig (2 tailed)		.134	.000	.108	.404
Ilorin Guinea corn Yield	Pearson Correlation	1	**-.458***	-.351	-.166	.113
	Sig (2 tailed)		.011	.090	.381	.554
Lafia Guinea corn Yield	Pearson Correlation	1	-.168	**-.658****	.385*	**.376***
	Sig (2 tailed)		.375	.000	.035	.041

*Correlation is significant at the 0.05 level (2 tailed)
**Correlation is significant at the 0.01 level (2 tailed)

Figure 4.7 depicts the distribution pattern of the Pearson correlation coefficient between guinea corn yield and climatic variables in the study area. The Figure showed more of a negative relationship between guinea corn yield and the climatic variables of rainfall and maximum temperature compared to minimum temperature and relative humidity.

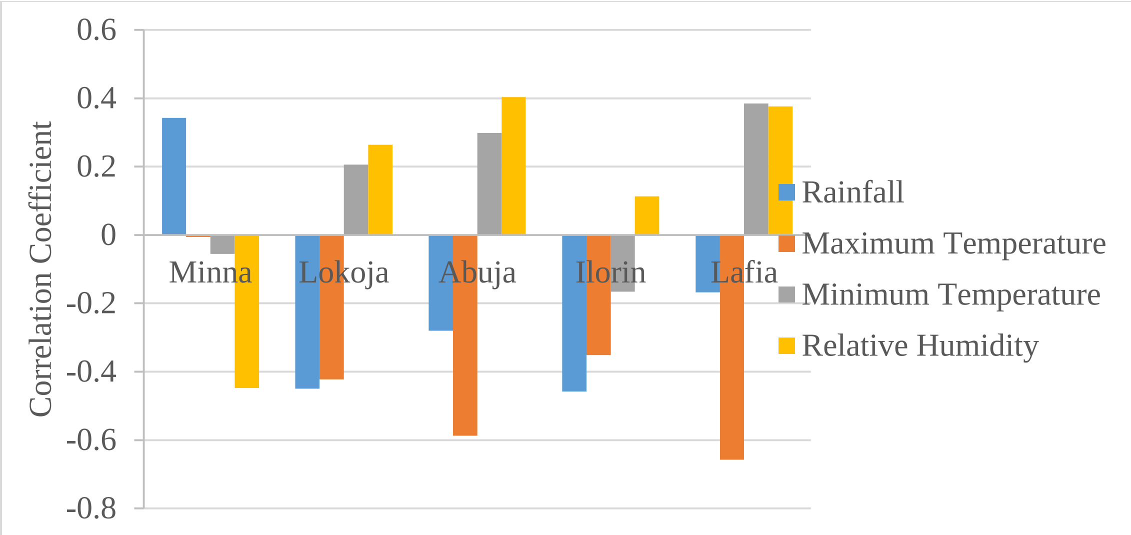


Figure 4.7. Pattern of Correlation Coefficient for Guinea corn Yield and Climatic Variables.

4.3.2. Analysis of multiple regression

Table 4.25 to 4.33 presents multiple regression analysis for crop yield (Rice, Maize, and Guinea corn) and climatic variables (Rainfall, Temperature, and Relative Humidity). The Tables summarised the outcome of the regression analysis for climatic variables and crop yield during the study period 1989-2018.

Table 4.25 showed the model summary for rice yield and climatic variables with coefficients of determination of 23 %, 27 %, and 10 % for Minna, Lokoja, and Ilorin stations, respectively. This indicates a weak positive correlation compared to Abuja and Lafia stations where the coefficient of determination was 54 % and 56 %, respectively, indicating a strong positive correlation. Therefore, the result implies that 54 % and 56 %

of the variance in rice yield at Abuja and Lafia stations can be described by the climatic variables having a strong effect on crop yield.

Table 4.25. Summary of Multiple Regression Model for Rice Yield

Station	R	R Square	Adjusted R Square	Std. Error of the Estimate
Minna	.482[a]	.232	.110	.50860
Lokoja	.521[a]	.272	.155	.73377
Abuja	.735[a]	.540	.466	.44778
Ilorin	.330[a]	.109	-.034	.72929
Lafia	.751[a]	.565	.495	1.69669

a. Predictor: (Constant), RR, Tmax, Tmin and RH

The result of the ANOVA is depicted in Table 4.26. Generally, the result showed a significant relationship between climatic variables and rice yield at F (4.25) =7.326, p=0.00 and F (4.25) =8.103, p=0.00 in Abuja and Lafia stations. In contrast, the Minna, Lokoja, and Ilorin stations showed a non-significance relationship at p>0.05, respectively. The result implies that the climatic variables had little effect on rice yield in Minna, Lokoja and Ilorin stations and were considered statistically insignificant.

Table 4.26. Summary of Analysis of Variance for Rice Yield

Station	Model	Sum of Square	Df	Mean Square	F	Sig.
Minna	Regression	1.958	4	0.490	1.893	.143[b]
	Residual	6.467	25	0.259		
	Total	8.425	29			
Lokoja	Regression	5.024	4	1.256	2.333	.083[b]
	Residual	13.460	25	0.538		
	Total	18.484	29			
Abuja	Regression	5.875	4	1.469	7.326	.000[b]
	Residual	5.013	25	0.201		
	Total	10.888	29			
Ilorin	Regression	1.623	4	0.406	0.763	.559[b]
	Residual	13.297	25	0.532		
	Total	14.919	29			
Lafia	Regression	93.302	4	23.326	8.103	.000[b]
	Residual	71.969	25	2.879		
	Total	165.271	29			

a. Dependent Variable: Rice Yield; b. Predictors: (Constant), Rainfall, Max Temp, Min Temp, RH. P = 0.05%

The multiple regression coefficients for climatic variables and Rice yield is presented in Table 4.27. The standardised beta coefficient for the independent variable (Rainfall, Temperature and Relative Humidity) in Minna station showed that rainfall, minimum temperature, and relative humidity contributed positively to rice yield with 43 %, 28 %, and 01 %, respectively, while maximum temperature contributed inversely with 11 %. The finding implies that rainfall played a dominant role in rice production in Minna station compared to the other variables. Results for Lokoja, Abuja and Ilorin stations showed that relative humidity and minimum temperature contributed positively to rice yield while rainfall and maximum temperature contributed inversely. Furthermore, rainfall and maximum temperature contributed positively with 62 % and 5 % in Lafia station while minimum temperature and relative humidity contributed inversely with 26 % and 11 %, respectively. The finding implies that the climatic variables considered for this study did not exert the same effect on rice yield across the stations. It also implies that rice yield can be influenced by local factors (topography, pest and diseases, and fertiliser) other than climate.

Table 4.27. Multiple Regression Coefficients for Rice Yield

Station	Variables	Unstandardized Coefficients		Standardized Coefficients		Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
Minna	(Constant)	-4.659	7.151		-.652	.521	-19.386	10.068
	RAINFALL	.001	.001	.435	2.253	.033	.000	.003
	MAX TEMP	.000	.001	-.113	-.552	.586	-.001	.001
	MIN TEMP	.001	.001	.286	1.290	.209	-.001	.003
	RH	.000	.003	.019	.087	.931	-.006	.007
Lokoja	(Constant)	-7.911	12.065		-.656	.518	-32.760	16.939
	RAINFALL	.000	.001	-.081	-.363	.720	-.001	.001
	MAX TEMP	-.001	.001	-.243	-1.097	.283	-.002	.001
	MIN TEMP	.001	.001	.189	1.077	.292	-.001	.004
	RH	.008	.005	.286	1.478	.152	-.003	.019
Abuja	(Constant)	-1.791	6.367		-.281	.781	-14.905	11.323
	RAINFALL	-.001	.000	-.340	-2.234	.035	-.002	.000
	MAX TEMP	-.001	.000	-.519	-3.735	.001	-.002	-.001
	MIN TEMP	.002	.001	.384	2.537	.018	.000	.004
	RH	.003	.003	.167	1.157	.258	-.002	.008
Ilorin	(Constant)	-3.080	15.093		-.204	.840	-34.165	28.005
	RAINFALL	-.001	.001	-.182	-.900	.377	-.002	.001
	MAX TEMP	-.001	.001	-.184	-.838	.410	-.003	.001
	MIN TEMP	.002	.002	.266	1.272	.215	-.001	.005
	RH	.001	.006	.019	.097	.923	-.011	.012
Lafia	(Constant)	12.474	26.268		.475	.639	-41.626	66.573
	RAINFALL	.000	.001	.051	.338	.738	-.001	.002
	MAX TEMP	.004	.001	.624	4.140	.000	.002	.005
	MIN TEMP	-.005	.003	-.266	-1.935	.064	-.011	.000
	RH	-.009	.012	-.112	-.798	.432	-.033	.015

a. Dependent Variable: RICE YIELD

Table 4.27, which gives the final predictive model as deduced from the unstandardized coefficients provides the equation for the multiple regression for the independent variable (Climate) with definite contribution of their impacts on the dependent variables (Rice Yield) as presented in the following equations:

$$Ry\ Minna = -4.659 + 0.001RR + 0.000T_{max} + 0.001T_{min} + 0.000RH \quad 4.1$$

$$Ry\ Lokoja = -7.911 + 0.00RR - 0.001T_{max} + 0.001T_{min} + 0.008RH \quad 4.2$$

$$Ry\ Abuja = -1.791 - 0.001RR - 0.001T_{max} + 0.002T_{min} + 0.003RH \quad 4.3$$

$$Ry\ Ilorin = -3.080 - 0.001RR - 0.001T_{max} + 0.002T_{min} + 0.001RH \quad 4.4$$

$$Ry\ Lafia = 12.474 + 0.00RR + 0.004T_{max} - 0.005T_{min} - 0.009RH \quad 4.5$$

Where

Ry = Rice yield, RR = Rainfall, Tmax = Maximum Temperature, Tmin = Minimum Temperature and RH = Relative Humidity.

Table 4.28 depicts the analysis of multiple regression for climatic variables and maize yield in the study area. The result summarises the multiple regression model for climatic variables and maize yield with a coefficient of 57 % for Lafia station, indicating a strong positive correlation. In contrast, Minna, Lokoja, Abuja, and Ilorin stations had 21 %, 27 %, 15 %, and 7 %, respectively, showing a weak positive relationship. These indicated that climatic variables caused 57 % of the variance in maize yield in Lafia station, whereas the remaining 43 % could be due to other local factors apart from climate. The result also showed that increased rainfall, temperature, and relative humidity are likely to lead to lower maize yield in Minna, Lokoja, Abuja, and Ilorin stations.

Table 4.28. Summary of Multiple Regression Model for Maize Yield

Station	R	R Square	Adjusted R Square	Std. Error of the Estimate
Minna	.467[a]	.219	.093	.50475
Lokoja	.524[a]	.275	.159	.48891
Abuja	.394[a]	.155	.020	.42070
Ilorin	.278[a]	.077	-.071	.20270
Lafia	.758[a]	.574	.506	1.03862

a. Predictors: (Constant), Rainfall, Max Temp, Min Temp, Relative Humidity

Table 4.29 depicts the Analysis of Variance (ANOVA) for climatic variables and maize yield in the study area. Results revealed a significant relationship between maize yield and climatic variables at F (4.25) = 8.425, p=0.00 in Lafia station, while Minna, Lokoja, Abuja and Ilorin stations showed a non-significance relationship at P>0.05, respectively. Therefore, the result implies that the climatic variables had little influence on maize yield in Minna, Lokoja, Abuja, and Ilorin stations and can be considered statistically insignificant.

Table 4.29. Summary of Analysis of Variance for Maize Yield

Station	Model	Sum of Squares	Df	Mean Square	F	Sig.
Minna	Regression	1.781	4	.445	1.748	.171[b]
	Residual	6.369	25	.255		
	Total	8.150	29			
Lokoja	Regression	2.264	4	.566	2.368	.080[b]
	Residual	5.976	25	.239		
	Total	8.240	29			
Abuja	Regression	.811	4	.203	1.145	.358[b]
	Residual	4.425	25	.177		
	Total	5.235	29			
Ilorin	Regression	.086	4	.021	.522	.721[b]
	Residual	1.027	25	.041		
	Total	1.113	29			
Lafia	Regression	36.352	4	9.088	8.425	.000[b]
	Residual	26.968	25	1.079		
	Total	63.321	29			

a. Dependent Variable: Maize Yield; b. Predictors: (Constant), Rainfall Tmax, Tmin and RH

Table 4.30 presents the multiple regression coefficient for climatic variables and maize yield. The standardised beta coefficient for the independent variable (Rainfall, Temperature and Relative Humidity) in Minna station showed that rainfall and maximum temperature contributed positively to maize yield with 34 % and 10 % while minimum temperature and relative humidity contributed inversely with 12 % and 18 %

respectively. The finding implies that rainfall played a dominant role in maize production in Minna station compared to the other variables. The result for the Lokoja station showed that only rainfall contributed positively to maize yield with 20 %. On the other hand, rainfall and relative humidity contributed positively at 16 % and 28 % in Abuja station.

The result for the Ilorin station showed a positive contribution of rainfall at 08 % while Lafia station showed a 09% positive contribution of Relative humidity to maize yield. Generally, the result shows that the climatic variables considered for this study did not exert the same effect on Maize yield across the stations. The finding also implies that maize yield can be influence by local factors apart from climate.

Table 4.30. Coefficients of Multiple Regression for Maize Yield

Station	Variables	Unstandardised Coefficients		Standardised Coefficients	T	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
Minna	(Constant)	3.300	7.097		.465	.646	-11.316	17.916
	RAINFALL	.001	.001	.345	1.773	.088	.000	.002
	MAX TEMP	.000	.001	.101	.486	.631	-.001	.001
	MIN TEMP	.000	.001	-.121	-.541	.593	-.002	.001
	RH	-.003	.003	-.188	-.844	.407	-.009	.004
Lokoja	(Constant)	6.618	8.039		.823	.418	-9.939	23.175
	RAINFALL	.000	.000	-.072	-.327	.747	-.001	.001
	MAX TEMP	-.001	.000	-.501	-2.268	.032	-.002	.000
	MIN TEMP	.001	.001	.202	1.155	.259	-.001	.003
	RH	-.002	.004	-.084	-.435	.667	-.009	.006
Abuja	(Constant)	5.728	5.982		.958	.347	-6.592	18.049
	RAINFALL	.000	.000	.162	.785	.440	.000	.001
	MAX TEMP	.000	.000	-.274	-1.452	.159	-.001	.000
	MIN TEMP	.000	.001	-.064	-.314	.756	-.002	.001
	RH	.004	.002	.286	1.459	.157	-.001	.009
Ilorin	(Constant)	7.048	4.195		1.680	.105	-1.592	15.688
	RAINFALL	8.926E-05	.000	.081	.392	.698	.000	.001
	MAX TEMP	.000	.000	-.239	-1.070	.295	-.001	.000
	MIN TEMP	.000	.000	-.062	-.290	.774	-.001	.001
	RH	-.001	.002	-.113	-.583	.565	-.004	.002
Lafia	(Constant)	5.001	16.080		.311	.758	-28.116	38.117
	RAINFALL	-3.28E-05	.001	-.009	-.064	.949	-.001	.001
	MAX TEMP	.002	.001	.665	4.464	.000	.001	.003
	MIN TEMP	-.003	.002	-.250	-1.840	.078	-.007	.000
	RH	-.005	.007	-.099	-.717	.480	-.020	.010

a. Dependent Variable: Maize Yield

Table 4.30, which gives the final predictive model as deduced from the unstandardized coefficients provides the equation for multiple regression for the independent variable

(Climate) with definite contribution of their impacts on the dependent variable (Maize yield) as presented in the following equations:

$$Mzy\ Minna = 3.300 + 0.345RR + 0.101T_{max} - 0.121T_{min} - 0.188RH \quad 4.6$$

$$Mzy\ Lokoja = 6.618 - 0.072RR - 0.501T_{max} + 0.202T_{min} - 0.084RH \quad 4.7$$

$$Mzy\ Abuja = 5.728 + 0.162RR - 0.274T_{max} - 0.064T_{min} + 0.286RH \quad 4.8$$

$$Mzy\ Ilorin = 7.048 + 0.081RR - 0.239T_{max} - 0.062T_{min} - 0.133RH \quad 4.9$$

$$Mzy\ Lafia = 5.001 - 0.009RR + 0.665T_{max} - 0.250T_{min} - 0.009RH \quad 4.10$$

Where Mzy = Maize yield; RR = Rainfall; Tmax = Maximum Temperature; Tmin = Minimum Temperature and RH = Relative Humidity.

Table 4.31 depicts the multiple regression model summary for climatic variables and Guinea corn yield in the study area. The result showed a coefficient of determination of 37 %, 40 %, 27 %, 24 %, and 47 %, respectively, for Minna, Lokoja, Abuja, Ilorin, and Lafia stations. The findings indicate a general weaker positive correlation across the stations. This is attributable to the fact that it is more tolerant to climatic extremes with much longer growing period.

Table 4.31. Summary of Multiple Regression Model for Guinea corn Yield

Station	R	R Square	Adjusted R Square	Std. Error of the Estimate
Minna	.608[a]	.370	.269	.63935
Lokoja	.636[a]	.404	.309	.27465
Abuja	.526[a]	.277	.161	1.21488
Ilorin	.493[a]	.244	.122	.59211
Lafia	.692[a]	.479	.396	.30487

a. Predictors: (Constant), Rainfall, Max Temperature, Min Temperature Relative Humidity

Table 4.32 depicts the result of ANOVA for guinea corn yield and climatic variables. The result showed a statistically significant relationship between guinea corn yield and the climatic variables at F (4.25) = 5.749, p=0.00 in Lafia stations while Minna, Lokoja, Abuja, and Ilorin station showed non-significant relationship at p> 0.05 respectively. Thus, finding from the study implies that climatic variables had little influence on guinea corn yield across the stations and therefore can be considered statistically insignificant.

Table 4.32. Summary of Analysis of Variance for Guinea corn Yield

Station	Model	Sum of Squares	Df	Mean Square	F	Sig.
MInna	Regression	6.004	4	1.501	3.672	$.017^{b}$
	Residual	10.219	25	.409		
	Total	16.223	29			
Lokoja	Regression	1.279	4	.320	4.240	$.009^{b}$
	Residual	1.886	25	.075		
	Total	3.165	29			
Abuja	Regression	14.138	4	3.534	2.395	$.077^{b}$
	Residual	36.898	25	1.476		
	Total	51.036	29			
Ilorin	Regression	2.821	4	.705	2.012	$.124^{b}$
	Residual	8.765	25	.351		
	Total	11.586	29			
Lafia	Regression	2.137	4	.534	5.749	$.002^{b}$
	Residual	2.324	25	.093		
	Total	4.461	29			

a. Dependent Variable: Guinea corn Yield; b. Predictor: (Constant), Rainfall, Tmax, Tmin and RH.

The multiple regression coefficients for climatic variables and guinea corn yield is depicted in Table 4.33. The standardised beta coefficient for the independent variables (Rainfall, Temperature, and Relative Humidity) in Minna station showed that rainfall and minimum temperature contributed positively to guinea corn yield with 34 % and 31 %, while maximum temperature and relative humidity contributed inversely with 06 % and 60 % respectively. Further results showed that all the climatic variables considered in this study contributed inversely to guinea corn yield in Lokoja station at 49 %, 24 %, 02 %, and 07 % for rainfall, maximum temperature, minimum temperature, and relative humidity, respectively.

The Abuja station results showed that rainfall, maximum temperature and relative humidity contributed positively with 24 %, 38 % and 04 %, respectively, while minimum temperature contributed inversely with 41 %. The result for the Ilorin station showed that only relative humidity contributed positively with 04 %, while rainfall, maximum temperature, and minimum temperature contributed inversely with 39 %, 16 %, and 05 %, respectively. The result for the Lafia station showed that only minimum temperature contributed positively with 18 %, while rainfall, maximum temperature, and relative humidity contributed inversely with 07 %, 67 %, and 15 %, respectively. The finding implies that guinea corn yield can be influenced by local factors apart from climate.

Table 4.33. Multiple Regression Coefficient for Guinea-corn yield

Stations	Variables	Unstandardised Coefficient		Standardised Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
Minna	(Constant)	-2.464	8.989		-.274	.786	-20.977	16.050
	RAINFALL	.001	.001	.342	1.955	.062	.000	.003
	MAX TEMP	.000	.001	-.069	-.370	.715	-.002	.001
	MIN TEMP	.002	.001	.318	1.583	.126	.000	.004
	RH	-.012	.004	-.602	-3.018	.006	-.020	-.004
Lokoja	(Constant)	6.213	4.516		1.376	.181	-3.088	15.515
	RAINFALL	-.001	.000	-.493	-2.452	.022	-.001	.000
	MAX TEMP	.000	.000	-.240	-1.197	.243	-.001	.000
	MIN TEMP	-4.65E-05	.000	-.017	-.105	.917	-.001	.001
	RH	-.001	.002	-.073	-.418	.680	-.005	.003
Abuja	(Constant)	14.204	17.275		.822	.419	-21.375	49.783
	RAINFALL	.001	.001	.239	1.250	.223	-.001	.003
	MAX TEMP	.002	.001	.377	2.162	.040	.000	.004
	MIN TEMP	-.005	.002	-.410	-2.163	.040	-.009	.000
	RH	.002	.007	.042	.231	.819	-.013	.016
Ilorin	(Constant)	12.954	12.254		1.057	.301	-12.284	38.192
	RAINFALL	-.001	.001	-.393	-2.109	.045	-.003	.000
	MAX TEMP	-.001	.001	-.159	-.783	.441	-.003	.001
	MIN TEMP	.000	.001	-.051	-.265	.793	-.003	.002
	RH	.001	.005	.044	.249	.805	-.008	.011
Lafia	(Constant)	5.654	4.720		1.198	.242	-4.067	15.375
	RAINFALL	-6.41E-05	.000	-.070	-.426	.674	.000	.000
	MAX TEMP	-.001	.000	-.665	-4.038	.000	-.001	.000
	MIN TEMP	.001	.000	.183	1.219	.234	.000	.002
	RH	-.002	.002	-.149	-.975	.339	-.006	.002

a. Dependent Variable: GUINEA-CORN YIELD

Table 4.33, which provides the final predictive model as inferred from the unstandardised coefficients provides the multiple regression equation for the independent variable (Climate) with definite contribution of their impacts on the dependent variables (Guinea corn) as presented in the following equations:

$$Gy\ Minna = -2.464 + 0.342RR - 0.069T_{max} + 0.318T_{min} - 0.602RH \quad 4.11$$

$$Gy\ Lokoja = 6.213 - 0.493RR - 0.240T_{max} - 0.017T_{min} - 0.073RH \quad 4.12$$

$$Gy\ Abuja = 14.204 + 0.239RR + 0.377T_{max} - 0.410T_{min} + 0.042RH \quad 4.13$$

$$Gy\ Ilorin = 12.954 - 0.393RR - 0.159T_{max} - 0.051T_{min} + 0.044RH \quad 4.14$$

$$Gy\ Lafia = 5.654 - 0.070RR - 0.665T_{max} + 0.183T_{min} - 0.149RH \quad 4.15$$

Where Gy = Guinea corn yield; RR = Rainfall; Tmax = Maximum Temperature; Tmin = Minimum Temperature and RH = Relative Humidity.

4.4. Analysis of the Effects of Extreme Climatic Variability on Crop Yield in the Study Area.

4.4.1: Trend in extreme rainfall indices

The linear trend of extreme rainfall indices in the study area is presented in Figures 4.8 to 4.16. Generally, the rainfall indices for Consecutive Dry Day (CDD), Consecutive Wet Day (CWD), Simple Daily Intensity Index (SDII), R1D, R5D, Very Wet Day (R95T), R10, R20, and R50 showed trend over the study area during the period of study (1989-2018). The anomalies in the extreme indices may suggest a more intense enhancement of the change in the natural variability in the recent climate.

Figure 4.8(a – e) depicts rainfall indices for a consecutive dry day in the study area. Results showed an upward trend in all the stations during the study period. The Minna, Lokoja, Abuja, Ilorin, and Lafia stations detected an increasing trend at 15.73, 9.26, 19.20, 9.26 and 9.26 days. Generally, the finding showed an increased trend in the number of consecutive dry days across the stations and, therefore, an indication for dry spell occurrence in the study area, especially in Minna and Abuja stations with the highest number of consecutive dry days. The dry spell phenomenon, which is a condition for non-availability or insufficiency in moisture, is likely to negatively impact the selected crops' production.

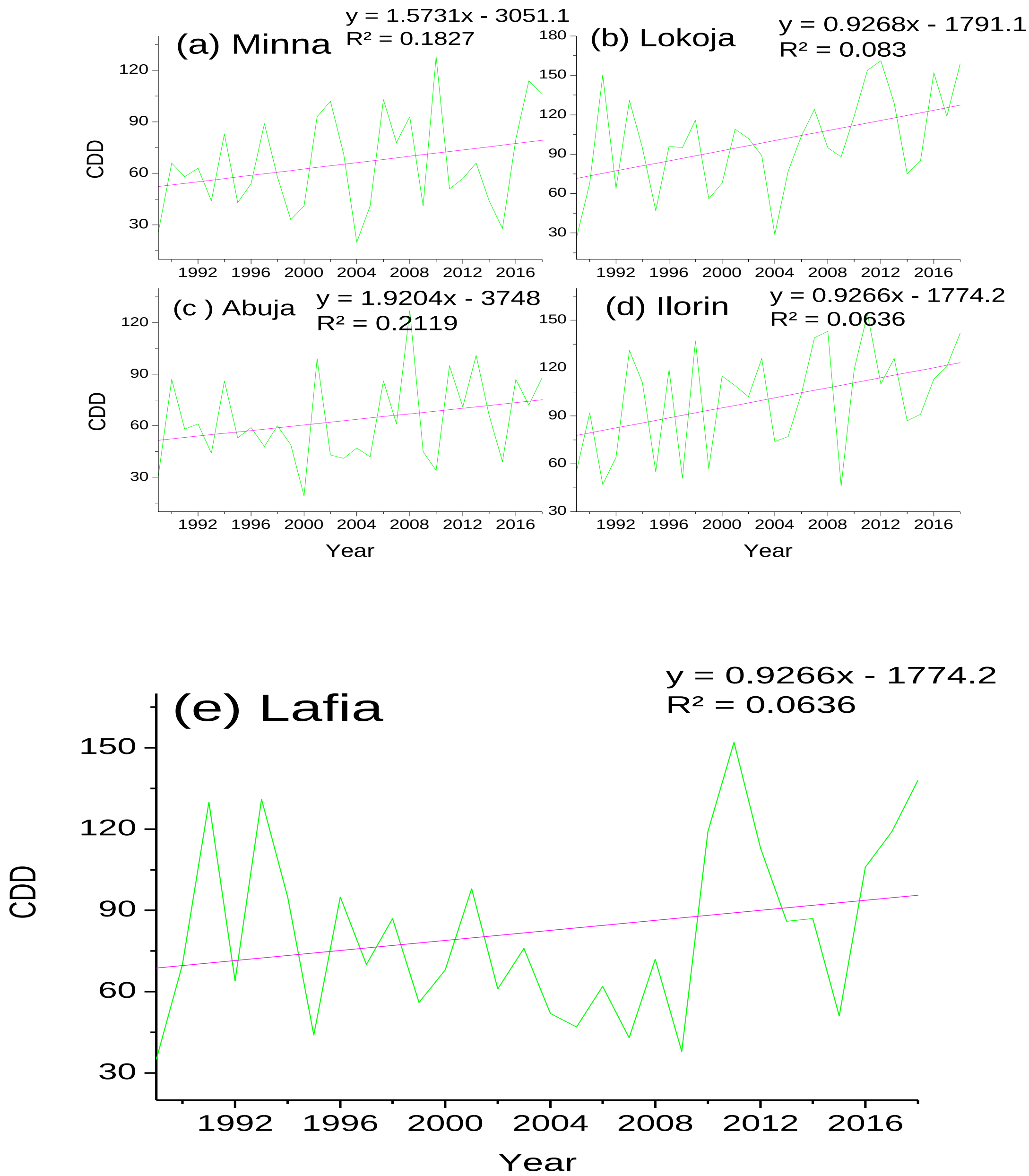


Figure 4. 8(a – e). Trend in Rainfall Index: Consecutive Dry Day (CDD)

Figure 4.9 (a – e) depicts the analysis of trend in rainfall indices for Consecutive Wet days (CWD) in the study area. The result showed a decreasing trend for CWD across the stations. For example, the Minna, Lokoja, Abuja, Ilorin, and Lafia stations showed a decreasing trend at 1.52, 1.66, 2.89, 0.82, and 2.84 days, respetively. Although generally, the finding revealed a decreasing number of consecutive rainfall days across the study area, the finding may have serious implications for the growing development of cereal crops, especially rice production that require much higher rainfall days to perform optimally.

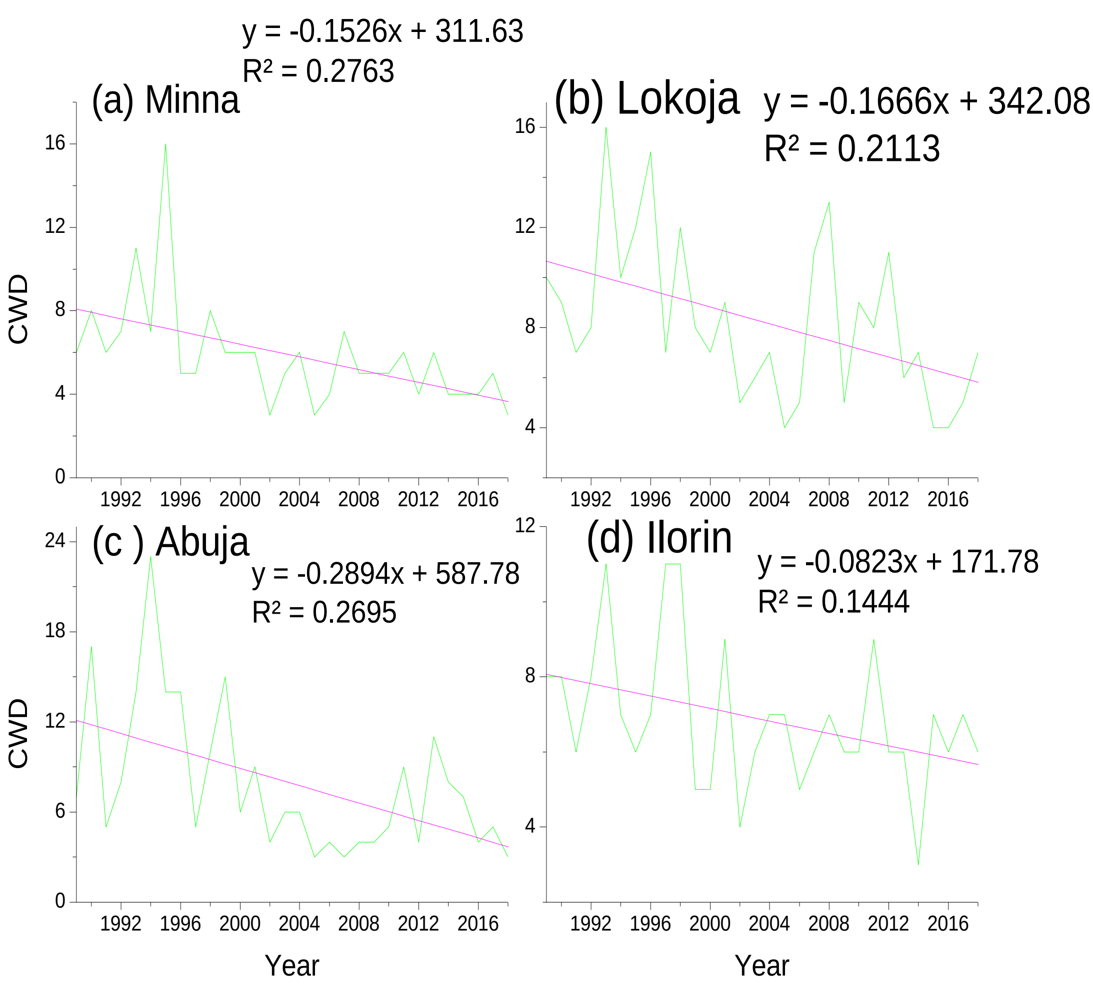


Figure 4.9(a – d). Trend in Rainfall Indices: Consecutive Wet Day (CWD) for (Minna, Lokoja, Abuja and Ilorin)

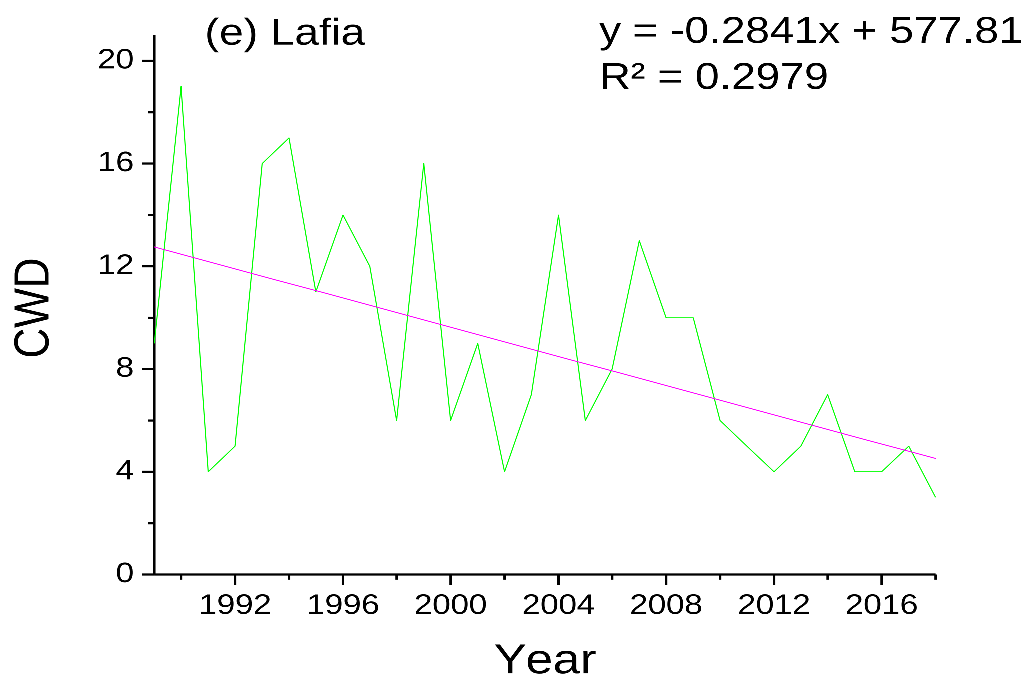


Figure 4.9e. Trend in Rainfall Indices: Consecutive Wet Day (CWD) for Lafia

Figure 4.10(a-e) depicts the trend analysis in rainfall indices for Simple Daily Intensity Index (SDII). The result showed increasing trend in Minna, Abuja, and Ilorin stations at 0.9, 2.04, and 0.37 day/mm, respectively, while Lokoja and Lafia stations showed decreasing trend at 0.66 and 0.65 day/mm.

