EVALUATION OF ROOT AND TUBER CROPS YIELD UNDER THE CHANGING CLIMATIC CONDITIONS IN KWARA STATE, NIGERIA

BY

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MTECH/SNAS/2013/4219

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MTECH) IN CLIMATE CHANGE AND ADAPTED LAND USE

SEPTEMBER, 2015

DECLARATION

I hereby declare that this thesis, titled “Evaluation of Root and Tuber Crops Yield under the Changing Climatic Conditions in Kwara State, Nigeria” is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

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CERTIFICATION

The thesis titled: Evaluation of Root and Tuber Crops Yield under the Changing Climatic Condition in Kwara State, Nigeria by LARBI, Isaac (MTECH/SNAS/2013/4219) meets the regulations governing the award of the degree of Master of Technology of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Prof. A. S. Gana ……..……………………
Supervisor Signature & Date

Dr. A. A. Okhimamhe ……………………………
Director of WASCAL-FUT, Minna Signature & Date

Prof. M.G.M. Kolo ……………………………
Dean of Postgraduate School Signature & Date

DEDICATION

I dedicate this work to my mother, Vida Agyei, the family of Lawyer Augustine Ameyaw Nyamekye and the entire family of Madam Adwoa Awusi.

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ABSTRACT

This study evaluated root and tuber crops yield under the changing climatic conditions in Kwara State, located in the Guinea savannah Zone of Nigeria. Rainfall data (1975-2014), minimum and maximum temperature (1985-2014) and yield data of cassava and yam covering a period of twenty years (1995-2014) were used for the assessment. A questionnaire was administered to a sample of 150 tuber crops farmers in twelve villages from Ilorin East, Asa and Moro Local Government Areas of Kwara State. The questionnaire was formulated to collect information on farmers Socio-economic characteristics, awareness and Perception of climate change and the various adaptation strategies been used. Trend analysis and standardized anomaly were performed on rainfall and temperature. Modified Walter's method was used to determine rainfall onset, cessation and length of raining season. Co-integration and Error correction model test were the analytical tools employed in the analysis of effect of climate on cassava and yam yield. The results shows that, there is an increased in annual rainfall of about 3.5mm/year from 1975 to 2014. Minimum and maximum temperature from 1985 to 2014 have also statistically increased at 95% confidence level with minimum temperature increasing at a faster rate compared to maximum temperature. In addition, the analysis of daily rainfall data showed that, on the average, the onset and cessation dates were 30th March and 12th October, depicting both an early onset and cessation of rainfall leading to a decrease in length of raining season. The results obtained from Co-integration and Error correction model test indicate that there is a long-run relationships between the crop yield and annual rainfall, temperature and length of raining season. The output of yam was found to have a significant positive relationship with a coefficient of 0.00041 with the amount of rainfall. This shows that the production of yam irrespective of their increasing output was still dependent on the amount of rainfall. However, there was a negative relationship between cassava yield and rainfall though was not significant but temperature and length of raining season were significant in cassava model. Hence, increase in temperature and shortening of length of raining season will adversely affect the yield of cassava. The socio-economic survey revealed that majority of the respondents (91.3%) are aware of climate change with more than 92% of farmers indicating that temperature in the area had increased and about 56.2% of the respondents indicating that rainfall has