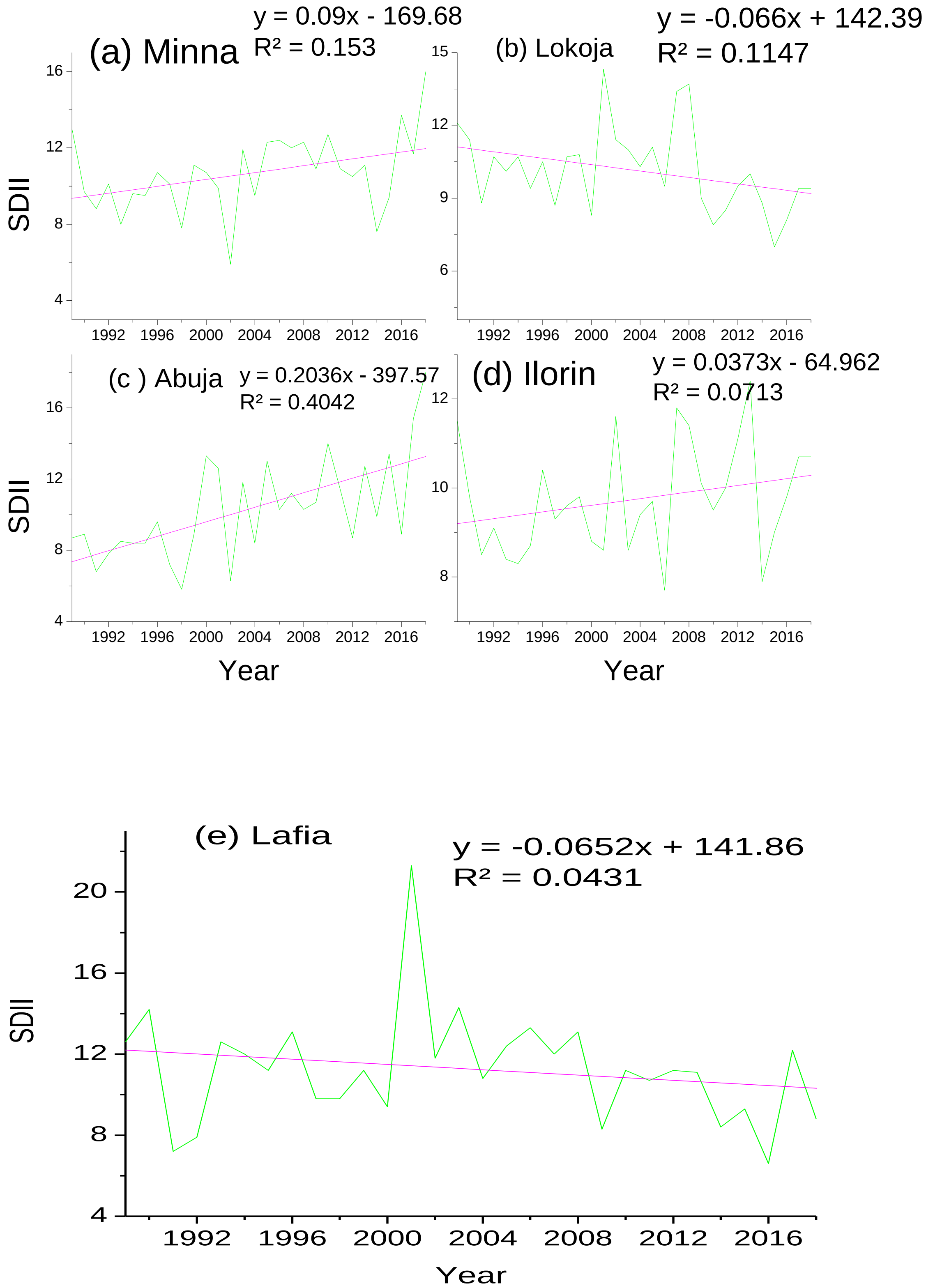


Figure 4.10(a – e). Trend in Rainfall Indices: Simple Daily Intensity Index (SDII)

Figure 4.11(a-e) depicts the analysis of trend in rainfall indices for maximum 1-day rainfall (R1D) in the study area. The result showed an increasing trend across the stations. For example, the Minna, Lokoja, Abuja, Ilorin, and Lafia detected an increasing trend at 20.27 mm, 5.44 mm, 23.95 mm, 5.71 mm, and 3.93 mm, respectively. The finding implies that the increased rainfall on a single day may lead to increased flood occurrences in the study area.

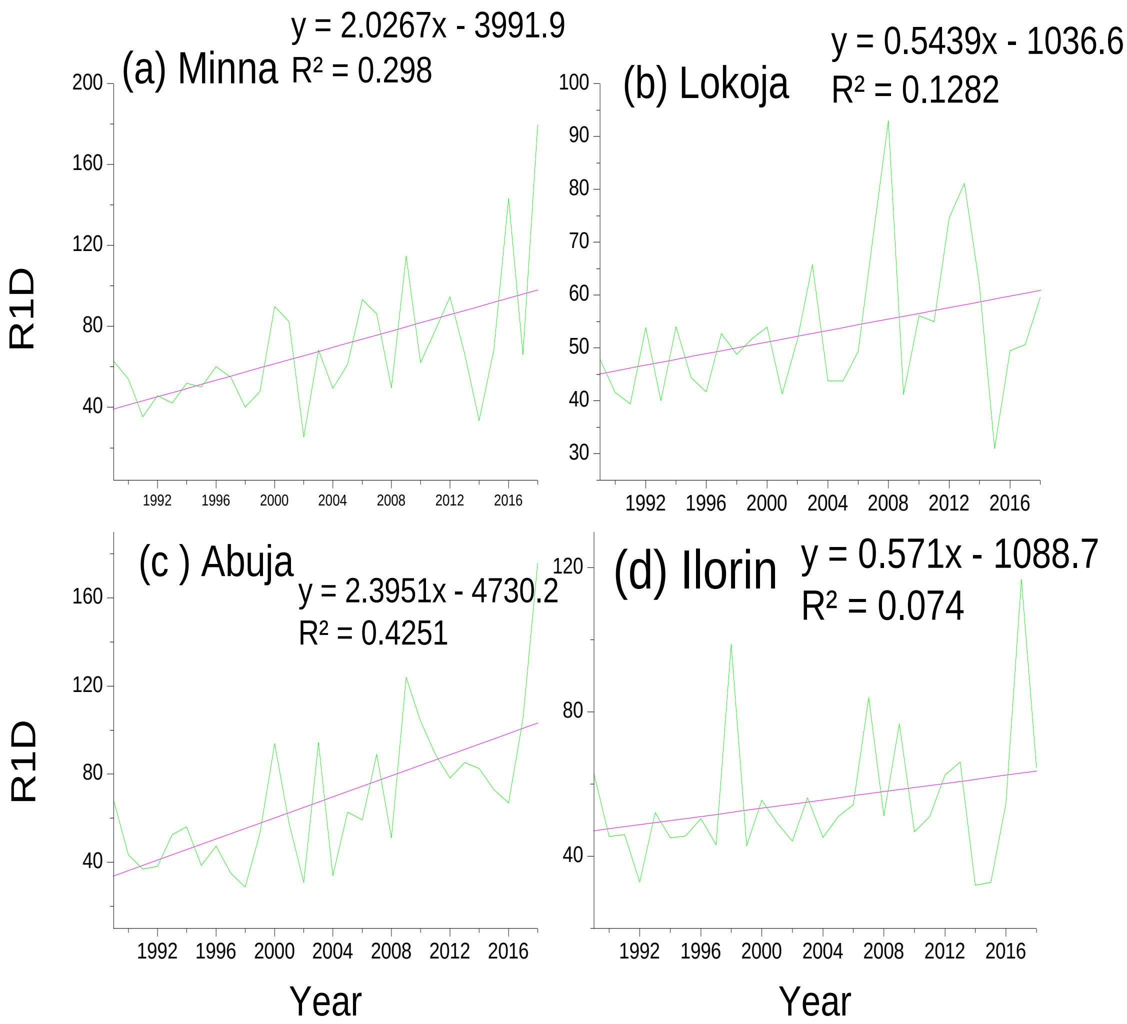


Figure 4.11 (a-d). Trend in Rainfall Indices: Maximum 1-day Rainfall (R1D) for (Minna, Lokoja, Abuja and Ilorin)

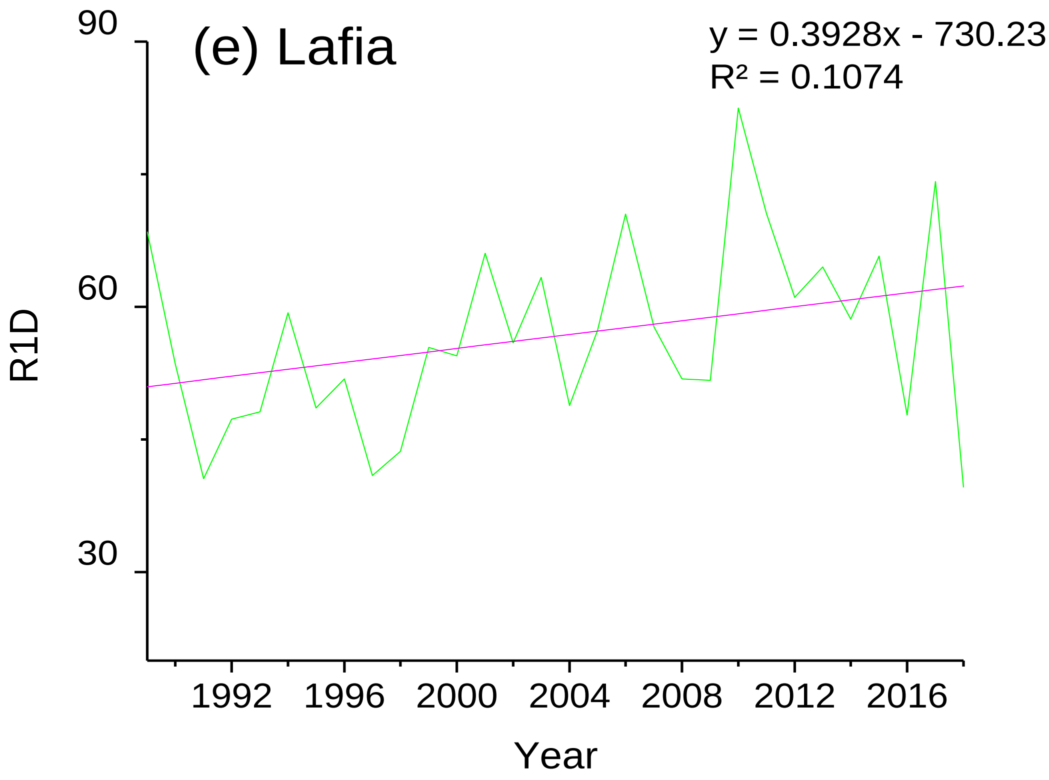


Figure 4.11e. Trend in Rainfall Indices: Maximum 1-day Rainfall (R1D) for Lafia

Figure 4.12(a-e) depicts the analysis of the trend in rainfall indices for maximum 5-day rainfall (R5D) in the study area. The result showed an increasing trend in Minna, Abuja, and Ilorin stations at 12.54 mm, 21.02 mm, and 3.60 mm, respectively while Lokoja and Lafia stations showed a decreasing trend at 7.81 mm and 11.72 mm, respectively. Generally, the finding shows that maximum 5-day rainfall decreased toward the southeastern part of the study area, which could be linked to rainfall variability resulting from the areas' longitudinal position.

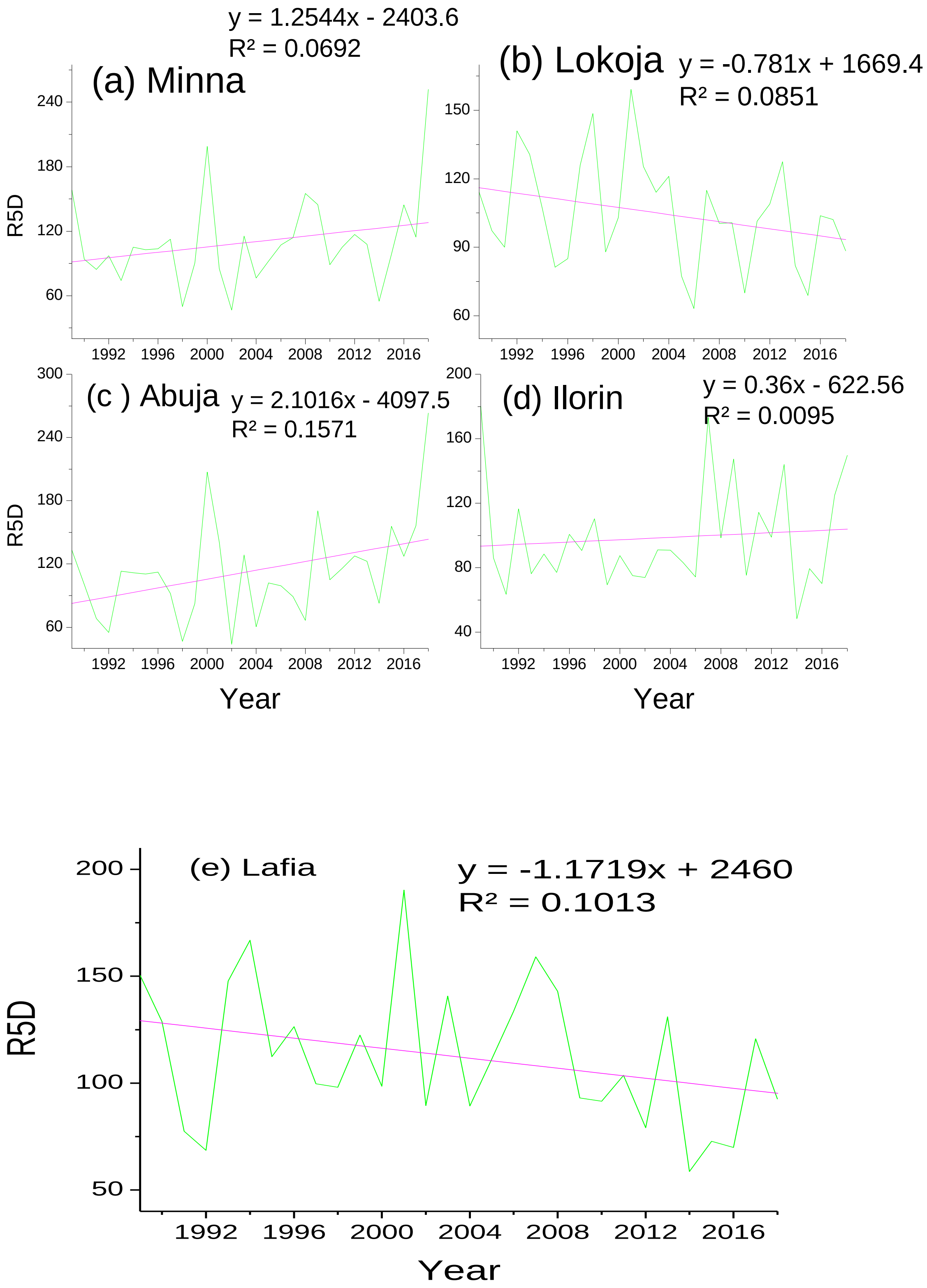


Figure 4.12 (a-e). Trend in Rainfall Indices: Maximum 5-day Rainfall (R5D) in the Study Area

Figure 4.13 (a-e) depicts the analysis of the trend in rainfall indices for Very Wet Day Rainfall (R95T) in the study area. The result showed an increasing trend in Minna, Abuja, and Ilorin stations at 33.22 %, 10.38 %, and 14.10 %, respectively, while Lokoja and Lafia stations depicted decreasing trend at 25.09 % and 25.31 %. The declining trend in the number of very wet day rainfall (R95T) in some parts of the study area could affect the growing development of the crops, especially Rice, which requires adequate rainfall distribution to perform optimally.

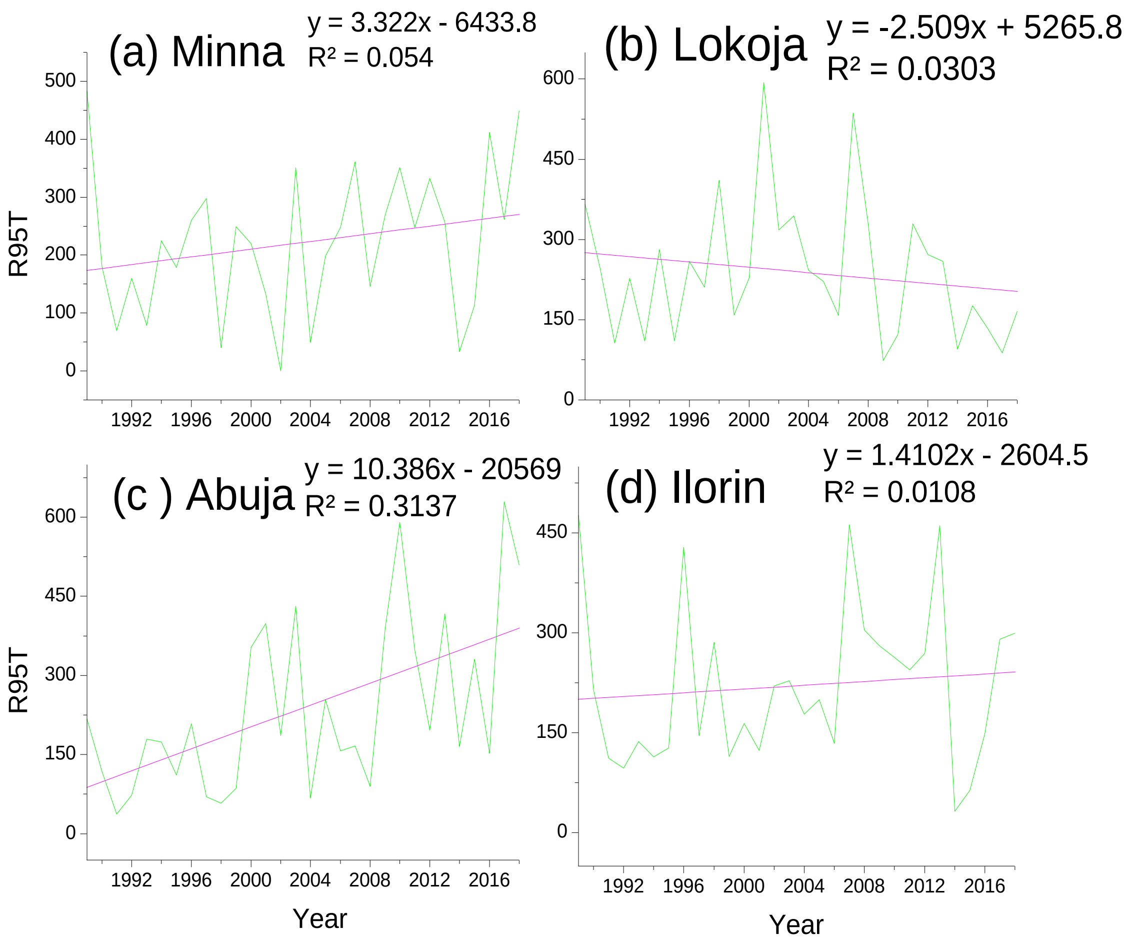


Figure 4.13 (a-d). Trend in Rainfall Indices: Very Wet Day (R95T) for (Minna, Lokoja, Abuja and Ilorin)

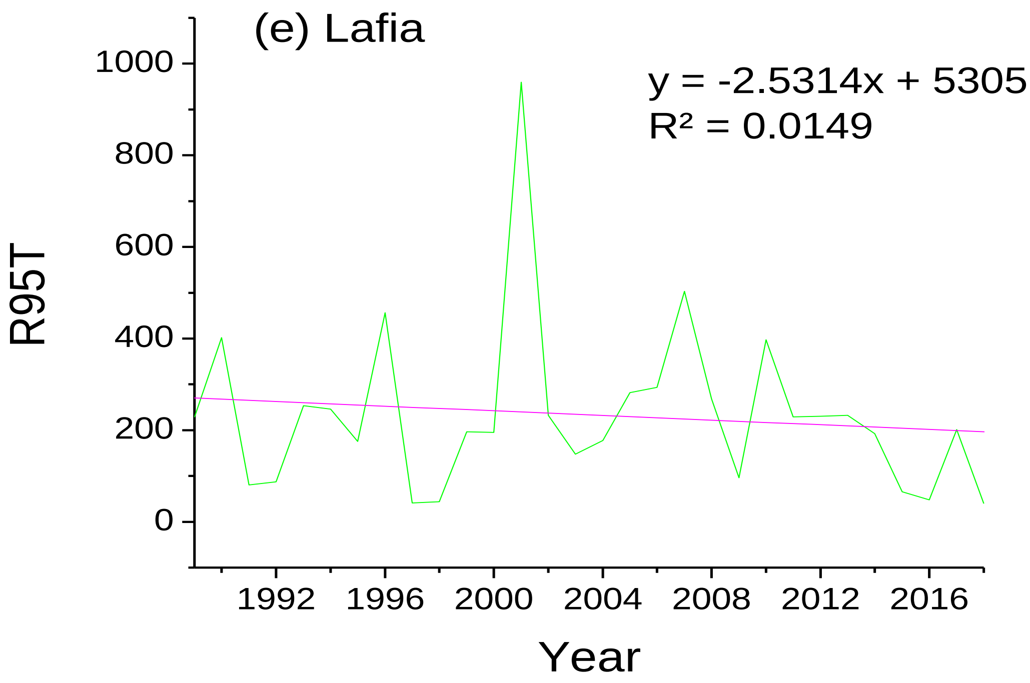


Figure 4.13e. Trend in Rainfall Indices: Very Wet Day (R95T) for Lafia

Figure 4.14 (a-e) depicts the analysis of rainfall indices for the Number of Heavy Rainfall Days (R10). The result showed a decreasing trend across the stations. For example, the Minna, Lokoja, Abuja, Ilorin, and Lafia stations depicted decreasing trend at 2.86 days, 9.90 days, 3.50 days, 2.61 days, and 13.25 days, respectively. The decreasing number of heavy rainfall days is an indication that the study area is not open to flood event except flooding resulting from released of excess water from the hydro-electric dams located within the study area.

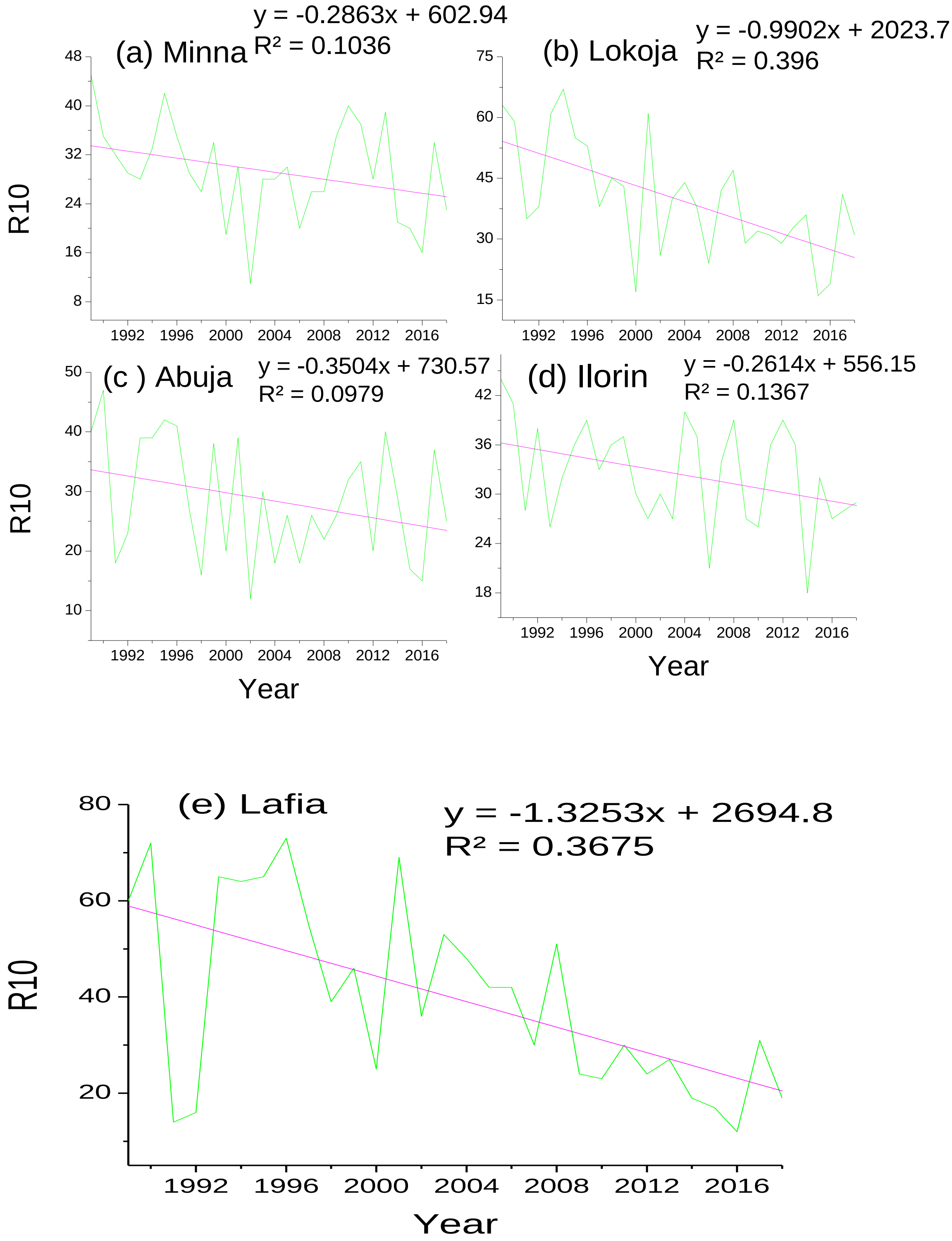


Figure 4.14 (a-e). Trend in Rainfall Indices: Number of Heavy Rainfall Day (R10) in the Study Area

Figure 4.15 (a-e) shows an analysis of rainfall indices of Number for Heavier Rainfall Days (R20). The result showed an increasing trend in Minna and Abuja stations at 0.28

days and 0.57 days, while Lokoja, Ilorin, and Lafia stations show decreasing trend at 3.93 days, 0.065 days, and 7.22 days, respectively. Previous findings suggest that heavy rainfall is associated with the destruction of property, especially in areas prone to flash floods (Ongoma *et al*., 2016)

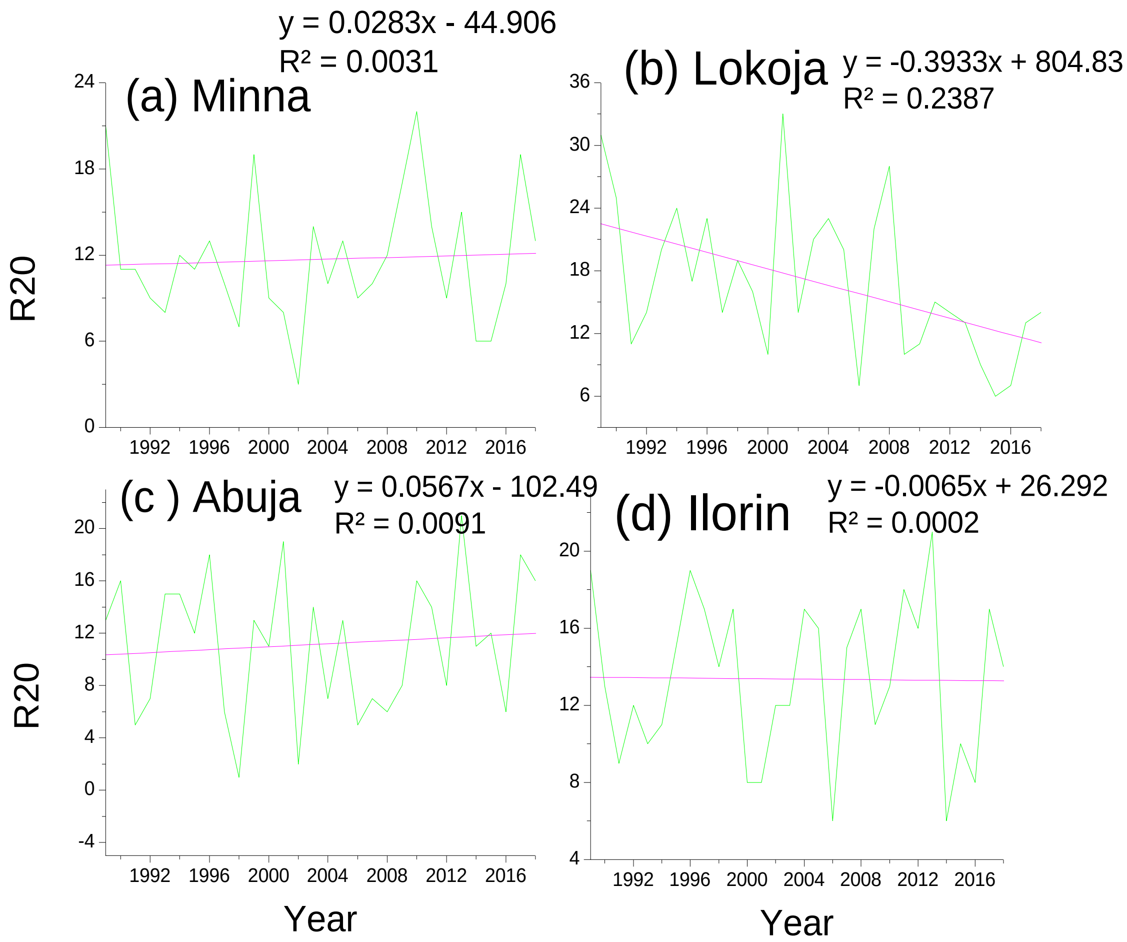


Figure 4.15 (a – d). Rainfall Index: Number of Heavier Rainfall Days (R20) for (Minna, Lokoja, Abuja and Ilorin)

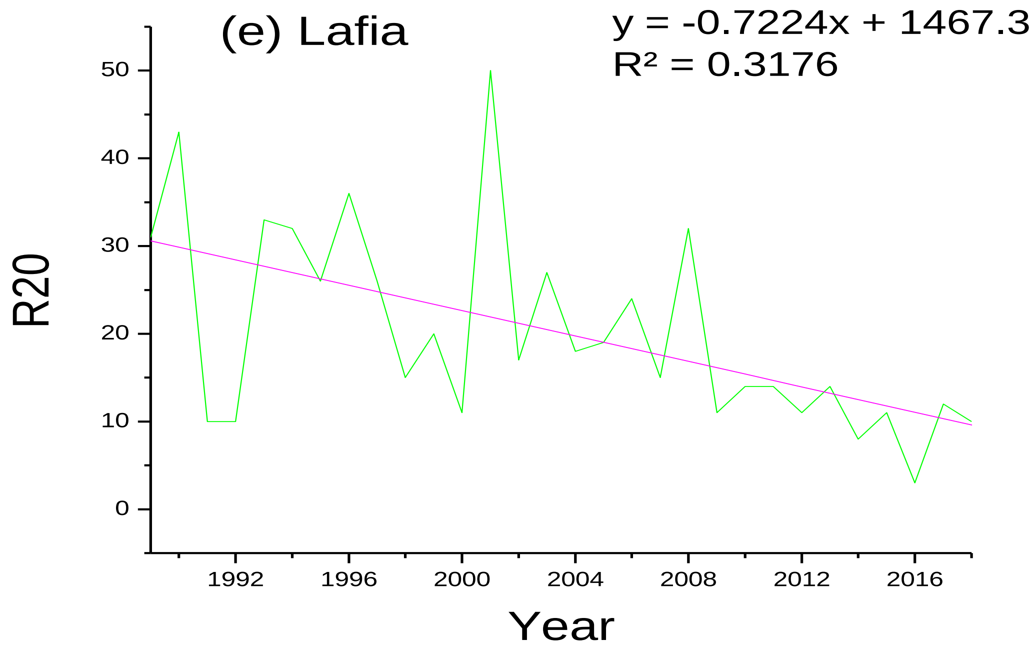


Figure 4.15e. Trend in Rainfall Index: Number of Heavier Rainfall Days (R20) for Lafia

Figure 4.16 (a-e) depicts the analysis of rainfall indices for the Number of Rainstorm days (R50). The result showed an upward trend in the number of rainstorm days across the station. The Minna, Lokoja, Abuja, Ilorin and Lafia stations detected upward trend at 0.45 days, 0.26 days, 0.88 days, 0.51 days and 0.07 days, respectively.

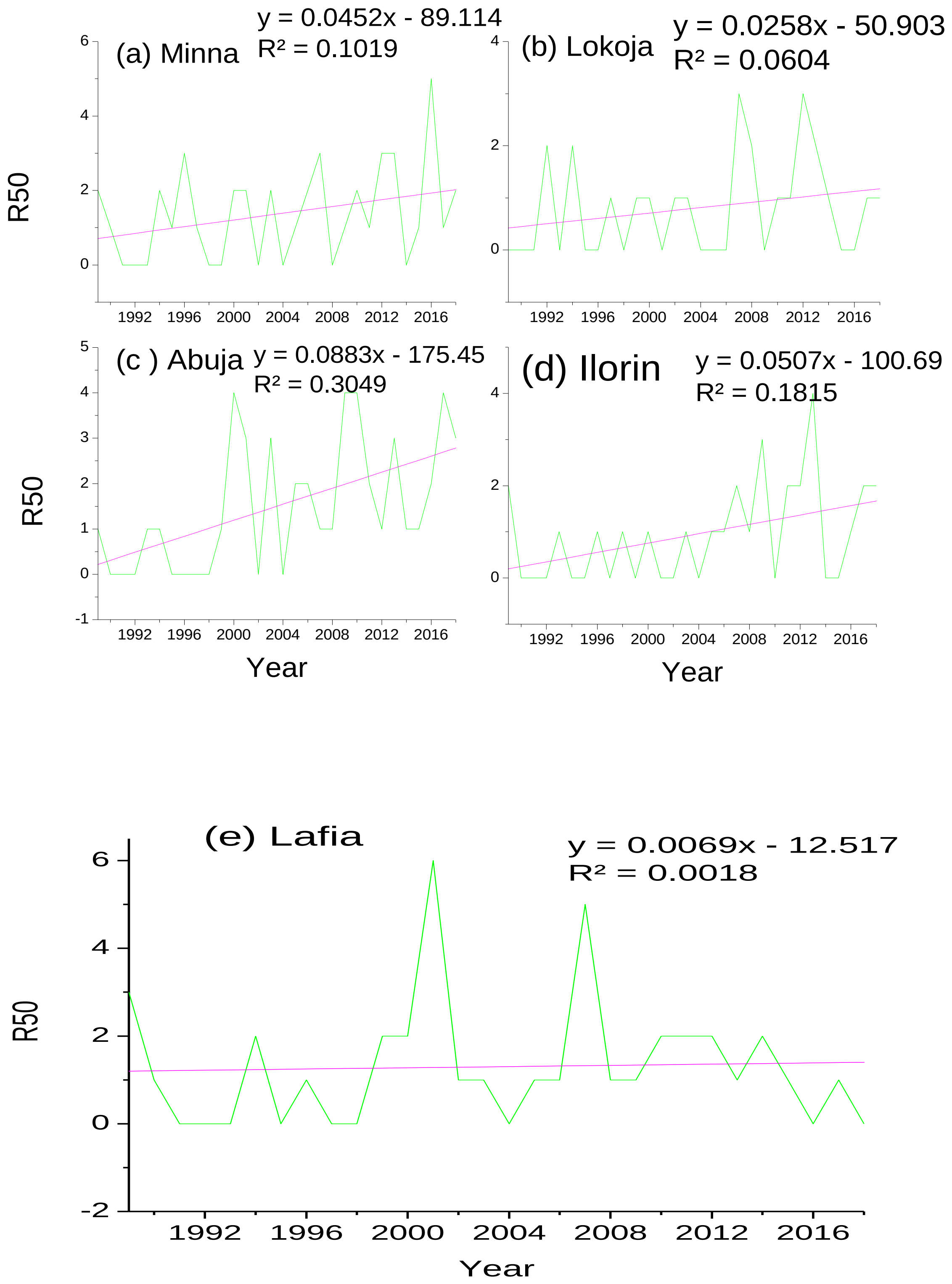


Figure 4.16 (a-e). Trend in Rainfall Index: Number of Rainstorm Days (R50) in the Study Area

4.4.2 Trend in temperature indices

Figures 4.17 to 4.21 depicts the trend in extreme temperature indices in the study area. Generally, the results for Monthly Minimum Value of Daily Maximum Temperature (TXn), Monthly Maximum Value of Daily Maximum Temperature (TXx), Monthly Minimum Value of Daily Minimum Temperature (TNn), Monthly Maximum Value of Daily Minimum Temperature (TNx), and Monthly Mean Difference between TX and TN which is referred to as DTR, showed varying trend across the study area during the study period (1989-2018).

Figure 4.17(a-e) depicts extreme temperature indices' analysis for the maximum monthly value of daily minimum temperature (TXn). The result showed a downward trend across the stations. The Minna, Lokoja, Abuja, Ilorin and Lafia stations detected decreasing trend at 044 ^{0}C, 0.59 ^{0}C, 1.10 ^{0}C, 0.38 ^{0}C and 1.59 ^{0}C, respectively. The downward trend in temperature indices provide evidence of the weakening of temperature extremes in the Guinea savanna zone in the last few decades.

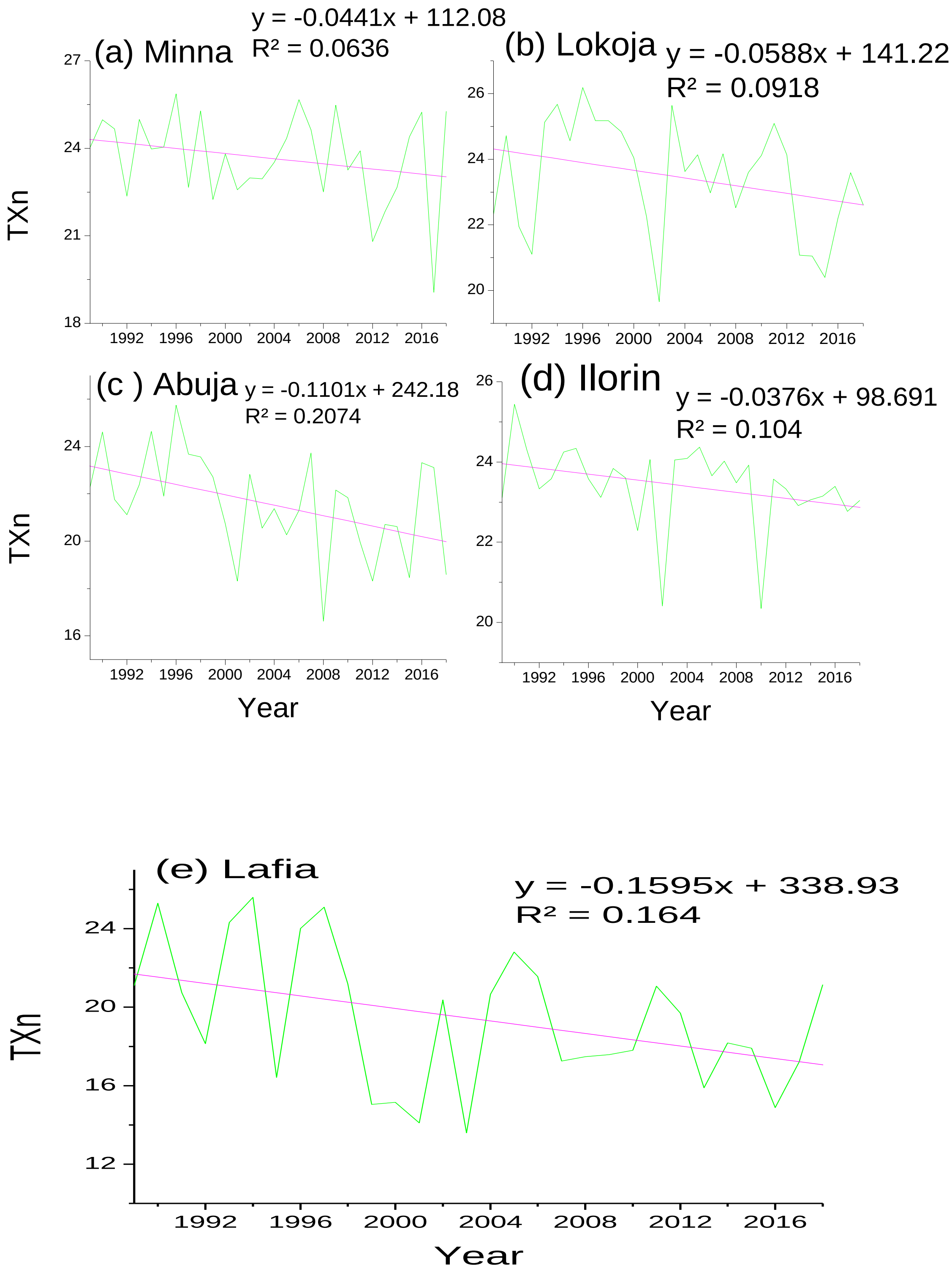


Figure 4.17(a-e). Trend in Monthly Minimum Value of Daily Maximum Temperature (TXn) in the Study Area

Figure 4.18(a-e) depicts the temperature indices' analysis for a monthly maximum value of daily maximum temperature (TXx). The result showed an increasing trend in Minna and Ilorin stations at 0,11 ^{0}C and 0.46 ^{0}C, while Lokoja, Abuja, and Lafia show decreasing trends at 0.65 ^{0}C, 0.56 ^{0}C, and 1.07 ^{0}C, respectively.

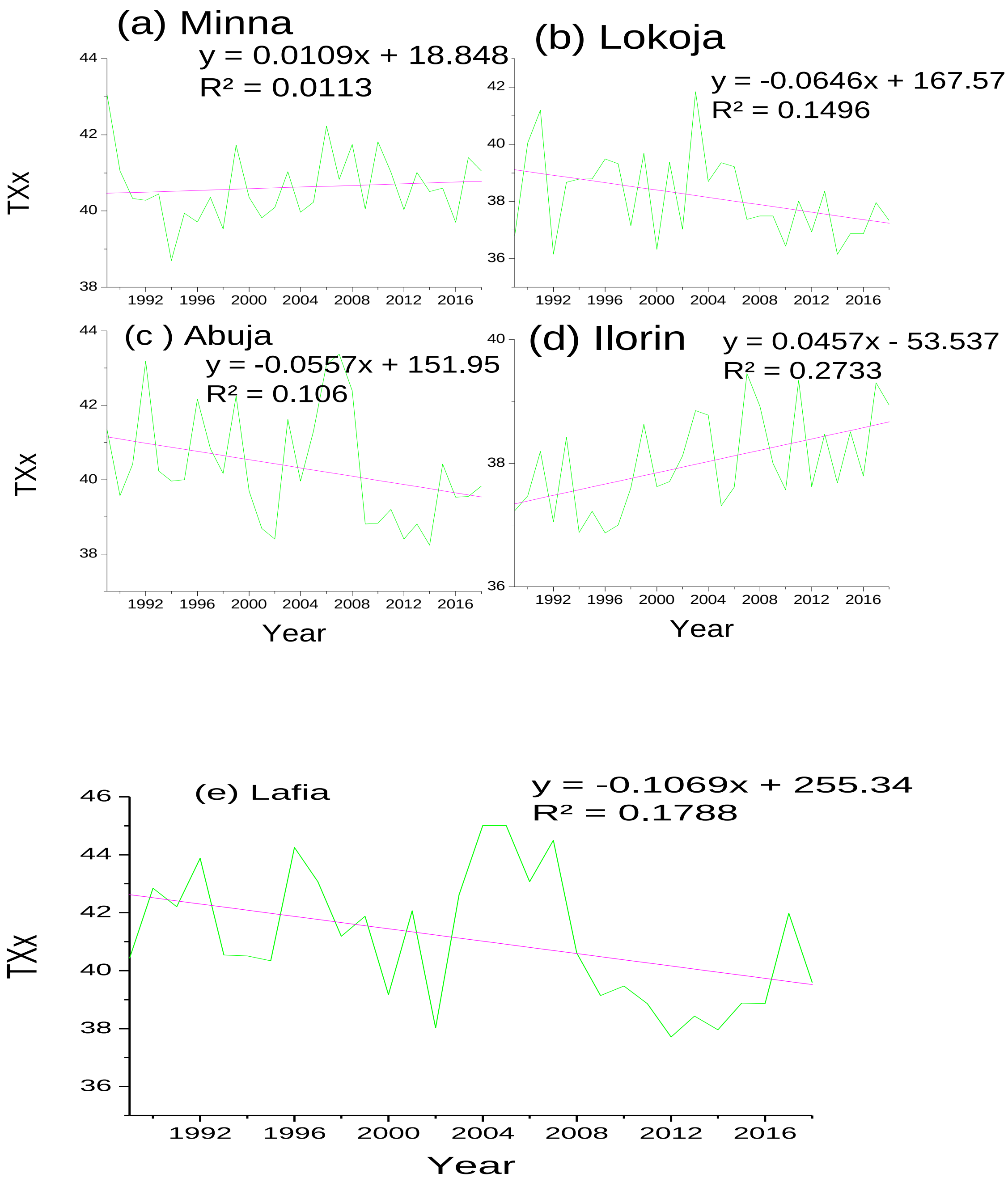


Figure 4.18(a-e). Trend in Monthly Maximum Value of Daily Maximum Temperature (TXx)

Figure 4.19(a-e) depicts the temperature indices' analysis for a monthly minimum value of daily minimum temperature (TNn). The result shows an upward trend in Abuja and Lafia stations at 0.49 ^{0}C and 0.52 ^{0}C. While Minna, Lokoja, and Ilorin stations show a downward trend at 0.05 ^{0}C, 0.28 ^{0}C, and 0.26 ^{0}C, respectively.

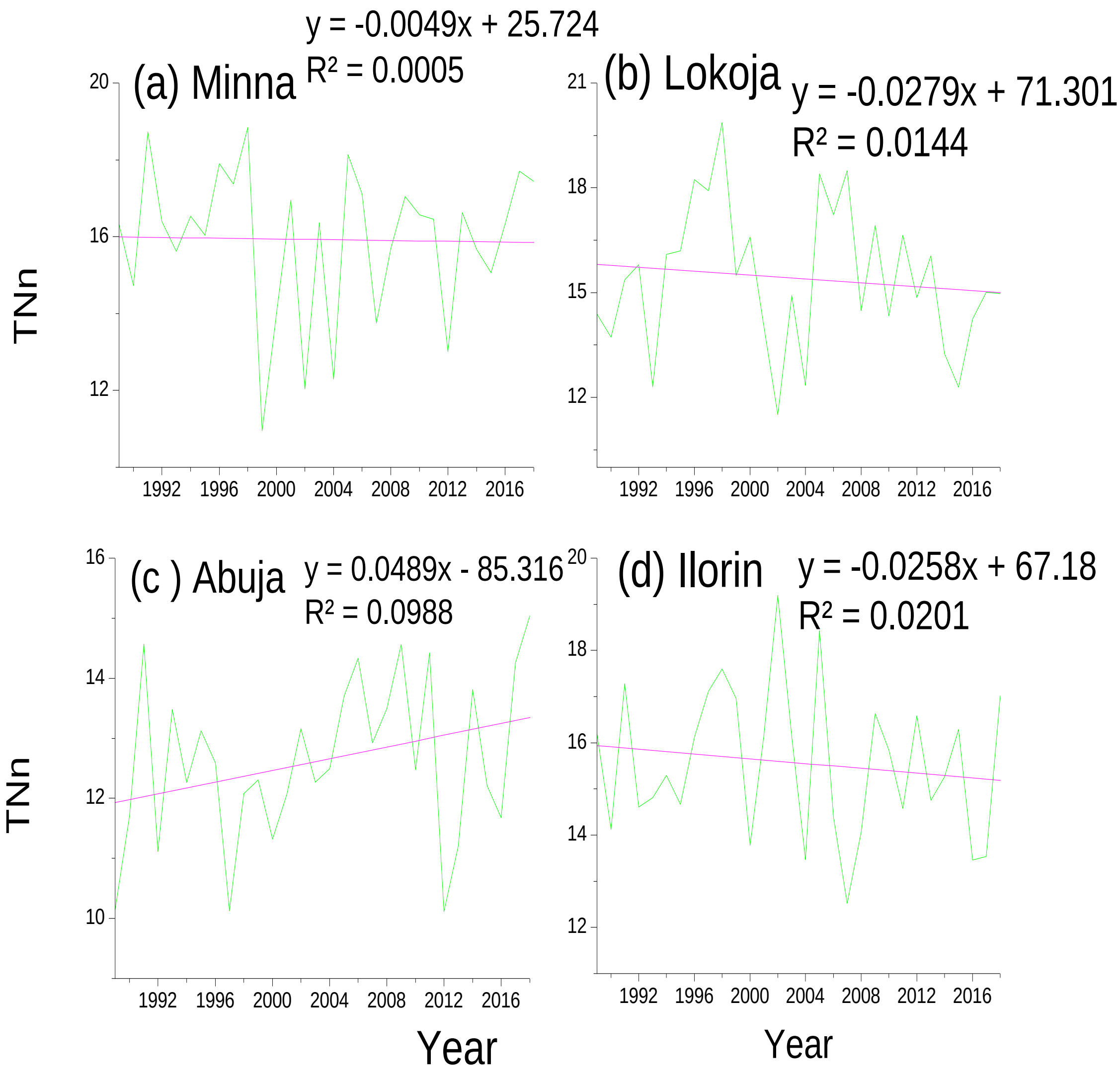


Figure 4.19(a-d). Trend in Monthly Minimum Value of Daily Minimum Temperature (TNn) for (Minna, Lokoja, Abuja and Ilorin)

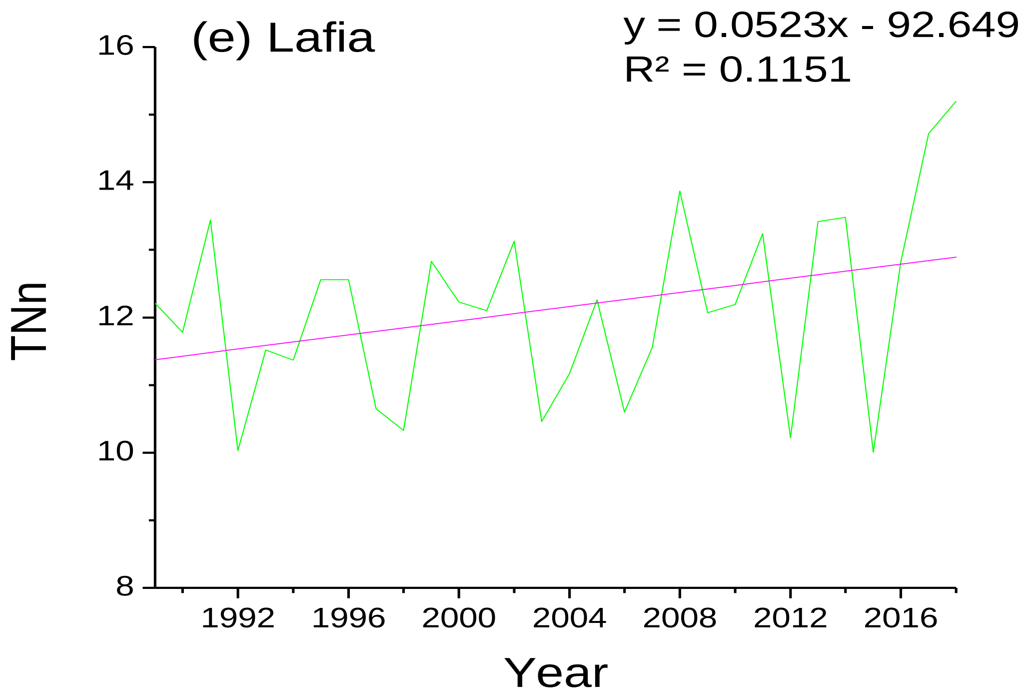


Figure 4.19e. Trend in Monthly Minimum Value of Daily Minimum Temperature (TNn) for Lafia

Figure 4.20(a-e) depicts the temperature indices' analysis for a monthly maximum value of daily minimum temperature (TNx). The result showed an upward trend in all the stations except in Abuja, which showed no trend. The Minna, Lokoja, Ilorin, and Lafia stations showed an upward trend at 0.72 0C, 1.39 0C, 0.54 0C, and 0.11 0C, respectively, while the Abuja station showed no trend during the study period.

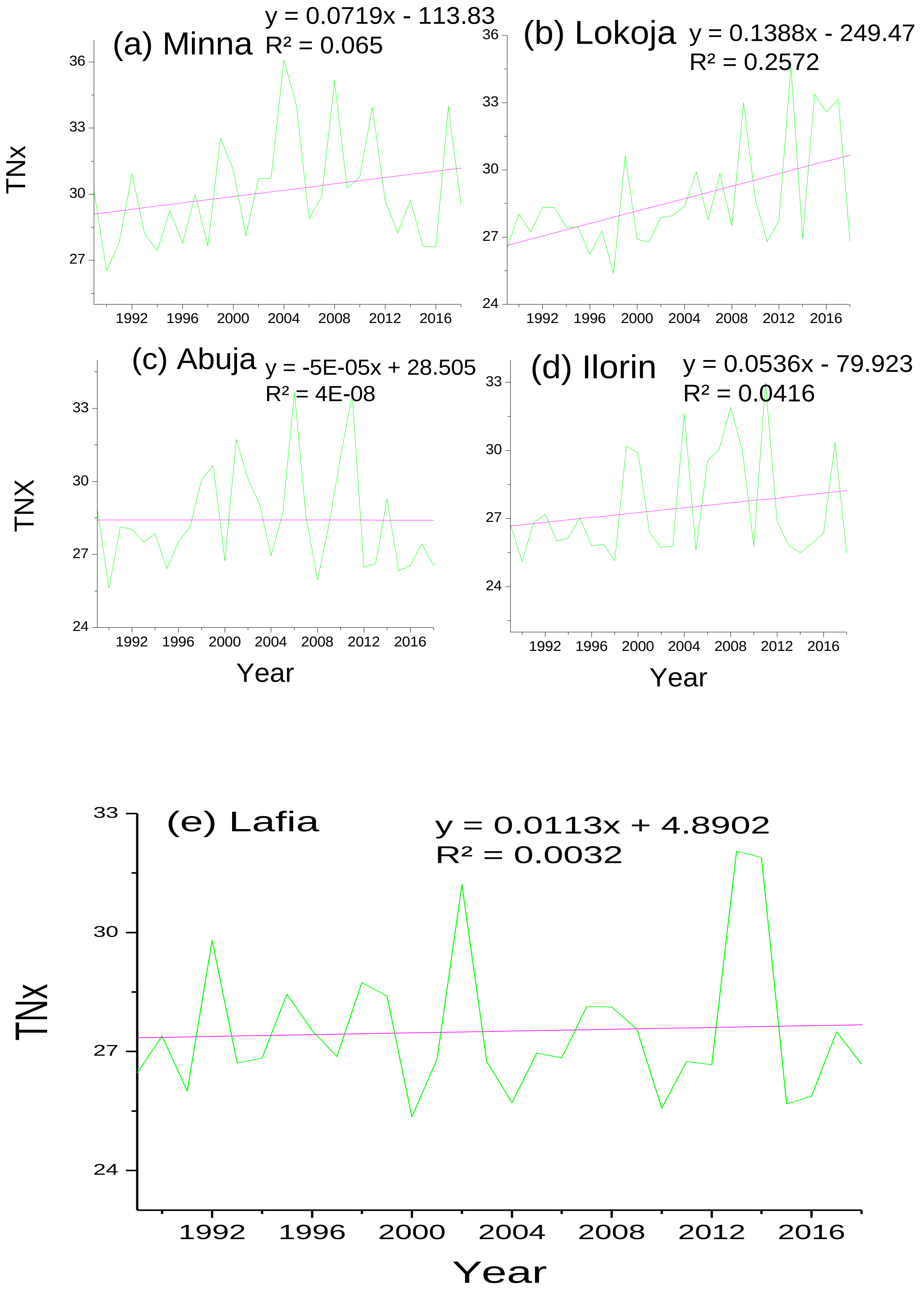


Figure 4.20(a-e). Trend in Monthly Maximum Value of Daily Minimum Temperature (TNx)

Figure 4.21(a-e) shows the analysis of extreme temperature indices for the monthly mean difference between the maximum and minimum temperature, which is referred to as the Diurnal Temperature Range (DTR). The result showed a downward trend across the stations. The Minna, Lokoja, Abuja, Ilorin, and Lafia stations showed a downward trend at 0.11 days, 0.59 days, 0.58 days, 0.08 days, and 1.07 days, respectively.

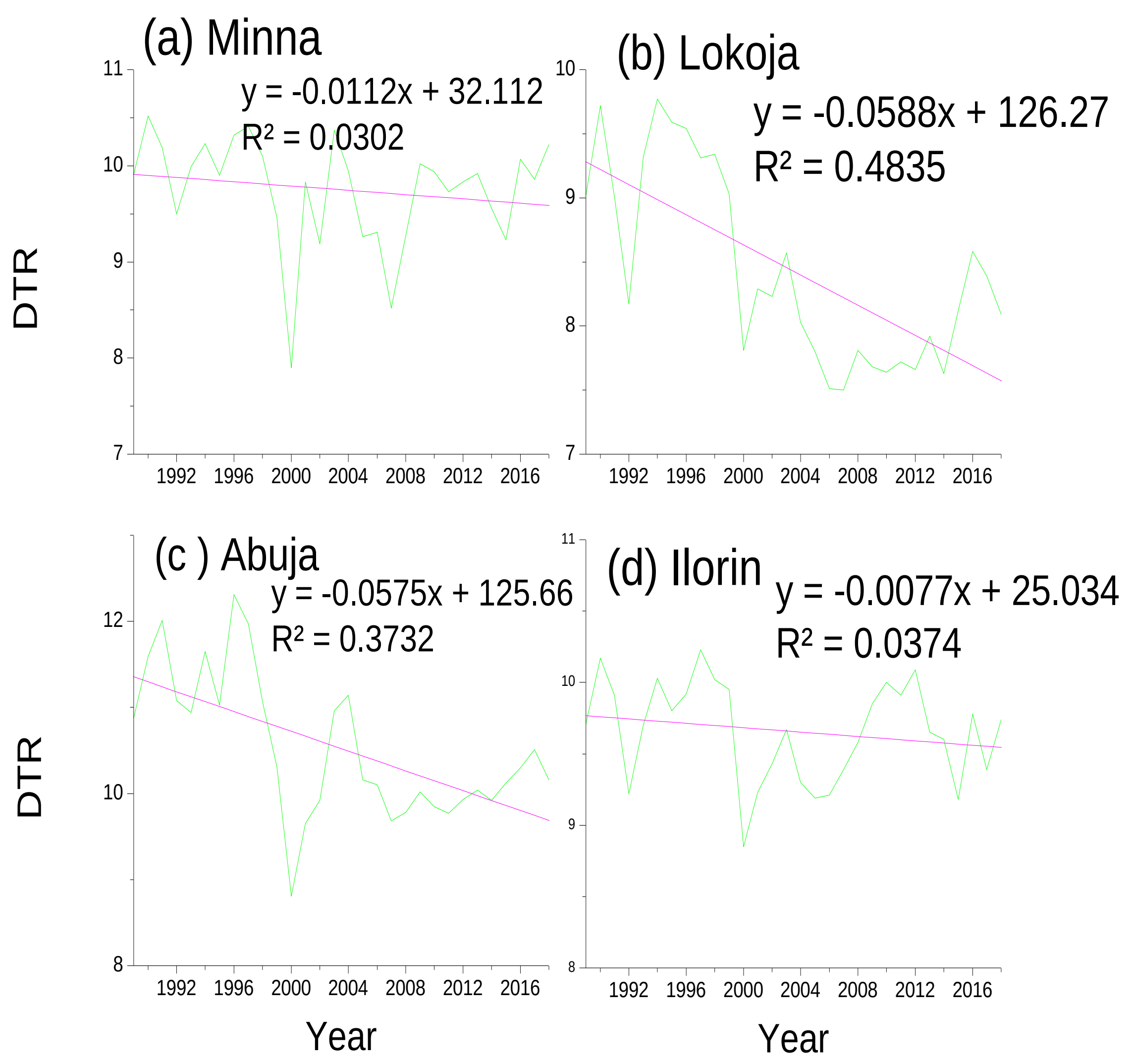


Figure 4.21(a-d). Trend in Monthly Mean Difference between TX and TN (DTR) for (Minna, Lokoja, Abuja and Ilorin)

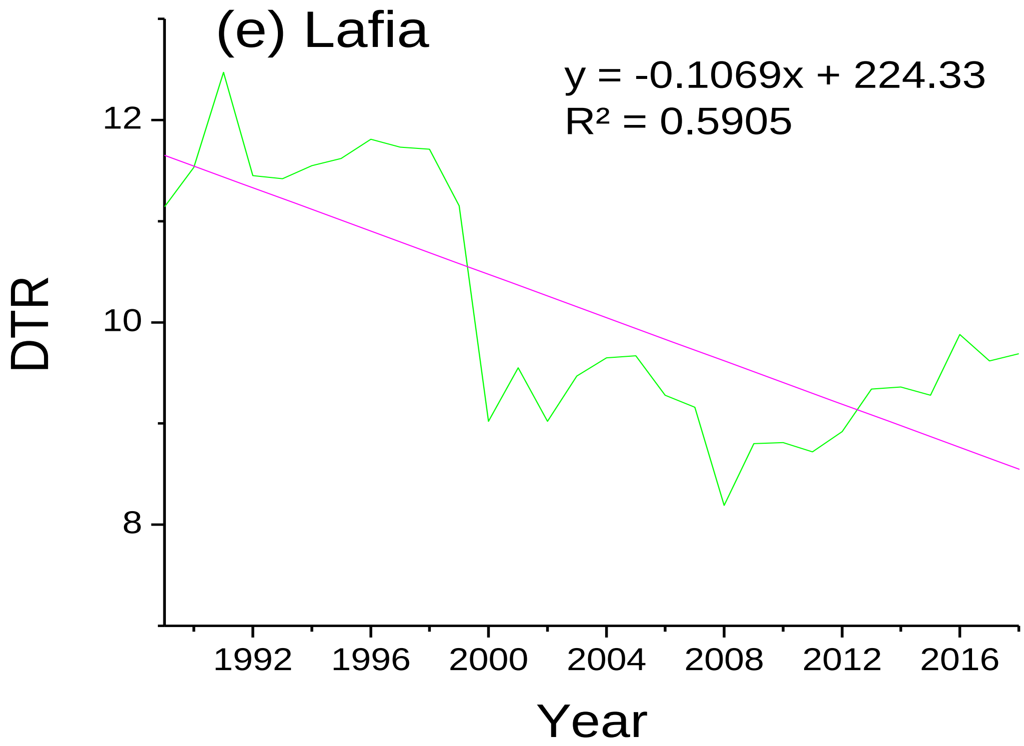


Figure 4.21e. Trend in Monthly Mean Difference between TX and TN (DTR) for Lafia

4.4.3 Analysis of Spearman Rho Rank Correlation between extreme rainfall indices and crop yield in the study area

The correlation coefficients between Consecutive Dry Day (CDD), Consecutive Wet Day (CWD), Simple Daily Intensity Index (SDII), R1D, R5D, Very Wet Day (R95T), R10, R20 and R50, and crop yield are presented in Tables 4.34, 4.35 and 4.36. In general, the results showed a significant correlation between extreme rainfall indices and rice yield across the study area compared to maize and guinea corn yield. This implies that rice yield responded more to changes in extreme rainfall pattern than maize and guinea corn yield in the same station.

Table 4.34 depicts the correlation analysis between extreme rainfall indices and rice yield. Result showed a non-significant positive correlation in bulk of the stations.

Consecutive dry day (CDD) showed a non-significant correlation with rice yield in all the stations during the study period. Result for consecutive wet day (CWD) showed a significant negative correlation in Abuja and Ilorin stations at ($P < 0.01$) and ($P < 0.05$). Result for simple daily intensity index (SDII) showed a significant positive correlation with rice yield in Minna and Ilorin stations at ($P <0.05$) for each of the station.

Further results showed a non-significant positive correlation for maximum 1-day rainfall (R1D) and maximum 5-day rainfall (R5D) in all the station except in Lokoja and Lafia where a non-significant negative correlation was detected for the two indices. The result of the correlation between rice yield and number of heavy rainfall days (R10) showed a significant positive relationship in Abuja and Lafia stations at ($P < 0.05$) and ($P < 0.01$) while Lokoja stations detected a significant negative correlation at ($P < 0.01$). Further, a significant positive correlation was detected for number of heavier rainfall days (R20) in Minna and Lafia stations at ($P < 0.01$) and ($P < 0.05$) while Lokoja station showed a significant negative correlation at ($P < 0.05$). Result for number of rainstorm days (R50) showed a significant positive correlation in Abuja at ($P < 0.05$) while other stations showed non-significant correlation. Generally, the Table revealed that rice yield responded differently to changes in extreme rainfall pattern across the study area.

Table 4.34. Correlation Coefficient for Extreme Rainfall Indices and Rice Yield

Station	CDD	CWD	SDII	R1D	R5D	R95T	R10	R20	R50
Minna	-.011	-.086	**.456***	.221	.211	.330	.237	**.471****	.072
Sig (2- tailed)	.952	.652	.011	.241	.264	.075	.207	.009	.705
Lokoja	.067	-.170	-.438	.307	-.068	.079	**-.483****	**-.403***	.169
Sig (2- tailed)	.725	.370	.016	.099	.721	.679	.007	.027	.371
Abuja	.236	**-.487****	.444	.361	.154	.340	**.473****	-.068	**385***
Sig (2- tailed)	.209	006	.014	.050	.417	.066	.008	.720	.035
Ilorin	.094	**-.432***	**.362***	.205	.019	.256	-.296	-.045	.303
Sig (2- tailed)	.620	.017	.050	.277	.919	.172	.112	.812	.104
Lafia	-.135	.348	.194	-.288	.249	**.154***	**.453***	**.433***	-.109
Sig (2- tailed)	.476	.059	.303	.123	.184	.416	.012	.017	.567

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

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

Figure 4.22 depicts the distribution pattern of the correlation between extreme rainfall indices and rice yield in the study area. The result showed a more positive correlation between the extreme rainfall indices and rice yield at Minna, Abuja, and Lafia stations than Lokoja and Ilorin stations during the study period. The finding could be as a result of station's specific physical characteristics which favoured rice cultivation. The finding also implies that the increased number of consecutive wet day (CWD) had provided enough moisture to support the growth of rice.

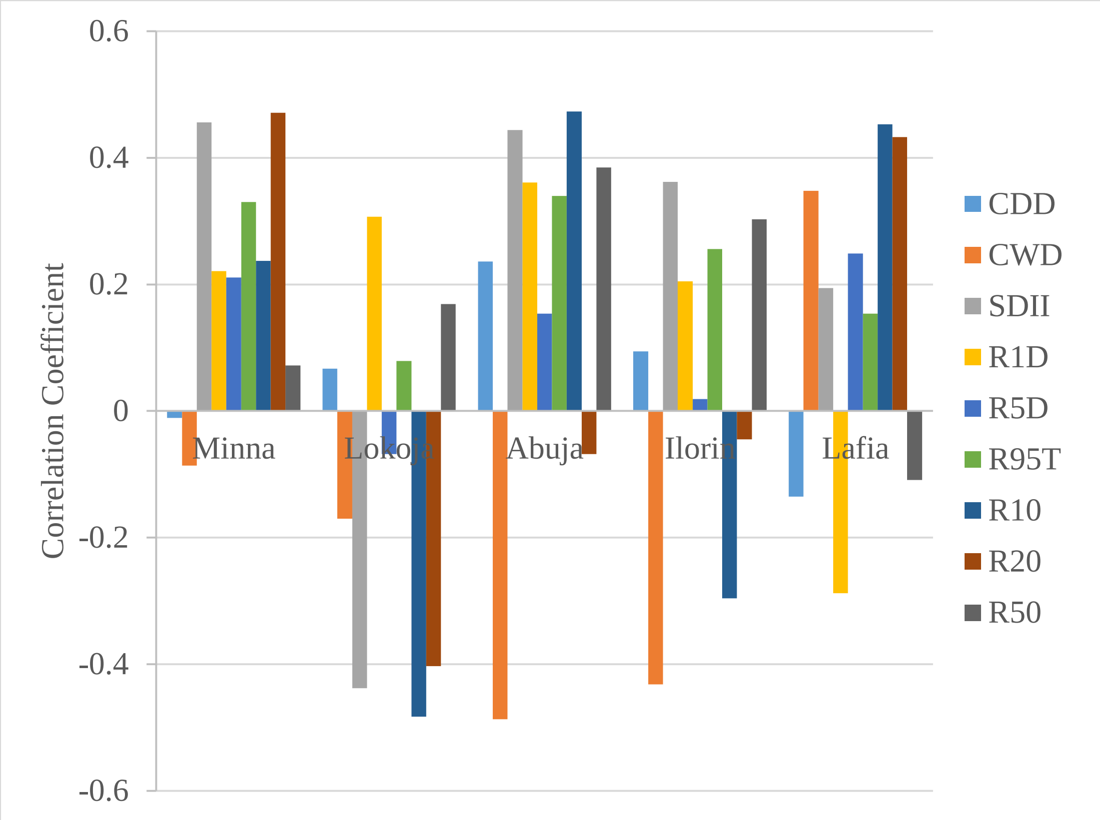


Figure 4.22. Pattern of Correlation Coefficient for Extreme Rainfall Indices and Rice Yield in the Study Area

Table 4.35 depicts the correlation analysis between extreme rainfall indices and maize yield in the study area. Result showed non-significant correlations in bulk of the stations. The result of the correlation between CDD, SDII, R1D, R5D, R20 and R50 with maize yield showed a non-significant relationship across the stations. Further, CWD and R10 showed a significant negative correlation in the Lokoja station at (P < 0.01) and (P < 0.05), respectively, while R95T showed a significant positive correlation in Abuja station at (P<0.05). Generally, the finding showed a weaker relationship between extreme rainfall indices and maize yield in the study area. This implies that the higher the occurrence of extreme rainfall indices, particularly R5D, R10 and R20 the lower the yield of maize crop. Finding also implies that the extreme level of rainfall (flood) affects maize yield negatively as showed in the correlation analysis.

Table 4.35. Correlation Coefficient for Extreme Rainfall Indices and Maize Yield

Station	CDD	CWD	SDII	R1D	R5D	R95T	R10	R20	R50
Minna	-.145	.060	.136	.098	.182	.252	.279	.330	.136
Sig (2 tailed)	.444	.752	.474	.607	.335	.179	.135	.075	.474
Lokoja	.305	**-.557****	-.067	.341	-.002	.027	**-.406***	-.222	.166
Sig (2 tailed)	.102	.001	.726	.065	.990	.888	.026	.238	.382
Abuja	.344	.125	.261	.340	.438	**.398***	-.080	.223	.302
Sig (2 tailed)	.062	.509	.164	.066	.015	.029	.676	.235	.105
Ilorin	.176	-.260	.305	.205	.019	.250	-.053	.098	.328
Sig (2 tailed)	.351	.165	.101	.277	.919	.183	.782	.607	.076
Lafia	.085	.126	-.090	-.291	.095	-.089	.120	.101	-.182
Sig (2 tailed)	.653	.507	.637	.118	.617	.640	.528	.594	.337

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Figure 4.23 depicts the distribution pattern of the correlation between extreme rainfall indices and maize yield in the study. The Figure shows a more positive correlation at Minna, Abuja, and Ilorin stations than Lokoja and Lafia stations. R1D and R95T showed a positive correlation in all the stations except in Lafia, where a negative relationship was detected. The finding could also be a result of the station's specific physical characteristics.

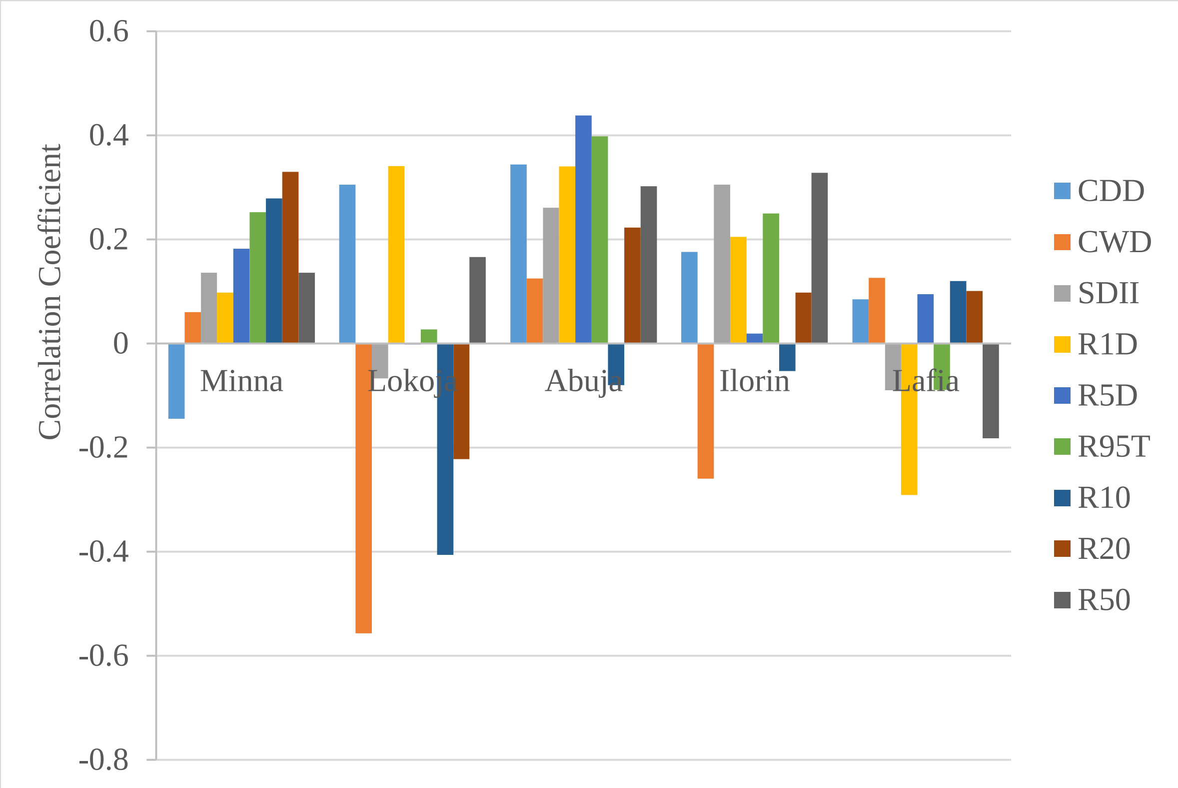


Figure 4.23. Pattern of Correlation Coefficient for Extreme Rainfall Indices and Maize Yield in the Study Area.

Table 4.36 depicts the correlation analysis between extreme rainfall indices and Guinea corn yield in the study area. Results showed a non-significant negative correlation in the bulk of the stations. Result for SDII, R95T, R5D and R50 showed non-significant correlation with guinea corn yield across the stations. The CDD depicted significant positive correlation in Lafia station at (P < 0.05). Also, CWD showed a significant negative correlation in Lokoja and Lafia at (P<0.01) and (P<0.05), respectively. Further, R1D showed a significant positive correlation in Lokoja at (P<0.05). The result for R10 showed a significant positive correlation in Minna at (P<0.05) and a significant negative correlation in Lokoja at (P<0.01). Finally, result for R20 showed a significant negative correlation with guinea corn yield in Lokoja at (P<0.01). Findings from the study revealed that at the extreme level of rainfall (flood) guinea yield responded negatively, which implies that guinea corn cultivation should be done on upland areas to minimize damages resulting from extreme events such as flooding.

Table 4.36. Correlation Coefficient for Extreme Rainfall Indices and Guinea corn Yield

Station	CDD	CWD	SDII	R1D	R5D	R95T	R10	R20	R50
Minna	-.217	.349	-.092	-.206	.036	.042	**.416***	.294	-.141
Sig (2 tailed)	.248	.059	.629	.275	.851	.827	.022	.115	.458
Lokoja	.054	-.**511****	-.352	.**379***	-.246	-.124	-.**626****	**-.489****	.246
Sig (2 tailed)	.775	004	.057	.039	.189	.515	.000	.006	.190
Abuja	-.151	.297	-.349	-.201	-.020	-.140	.160	.068	-.343
Sig (2 tailed)	.425	.111	.059	.288	.917	.459	.400	.721	.064
Ilorin	.081	-.359	.201	.143	-.051	.097	-.301	-.182	.180
Sig (2 tailed)	.672	.051	.286	.151	.788	.611	.106	.335	.342
Lafia	**.436***	**-.365***	.044	.461*	.107	.142	.263	-.124	-.036
Sig (2 tailed)	.016	.047	.817	.010	.575	.454	.160	.513	.850

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Figure 4.24 depicts the distribution pattern of the correlation between extreme rainfall indices and Guinea corn yield in the study. Generally, the results showed mixed negative and positive correlations across the stations. On a station-by-station basis, the Lokoja and Abuja stations exhibited more negative relationship than Minna, Ilorin and Lafia stations. The finding implies that guinea corn yield responded differently to changes in extreme rainfall indices on a station by station basis, which means that indices did not exert the same effect on guinea corn yield across the study area.

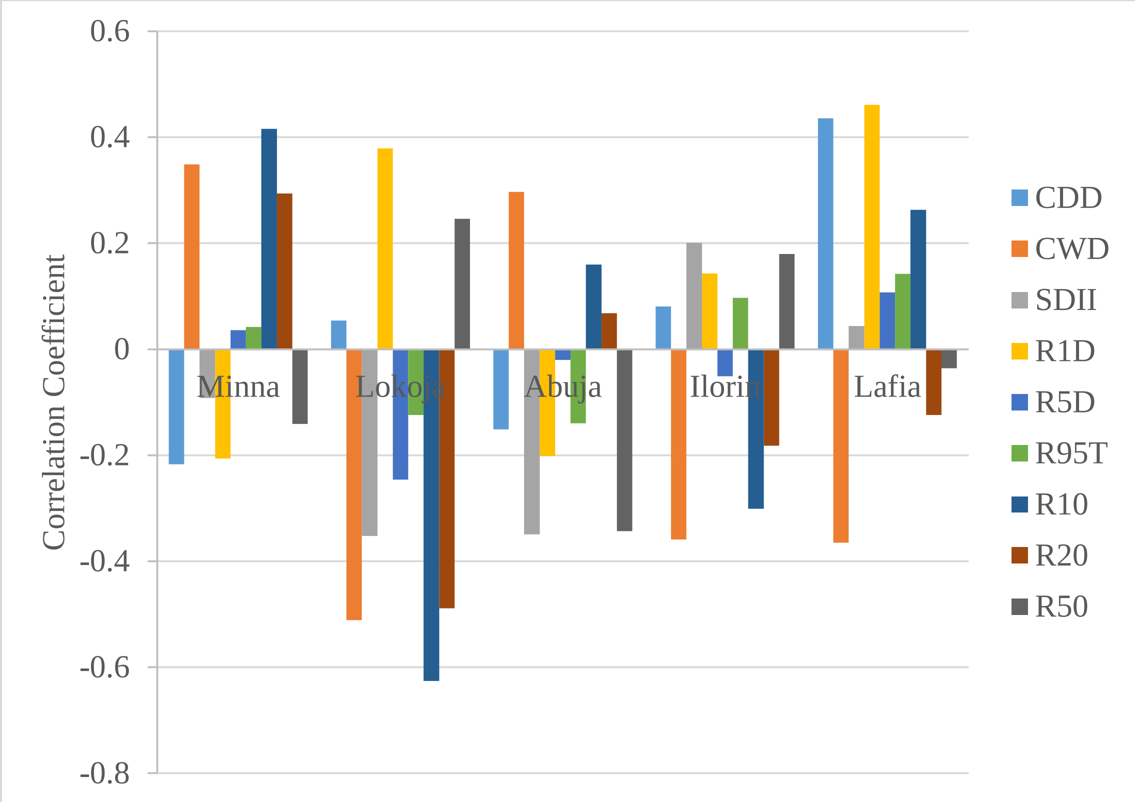


Figure 4.24. Correlation Coefficient for Extreme Rainfall Indices and Guinea corn Yield in the Study Area

4.4.4. Analysis of spearman rank correlation for extreme temperature indices and crop yield in the study area

The coefficients of correlation for extreme temperature indices of Monthly Minimum Value of Daily Maximum Temperature (TXn), Monthly Maximum Value of Daily Maximum Temperature (TXx), Monthly Minimum Value of Daily Minimum Temperature (TNn), Monthly Maximum Value of Daily Minimum Temperature (TNx), Monthly Mean Difference between TX and TN which is referred to as DTR, and crop yield is presented in Table 4.37, 4.38 and 4.39. In general, the results showed a non-significant negative correlation in the bulk of the stations. This implies that the selected crops responded negatively to temperature indices than rainfall indices in the study area.

Table 4.37 depicts the analysis of Spearman rank correlation for extreme temperature indices and rice yield. The result showed a significant negative correlation for monthly minimum value of daily maximum temperature (TXn) and Rice yield in Abuja and Ilorin at ($P< 0.01$) for each of the stations and a significant positive correlation in Lafia at ($P< 0.01$). Further, result for monthly maximum value of daily maximum temperature (TXx) showed a significant negative correlation in Abuja and Ilorin stations at ($P< 0.05$) and ($P< 0.01$), respectively, and a significant positive correlation in Minna at ($P< 0.05$). However, result for monthly mean difference between TX and TN (DTR) showed a significant negative correlation in Lokoja and Abuja stations at ($P< 0.05$) and ($p < 0.01$), respectively, and a significant positive correlation in Lafia at ($P< 0.01$). Result for monthly minimum value of daily minimum temperature (TNn) and monthly maximum value of daily minimum temperature (TNx) showed non-significant correlation with rice yield across the station during the study period. Generally, the finding implies that the extreme temperature indices were not the major determinant factors for rice yield in the study area.

Table 4.37. Correlation Coefficient for Extreme Temperature Indices and Rice Yield

Station		TXn	TXx	TNn	TNx	DTR
Minna	Spearman rank Correlation	.334	**.423***	.010	.265	-.020
	Sig (2 tailed)	.071	.020	.959	.157	.916
Lokoja	Spearman rank Correlation	-.094	-.326	.163	.000	**-.409***
	Sig (2 tailed)	.619	.079	.388	.999	.025
Abuja	Spearman rank Correlation	**-.500****	**-.419***	.167	.088	**-.540****
	Sig (2 tailed)	.005	.021	.377	.645	.002
Ilorin	Spearman rank Correlation	**-.544****	**-.499****	-.047	-.016	-.232
	Sig (2 tailed)	002	.005	.805	.932	.218
Lafia	Spearman rank Correlation	**.573****	.299	-.274	.136	**.523****
	Sig (2 tailed)	.001	.109	.143	.474	.003

*Correlation is significant at the 0.05 level (2 tailed)
**Correlation is significant at the 0.01 level (2 tailed)

Figure 4.25 depicts the distribution pattern of the correlation between extreme temperature indices and rice yield in the study area. The result showed a negative correlation between the indices and rice yield in the Ilorin station. The results for Minna and Lafia stations showed a more positive correlation, while Lokoja and Abuja stations exhibited more negative correlation.

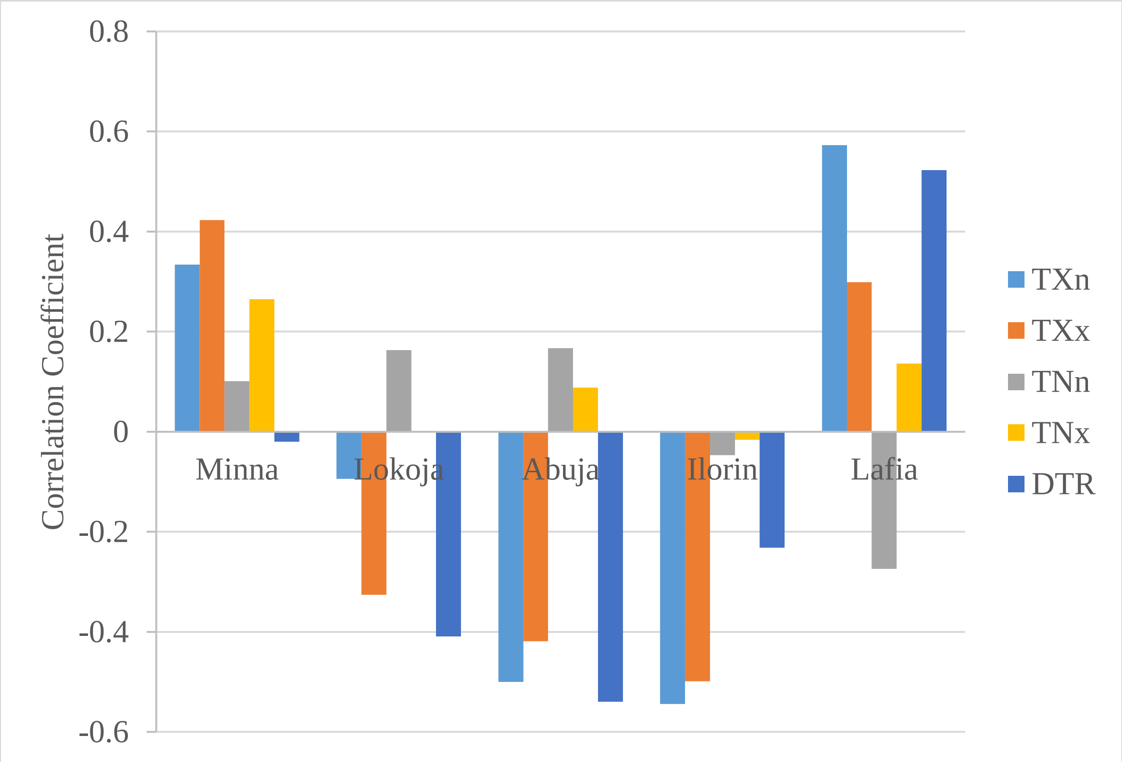


Figure 4.25. Pattern of Correlation Coefficient for Temperature Indices and Rice Yield

Table 4.38 depicts the correlation coefficient for maize yield and extreme temperature indices in the study area. The result showed non-significant correlation in the bulk of the stations. Result for TNn, and TNx revealed a non-significant correlation with maize yield across the stations. Further, TXx showed a significant negative correlation in Abuja at ($P < 0.01$) and a significant positive correlation in Ilorin at ($P<0.05$). Result for DTR showed a significant negative correlation in Lokoja at ($P < 0.01$) and a significant positive correlation in Lafia at ($P < 0.05$). Finding implies that there existed a weak relationship between the extreme temperature indices and maize yield across the study location.

Table 4.38. Correlation Coefficient for Extreme Temperature Indices and Maize Yield in the Study Area

Station		TXn	TXx	TNn	TNx	DTR
Minna	Spearman rank Correlation	.159	.218	.029	-.269	.256
	Sig (2 tailed)	.402	.247	.879	.151	.172
Lokoja	Spearman rank Correlation	-.222	-.114	-.023	.292	**-.521****
	Sig (2 tailed)	.239	.548	.904	.118	.003
Abuja	Spearman rank Correlation	-.226	**-.551****	-.148	-.038	-.223
	Sig (2 tailed)	.229	.002	.437	.843	.237
Ilorin	Spearman rank Correlation	-.287	**.375***	-.323	.068	-.195
	Sig (2 tailed)	.124	.041	.082	.721	.301
Lafia	Spearman rank Correlation	.346	.027	-.133	.102	**.627****
	Sig (2 tailed)	.061	.889	.483	592	.000

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Figure 4.26 depicts the distribution pattern of the correlation between extreme temperature indices and maize yield in the study area. Result showed a negative correlation for all the indices and Maize yield in Abuja station, while other stations show mixed negative and positive correlation.

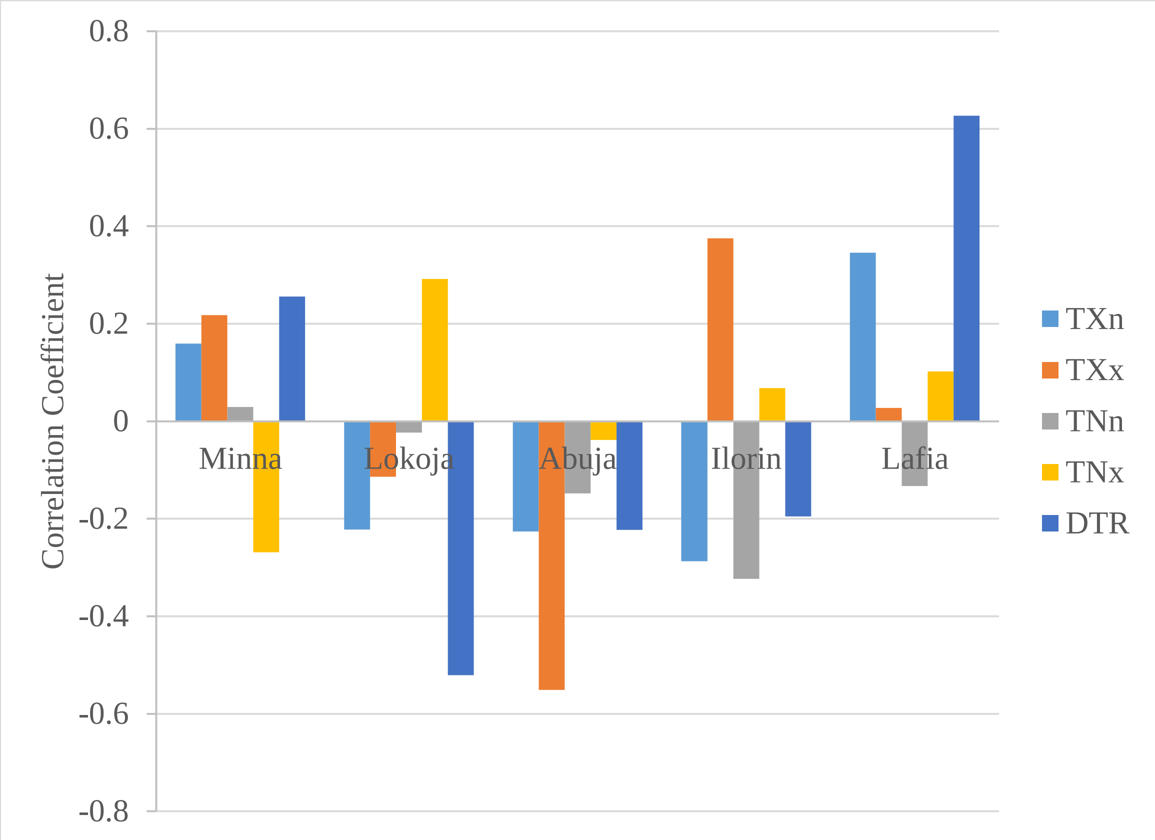


Figure 4.26. Pattern of Correlation between Extreme Temperature Indices and Maize Yield in the Study Area.

Table 4.30 depicts the correlation coefficient for guinea corn yield and extreme temperature indices in the study area. Generally, the Table shows a non-significant negative correlation in the bulk of the stations. The correlation between TXn and guinea corn yield showed a significant negative correlation in the Ilorin station at (P < 0.05). Also, a significant positive correlation was detected for TXx in the Ilorin station at (P < 0.05). Further, the result showed a significant positive correlation for TNx in Lokoja station at (P < 0.05). The result for DTR showed a significant negative correlation in Lokoja and Lafia stations at (P < 0.01) for each of the stations and a significant positive correlation at (P< 0.05) in Abuja station. Finding revealed that the extreme temperature indices did not exert much effect on guinea corn yield across the study area. Therefore at the extreme level of temperature in the study area guinea corn yield will not be affected.

Table 4.39. Correlation Coefficient for Extreme Temperature Indices and Guinea corn Yield

Station		TXn	TXx	TNn	TNx	DTR
Minna	Spearman rank Correlation	.092	.049	.068	-.170	.324
	Sig (2 tailed)	.629	.797	.722	.370	.080
Lokoja	Spearman rank Correlation	-.358	-.351	-.062	**.373***	**-.605****
	Sig (2 tailed)	.052	.057	.744	.042	.000
Abuja	Spearman rank Correlation	.113	-.095	-.111	-.268	**.421***
	Sig (2 tailed)	.550	.618	.558	.152	.021
Ilorin	Spearman rank Correlation	**-.456***	**.440***	-.040	-.146	-.310
	Sig (2 tailed)	.011	.015	.833	.443 .	095
Lafia	Spearman rank Correlation	-.176	.038	.029	.049	**-.645****
	Sig (2 tailed)	.353	.843	.878	.797	.000

*Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed)

Figure 4.27 depicts the distribution pattern of the correlation between extreme temperature indices and guinea corn yield in the study area. Generally, the Figure showed negative pattern of relationship across the study location. Finding implies that guinea corn yield responded inversely to the changes in various level of extreme temperature in the study area.

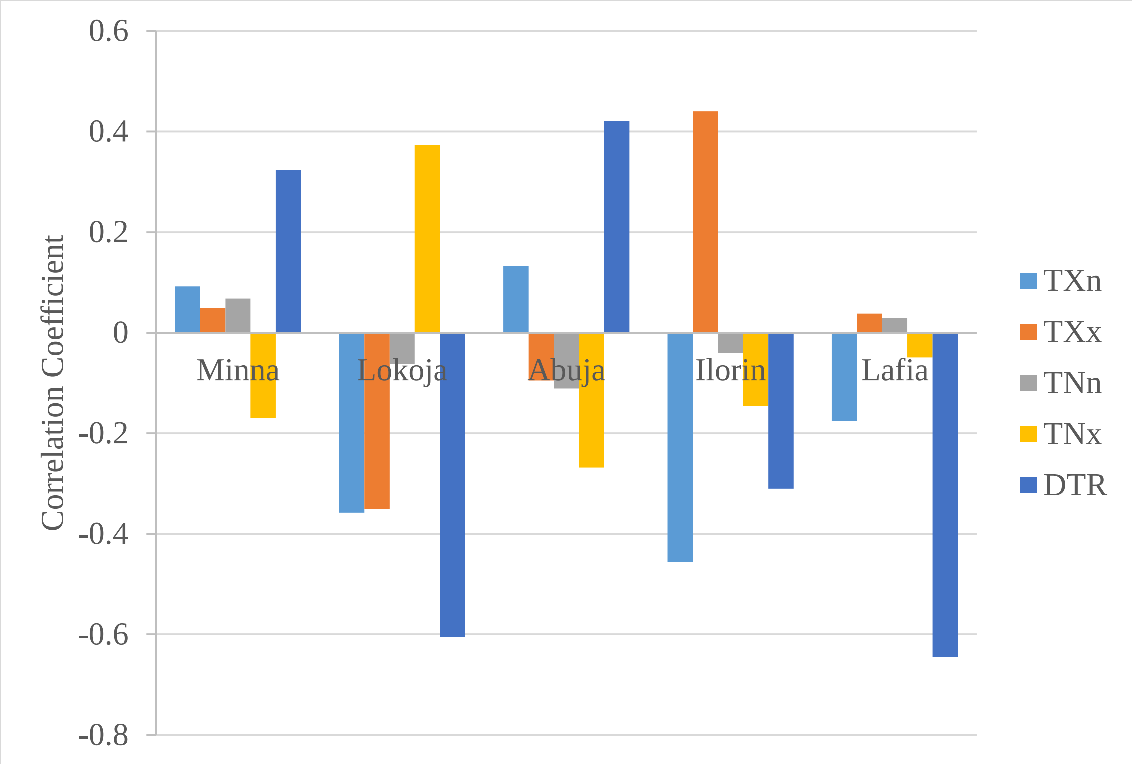


Figure 4.27. Pattern of Correlation between Extreme Temperature Indices and Guinea corn Yield.

4.5. Adaptation and Mitigation Strategies to Climatic Variables on Crop Production

4.5.1. Socio-economic characteristics of the population

Table 4.40 depicts the distribution of the socio-economic attributes of the population. Result showed that 45 % were between the ages of 30 and 40 years, 35 % were between 41 and 50 years, 12.3 % were between 51 and 60 years while 7.3 % were 60 years and above. Findings showed that about 80 % of the respondents were between the ages of 30 and 50 years which indicates that there were more youth population among the respondent. This may be indicative of the involvement of more youths in agricultural production and gradual solution to the challenge of ageing farming population in Nigeria.

Further results showed that more males (about 83 %) were involved in cereal crop production when compared with females (17 %) in the study areas. Finding revealed the gender dimension in agricultural production across the study areas.

On the marital status of the respondents, results showed that 77.2 % of the population were married, 14.9 % were single, 5.3 % were widowed while 2.6 % were divorced. Moreover, finding revealed that 77.2 % of the population were married which means that agriculture is an important occupation and means of meeting the family nutritional needs.

On the educational status of the population, results showed that 25.1 %, 45 % and 11.1 % had primary, secondary and tertiary education, respectively while 18.7 % had no formal education. Education is an essential factor that aids the adoption of improved farming methods. The frequency of low level of education among the study population may hinder the success of certain agricultural innovations system such as the e-wallet exercise of the Federal Government, where the farmer was expected to register online and access fertilizer and other agricultural facilities.

On the distribution of respondent with other means of livelihood apart from crop production, results showed that 48 % were into trading, 7.9 % were into art and craft, 24.3 % were public servants, 13.5 % were commercial motorcycle riders while 6.3 % were involved in occupation such as bricklaying, carpentry, vulcanizing, driving and motor mechanic, Student and working in private companies etc.

Table 4.40. Socio-economic Characteristics of the Population

	Frequency	Percentage
Age of Respondent		
30 – 40	154	45%
41 – 50	121	35.4%
51 – 60	42	12.3%
60 and above	25	7.3%
Total	342	100
Gender Distribution		
Male	284	83.0%
Female	58	17.0%
Total	342	100
Marital Status		
Married	264	77.2%
Single	51	14.9%
Widowed	18	5.3%
Divorced	9	2.6%
Total	342	100
Educational Qualification		
Primary	86	25.1%
Secondary	154	45.0%
Post-secondary	38	11.1%
No formal education	64	18.7%
Other Occupation of Respondent		
Petty Trading	164	48.0%
Art/Craft	27	7.9%
Public/Civil Servant	83	24.3%
Commercial Motorcycle Riding	46	13.5%
Others	22	6.3%
Total	342	100

The distribution of major cereal crop production in the study area is depicted in Figure 4.28. Result showed that 29.8 % of the population were into rice cultivation, 18.7 % and 9.1 % cultivated maize and guinea corn, respectively as their major crops. About 12.3 % of the farmers integrated rice and maize crop, 7 % integrated rice and guinea corn, 11.1 % integrated maize and guinea corn while only 12 % of the farmers cultivated all the three major crops considered in this study. The finding implies that the farmers have adopted multiple cropping system as an alternative means of adaptation.

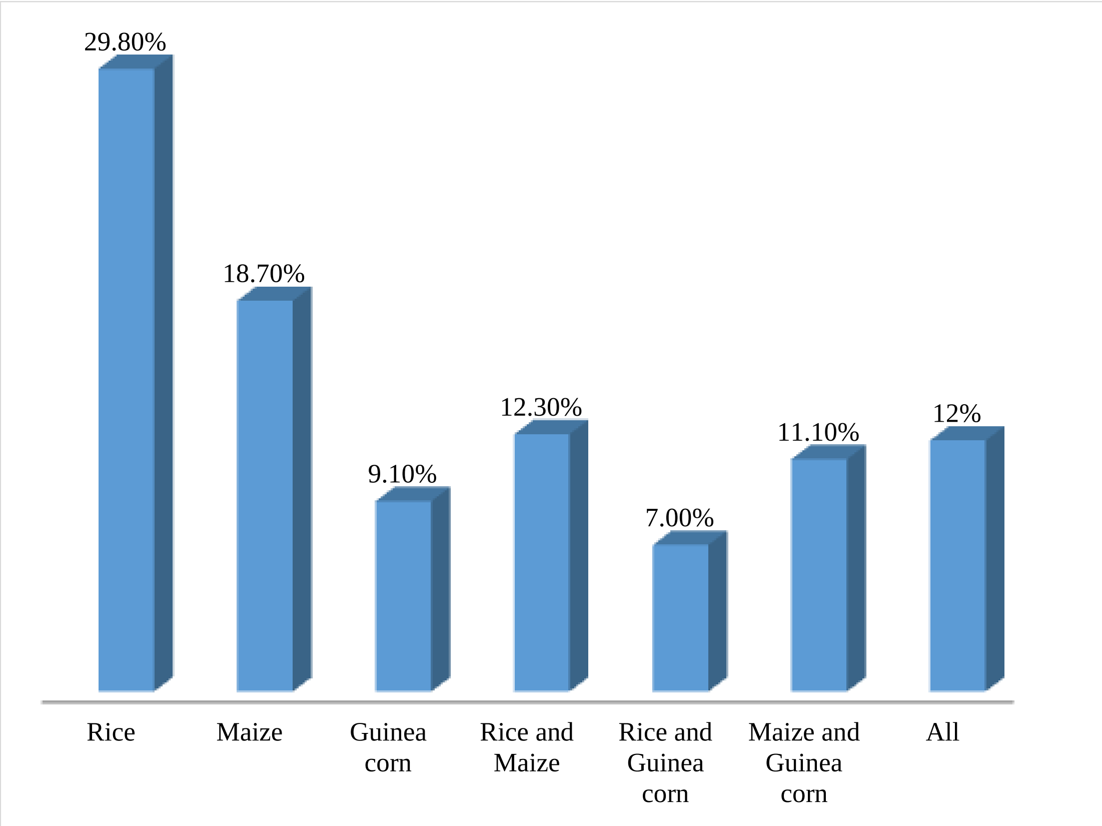


Figure 4.28. Distribution of Major Cereal Crop Cultivation in the Study Area

The distribution of years of crop production is shown in Figure 2.29. Result showed that 49.1 % of the farmers had 10 to 15 years' experience in production, 30.4 % had 16 to 30 years' experience. 12.6 % had 21 to 30 years' experience while 7.9 % had experience of 31 years and above. The finding implies that the respondent had requisite years of experience to provide the needed response to questions put forward.

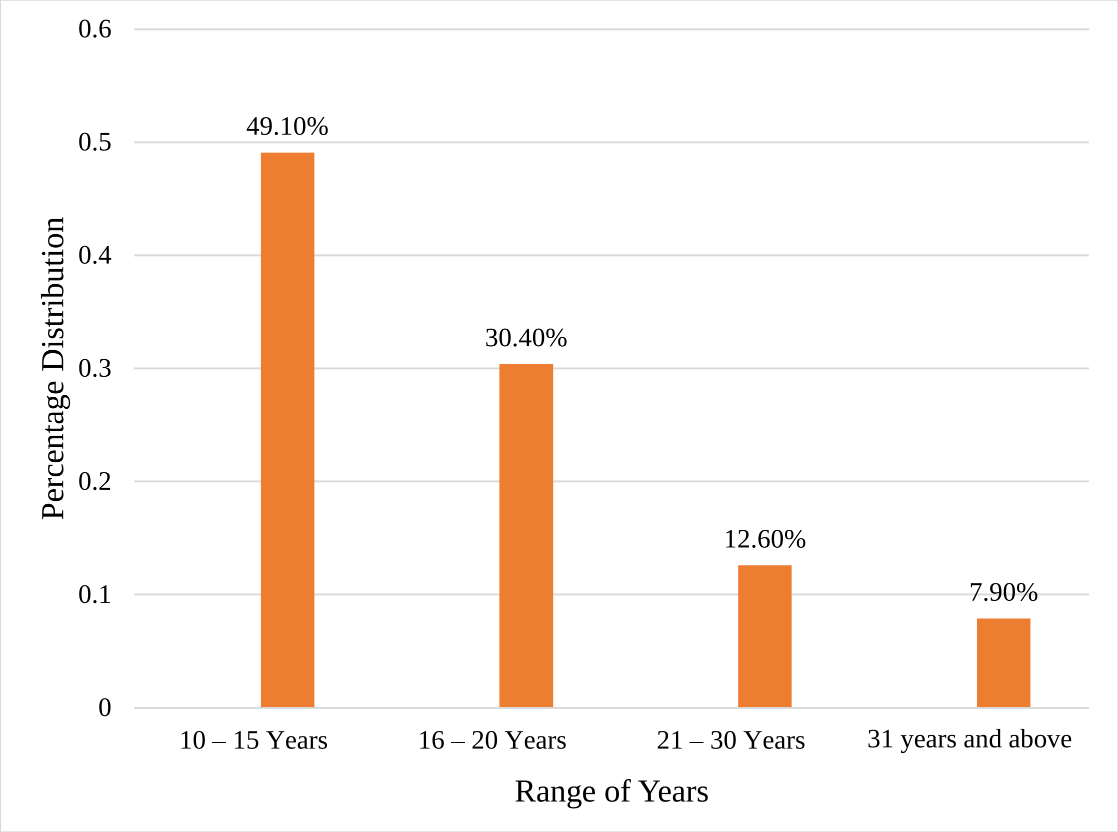


Figure 4.29. Distribution of Years of Crop Production

Figure 4.30 depicts the distribution of involvement of the respondents in other agricultural practices apart from crop production. Result showed that 56.7 % were into livestock farming, 9.1 % were into fish farming while 7.9 % were involved in postharvest processing. Further result showed that 5.6 %, 6.1 % and 3.2 % integrated livestock, fish farming and postharvest processing as other farming practices while 11.4 % did not practice any other farming system. The livestock were reared in small scale, mostly behind the farmers' house. Cattle were raised to provide draft power. The farmers also reared sheep, goat, chicken, and rabbit among others to provide family nutritional requirements and urgent expenses.

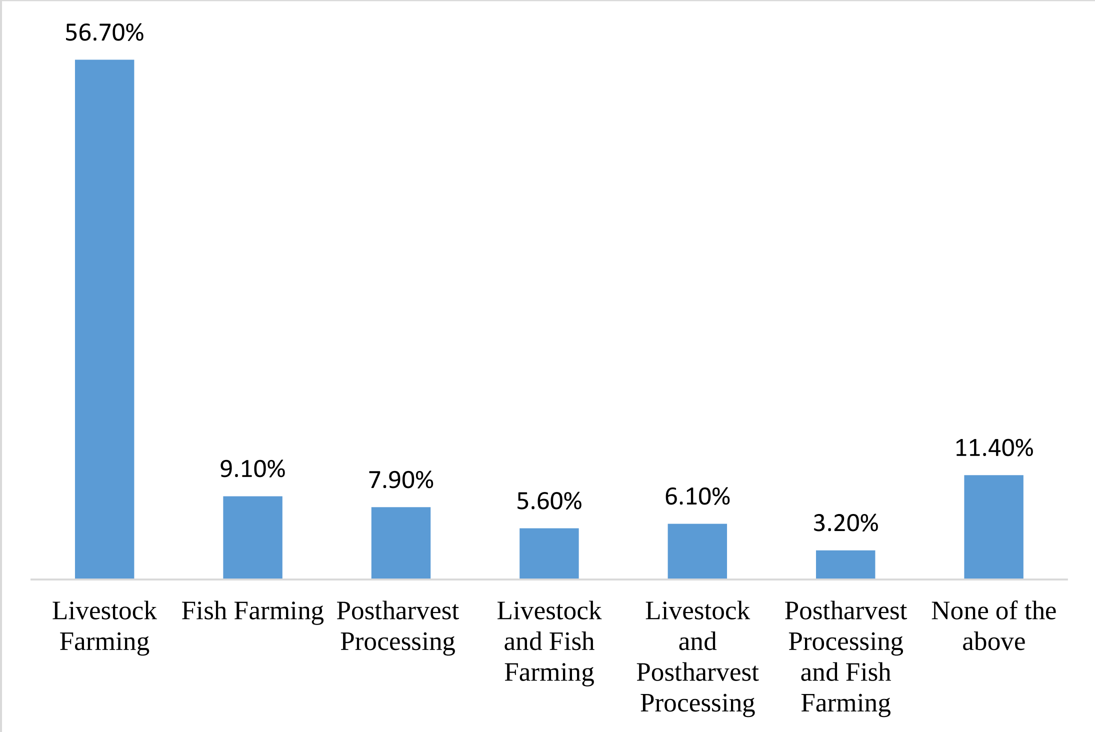


Figure 4.30. Distribution of other Agricultural Practices of the Population

4.5.2. Adaptation measures available in the study areas

Figure 4.31 depicts responses on types of seed cultivated. Result showed that 50.9 % of the farmers cultivated hybrid crop variety, 33 % used local variety while about 16.1 % had no knowledge of the variety of seed they cultivated. Finding implies that the adopted village concept of the National Agricultural Research Systems is yielding positive result as shown in the number of farmers cultivating hybrid crop variety (50.9 %). The finding also shows that the farmers were aware of certain hybrid crop variety such as Federal Agriculture Research Oryza (FARO) 44, 58, 63 and 65 which are resistance to flood and drought conditions.

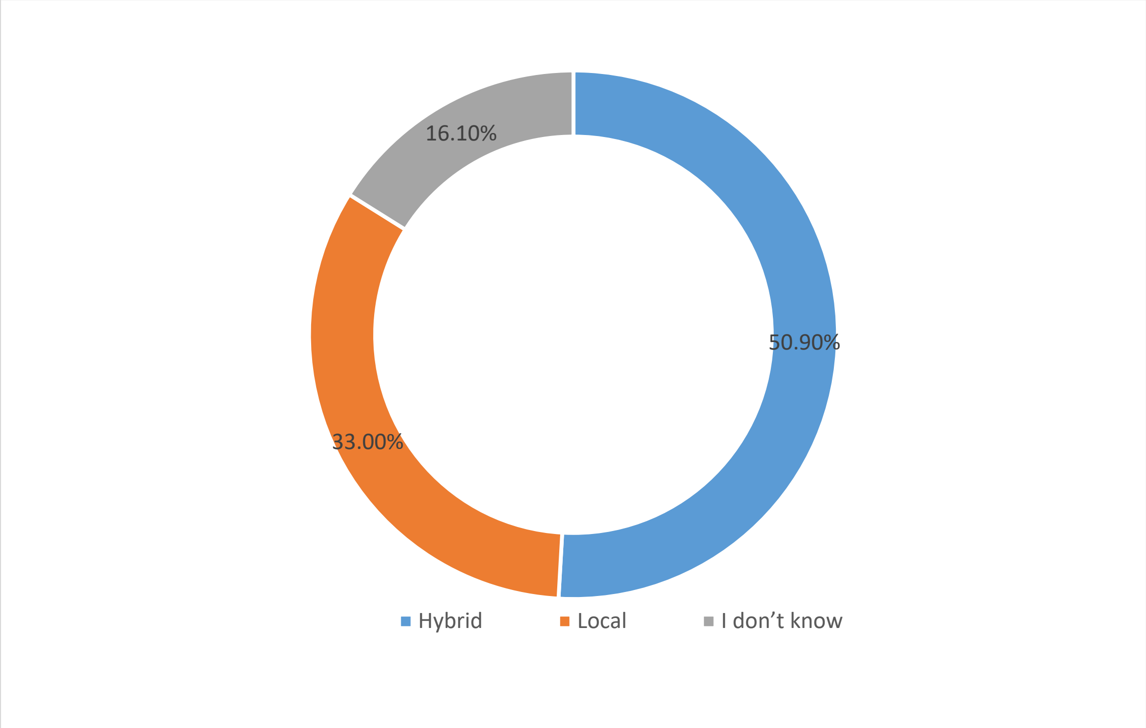


Figure 4.31. Distribution of Types of Seed Cultivated in the Study Area

Figure 4.32 depicts the distribution of responses on sources of seed cultivated. Result showed that 57.6 % of the farmers get their seeds from the Agricultural Research Institutions, 9.4 % sourced their seeds from private seed companies, 21.3 % of the seed cultivated were obtained from the market while 11.7 % of the seeds were sourced from past harvest. Finding implies that despite awareness on some improved seed varieties in the Research Institutes and private seed companies some farmers still preferred using their past harvest or local seed from the market, this could be due to poverty level or inability to access the seed when required. The finding therefore underscores the need for government intervention to subsidize seeds and make it readily available to farmers.

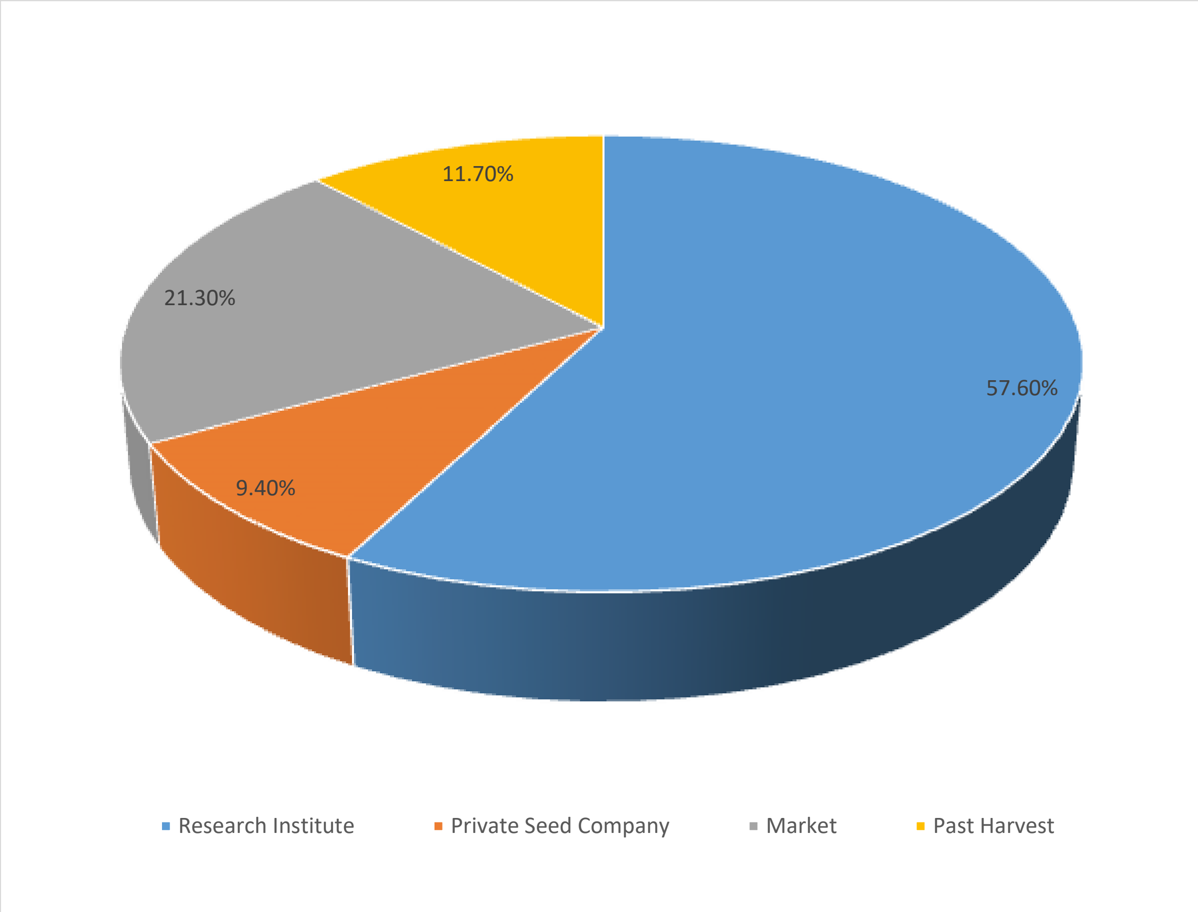


Figure 4.32. Distribution of Sources of Seeds Cultivated by the Farmers

Figure 4. 33 depicts number of times the farmers embark on crop cultivation in a single year. Result showed that 79.8 % of the farmers cultivated once in a single year, 14 % cultivated twice in a year while 3.2 % indicated no certainty in the number time they cultivated in a single year. This implies that most of the farmers were into rain fed agriculture, where they solely rely on rainfall for crop production, and therefore are strictly cultivating once in a year.

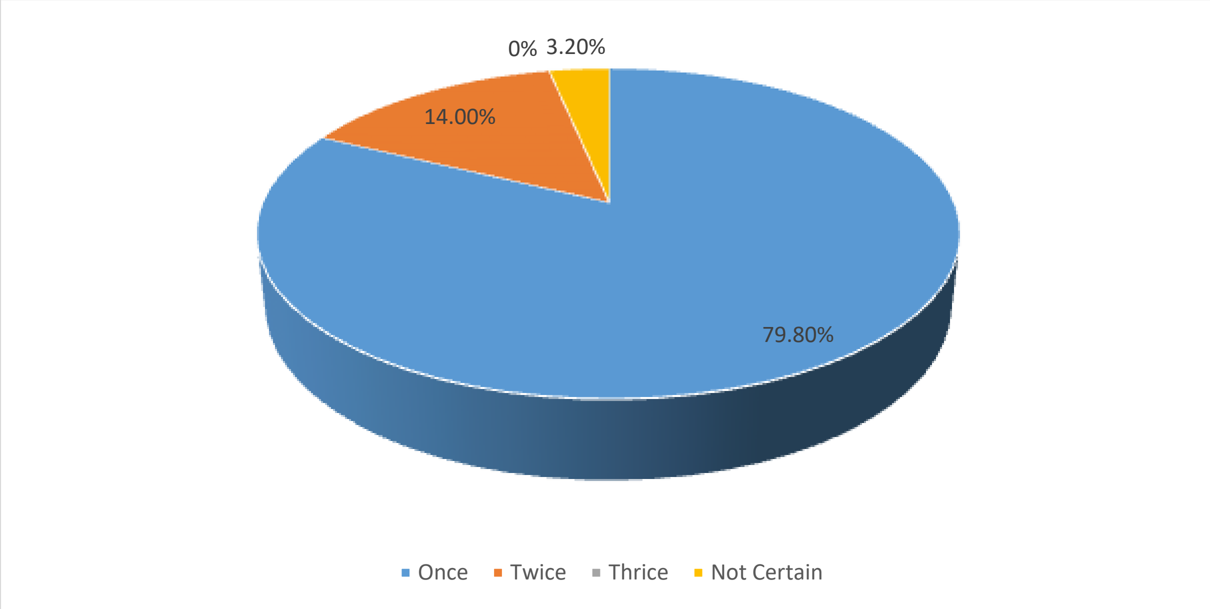


Figure 4.33. Distribution of Number of Times Farmers Cultivate in a Single Year

Table 4.41 depicts responses on the use of adaptation measures to crop production. Result showed that 11.1 % used irrigation very often, 33.6 % often used irrigation, 37.2 % rarely used irrigation facility while 18.1 % never used any form of irrigation system in their farming operations. Irrigation facilities are expensive and could be out of reach of the peasant farmers, efforts need to intensified by the government to subsidize irrigation equipment and encourage farmers on it usage especially during the period of prolonged absence in rainfall.

On the adoption of erosion control measures, result showed that 17.8 % used erosion control measure very often, 51.5 % often used erosion control measure, 27.5 % rarely used erosion control measure while 3.2% of never used erosion control measure on their farm.

Responses on cultivation of drought resistant crop variety, result showed that 13.7 %, and 23.1 % cultivated drought resistant crop very often and often while 42.4 % and 20.8 % indicated rarely and never. Finding implies that the farmers may be unaware of the advantages of cultivating the crop variety, also the variety may be expensive and in most cases not readily available to farmers at commercial quantity.

On the use of flood resistant crops, result showed that 17.0 % used flood resistant crops very often, 36.8 % often used flood resistant crop while 39.2 % and 7 % rarely and never used flood resistant crop. Finding implies that despite the study area were located at closed proximity to the research Institutions, the level of adoption of improved crop varieties was low and therefore underscore the need for government intervention to support and encourage the peasant farmers to adopt improved varieties so as to strengthen their resilience to changing climate.

On the analysis of use of pest and disease resistant crop variety, result showed that 15.5 % of the population used pest and disease resistant crop very often, 31.3 % often used while 39.2 % and 14 % rarely and never used pest and disease resistant crop. Finding implies that low level of low adoption of pest and disease resistant crop variety could be linked to low awareness, availability and affordability to the farmers.

Further result showed that 37.4 % of the study population practiced crop rotation method very often, 51.5 % often practiced, 8.5% rarely practiced while 2.6 % never practiced rotational cropping system.

Result also showed that 22.8 % of the respondents very often allowed fallowing of farmland, 47.7 % often practiced fallowing of farmland, 25.4 % rarely and 4.1 % never practiced fallowing of farmland.

Result from Table 4.41 revealed that 33.20 % of the respondents practiced crop relocation very often, 53.20 % often practiced, 2.9 % rarely practiced while 0.6 % never practiced crop relocation.

On the issue of adjustment of planting date as a strategy for adaptation, result revealed that 37.10 % of the population showed very often, 53.20 % showed often and 9.7 % showed rarely. Finding implies that most of the farmers often adhere to adjustment in planting date as strategies to adapt to the impact of changing variability and climate.

Finally, on the issue of training received on farm management practices in the last five years, result showed that about 67.2% of the respondent had regular training on farm management practice while 28.4% had no regular training and 4.4% never had any formal training on farm management.

Finding from the study indicated that a higher proportion of the respondents were aware of major adaptation measures on their production. The finding is also an attestation that the concept of adopted village which is to provide improved and better farm management practices to host communities and the nation at large is yielding positive result as shown in the analysis.

Table 4.41. Frequency of Adoption of Adaptation Strategies by the respondents

Adaptation Measures	Very Often	Often	Rarely	Never
Use of irrigation facility	38(11.1%)	115(33.6%)	127(37.2%)	2(18.1%)
Use of erosion control measure	61(17.8%)	176(51.5%)	94(27.5%)	11(3.2%)
Cultivation of drought resistant crops	47(13.7%)	79(23.1%)	145(42.4)	71(20.8%)
Cultivation of flood resistant crops	58(17.0%)	126(36.8%)	134(39.2%)	24(7.0%)
Use of pest and disease resistant crops	53(15.5%)	107(31.3%)	134(39.2%)	8(14.0%)
Crop rotational practice	128(37.4%)	176(51.5%)	29(8.5%)	9(2.6%)
Fallowing of farmland	78(22.8%)	163(47.7%)	87(25.4%)	14(4.1%)
Crop relocation practice	114(33.30%)	182(53.20%)	44(12.9%)	2(0.6%)
Adjustment in planting date	127(37.10%)	182(53.20%)	33(9.7%)	0%
Training on Farm Management Practice	104(30.4%)	126(36.8)	97(28.4%)	15(4.4%)

Figure 4.34 depicts the distribution of types of weather service information accessibility to farmers. Result showed that 3.5 % of the population had access to weather forecasting information, 39.2 % received information on early warning system while 57.3 % got general weather information regularly. When asked on the sources of the weather information, majority of the farmers confirmed receiving their weather service information from Agricultural Research Institutions located within their communities while few indicated Nigeria Meteorological Agency as sources of their weather information. The finding implies that the farmers had access to routine weather service information which could improve their preparedness for early warning actions.

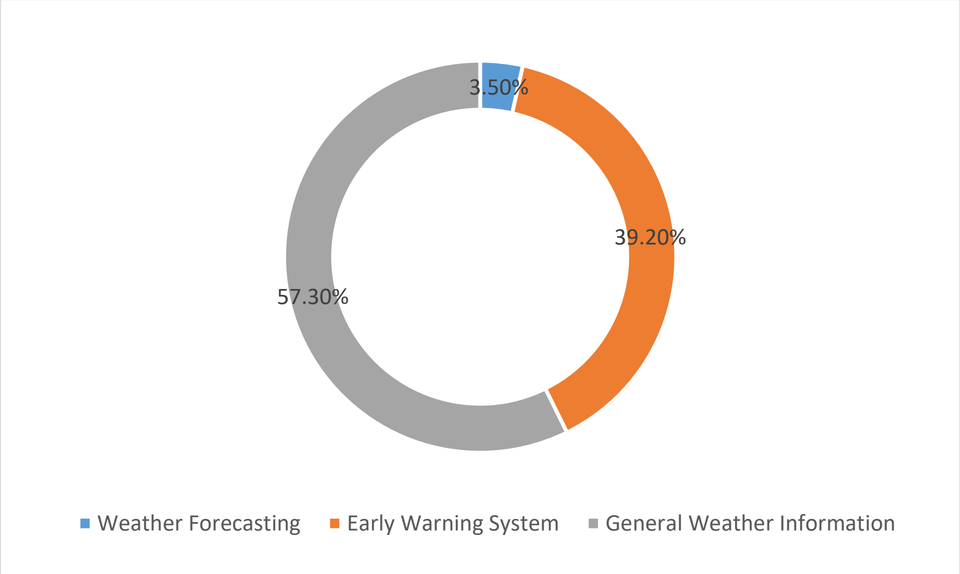


Figure 4.34. Types of Information on Weather Services in the Study Areas

Result of the field interview conducted with selected farmers during questionnaire administration showed that majority of them were aware of climate variability and the resultant effect on their production. Some of the effects identified by the farmers were:

i. Low productivity.
ii. Increased incidences of crop failure due to fluctuation and untimely cessation of rain.
iii. High rate of spoilage of harvests in the field due to excessive rainfall at the end of the season. This has also made dry season farming challenging.
iv. High incidence of pests and weeds.

4.5.3. Available mitigation strategies to climate variability

Figure 4.35 depicts responses on tree management on farmland by the farmers. Result showed that 21.1 % of the farmers had increase in number of trees available on their farmlands, 69.3 % experiences a decrease while 9.6 % had no change in the number of trees on their farms. Finding implies that despite the fact that the farmers have adopted major adaptation strategies, they may be lacking in mitigation measures such as planting of tree on farmland to control erosion and to serve as wind break. When asked on the sources of fuel for cooking, majority of the respondent confirmed using charcoal and firewood for cooking which is an indication that the farmers cut down trees in their farms to meet domestic cooking need.

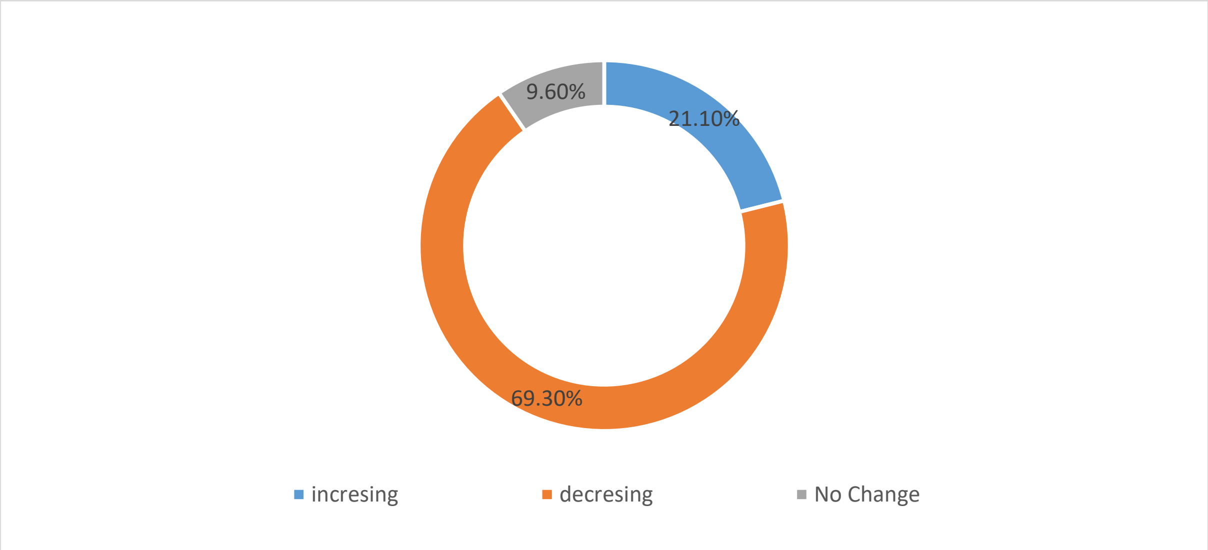


Figure 4.35. Response on Change in Number of Trees on the Farm

Figure 4.36 showed the analysis of responses on crop residue management by the farmers in the study areas. Result showed that 31.3 % of the farmers used slash and burn, 35.7 % used crop residue as animal feed, 27.2 % allowed the residue to decompose on their farmland while 5.8 % sold their crop residue in the market. Finding implies that most of respondents were unaware of the significance of incorporating crop residue into the soil. This method helps to enrich the soil and increase it fertility thereby reducing over reliance on the use of inorganic manure.

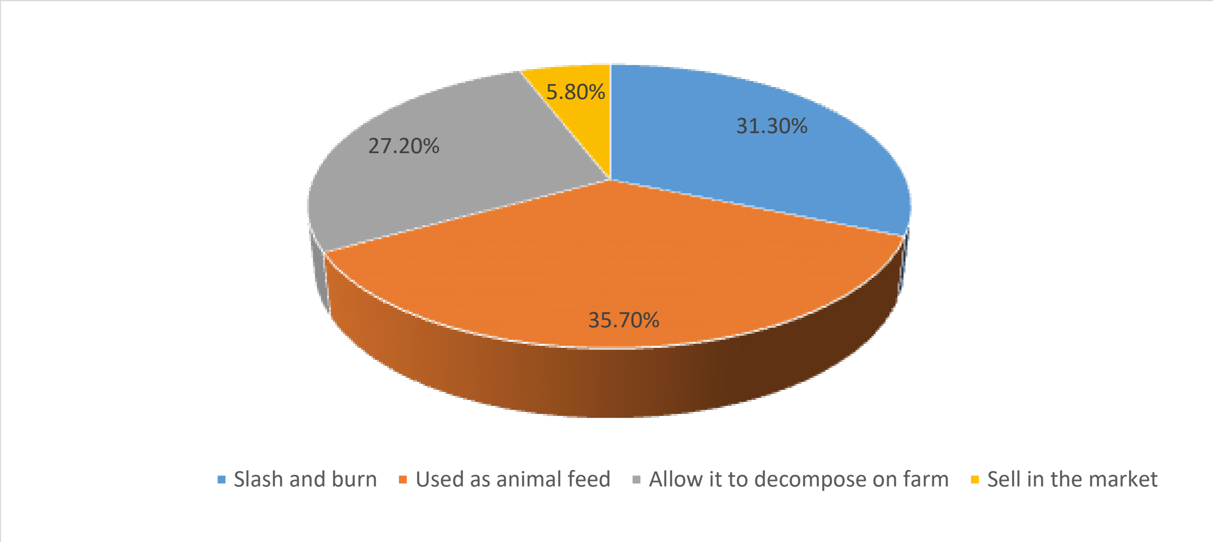


Figure 4.36. Response on Crop Residue Management in the Study Areas

Figure 4.38 depicts responses on method of fertilizer application by the respondent. Result showed that 29.8 % of the respondents used point method of fertilizer application, 53.3 % used broadcast method while 14.9 % used both point and broadcast methods. Finding implies that the point method of fertilizer application which seeks to improve quality of crop under cultivation and enhance soil quality is not widely used by the farmers. This underscores the need for more enlightenment from the extension officer on best practices in term of fertilizer application.

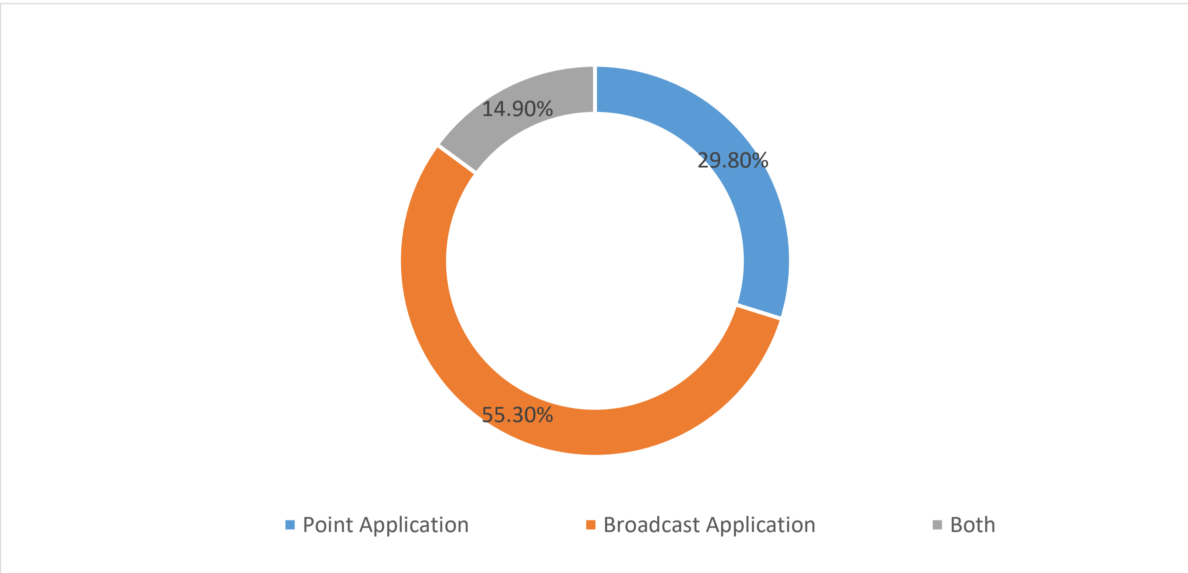


Figure 4.38. Methods of Fertilizer Application in the Study Areas

Table 4.42 depicts the frequency of adoption of mitigation measures. Result shows that about 95.6 % of the respondents used both organic and inorganic fertilizers regularly on their farms while 4.4% rarely used fertilizer on their production. This implies that fertilizer application on crop was a common practice among the farmers across the study area.

Further, result revealed that 6.2 % of the farmers carried out soil testing very often before fertilizer application on their farms, 13.7 % often carried out soil testing, 22.2% rarely carried out soil test while 57.9% never conducted any soil testing on their farm prior to fertilizer application.

On waste recycling as adaptation measure, result showed that 30.1 % of the farmers recycle their waste very often, 51.2 % often recycle their farm waste, 12.6 % rarely practiced waste recycling while 6.1 % had never recycled waste of their farming operation.

Result from Table 4.42 showed that 11.1 % of the population practiced bush burning very often as farm clearing measure, 20.8 % often practiced bush burning, 55.8 % rarely engaged in farm clearing through bush burning while 12.3 % never practiced bush burning in their farming operation.

Result from the Table showed that 6.7 % of the respondents experienced accidental fire outbreak on their farm lands very often, 19.6 % showed often, 62.3 % indicated rarely while 11.4 % never experienced accidental fire on their farming operation. The finding implies that despite the effort to educate and enlighten the farmers on certain mitigation measures, they still operate their primitive and unproductive method of farming and thereby reducing their comparative advantage and competiveness.

Table 4.42. Adoption of Mitigation Strategies in the Study Areas

Mitigation Measure	Very Often	Often	Rarely	Never
Use of fertilizer (Organic/inorganic)	284(83.0%)	43(12.6%)	15(4.4%)	00
Soil testing before fertilizer application	21(6.2%)	47(13.7%)	198(57.9%)	6(22.2%
Waste recycling	103(30.1%)	175(51.2%)	43(12.6)	21(6.1%)
Bush burning as measure of farm clearing	38(11.1%)	71(20.8%)	191(55.8%)	42(12.3%)
Occurrence of accidental fire on farmland	23(6.7%)	67(19.6%)	213(62.3%)	39(11.4%)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Findings from the study showed that a shift in rainfall occurred across the study area. It revealed that over the years there was a downward trend in rainfall during the onset period in May and upward trend towards the cessation period in October. Maximum temperature, minimum temperature and relative humidity showed an upwards trend in most stations on monthly and annual time scales. Also, the result of Mann-Kendall test for trend detection in annual crop yield showed mixed trend across the study areas.

The study revealed that the distribution of the impacts of climatic variabiles on yield of the crops were not uniform across stations, as all the climatic variables considered did not exert same effect on the crop yield. Therefore, the general interpretation of the relationship between climatic variables and crop yield should be done with caution and that every variable should be studied on its own merit.

The study also established that rice yield respond positively to changes in extreme rainfall indices compared to maize and guinea corn yield in the same location. Also, the three crops studied (rice, maize and guinea corn) responded more to changes in rainfall extreme indices when compared to changes in extreme temperature indices in same station. This implies that rainfall impacts more on selected crop than temperature.

In an attemt to improve crop production and minimise the risk resulting from climate variability and change impact, the farmers adopted several coping strategies which included the use of early maturing crop varieties, flood and drought tolerant crop varieties, diversification of livelihood and adherence to weather service information among others.

5.2 Recommendations

From the research findings, the following recommendations were made;

i. Continuous monitoring of climate of the study area is important to understand the changing pattern so as to provide remedial measures for adaptation.

ii. Mainstreaming farming calendar into the changing climate regime to ensure improved crop yield.

iii. More climate smart technologies and innovative practices should be encouraged and made available to the farmers through extension services for sustainable and increased yield.

iv. Introduction of Agricultural risk insurance for crop farmers in the study area. This will help boast their confidence and safeguard against total loss in case of crop failure.

v. Training and re-training of the farmers on land and water management strategies such as soil fertility enhancement, erosion control, water harvesting and irrigation farming among others.

vi. Concerted efforts should be put in place by relevant stakeholders to develop new and improved crop varieties corresponding to farmers' needs and preference criteria.

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APPENDICES

APPENDIX A: Questionnaire

This questionnaire is designed to elicit information on the Impact of Climate Variability on Cereal Crop Production in North Central States, Nigeria. It is purely an academic exercise in partial fulfillment of PhD in Environmental Management, Federal University of Technology, Minna. I therefore, solicit your sincere response to help enrich this research work. All information provided will be treated confidentially and be used solely for this research.

Thank you.

Musa Musa

Please tick and fill the appropriate responses in the space provided.

SECTION 1

SOCIO-ECONOMIC CHARACTERISTICS OF THE RESPONDENTS

1. Name of Community/Village…………………………………………………….

   Local Government

   Area……………………………………………………………………………..
2. State

   ……………………………………………………………………………………
3. Age of farmer: below 20 years [ ] 21-30 years [ ] 31-40 years [ ] 41-50 years [ ]

   51-60 years [ ] above 60 years [ ]
4. Gender: Male [ ] Female [ ]

5. Marital status: Married[ ] Single [ ] Widow [ ] Separated [ ] Divorced [ ]
6. What is your highest educational qualification? Primary[ ] Secondary [ ] Post-secondary [ ] No formal education [ ]
7. Occupation of the Respondent? Farming [ ] Petty Trading [ ] Art/Craft [ ] Public/Civil Servant [ ] Okada riding [ ] Others specify…………………………

SECTION 2

ADAPTATION PRACTICES ADOPTED BY THE FARMERS

8. Which of the cereal crops do you produce mainly? (a) Rice (b) Maize (c) Guinea corn (d) Rice and Maize (e) Rice and Guinea corn (f) Maize and Guinea corn (g) All of the above
9. How long have you been producing the chosen crop? (a) 10 to 15 years (b) 16 to 20 years (c) 21 to 30 years (d) 31 years and above
10. Do you engage in other agricultural practices apart from crop production (a) Yes (b) No
11. What variety of seed do you use? (a) Hybrid (b) Local (c) I don't know
12. Where is your source of seed? (a) Research Institutes (b) Seed companies (c) Market (d) Past harvest
13. How often do you cultivate in a year? (a) Once (b) Twice (c) thrice
14. How often do you apply irrigation facility on your farm? (a) Very often (b) Often (c) Rarely (d) Never
15. How often do you engage in erosion control on your farm?

    (a) Very often (b) Often (c) Rarely (d) Never

16. How often do you cultivate drought tolerant crops? (a) Very often (b) Often (c) Rarely (d) Never
17. What type of flood control method do you use? (a) Flood water harvesting (b) Construction of ridges (c) Planting of flood resistant crop variety (d) Avoiding cultivation on flood plain (e) Others Specify ……………………………………………………………………………………..
18. In the event of drought or flood, do you agreed with crop relocation as a possible adaptation option?

    (a) Strongly Agreed (b) Agreed (c) Strongly Disagreed (d) Disagreed(e) Indifferent
19. How often do you cultivate pest and disease resistant crops? (a) Very often (b) Often (c) Rarely (d) Never.
20. How often do you practice crop rotation? (a) Very often (b) Often (c) Rarely (d) Never
21. How long do you allow fallowing of your farm land? (a) Every 2 years (b) 3-5 years (c) 5 years and above (d) Never
22. What type of weather services do you have access to?

    (a) Weather forecasting (b) Early warning system (c) General weather information (d) Others specify ………..
23. Do you agree with any adjustment in planting calendar? (a) Strongly agreed (b) agreed (c) Strongly disagreed (d) Disagreed (e) Indifferent
24. How often do you receive formal training on farm management skills?

    (a) Very often (b) Often (c) Rarely (d) Never

MITIGATION STRATEGIES ADOPTED BY THE FARMERS

25. In terms of numbers, what type of changes has taken place regarding trees on your farm?

    (a) Increased (b) Reduced (c) No change

26. How do you manage crop residues on your farm after harvest?

(a) Slash and burn

(b) Feed to my animals

(c) Leave to decompose on the field

(d) Sell in the market

27. How often do you use fertilizer on your crops? (a) Very often (b) Often (c) Rarely (d) Never

28. What type of fertilizer do you use? (a) Organic (b) Inorganic

29. What method do you use for your fertilizer application?

    (a) Point (b) Broadcast (c) Others …………………………………

30. Do you agree that it is important to carry out soil test before using fertilizer on the farm?

    (a) Strongly agreed (b) Agreed (c) Strongly disagreed (d) Disagreed (e) Indifferent

31. How often do you recycle waste from your farm (a) Very Often (b) Often (c) Rarely (d) Never

32. How often do you engage in bush burning on and around your farm?

(a) Very often (b) Often (c) Rarely (d) Never

33. How often do you experience accidental fire incidence on your farm?

(a) Very often (b) Often (c) Rarely (d) Never

APPENDIX B: Monthly Rainfall Data in the Study Area

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	0	11.57	18.57	62.8	85.8	195.1	226.28	354.64	267.22	87.75	0	3.96
1990	0	0	28.17	25.27	57.98	125.1	215.89	298.86	210.09	63.67	0.91	2.76
1991	1.15	2.52	2.84	54.68	116.4	147.4	139.43	167.81	140.25	63.98	0.6	3.95
1992	0	9.83	25.45	73.98	108.2	156.1	215.29	120.74	96.89	38.25	0.21	0
1993	0	0.43	0.73	65.75	113.5	131.2	153.19	158.07	131.5	26.47	13.92	0
1994	0	0.73	27.57	11.55	51.11	109.9	252.83	240.01	248.74	36.97	3.18	5.39
1995	3.82	0.3	10.17	39.43	95.22	113.9	195.59	233.87	266.01	118.56	1.36	0
1996	0	0.4	20.11	42.88	87.12	90.59	180.47	343.19	187.09	106.9	7.24	2.96
1997	0	3.79	20.49	49.62	101.3	131.5	200.49	170.72	156.91	50.87	0	0
1998	0	0	45.56	65.37	131.1	87.27	103.48	131.5	82.73	64.13	0.06	27.46
1999	4.09	1.01	0.22	23.16	173.1	182.6	224.25	226.68	106.13	87.3	0	0.15
2000	0	3.34	4.71	28.19	82.9	57.83	37.84	232.38	91.59	127.4	8.09	0
2001	0	0	14.36	76.36	72.04	129.1	166.22	191.14	93.32	100.34	7.35	1.27
2002	0	0	0	24.18	51.67	32.9	36.65	62.24	78.56	16.22	0.18	0
2003	0	0.87	19.79	63	142.5	72.76	224.8	211.43	177.83	73.11	3.14	0
2004	3.47	23.23	9.75	64.47	112.6	92.51	104.45	124.22	187.15	41.52	10.2	0
2005	5.27	1.85	6.57	63.44	90.67	160	142.27	167.65	78.07	95.45	13.83	0
2006	0	4.62	12.82	40.56	94.4	120.8	62.33	138.82	121.22	145.38	0.64	0
2007	0.02	0.42	31.31	12.52	96.93	131.6	109.61	237.34	161.9	87.37	2.41	0
2008	0	0	18.73	47.42	18.18	175.2	66.55	326.32	57.07	35.24	0.58	4.24
2009	1.87	0.05	26	34.78	27.63	120.9	239.8	305.25	231.15	83.81	0	1.6
2010	0	0	0	112.5	148.1	234.5	141.07	251.65	162.94	150.4	2.49	0
2011	0.59	0	0.08	34.87	106.2	53.08	277.92	221.01	212.64	162.43	17.58	0
2012	0	3.55	0	21.89	87.94	175.9	164.72	138.68	178.58	113.5	0	0
2013	0	0	0.07	50.4	215.4	89.46	219.42	216.85	163.15	166.32	1.25	0
2014	10.9	4.38	20.71	44.38	37.63	114.5	147.94	68.17	122.02	154.29	0	0
2015	5.2	2.56	21.1	66.55	55.33	72.47	56.98	181.13	63.46	170.02	0	0

2016	0	8.68	8.54	0.75	21.83	70.1	300.06	122.18	211.44	143.85	0.77	0
2017	0	0	17.16	30.79	233.5	108.5	181.26	143.12	183.8	167.25	0	0
2018	0	0	9.94	28.05	160.7	131.7	76.75	350.99	87.71	126.53	0.54	0.54

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	6.56	23.95	60.87	90.17	177.59	311.88	225.16	212.75	253.74	318.1	34.9	16.46
1990	6.23	0	64.53	133.57	156.11	280.25	235.75	243.34	253.31	281.5	12.36	0.31
1991	4.06	19.99	13.58	164.41	143.46	103.84	153.16	35.32	134.27	137.4	17.39	25.97
1992	12.84	13.68	19.67	144.87	119.39	137.37	330.68	64.14	127.44	77.88	0.11	13.99
1993	0	2.11	34.89	106.74	257.62	304.76	230.31	147.05	198.84	192.8	32.01	0.69
1994	0	17.65	68.15	108.71	180.97	304.57	278.35	231.61	289.8	176.5	54.92	7.78
1995	14.47	1.63	83.62	104.21	135.81	207.36	238.08	149.62	272.81	275.9	22.01	0
1996	17.18	26.14	67.52	117	131.76	226.19	278.07	296.62	189.51	135.2	57.73	0.28
1997	0.99	31.81	89.41	142.41	169.53	321	140.86	134.54	60.31	85.95	12.07	0.37
1998	8.32	0	108.55	202.43	178.44	339.8	93.95	69.26	173.31	79.23	36.8	29.46
1999	19.14	2.48	29.93	143.48	166.96	236.54	234.32	132.22	131.99	126.8	2.33	5.32
2000	2.85	4.13	2.99	62.03	45.1	61.47	45.52	129.62	146.6	157.5	17.79	0.24
2001	0	0.88	21.28	91.85	212.55	487.3	312.67	187.84	132.02	223.6	29.49	12.35
2002	0	0.04	0	120.33	191.12	159.52	69.08	58.59	170.33	85.1	12.2	6.08
2003	0	6.89	63.94	194.23	112.68	125.32	289.31	118.47	83.88	242.5	28.33	6.88
2004	25.05	57.27	3.44	220.3	153.41	165.44	122.82	99.85	219.56	181.5	39.21	0
2005	15.28	17.72	17.21	140.44	237.91	114.16	137.04	99.67	198.03	93.66	15.2	0
2006	0	10.11	48.16	23.37	116.28	130.72	43.67	82.47	114.05	96.34	23.6	1.26
2007	1.45	2.46	52.7	38.29	233.61	178.35	164.3	306.59	216.91	83.03	46.11	0.35
2008	0	29.19	21.28	157.63	142.16	222.94	50.58	356.34	286.06	118.8	20.07	5.5
2009	8.71	12.47	32.46	34.46	41.76	90.98	214.16	124.86	168.64	71.44	0	1.24
2010	0.07	0.03	12.44	149.93	157.65	67.27	122.69	109.57	99.43	191.9	64.59	0
2011	4.19	8.16	14.87	94.68	123.33	104.42	115.85	192.51	288.3	126.9	66.96	5.63
2012	0	32.94	9.46	50.12	176.5	159.14	141.47	136.79	191.85	105.4	10.18	0.17

2013	2.85	5.25	5.24	67.28	113.73	170.69	153.55	156.34	137.08	257.3	24.4	1.63
2014	11	45.31	45.36	66.31	144.88	96.34	157.1	101.2	175.05	174.2	10.25	55
2015	19.84	18.14	18.96	59.94	91.89	52.86	41.38	122.25	129.24	192.8	11.45	1.04
2016	1.03	6.81	74.99	6.01	60.65	99.4	205.4	68.99	120.41	159.4	18.33	0
2017	0.99	0	71.49	51.08	142.43	95.23	171.51	118.22	280.91	144.3	3.78	0.76
2018	0.13	0.38	39.07	65.15	83.57	152.88	183.3	253.06	87.8	138.7	17.65	3.89

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	3.6	12.1	29.69	46.75	63.53	163.21	189.32	376.8	207.74	106.02	9.3	9.33
1990	3.41	0	20.77	40.71	74.08	201.26	320.83	332	213.04	75.69	2.51	0.38
1991	0.43	0.43	0	23.72	56.42	88.82	156.33	150.1	86.99	24.99	1.64	1.51
1992	0	3.26	17.23	16.09	68.46	98.64	203.08	139.9	63.5	14.1	0	0
1993	0	0	0.28	32.57	106.09	219.44	337.99	232.6	189.69	63.83	11.33	0
1994	0	7.66	28.73	42.57	79.68	115.72	315.09	351	244.36	68.4	16.06	1.45
1995	11.4	0	31.96	31.91	80.58	132.99	259.35	263.2	294.61	95.83	1.67	0
1996	0.05	7.47	8.49	15.8	41.55	180.6	283.86	394.4	147.39	77.35	10.98	0.3
1997	0.95	9.72	22.86	55.8	56.14	138.2	213.48	170.4	101.01	45.11	0	0
1998	0	9.52	16.8	21.79	89.77	84.87	91.03	141.6	89.69	26.42	9.67	9.4
1999	3.61	0	8.85	38.47	90.41	162.73	268.54	244.9	189.09	65.52	0.5	3.52
2000	0	3.34	0.22	46.23	70.99	65.35	20.43	260.9	124.53	200.25	7.65	0
2001	0	0	4.48	36.15	84.54	312.36	374.32	217.2	90.24	103.24	13.07	2.1
2002	0	0	0	21.94	77.11	75.1	41.96	58.08	94.22	20.13	4.27	2.79
2003	0	0.18	13.27	67.85	129.09	65.98	300.86	239.2	165	40.99	8.86	1.16
2004	2.45	29.2	4.73	36.79	107.02	77.43	128.82	122.5	117.03	20.73	3.38	0
2005	3.58	3.13	2.3	16.9	112.62	165.65	176.9	162.8	85.33	80.17	10.39	0
2006	0	2.55	5.67	20.16	117.64	136.42	45.18	84.72	101.56	123.76	3.34	0
2007	0	0.17	44.81	12.4	80.65	117.88	62.16	184.4	86.36	91.63	2.92	0
2008	0	1.19	5.99	27.9	20.51	146.57	114.61	174.7	45.8	11.47	0	0.14
2009	1.95	0	25.99	34.7	58.26	130.53	207.27	378.3	48.16	22.36	0	12.26
2010	0	0	0	131.5	227.91	171.3	148.28	249	103.87	160.76	16.26	0
2011	0.61	0	0	36.16	148.08	64.2	299.17	292.1	121.75	120.37	31.45	0

2012	0	0.25	0	27.48	43.68	116.61	192.33	127.2	126.99	88.71	0	0
2013	0	0	0	30.24	183.81	49.29	293.12	174.1	270.42	229.01	9.21	0
2014	82.7	32	28.58	35.12	47.32	169.94	165.04	104.2	177.81	199.14	0	0
2015	1.77	0.19	30.44	70.24	93.09	77.63	110.19	244	121.57	147.76	0.02	0
2016	0	0.35	2.25	1.77	27.68	41.05	138.5	139.9	188.52	177.97	1.89	0
2017	0	0	35.7	90.55	200.39	96.41	322.71	249.5	161.55	116.83	0	0
2018	0	0	0.8	19.17	141.82	194.89	74.31	430.1	124.94	181.43	1.39	0

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	0.59	27.21	61.75	82.72	92.69	170.8	239.58	347.76	216.5	95.31	8.08	3.4
1990	0	0	67.87	95.83	66.11	131.9	162.7	213.64	177.68	147.64	6.88	1.42
1991	8.16	23.79	18.8	111.1	148	95.32	140.74	82.28	143.65	91.15	11.99	18.19
1992	2.45	27.94	25.58	152.2	136.2	103.3	274.03	94.36	126.77	65.93	0.06	3.44
1993	0	3.07	10.83	130.8	164.4	112.4	94.09	79.46	147.64	65.91	27.2	0.21
1994	0	6.77	56.91	37.96	62.53	164.5	157.7	166.88	237.04	65.91	25.21	10.08
1995	1.1	2.88	57.81	76.94	82.97	114.2	227.49	115.57	173.04	215.74	12.47	0
1996	6.21	6.3	45.12	104.8	135.4	131.3	251.43	294.61	194.06	125.23	23.3	3.32
1997	0.07	26.68	105.1	59.18	111.3	219.3	164.97	155.81	112.86	85.65	2.31	0.07
1998	4.96	0	92.91	164.4	129.9	147.1	85.74	145.87	144.78	151.79	1.21	50.98
1999	18.98	4.93	4.09	105.6	163.6	164.9	143.94	117.59	102.24	177.38	18.96	1.24
2000	14.48	18.36	61.57	88.92	50.57	168.2	199.81	119.24	45.4	94.27	12.66	0.49
2001	0.27	5.53	49.24	75.99	79.69	103.9	194.56	129.73	158.13	57.86	9.6	5.3
2002	0	4.6	9.88	162.1	134.3	121.3	74.24	49.46	149.71	54.36	30.43	20.13
2003	1.11	16.82	64.53	89.72	43.17	134.1	180.68	107.38	61.95	163.56	8.36	0
2004	24.4	20.91	12.23	150.9	104.3	185.1	134.68	92.99	240.38	119.82	26.86	0
2005	17.47	14.88	16.96	155.2	141	96.9	180.69	93.81	180.08	152.47	34.76	0
2006	0	12.45	52.46	52.35	56.93	120.7	54.12	100.18	150.15	69.78	4.16	0.16
2007	4.24	4.1	49.02	50.04	125.4	112.3	277.6	217.92	185.7	55.78	39.74	0.08
2008	0	0.29	36.27	96.7	98.02	210.7	81.09	223.96	278.14	72.29	24.92	1.63
2009	8.4	17.36	9.22	38.83	61.87	204.6	247.08	56.21	202.74	81.89	0.59	16.81
2010	25.71	12.96	11.37	118.5	52.25	81.81	109.6	142.21	165.36	135.22	18.17	0.05

2011	0.33	23.97	16.72	84.9	105.9	73.24	104.43	191.41	269.3	227.52	68.27	28.51
2012	0	34.32	26.5	55.08	114.1	149.2	142.65	224.22	147.46	155.81	5.61	0.87
2013	0.76	40.9	4.8	134.1	129.8	151.7	134.7	113.6	328.45	156.57	57.6	6.34
2014	1.52	41.89	19.98	43.46	81.28	94.5	96.53	39.21	192.94	164.14	1.66	6.52
2015	15.06	7.12	41.7	75.68	94.59	60.03	42.52	110.5	215.04	152.72	22.32	0.66
2016	0.76	14.83	84.21	50.34	129.8	74.85	112.61	76.14	116.19	173.89	36.07	0
2017	2.32	0	86.87	74.02	62.46	103	166.96	66.28	330.87	158.42	5.09	0.03
2018	0.52	2.27	39.83	81.98	136	134.2	278.9	108.27	184.34	49.53	5.51	50.55

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	8.57	21.4	93.58	134.4	142.5	251.9	191.71	358.8	188.56	352.65	34.05	15.91
1990	7.7	0	48.88	140.1	172.23	280.6	396.11	418.2	351.53	258.16	10.06	0
1991	1.5	1.38	1.36	44.57	51.76	35.84	190.19	111.4	79.13	29.62	5.1	1.54
1992	0.06	2.19	21.42	25.26	89.95	37.76	198.99	158.5	27.38	13.64	0	0.08
1993	0	0.49	32.73	29.23	197.46	300.6	368.58	206.5	241.63	290.54	34.92	0
1994	0	10.1	91.13	127.7	180.63	203	274.83	420.6	292.12	187.35	59.46	1.41
1995	21.08	0	84.11	96.1	165.11	241.8	246.24	222.4	359.87	284.78	24.8	0
1996	0.09	22	64.66	105.6	156.81	286.2	373.02	424.5	272.81	206.53	57.7	0
1997	3.58	20.3	95.84	179.9	125.37	289.7	269.84	231.5	170.98	184.79	2.06	0.16
1998	0	8.36	57	88.75	147.9	130.2	152.68	136.5	194.91	45.35	42.57	2.4
1999	8.87	0	38.65	103.9	164.6	191.6	301.71	234.7	191.46	91.77	1.86	5.99
2000	0	8.16	3.35	68.33	119.66	109	32.92	171.3	139.16	198.77	20.9	0
2001	0.08	0.05	19.57	62.6	203.52	636.9	504.36	331.9	205.97	253.06	62.26	14.07
2002	0	3.15	6.28	141.6	198.1	136.3	87.67	100.6	225.47	71.25	52.19	8.44
2003	1.39	0.68	55.61	204	116.9	70.28	374.68	260.8	202.46	127.86	49.91	3.4
2004	0.97	53.8	28.27	161	168.99	123	131.36	148.6	259.69	145.49	67.54	1.71
2005	4.19	13	4.24	182.3	214.33	133.5	167.49	192.7	184.61	30.99	39.46	4.42
2006	0	20.4	33.2	52.74	150.08	131.8	92.48	157.4	471.67	145.94	25.33	0.26
2007	3.42	8.48	38.65	14.53	90.96	99.06	67.65	454.3	249.9	98.18	23.07	0.16
2008	0	6.79	53.42	57.74	34.7	265.9	194.49	452.1	268.25	191.14	12.11	7.95
2009	11.07	3.61	30.85	34.85	76.5	97.49	131.51	140.9	274.05	66.24	0	6.31

2010	0.17	0.06	0	79.69	165.22	114.1	143.76	181.5	58.53	186.04	9.04	0
2011	0	0	0	23.11	158.31	99.27	223.34	243.7	101.51	92.48	22.45	0
2012	0	3.08	0	16.75	172.85	114.3	83.11	95.6	138.96	126.29	0	1.06
2013	0	0	0	66.35	93.54	116.8	275.87	126.3	125.67	158.5	1.19	0.1
2014	50.47	4.94	51.59	99.68	55.46	73.92	111.28	43.44	49.89	103.69	6.17	1.42
2015	3.64	1.75	22.64	46.1	95.23	66.88	73.5	169.7	85.09	127.44	5.48	0
2016	0	7.99	16.29	13.88	17.58	42.64	60.16	71.26	126.88	158.58	1.35	0
2017	0	0	33.5	78.29	117.26	71.63	229.79	139.6	163.72	194.58	0	0
2018	0	0	12.34	19.69	122.25	123.7	141.17	190.1	184.8	228.91	26.7	0

APPENDIX C: Monthly Maximum Temperature Data in the Study Area

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	1066.8	1061.4	1171.2	1063.4	1051.5	907.8	903.4	873.4	892.3	1007	1035	1042
1990	1033.1	979.45	1123.9	1072.2	1036.7	924.6	901.2	895	902.6	982.5	1052	1065
1991	1093.8	1002.4	1165.7	1081.1	1019.1	946.7	898.4	925.2	909.9	1012	1062	1109
1992	1116.6	1063.3	1132.8	1061.3	933.02	916.3	891.6	879	913.2	947	1005	1027
1993	1036.7	1056.3	1173.4	1075.3	1007.9	905.7	875	866.3	885.3	997.7	988.4	1089
1994	1036	1032.6	1112.2	1099.7	1045.3	941.2	914.1	918	908.1	998.2	1067	1080
1995	1071.5	1009.2	1158.8	1048	1019.6	910.3	899.4	878.1	909.5	970.9	999.3	1055
1996	1061.9	1020	1164.5	1066.1	1024.2	937.5	930.5	921.7	914.3	996.3	1030	1099
1997	1140	1100.8	1173.6	1082.6	1038.8	917.6	930.8	902.7	876.3	978.7	1028	1125
1998	1129.5	995.82	1132.8	1035.9	984.28	916.3	919.7	918.7	931.4	1009	1054	1091
1999	1105.8	1067.5	1161.2	1117.4	1013	924.2	907.5	866.3	870.5	906.6	908	1005
2000	959.79	942.29	1094.1	1001.9	961.99	870.2	852.5	872	824.5	913.4	948.3	981
2001	1011.3	972.32	1107.5	1053.5	976.08	912.1	892.5	821.1	860.8	957.7	983.6	976.4
2002	1028.1	955.45	1073.7	1000.3	966.2	863.2	871.1	824.6	831.8	952.4	1005	1078
2003	972.95	994.98	1136.5	1024.8	968.56	894.7	884.3	895.2	886.2	952.5	1060	1077
2004	1096.3	1033.5	1164.4	1049.7	1022.7	894.3	882	864	898.6	1005	1033	1078
2005	1096.6	1048.3	1147.3	1075	972.95	882	898.9	869.6	875.6	974.9	955.2	1039
2006	1016.7	1059.2	1139.7	1047.8	985.47	880.2	854.4	865.8	905.6	928.3	1004	1023
2007	1082.2	991.79	1074.7	1048	984.2	903	904.5	871.3	860.5	950.2	957.5	1002
2008	969.01	913.94	1069.5	1035.7	970.18	818.8	877.9	910.7	914	978.1	995.4	1073
2009	1034.9	1024.6	1167.3	1075.7	1046.5	949.5	911.5	903.8	923.8	976.7	1052	1080
2010	1074.7	1038.6	1207.9	1047.7	1050.2	937	924.2	917.5	917.9	980.2	1006	1087
2011	1090.6	1048.8	1181.8	1138.6	1059.1	934.6	923.4	921.8	887.4	963.3	1034	1074
2012	1047.4	1024.3	1183.5	1086.1	1032.8	937.1	927.5	907.5	890.5	950.1	987.2	1042
2013	1009.4	1042.5	1161.4	1065.9	993.03	910.4	903.1	892.8	894.8	985.5	1047	1062
2014	1097.1	1032.4	1129.5	1024.8	966.08	901.6	900.7	889.6	893.8	947.8	998.6	1046
2015	1073.5	991.92	1062.9	1021.3	951.14	882.4	905.7	866.2	831.8	919.3	972.3	998.3
2016	1032	1003.9	1114.9	1023.4	1025.3	892.2	934.3	875.2	877.6	990.3	1051	995.9
2017	1058.3	1062.4	1150.3	1088.2	1008.1	914.6	938.3	919.3	909.6	967.9	1025	1042
2018	1053.9	993.48	1151	1049.1	1011.6	897.6	920.6	859.5	868.9	936.3	1008	1008

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	1010.2	1000	1037.3	957.1	967.23	883.9	857	865.5	891.8	959.2	1009	999
1990	1010.3	994.4	1111.1	986.8	975	903.9	900.6	891	883.7	956.5	985.2	1021.1
1991	1035	983	1169.2	956.2	954.58	901.3	853.4	866.5	853.5	935.7	956.9	983.03
1992	1024.1	947.3	1039.4	936.6	920.92	885.1	868.6	846.9	858.7	886.4	934.1	960.27
1993	992.64	1015	1077.2	983.5	994.2	888.8	869.9	867.7	897.3	973.7	994	1063.3
1994	1058.9	1022	1080.6	1009	1022.7	914.4	923	911.2	928.3	995.9	986.4	1033.4
1995	1030.6	986.5	1087.1	949.5	998.42	922.7	918.3	917.7	915.2	968.7	974.1	1044
1996	1074.6	993	1042.1	983.4	967.37	934.5	929.6	958.7	912.2	952.4	951.1	1036.9
1997	1030.8	1065	1079.4	974.1	979.32	904	906.1	880.7	859.3	935	981.8	1021.9
1998	1031.9	979.5	1045.1	930.8	943.13	872.8	862.9	869.1	886.5	968.7	972.2	1030.5
1999	1036.4	1019	1121.9	1045	1034.9	944.3	909	878.8	814.7	885.1	928.9	939.96
2000	928.4	871.3	987	927.6	901.01	850.8	843.9	851.5	817.6	857.8	894	983.88
2001	966.49	922.3	1018.8	931.2	914.97	846.2	829.1	793.9	801.1	896.8	951.9	959.93
2002	964.93	921.3	1017.5	865	884.86	825.8	842.1	808.3	812.7	898.8	915	989.83
2003	954.7	959.4	1054.5	933.6	877.47	869.3	826.7	838.1	857.2	894	936.5	963.2
2004	976.9	907.3	1069.5	947.9	901.54	857.1	832.7	848.7	852	922.2	916.6	974.32
2005	997.12	904.2	984.68	932.6	885.65	841	842.5	821.4	824	893.8	893.7	953.78
2006	938.35	950.5	1017.4	959.9	915.09	831.8	811.3	821.6	846.4	877.6	925.8	930.27
2007	1000.1	927.1	979.89	950.1	923.19	853.5	865.2	854.3	820.1	903.4	920.6	1019.5
2008	1006.1	932.7	1027.9	953.7	914.67	859	846.8	871.6	870.1	904.9	914.9	964.32
2009	930.21	942.2	1066.4	977.7	938.38	865.5	846.2	859.2	876.6	906.2	965.5	953.4
2010	998.66	963	1050.9	909.4	909.99	848.5	861.8	855.8	845.2	897.4	910.1	966.9
2011	973.66	953.4	1046.2	981.7	960.7	878.8	872.9	870.5	846.5	908.4	926.4	967.82
2012	949.82	916.2	1033.8	935.5	956.35	869.5	846.9	846.2	846.7	898	899.3	908.9
2013	933.05	946	1066.3	988.7	943.54	869.6	872.5	854.9	847.9	906.4	944.5	947.68
2014	1000.6	909.9	1004.2	921.5	910.26	857.6	847.2	838.8	816.3	887.8	932.3	965.36
2015	998.5	914.3	961.27	933.7	908.14	848.6	865.1	811.8	805.5	878.7	896.9	983.44
2016	990.6	962.3	1029.3	941.5	947.09	849.2	858.9	859.6	830.7	914.2	965.9	964.82
2017	1002.6	1001	1041.2	977.6	935.37	856.8	861.9	850	849.1	885.3	939.1	972.45
2018	970.82	918	1050.4	960	943.11	857.4	858.8	834.3	823.3	890.6	945.4	996.18

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	1019	1009.2	1115	1018	1002	874.4	841.56	834.4	870.4	949.3	999.3	986.79

1990	973	939.32	1123	1035	975	919.4	894.24	874	891.4	963	987.6	1013.5
1991	1093	956.54	1107	1072	988.2	930.2	871.66	891.3	904.7	987.3	1035	1129.4
1992	1041	1081.4	1100	1037	899.4	877.2	827.07	834.8	873.5	964.4	979.1	958.83
1993	994	968.72	1134	1031	970.7	884.7	843.26	847	884.3	988.5	991.7	1048.8
1994	1008	1015.3	1137	1047	1024	927.2	910.09	882.4	904.5	1015	1038	1027.4
1995	1048	976.26	1131	987.1	1007	910.4	892.91	864.3	880.2	974.1	965.3	1009.2
1996	1046	971.92	1149	1029	997	935.5	926.19	939.2	904.9	994.9	973.5	1084.6
1997	1126	1096	1157	1026	986.1	864	911.89	873.1	855.5	952.5	946.6	1071.5
1998	1124	910.57	1091	985	951.9	879.5	884.23	877.2	863.7	999.7	1047	1036.1
1999	1045	1035.9	1081	1074	1019	930.7	877.9	856.3	812.1	864.7	849	921.98
2000	914	908.77	1037	946.4	903.1	822.9	800.66	848.9	791.2	883.6	897.8	925.37
2001	960	921.72	1052	1014	918	845.7	834.42	793.3	802.4	903.1	925.6	901.93
2002	966	902.15	1008	944.1	907.9	817.2	821.31	787.9	782.8	887.7	927.9	999.57
2003	933	948.2	1113	1023	910.2	848.1	825.16	848.3	855.3	915.3	988.6	1028.3
2004	1032	990.93	1071	1008	939.8	860.4	828.81	814	860.3	977	998.1	1012.2
2005	1088	952.07	1041	1051	938.9	839.2	847.91	826.7	828.6	937.1	908.6	982.61
2006	970	1024.5	1137	1007	938.7	828.2	818.43	816.2	879.2	888	945.6	963.09
2007	1031	960.56	1010	1010	945.5	877.6	866.67	834.5	814.2	912.2	903.9	922.47
2008	881	843.27	994.4	969.7	910.5	736	820.76	845.5	876.5	939.8	944.9	977.13
2009	967	943.14	1094	1025	985.6	864.9	868.94	843.4	878	929.7	1012	1024.3
2010	1016	976.64	1131	955	962.6	885.3	872.54	848.1	867.8	912	939.9	1021.3
2011	1001	940.86	1087	1040	939.4	867.2	849.06	850.8	831.7	873.9	972.4	1007.6
2012	955	921.36	1105	996.4	976.2	869	870.42	843.3	841.7	915.3	887.7	1013.4
2013	938	978.96	1075	998.8	915.6	862.5	843.72	830	834.6	927	965	1033.1
2014	1038	976.33	1046	968.6	916.1	856.1	849.09	822.7	853.3	928.3	968.2	1015.4
2015	1039	952.82	1037	977.3	903.6	870.1	866.56	817.8	778.7	873.4	893.1	933.31
2016	967	949.21	1026	959.6	955.8	843.4	884.87	833.5	819.9	927.7	960.4	916.67
2017	982	978.84	1047	983.6	963.1	861.8	876.7	859.9	844.1	928.4	988.5	1015.1
2018	1007	962.38	1091	1007	971	876.6	892.12	837.6	852.3	904	942.2	942.73

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	1019	1003	1070.3	988.68	1002.3	898.55	869.6	842.1	863.7	967.2	989.53	982.82
1990	998	955.9	1054.8	997.4	984.84	898.34	874.3	856.8	859.5	938.8	998.39	1002.7
1991	1017	964.2	1131.1	990.27	980.56	919.49	860.4	877.2	863.5	949.3	989.21	1005.8

1992	1043	976.3	1056.3	955.73	915.53	902.27	870.7	840.4	866.6	894.5	946.16	968.04
1993	994.5	1023	1106.2	1001.3	964.45	872.86	832.5	833.3	846.2	931.4	936.51	1022.9
1994	1015	980.7	1036.9	1021.8	1000	907.3	868.7	882.1	875.7	946.8	984.23	1006.3
1995	1016	967	1079.8	971.49	982.6	896.92	858.6	851	875.5	919.6	960.02	1005.5
1996	1018	990.9	1081.5	1009.7	979.99	891.65	876.6	885.1	873.8	929.5	957.6	1006.6
1997	1040	1022	1076	1009.3	1008.7	923.48	908.8	873.5	855.3	947.3	997.34	1050.9
1998	1054	981.6	1067.8	966.96	959.61	894.55	878.4	875.1	900.3	962.2	971.32	1020.2
1999	1049	1008	1124.7	1053.3	992.84	906.45	897.8	840.5	859.7	912.3	990.02	1024.3
2000	979.2	934.6	1043.2	975.37	971.81	897.48	854.4	859.7	815.3	879.7	927.21	961.56
2001	973.7	941.9	1050.9	972.82	950.92	909.52	878.3	814	838.9	924.9	961.29	1011.5
2002	990.4	942.4	1096.8	973.19	934.28	862.12	867.5	814.2	829.5	919.9	990.26	1040.7
2003	945	993.5	1072.4	977.14	975.17	899.61	870.5	863.2	850.1	909.3	995.98	989.28
2004	1028	959.7	1114.4	977.14	959.65	861.13	854.3	865.8	876.9	963.7	961.15	992.26
2005	1024	996.8	1080.5	1001	953.94	874.06	877.3	851.6	876	939.8	957.84	1003.4
2006	988.3	977.5	1057.9	988.8	954.8	849.51	835.4	831.3	858.8	923.2	977.74	1002.8
2007	1009	955.7	1018.1	989.84	928.48	892.24	887.7	844.5	848.1	933.9	966.72	1022.8
2008	1003	941.2	1083.4	990.01	951.98	887.25	875	877.5	890.2	947.1	957.12	1025.6
2009	963.4	1006	1093.9	1013.4	965.83	898.71	865.2	852.9	886	948.9	982.29	1026
2010	1047	1011	1104.7	961.54	957.71	892.91	883.6	858	888.2	942.4	957.17	1042
2011	1053	1013	1105.3	1045.7	992.55	913.96	895.7	888.1	877.7	948.1	971.42	1016.8
2012	1027	941.8	1071.3	1005	1005.9	905.88	860.8	853.7	857.8	913.7	943.36	995.3
2013	984.7	988.9	1076.4	991.47	961.81	888.65	866.9	844.2	850.2	945.6	988.36	969.51
2014	1046	979.4	1039.6	960.29	953.29	889.3	862.7	840.1	865.4	902.5	992.34	1010.3
2015	1002	953.8	1007.8	974.93	937.26	868.19	880.3	817.3	805.3	867.9	930.2	1008.8
2016	1014	966.7	1078.1	992.52	966.71	859.08	863.3	861.2	836.2	930.7	988.8	961
2017	1019	1018	1075.1	995.27	956.11	854.82	850.9	826.6	831.7	893.5	932.76	949.82
2018	968.4	944.5	1154.3	1009.4	966.3	891.48	871.6	819.6	831.5	930.8	982.57	1023.6

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	1019.3	1003	1070	989	1002	898.6	869.6	842.1	863.7	967	989.5	982.8
1990	997.95	955.9	1055	997	984.8	898.3	874.3	856.8	859.5	939	998.4	1003
1991	1017.5	964.2	1131	990	980.6	919.5	860.4	877.2	863.5	949	989.2	1006
1992	1042.6	976.3	1056	956	915.5	902.3	870.7	840.4	866.6	895	946.2	968
1993	994.45	1023	1106	1001	964.5	872.9	832.5	833.3	846.2	931	936.5	1023
1994	1015.1	980.7	1037	1022	1000	907.3	868.7	882.1	875.7	947	984.2	1006

1995	1015.6	967	1080	971	982.6	896.9	858.6	851	875.5	920	960	1006
1996	1017.8	990.9	1082	1010	980	891.7	876.6	885.1	873.8	929	957.6	1007
1997	1039.9	1022	1076	1009	1009	923.5	908.8	873.5	855.3	947	997.3	1051
1998	1053.9	981.6	1068	967	959.6	894.6	878.4	875.1	900.3	962	971.3	1020
1999	1049.2	1008	1125	1053	992.8	906.5	897.8	840.5	859.7	912	990	1024
2000	979.23	934.6	1043	975	971.8	897.5	854.4	859.7	815.3	880	927.2	961.6
2001	973.66	941.9	1051	973	950.9	909.5	878.3	814	838.9	925	961.3	1012
2002	990.42	942.4	1097	973	934.3	862.1	867.5	814.2	829.5	920	990.3	1041
2003	944.97	993.5	1072	977	975.2	899.6	870.5	863.2	850.1	909	996	989.3
2004	1028.1	959.7	1114	977	959.7	861.1	854.3	865.8	876.9	964	961.2	992.3
2005	1023.7	996.8	1081	1001	953.9	874.1	877.3	851.6	876	940	957.8	1003
2006	988.28	977.5	1058	989	954.8	849.5	835.4	831.3	858.8	923	977.7	1003
2007	1008.8	955.7	1018	990	928.5	892.2	887.7	844.5	848.1	934	966.7	1023
2008	1003.5	941.2	1083	990	952	887.3	875	877.5	890.2	947	957.1	1026
2009	963.36	1006	1094	1013	965.8	898.7	865.2	852.9	886	949	982.3	1026
2010	1047.2	1011	1105	962	957.7	892.9	883.6	858	888.2	942	957.2	1042
2011	1053.4	1013	1105	1046	992.6	914	895.7	888.1	877.7	948	971.4	1017
2012	1026.7	941.8	1071	1005	1006	905.9	860.8	853.7	857.8	914	943.4	995.3
2013	984.67	988.9	1076	991	961.8	888.7	866.9	844.2	850.2	946	988.4	969.5
2014	1046.3	979.4	1040	960	953.3	889.3	862.7	840.1	865.4	902	992.3	1010
2015	1001.9	953.8	1008	975	937.3	868.2	880.3	817.3	805.3	868	930.2	1009
2016	1014.1	966.7	1078	993	966.7	859.1	863.3	861.2	836.2	931	988.8	961
2017	1018.6	1018	1075	995	956.1	854.8	850.9	826.6	831.7	894	932.8	949.8
2018	968.4	944.5	1154	1009	966.3	891.5	871.6	819.6	831.5	931	982.6	1024

APPENDIX D: Monthly Minimum Temperature Data in the Study Area

Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	676.1	697.3	826.64	782.78	775.9	691.24	705.56	699.87	674.71	692.24	616.12	618.6
1990	578.86	612.4	752.57	757.88	754.2	691.42	702.17	694.87	672.05	674.65	615.96	640.7
1991	701.37	646.3	754.6	761.61	753.8	706.7	708.27	706.1	677.66	702.23	686.96	706.7
1992	680.59	700.4	812.79	756.71	735.6	702.11	711.67	700.56	687.74	693.17	630.63	633.4
1993	636.88	673.4	808.63	769.78	753.6	686.51	687.18	687.73	659.6	699.37	627.08	618.7
1994	631.75	666.4	761.8	766.47	768.5	698.1	710.77	705.16	671.99	716.22	677.39	652.2
1995	676.38	670.5	801.6	765.11	754.9	690.92	713.81	701.69	682.94	695.29	613.25	584.6
1996	620.19	630.3	799.24	772.12	751.9	707.56	726.52	713.16	689.13	699.9	622.04	674.7
1997	681.83	716.2	808.82	770.54	763.2	694.94	715.04	706.61	682.02	694.17	607.22	661.4
1998	704.58	642.1	779.85	746.48	732.9	701.6	715.66	714.11	684.38	715.14	659.23	642.9
1999	678.35	721	817.09	798.47	781.7	688.08	696.06	715.58	683.42	725.19	625.54	635.8
2000	737.68	700.3	816.39	785.72	773.3	709.46	723.03	737.01	695.96	695.76	598.14	647.7
2001	756.79	715.2	842	776.78	782	689.45	705.49	699.5	683.72	713.13	665.71	660.6
2002	662.08	704.7	847.23	805.1	796.1	707.68	724.86	729.14	686.14	716.81	641.15	684.3
2003	636.87	656	789.15	760.89	761.8	735.59	771.53	728.43	707.15	733.47	645.23	663.1
2004	755.04	715	806.82	779.07	789.7	736.1	735.34	723.05	698.42	745.01	670.46	650.5
2005	706.21	716.1	801.7	772.08	782.5	725.83	740.02	743.22	716.36	753.15	703.09	743.2
2006	763.44	871.7	862	827.8	808.6	733.27	751.29	731.88	703.26	720.6	678.56	677.3

2007	799.86	736.8	861.81	844.1	834.4	764.02	768.9	731.73	720.37	754.04	696.33	705.8
2008	673.09	703.7	803.53	872.03	795	705.07	751.83	705.92	691.78	735.84	670.34	724.1
2009	692.68	738	861.78	785.68	801.1	729.23	723.53	721.16	694.35	721.54	668.87	718.1
2010	689.25	708.4	845.41	767.71	784.9	725.9	743.86	737.22	696.06	734.16	691	664
2011	706.83	736.7	863.86	829.31	803.4	748	719.11	722.63	695.86	719.44	697.57	650.2
2012	636.9	738.3	831.74	795.6	786.2	721.46	734.15	728.88	697.34	713.65	653.09	700.3
2013	671.19	744.9	859.22	785.19	748.1	712.6	700.19	698.53	687.98	716.93	696.48	658.2
2014	739.27	708.8	893.22	818.76	789.7	721.21	736.9	721.91	706.41	739.08	708.81	684.1
2015	734.71	745.7	830.58	782.76	806	736.52	762.98	737.76	721.27	745.07	747.38	674.1
2016	684.33	768.3	825.6	812.75	854.6	741.02	752.81	756.89	713.17	767.1	684.34	649.9
2017	712.68	739.9	853.15	842.11	792.7	734.6	760.64	751.12	722.03	753.24	729.69	686.4
2018	740.21	681.7	804.61	824.45	834.9	751.51	734.03	732.96	709.55	781.1	678.04	768.8

Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	645.3	663.09	761.76	714.25	723.5	670.63	675.79	670.36	659.95	692.42	635.8	665.73
1990	554.4	584.38	742.76	724.72	730.8	694.69	700.52	693.53	664.89	688.84	672.78	651.79
1991	668.7	625.94	750.83	709.34	708.7	692.14	683.12	664.55	650.87	674.4	695.53	648.97
1992	668.1	657.65	754.04	689.24	716.7	684.37	693.74	675.45	663.37	664.69	659.08	636.85
1993	608.2	651.2	766.76	735.95	740.3	693.97	-1E+09	706.2	685.79	700.7	652.59	625.92
1994	608.8	614.82	755.59	746.94	748.1	698.04	710.32	704.34	681.27	708.11	702.38	682.02
1995	695	667.3	776.36	728.12	741.3	692.33	712.61	695.06	688.81	687.55	651.51	584.33
1996	647.8	633.78	746.41	723.76	716.4	707.37	716.32	723.24	686.16	699.02	639.28	667.55

1997	664.8	702.12	781.64	718.96	725	673.64	685.2	682.85	657.12	675.94	621.91	644.27
1998	659.5	598.91	720.92	677.4	700.6	676.74	671.33	683.61	671.89	688.94	662.71	632.56
1999	637	677.81	796.54	743.61	777.3	696.47	689.88	706.85	676.7	737.87	698.94	648.25
2000	709.7	684.61	792.49	771.75	757.5	710.09	702.8	700.37	672.47	690.59	626.93	666.75
2001	739.8	570.27	773.48	707.27	746.7	673.32	683.68	695.39	670.55	712.39	711.02	688.96
2002	664.9	680.85	819.03	721.33	738.9	709.63	712.84	716.64	681.57	719.35	682.11	719.98
2003	658.5	694.35	787.16	713.68	725.4	713.72	741.44	731.64	687.66	714.82	705.24	688.09
2004	743.9	684.73	788.76	738.56	745.6	728.47	717.56	726.2	686.18	719.87	691.82	664.33
2005	681.3	675.37	770.89	726.19	746.5	707.19	721.31	717.27	699.6	738.17	716.27	756.53
2006	743.2	799.53	795.75	767.36	782.1	721.65	721.35	704.81	675.04	721.92	711.49	693.8
2007	771.7	718.27	812.75	769.48	755.2	734.29	724.88	688.72	682.24	734	714.07	730.1
2008	692.9	699.01	788.33	755.23	751.6	690.66	722.34	696.49	677.89	725.25	680	711.11
2009	662.1	719.54	816.62	730.2	746	703.66	706.45	705.81	680.08	708.53	713.37	743.06
2010	681.9	694.42	796.3	725.33	740.9	712.91	717.09	711.05	686.4	717.86	688.95	683.66
2011	719.3	712.89	804.86	750.73	766.4	720.63	710.88	707.53	690.14	707.12	706.06	672.99
2012	635.8	691.15	790.08	730.74	747.7	688.59	703.34	712.37	689.05	703.69	682.86	651.59
2013	672.1	715.99	835.67	759.42	736.7	695.8	695.65	699.82	685.95	707.64	701.5	660.19
2014	714.6	691.8	812.16	739.66	748.1	698.7	717.11	706.34	686.01	720.06	726.7	687.25
2015	726	717.94	773.43	720.05	767.1	711.25	728.24	700.27	689.69	725.28	731.76	701.03
2016	661.2	739.01	778.99	743.17	791.8	723.92	721.25	726.78	688.43	732.01	709.67	654.6
2017	675.4	730.6	794.54	772.29	736.4	707.21	731.12	715.16	695.87	719.55	755.45	694.9
2018	737.4	672.74	783.28	781.07	790.4	731.96	715.01	723.8	701.21	763.89	701.78	767.08

Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	565.47	610.14	737.07	752.76	716.32	656.82	651.19	640.74	623.64	622.64	524.61	542.33
1990	504.06	527.07	659.77	656.08	685.12	666.75	661.95	657.07	637.45	644.56	533.32	533.23
1991	619.68	540.19	670.83	700.74	696.66	646.28	655.8	657.74	632.21	602.56	574.41	604.55
1992	573.82	628.57	733.35	723.12	700.01	634.81	621.1	637.6	620.24	598.29	547.44	500.6

1993	581.66	563.45	754.32	713.44	711.98	663.8	647.35	661.79	640.73	625.94	568.24	520.59
1994	533.58	553.29	722.49	692.76	726.07	665.32	674.91	669.78	639.17	636.92	603.89	583.98
1995	589.83	592.67	730.13	740.17	710.24	656.31	671.26	639.58	638.23	684.69	531.32	503.9
1996	543.12	514.92	697.89	697.31	673.15	664.15	686.33	679.79	650.06	636.13	523.42	545.33
1997	543.37	614.22	745.08	680.38	693.56	614.3	659.57	654.94	630.62	642.61	512.51	515.17
1998	618.19	559.1	752.41	716.69	683.02	647.38	674.68	659.74	639.96	690.73	556.19	489.3
1999	559.26	628.87	665.27	706.42	772.72	664.65	661.12	677.63	641.01	672.88	551.47	516.97
2000	657.69	671.93	773.85	751.66	714.36	657.7	666.03	685.21	650.53	649.65	533.1	576.39
2001	651.4	540.55	749.83	715.58	712.96	667.43	670.74	651.87	659.87	648.57	602.53	546.26
2002	578.51	628.9	754.69	755.09	741.85	665.85	665.64	674.95	646.17	670.73	573	585.94
2003	569.12	591.96	735.58	730.38	688.98	693.03	714.14	679.32	642.62	669.51	575.26	553.08
2004	632.58	622.16	677.18	733.34	644.81	680.8	680.81	674.59	639.36	670.42	569.44	492.59
2005	566.49	598.52	678.06	688.34	738.11	678.44	689.04	694.74	678.38	711.95	634.94	640.8
2006	687.01	844.54	812.11	725.9	760.45	666.4	707.16	679.12	652.81	656.65	605.95	571.23
2007	719.12	706.99	770.93	773.36	778.36	721.25	721.13	676.72	672.42	688.95	625.22	628.79
2008	596.07	641.02	712.59	819.48	746.64	652.18	702.45	667.3	621.03	611.75	629.5	645.67
2009	595.79	658.64	786.71	735.75	730.6	665.86	676.21	665.69	636.22	704.76	599.26	623.35
2010	625.49	653.5	795.28	734.05	733.36	667.06	674.02	684.53	651.82	669	630.93	555.97
2011	642.37	675.41	822.59	783.29	752.37	685.07	672.59	678.08	648.67	663.74	649.83	590.28
2012	601.46	680.2	769.54	698.3	735.55	665.42	697.85	665.33	653.4	657.24	602.85	612.74
2013	571.55	679.78	774.79	734.47	699.03	660.09	652.33	658.11	624.67	655.81	610.06	537.41
2014	615.22	605.11	819.55	759.84	730.98	654.72	680.38	659.55	636.21	654.81	628.89	584.84
2015	609.32	624.08	733.01	711.09	741.65	685.63	700.69	669.6	675.72	674	660.36	588.28
2016	579.11	698.41	778.42	731.37	783.8	683.02	697.58	696.32	665.14	701.66	608.83	564.38
2017	593.75	630.19	774.2	773.66	731.49	678.55	679.31	672.57	652.67	688.98	625.84	568.62
2018	629.07	597.28	742.76	743.53	742.34	662.24	670.61	664.62	644.5	729.71	631.61	709.18

Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	635.17	655.53	741.48	701.08	708.99	655.35	656.53	647.23	638.66	673.57	639.63	603.33
1990	540.85	581.8	697.6	691.87	694.85	657.54	659.07	652.51	637.57	650.6	641.48	623.12

1991	640.62	600.25	724.78	690.9	694.07	670.52	664.31	656.29	635.97	659.83	683.06	641.84
1992	633.02	631.26	732.71	672.9	701.54	669.22	674.18	658.17	646.43	654.77	635.07	615.52
1993	585.55	632.56	751.57	708.14	703.27	649.59	646.12	647.29	627.72	663.88	621.36	620.86
1994	590.79	621.8	690.82	695.64	710.49	659.24	668.24	661.52	640.57	680.24	661.35	622.78
1995	629.33	635.35	731.7	699.71	696.6	663.3	665.48	662.76	649.84	659.72	618.08	554.69
1996	590.59	607.83	726.98	706.57	698.81	663.26	682.26	681.39	651.81	663.06	613.74	638.66
1997	637.92	659.48	730.19	695.9	708.09	661.88	670.05	668.47	643.76	660.45	617.28	636.44
1998	647.61	591.55	709.62	671.22	691.36	667	661.91	670.52	659.4	670.09	651.87	625.76
1999	619.93	650.36	774.59	748.22	726.29	671.09	684.03	667.15	650.78	683.06	659.55	635.11
2000	665.26	598.7	729.45	706.33	710.47	675.51	676.65	675	642.2	652.55	621.96	637.29
2001	665.49	685.35	766.22	700.13	728.96	663.13	661.59	683.28	651.58	687.59	678.32	650.31
2002	613.22	614.78	761.57	700.21	722.65	670.82	690.8	684.91	645.85	686.7	658.1	662.23
2003	584.89	630.64	734.53	691.17	723.1	694.98	717.67	689.59	685.81	696.81	659.38	650.26
2004	682.53	669.73	765.11	709.86	725.92	672.76	683.54	685.78	657.3	693.13	659.05	640.39
2005	652.99	663.83	748.18	701.04	716.12	667.64	677.23	687.73	655.85	678.25	671.17	698.14
2006	642.72	683.36	761.46	742.21	759.18	695.86	699.07	678.14	662.13	681.27	672.43	668.54
2007	733.88	680.3	757.82	765.53	750.78	694.47	716.4	684.57	673.73	726.4	666.57	702.01
2008	631.46	674.68	762.57	741	735.46	691.54	710.06	698.22	665.87	701.57	680.56	664.41
2009	623.68	666.63	795.74	751.68	741.55	691.35	693.7	687.92	658.89	700.56	686.49	729.17
2010	634.65	651.64	773.3	719.83	735.65	720.51	707.96	693.56	667.86	705.76	648.34	685.96
2011	687.31	694.62	769.19	733.33	746.75	709.06	703.27	687.05	670.37	681.96	673.11	659.79
2012	571.08	659.61	772.92	715.77	748.51	674.88	686.91	693.68	677.64	680.69	672.04	622.86
2013	629.32	671.49	759.99	716.26	723.93	678.59	681.33	660.03	658.92	694.69	691.99	652.63
2014	672.73	674.94	803.25	742.27	738.63	695.09	699.6	682.4	692.04	713.98	691.19	694.22
2015	738.48	710	764.52	727.21	767.74	701.38	735.53	687.01	672.14	698.45	715.07	668.38
2016	618.27	687.66	745.14	738.5	767.15	697.02	707.93	705.03	665.15	717.38	693.47	613.05
2017	648.81	711.07	789.19	755.01	724.55	680.19	718.47	700.63	670.45	692.47	720.36	685.58
2018	719.05	672.52	745.79	749.7	769.71	705.8	697.6	692.51	675.3	726.37	665.73	692.61
Year	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1989	513.9	585.24	743.15	762.7	736.54	674.84	680.79	675.81	663.67	685.54	561.64	568.43
1990	464.9	511.33	721.58	735.05	727.96	696	694.46	700.27	677.11	683.44	602.67	541.78

1991	579	572.57	718.97	733.73	707.89	658.7	673.06	678.04	649.34	626.3	594.51	583.65
1992	556.5	622.4	748.49	739.25	717.22	653.84	636.88	658.31	637.56	618.86	572.83	482.91
1993	560	579.49	767.59	769.35	750.12	690.35	621.65	711.84	684.7	675.42	592.7	510.22
1994	505.4	527.46	753.76	754.72	746.06	697.58	715.59	702.31	673.66	700.47	645.03	585.36
1995	596	592.72	764.04	759.35	737.09	691.35	717.41	652.64	693.51	671.8	579.45	505.89
1996	596	592.72	764.04	759.35	737.09	691.35	717.41	652.64	693.51	671.8	579.45	505.89
1997	535.4	629.09	767.8	721.92	701.75	639.86	666.84	674.4	656.91	662.85	494.58	473.71
1998	543	488.97	704.68	704.68	686.89	658.93	687.14	682.76	656.9	694.21	582.69	527.94
1999	572.2	597.37	756.8	718.84	772.88	690.28	684.96	712.1	668.62	692.54	584.84	527.31
2000	672.6	662.06	799.68	762.78	735.42	678.86	682.26	688.43	665.87	675.65	559.63	534.46
2001	611.3	514.85	721.38	753.23	718.54	665.46	685.06	687.79	668.64	695.17	634.07	567.4
2002	584.1	650.89	817.43	777.94	743.08	697.46	693.83	712.39	673.22	713.46	615.74	610.54
2003	587.6	666.21	803.76	751.6	741.11	712.69	733.23	718.25	674.73	702.43	646.01	558.2
2004	683.4	645.38	781.83	762.22	734.24	727.84	716.62	717.15	667.63	704.07	626.17	477.09
2005	564.2	639.53	748.9	733.3	758.31	702.05	715.52	723.31	695.45	746.5	654.85	650.8
2006	674.3	804.95	815.38	762.86	775.88	699.14	717.69	697.94	663.82	692.23	624.97	553.95
2007	700.7	693.55	789.24	790.26	791.02	742.63	729.12	684.68	688.38	722.13	638.77	604.4
2008	595.5	651.75	733	808.04	740.29	649.67	707.23	687.51	657.76	658.59	622.29	644.89
2009	578.7	668.73	817.21	750.2	747.24	688.17	696.97	691.3	667.8	708.87	613.79	623.88
2010	616	657.77	805.8	748.55	733.7	692.78	702.47	711.25	679.5	701.88	646.26	541.28
2011	643.9	709	841.81	799.36	769.6	715.6	702.11	710.34	673.96	695.1	652.34	580.9
2012	588.8	692.31	810.49	727.47	737.39	660.37	684.22	702.89	666.81	673.43	608.05	573.27
2013	584.4	683.12	771.31	757.68	736.02	676.72	646.89	690.52	655.88	667.86	642.41	547.28
2014	622	632.75	785.96	700.56	706.81	634.79	701.16	688	664.66	701.92	670.83	605.06
2015	663.3	638.08	784.1	731.41	749.76	695.8	717.56	687.51	673.39	708.3	678.03	598.46
2016	616.1	722.33	779.11	735.15	800.64	715.33	726.48	725.17	705.77	730.41	640.29	562.71
2017	592.2	645.84	799.49	789.3	747.18	702.74	708.15	708.69	690.58	718.44	705.03	603.41
2018	638	606.64	783.53	772.45	756.41	707.14	704.78	714.38	681.99	764.15	664.04	734.77

APPENDIX E: Relative Humidity Data in the Study Area

Year	Jan	feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	31.27	23.23	31.71	61.39	66.03	80.31	92.21	94.24	94.03	71.39	43.73	34.94
1990	12.13	7.31	28.36	62.4	68.92	79.04	91.33	93.58	95.07	75.97	41.08	34.2
1991	26.55	17.27	18.24	59.84	67.95	74.42	91.78	94.31	93.86	75.82	54.89	50.49
1992	20.57	33.02	39.48	56.62	81.48	78.42	89.24	95.04	94.81	81.52	44.89	22.37
1993	16.69	9.83	37.98	53.37	68.91	78.31	93.03	95.95	94.32	80.32	45.48	28.58
1994	20.24	20.95	34.4	47.08	66.83	76.35	93.95	95.46	94.23	79.84	62.4	31.58
1995	28.07	10.97	33.14	52.97	67.47	76.78	88.99	95.67	94.87	90.54	39.97	23.17
1996	25.37	16.05	35.96	52.55	69.26	75.63	89.54	96.25	94.46	87.7	43.63	25.23
1997	19.89	29.95	40.16	54.97	65.57	76.04	89.83	96.49	96.21	86.12	39.23	27.12
1998	28.19	5.12	35.45	56.32	71.87	83.85	94.81	95.42	93.91	92.6	59.46	32.64
1999	16.91	12.8	19.66	57.15	67.13	73.43	91.7	95.97	93.25	84.24	37.78	26.8
2000	20.49	20.38	33.44	46.17	58.59	76.99	92.18	93.62	93.61	85.94	45.97	25.87

2001	21.23	8.65	15.15	52.54	64.85	78.11	91.27	95.11	95.39	83.02	46.92	29.51
2002	17.29	8.74	30.75	53.67	61.51	82.04	91.2	95.48	94.54	79.15	47.92	28.71
2003	19.64	18.16	47.03	59.55	60.6	71.14	86.35	93.9	93.35	91.11	57.61	37.44
2004	25.29	19.62	24.73	55.29	60.69	76.76	88.85	94.42	92.63	91.13	61.37	29.59
2005	29.73	13.16	17.88	58.06	59.27	73.2	90.42	94.77	93	88.89	72.32	33.44
2006	22.41	32.51	41.38	55.22	66.16	79.22	93.44	94.6	93.19	88.32	63.42	53.05
2007	44.1	49.28	46.07	54.49	71.84	77.88	91.43	94.73	93.21	91.16	50.11	27.68
2008	17.45	27.39	29.88	59.83	76.4	82.87	94.35	93.65	91.24	94.16	70.82	35.92
2009	28.15	14.88	41.91	59.12	71.23	79.75	92.98	92.72	92.84	85.43	58.47	47.29
2010	44.34	39.88	40.52	68.77	73.62	82.03	91.4	94.16	92.35	93.15	64.97	30.99
2011	26.84	42.17	36.8	58.96	71.94	82.13	93.19	93.2	92.69	90.59	68.43	35.63
2012	20.4	46.77	38.06	52.97	65.76	73.82	88.45	93.57	92.17	91.03	59.33	31.9
2013	26.6	39.09	23.28	63.19	72.71	81.54	95.62	94.47	90.78	90.1	66.68	39.35
2014	33.85	24.91	50.29	65.62	75.73	78.72	94.34	93.45	94.53	85.44	59.76	44.69

2015	30.1	20.87	50.15	69.78	75.92	82.02	94.27	94.64	93.72	89.63	64.45	35.45
2016	19.46	30.35	41.94	42.91	75.26	81.1	91.89	94.43	93.45	92.48	47.68	30.42
2017	17.85	16.12	61.7	65.81	73.01	84.74	94.97	92.84	92.35	83.97	52.25	30
2018	27.22	8.13	28.85	54.62	73.86	82.91	92.48	94.54	92.66	76.78	46.57	28.41

Year	Jan	feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	67.88	64.51	73.91	86.19	88.32	95.9	95.4	94.58	93.57	91.66	77.61	71.26
1990	27.13	25.48	64.9	87.19	91.01	95.76	96.33	94.14	94.17	89.95	72.69	73.95
1991	69.86	53.48	58.53	88.75	88.81	94.37	94.75	93.71	92.4	91.8	87.44	86.41
1992	52.32	70.44	75.57	85.65	91.22	94.89	95.45	94.65	93.89	94.9	83.17	49.77
1993	40.1	35.9	76.05	87.5	89.07	96.32	95.7	95.41	93.83	93.85	73.91	61.82
1994	50.31	57.28	68.94	79.93	87.8	95.89	96.07	95.35	93.53	92.19	92.89	60.93
1995	59.15	40.51	71.7	76.18	90.22	95.01	96.14	94.8	93.72	92.2	67.14	41.16
1996	60.3	49.6	76.09	80.77	86.41	93.58	96.34	94.35	93.99	93.76	72.5	59.8
1997	58.99	66.29	78.07	83.26	89.22	93.55	96.92	95.35	95.64	93.11	66.47	62.14
1998	63.13	22.82	71.35	85.87	91.19	97.15	96.13	94.87	93.16	91.63	89.83	59.72
1999	38.81	42.05	53.31	83.57	86.84	93.08	96.73	94.75	93.81	92.68	72.92	51.84
2000	52.37	52.37	68.1	77.05	85.97	94.07	94.04	94.52	94.06	93.58	79.8	52.66
2001	50.57	30.52	45.22	81.88	89.83	95.72	95.26	95.2	94.93	92.59	79.62	55.44
2002	43.76	30.54	71.05	77.1	83.86	95.22	96.28	94.37	94.09	90.39	83.35	64.98
2003	42.62	49.36	82.25	80.71	83.22	91.66	95.3	93.03	93.04	90.77	83.99	61.98
2004	59.31	54.96	62.69	78.93	83	94.85	95.59	94.65	93.37	91.32	81.92	60.15
2005	63.17	35.49	48.79	78.23	80.27	93.29	94.73	94.61	93.18	90.8	85.12	66.87

2006	44.8	63.6	75.43	77.11	86.05	95.76	94.06	95.34	94.01	91.85	88.52	85.85
2007	82.56	86.65	85.34	88.97	91.23	93.32	96.48	95.15	95.82	92.32	78.08	57.38
2008	32.03	60.28	63.02	77.93	90.69	95.52	94.18	95.23	93.23	91.99	93.78	69.84
2009	59.21	44.78	76.99	84.38	87.88	93.28	94.33	95.64	95.43	92.85	89.12	77.66
2010	78.07	77.21	73.69	77.71	82.27	94.68	96.06	96.94	95.42	92.96	81.05	62.6
2011	58.23	70.28	65.32	70.35	81.27	96.82	96.09	96.33	95.55	93.35	90.08	65.74
2012	40.15	75.04	74.75	77.88	83.31	92.88	95.25	95.65	94.47	92.44	84.77	52.17
2013	49.1	76.01	57.94	85.48	90.25	96.4	95.85	96.88	95.93	91.99	86.97	65.17
2014	61.06	55.57	71.61	84.33	88.63	95.19	96.94	96.79	95.25	94.5	86.61	68.45
2015	56.4	49.96	74.8	82.63	90.42	97.61	96.14	97.12	96.1	93.34	86.87	61.37
2016	35.5	59.02	73.77	80.66	93.99	96.85	96.58	96.93	96.3	93.51	75.14	42.02
2017	34.17	33.99	80.27	87.69	93.92	96.9	96.38	97.56	96.73	91.07	83.46	59.43
2018	58.56	29.85	64.51	85.76	93.06	96.26	96.77	97.2	96.38	91.91	77.36	53.36

Year	Jan	feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	31.27	23.23	31.71	61.39	66.03	80.31	92.21	94.24	94.03	71.39	43.73	34.94
1990	12.13	7.31	28.36	62.4	68.92	79.04	91.33	93.58	95.07	75.97	41.08	34.2
1991	26.55	17.27	18.24	59.84	67.95	74.42	91.78	94.31	93.86	75.82	54.89	50.49
1992	20.57	33.02	39.48	56.62	81.48	78.42	89.24	95.04	94.81	81.52	44.89	22.37
1993	16.69	9.83	37.98	53.37	68.91	78.31	93.03	95.95	94.32	80.32	45.48	28.58
1994	20.24	20.95	34.4	47.08	66.83	76.35	93.95	95.46	94.23	79.84	62.4	31.58
1995	28.07	10.97	33.14	52.97	67.47	76.78	88.99	95.67	94.87	90.54	39.97	23.17
1996	25.37	16.05	35.96	52.55	69.26	75.63	89.54	96.25	94.46	87.7	43.63	25.23
1997	19.89	29.95	40.16	54.97	65.57	76.04	89.83	96.49	96.21	86.12	39.23	27.12
1998	28.19	5.12	35.45	56.32	71.87	83.85	94.81	95.42	93.91	92.6	59.46	32.64
1999	16.91	12.8	19.66	57.15	67.13	73.43	91.7	95.97	93.25	84.24	37.78	26.8
2000	20.49	20.38	33.44	46.17	58.59	76.99	92.18	93.62	93.61	85.94	45.97	25.87
2001	21.23	8.65	15.15	52.54	64.85	78.11	91.27	95.11	95.39	83.02	46.92	29.51
2002	17.29	8.74	30.75	53.67	61.51	82.04	91.2	95.48	94.54	79.15	47.92	28.71
2003	19.64	18.16	47.03	59.55	60.6	71.14	86.35	93.9	93.35	91.11	57.61	37.44

2004	25.29	19.62	24.73	55.29	60.69	76.76	88.85	94.42	92.63	91.13	61.37	29.59
2005	29.73	13.16	17.88	58.06	59.27	73.2	90.42	94.77	93	88.89	72.32	33.44
2006	22.41	32.51	41.38	55.22	66.16	79.22	93.44	94.6	93.19	88.32	63.42	53.05
2007	44.1	49.28	46.07	54.49	71.84	77.88	91.43	94.73	93.21	91.16	50.11	27.68
2008	17.45	27.39	29.88	59.83	76.4	82.87	94.35	93.65	91.24	94.16	70.82	35.92
2009	28.15	14.88	41.91	59.12	71.23	79.75	92.98	92.72	92.84	85.43	58.47	47.29
2010	44.34	39.88	40.52	68.77	73.62	82.03	91.4	94.16	92.35	93.15	64.97	30.99
2011	26.84	42.17	36.8	58.96	71.94	82.13	93.19	93.2	92.69	90.59	68.43	35.63
2012	20.4	46.77	38.06	52.97	65.76	73.82	88.45	93.57	92.17	91.03	59.33	31.9
2013	26.6	39.09	23.28	63.19	72.71	81.54	95.62	94.47	90.78	90.1	66.68	39.35
2014	33.85	24.91	50.29	65.62	75.73	78.72	94.34	93.45	94.53	85.44	59.76	44.69
2015	30.1	20.87	50.15	69.78	75.92	82.02	94.27	94.64	93.72	89.63	64.45	35.45
2016	19.46	30.35	41.94	42.91	75.26	81.1	91.89	94.43	93.45	92.48	47.68	30.42
2017	17.85	16.12	61.7	65.81	73.01	84.74	94.97	92.84	92.35	83.97	52.25	30
2018	27.22	8.13	28.85	54.62	73.86	82.91	92.48	94.54	92.66	76.78	46.57	28.41

Year	Jan	feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	73.46	70.18	77.62	83.36	82.99	92.62	95.09	94.61	94.53	93.15	84.18	73.49
1990	30.72	33.26	72.2	82.39	87.45	92.79	96.48	94.74	95.18	90.9	79.55	82.29
1991	77.49	63.05	69.68	84.77	85.07	92.58	95.42	93.99	92.92	93.01	90.84	89.24
1992	62.76	75.47	78.49	81.14	85.43	92.08	95.1	95.02	95.11	94.36	87.39	55.43
1993	42.23	46.01	78.62	85.65	86.3	93.39	95.91	95.65	94.54	94.78	77.51	66.93
1994	55.87	64.47	73.16	79.04	81.39	92.38	96.08	95.82	94.23	91.21	91.89	63.52
1995	67.29	51.68	74.51	73.22	81.97	93.54	95.81	95.16	93.56	92.22	67.61	42.62
1996	65.3	59.39	78.29	76.02	83.11	92.19	97.26	95.53	94.64	92.72	73.04	69.44
1997	63.95	70.96	80.27	80.79	87.98	92.28	96.93	95.82	95.34	92.39	71.76	70.47
1998	69.07	31.71	76.21	84.12	88.18	95.76	97.16	94.98	93.51	92.07	91.93	64.85
1999	43.87	49.49	63.19	86.13	83.15	93.07	96.23	94.62	94.06	93.31	80.01	57.09
2000	60.54	57.02	73.54	72.47	80.07	92.38	95.04	95.57	94.07	93.62	87.5	59.31
2001	60.02	39.13	53.6	73.56	86.12	94.28	95.72	95.1	95.7	93.05	89.28	62.75

2002	61.35	44.66	75.79	75.62	79.95	94.47	96.44	94.53	94.82	92.17	91.55	78.46
2003	52.09	56.65	79.37	78.12	76.89	90.8	95.08	93.59	93.49	91.69	87.49	65.59
2004	66.65	65.73	72.35	78.14	74.92	93.78	95.02	95	93.28	91.81	88.19	71.19
2005	70.4	46.78	55.14	75.8	77.23	92.47	94.61	94.64	94.53	91.4	88.77	77.58
2006	53.29	72.42	75.29	72.89	79.46	93.37	93.85	95.13	94.48	92.53	91.77	90.6
2007	88.94	87.75	85.85	90.09	90.64	93.73	96.29	96.02	96.47	93.24	84.83	70.41
2008	39.95	68.53	65.48	78.05	88.41	95.6	94.75	96.08	94.62	91.94	94.45	76.78
2009	62.27	56.91	72.4	77.23	79.35	90.68	94.51	95.4	95.32	93.43	92.57	84.29
2010	81.61	83.1	78.94	67.72	72.31	92.79	96.56	97.02	94.96	93.91	83.79	76.63
2011	69.42	72.63	71.91	70.15	80.74	97.06	96.77	96.83	95.76	94.09	92.41	76.33
2012	49.36	78.29	70.56	72.67	75.33	91.07	95.41	95.9	94.92	92.9	90.28	60.52
2013	56.89	81.55	67.13	81.22	82.11	95.08	95.95	96.85	96.4	92.79	90.13	73.95
2014	71.85	65.71	71.22	78.58	83.71	92.21	97.31	96.74	95.64	93.94	91.13	73.77
2015	71.78	62.56	74.87	79.05	87.84	96.44	96.49	97.58	96.72	94.15	91.68	71.87
2016	42.54	71.68	81.49	82.85	84.69	95.96	96.26	97.21	96.82	93.7	86.74	44.09
2017	43.45	45.14	79.21	81.59	86.09	95.32	95.77	96.73	96.97	92.54	89.18	71.2
2018	66.22	46.93	75.22	89.16	89.3	94.84	96.17	96.98	96.93	94.31	85.2	63.74

Year	Jan	feb	mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	67.88	64.51	73.91	86.19	88.32	95.9	95.4	94.58	93.57	91.66	77.61	71.26
1990	27.13	25.48	64.9	87.19	91.01	95.76	96.33	94.14	94.17	89.95	72.69	73.95
1991	69.86	53.48	58.53	88.75	88.81	94.37	94.75	93.71	92.4	91.8	87.44	86.41
1992	52.32	70.44	75.57	85.65	91.22	94.89	95.45	94.65	93.89	94.9	83.17	49.77
1993	40.1	35.9	76.05	87.5	89.07	96.32	95.7	95.41	93.83	93.85	73.91	61.82
1994	50.31	57.28	68.94	79.93	87.8	95.89	96.07	95.35	93.53	92.19	92.89	60.93
1995	59.15	40.51	71.7	76.18	90.22	95.01	96.14	94.8	93.72	92.2	67.14	41.16
1996	60.3	49.6	76.09	80.77	86.41	93.58	96.34	94.35	93.99	93.76	72.5	59.8
1997	58.99	66.29	78.07	83.26	89.22	93.55	96.92	95.35	95.64	93.11	66.47	62.14
1998	63.13	22.82	71.35	85.87	91.19	97.15	96.13	94.87	93.16	91.63	89.83	59.72
1999	38.81	42.05	53.31	83.57	86.84	93.08	96.73	94.75	93.81	92.68	72.92	51.84

2000	52.37	52.37	68.1	77.05	85.97	94.07	94.04	94.52	94.06	93.58	79.8	52.66
2001	50.57	30.52	45.22	81.88	89.83	95.72	95.26	95.2	94.93	92.59	79.62	55.44
2002	43.76	30.54	71.05	77.1	83.86	95.22	96.28	94.37	94.09	90.39	83.35	64.98
2003	42.62	49.36	82.25	80.71	83.22	91.66	95.3	93.03	93.04	90.77	83.99	61.98
2004	59.31	54.96	62.69	78.93	83	94.85	95.59	94.65	93.37	91.32	81.92	60.15
2005	63.17	35.49	48.79	78.23	80.27	93.29	94.73	94.61	93.18	90.8	85.12	66.87
2006	44.8	63.6	75.43	77.11	86.05	95.76	94.06	95.34	94.01	91.85	88.52	85.85
2007	82.56	86.65	85.34	88.97	91.23	93.32	96.48	95.15	95.82	92.32	78.08	57.38
2008	32.03	60.28	63.02	77.93	90.69	95.52	94.18	95.23	93.23	91.99	93.78	69.84
2009	59.21	44.78	76.99	84.38	87.88	93.28	94.33	95.64	95.43	92.85	89.12	77.66
2010	78.07	77.21	73.69	77.71	82.27	94.68	96.06	96.94	95.42	92.96	81.05	62.6
2011	58.23	70.28	65.32	70.35	81.27	96.82	96.09	96.33	95.55	93.35	90.08	65.74
2012	40.15	75.04	74.75	77.88	83.31	92.88	95.25	95.65	94.47	92.44	84.77	52.17
2013	49.1	76.01	57.94	85.48	90.25	96.4	95.85	96.88	95.93	91.99	86.97	65.17
2014	61.06	55.57	71.61	84.33	88.63	95.19	96.94	96.79	95.25	94.5	86.61	68.45
2015	56.4	49.96	74.8	82.63	90.42	97.61	96.14	97.12	96.1	93.34	86.87	61.37
2016	35.5	59.02	73.77	80.66	93.99	96.85	96.58	96.93	96.3	93.51	75.14	42.02
2017	34.17	33.99	80.27	87.69	93.92	96.9	96.38	97.56	96.73	91.07	83.46	59.43
2018	58.56	29.85	64.51	85.76	93.06	96.26	96.77	97.2	96.38	91.91	77.36	53.36

APPENDIX F: Crop Yield Data of the study area

Year	Rice	Maize	Guinea Corn
1990	2.94	2.40	1.91
1991	2.38	1.65	1.50
1992	1.81	0.91	1.09
1993	1.69	1.32	1.20
1994	2.36	1.41	1.40
1995	2.38	1.65	1.48
1996	2.25	1.54	1.25
1997	2.17	1.38	1.12
1998	2.13	1.13	1.05
1999	2.25	1.90	4.90
2000	2.17	1.50	1.31
2001	2.22	1.39	1.19
2002	2.43	1.27	1.07
2003	2.71	1.16	1.03
2004	2.67	1.21	0.96
2005	2.67	1.10	0.98
2006	2.95	1.18	0.88
2007	2.96	1.26	0.84
2008	2.85	1.25	0.94
2009	3.10	1.28	1.03
2010	3.22	1.42	1.06
2011	3.17	1.34	1.45
2012	1.11	0.63	0.72
2013	1.58	1.26	0.94
2014	1.61	1.36	1.11
2015	2.29	1.59	1.01
2016	2.28	2.11	1.23
2017	2.27	2.50	1.40
2018	2.38	2.49	1.39

Year	Rice	Maize	Guinea Corn
1990	0.45	0.45	0.84
1991	0.44	0.04	0.86
1992	0.53	0.53	0.88
1993	1.02	1.02	0.90
1994	1.51	1.51	0.92
1995	2.00	1.09	0.94
1996	2.49	1.19	0.96
1997	2.49	1.19	0.96

1998	2.39	1.37	0.99
1999	1.73	1.19	1.09
2000	2.31	1.69	1.91
2001	2.28	1.75	1.00
2002	2.07	1.71	1.02
2003	2.05	1.85	1.11
2004	2.03	1.94	1.16
2005	2.04	1.94	1.17
2006	2.23	1.78	1.16
2007	2.29	1.76	1.15
2008	2.34	1.60	1.46
2009	2.35	1.64	1.11
2010	2.33	1.63	1.09
2011	2.89	1.64	1.11
2012	2.36	1.68	1.17
2013	4.27	1.79	1.49
2014	2.51	1.69	1.25
2015	3.19	1.53	2.35
2016	2.40	2.14	1.61
2017	2.07	2.39	1.30
2018	2.18	2.41	1.33

Year	Rice	Maize	Guinea Corn
1990	0.69	1.77	5.18
1991	0.81	1.81	4.60
1992	0.93	1.85	4.02
1993	1.05	1.89	3.44
1994	1.17	1.93	2.86
1995	1.29	1.97	2.28
1996	1.41	2.01	1.70
1997	1.53	2.05	1.12
1998	1.65	2.09	0.54
1999	1.77	2.13	0.04
2000	1.89	2.17	0.62
2001	2.01	2.21	1.20
2002	2.13	2.25	1.78
2003	2.00	2.29	1.77
2004	2.32	1.60	1.81
2005	2.97	1.65	1.62
2006	2.04	1.85	1.62
2007	1.92	1.57	1.18
2008	1.79	1.51	1.15

2009	1.99	1.86	1.65
2010	2.04	1.86	1.65
2011	2.11	2.65	1.67
2012	2.13	2.75	1.71
2013	2.07	2.86	1.75
2014	2.33	2.91	2.21
2015	2.91	2.95	2.37
2016	2.83	2.91	2.54
2017	1.87	2.33	1.29
2018	2.08	2.28	1.25

Year	Rice	Maize	Guinea Corn
1990	1.76	1.46	1.43
1991	1.42	1.34	1.32
1992	1.08	1.22	1.21
1993	0.74	1.10	1.10
1994	1.14	1.09	1.21
1995	2.07	1.55	1.38
1996	1.59	1.19	1.19
1997	1.56	1.19	1.19
1998	1.62	0.88	1.29
1999	1.84	1.14	1.30
2000	2.70	1.25	1.62
2001	2.60	1.28	1.62
2002	3.43	1.16	1.63
2003	2.77	1.30	1.70
2004	2.28	1.47	1.27
2005	2.30	1.25	1.42
2006	2.36	1.35	1.27
2007	2.37	1.58	1.32
2008	2.41	1.37	1.53
2009	2.56	1.43	1.40
2010	3.08	1.50	1.54
2011	3.27	1.47	1.58
2012	2.99	1.49	1.52
2013	2.82	1.58	1.55
2014	2.96	1.59	3.87
2015	3.07	1.63	3.19
2016	3.02	1.55	2.34
2017	2.97	1.57	2.49
2018	3.12	1.65	2.61

Year	Rice	Maize	Guinea Corn
1989	9.83	6.75	1.50
1990	9.05	6.30	1.20
1991	8.27	5.85	0.90
1992	7.49	5.40	0.60
1993	6.71	4.95	0.30
1994	5.93	4.50	0.40
1995	5.15	4.05	0.30
1996	4.37	3.60	0.60
1997	3.59	3.15	0.90
1998	2.81	2.70	1.20
1999	2.03	2.25	1.50
2000	2.29	1.86	1.12
2001	2.35	2.03	1.20
2002	2.53	2.22	1.18
2003	2.15	1.85	1.23
2004	2.16	1.75	1.53
2005	2.50	1.75	1.57
2006	2.30	1.83	1.60
2007	2.38	3.59	1.62
2008	2.20	1.84	1.53
2009	2.21	2.04	1.62
2010	1.78	2.10	1.51
2011	2.74	2.15	1.61
2012	2.46	2.48	1.16
2013	2.03	2.57	1.23
2014	2.03	1.87	1.24
2015	1.97	2.36	1.21
2016	1.94	2.34	1.13
2017	1.83	2.31	1.14
2018	1.88	2.33	1.13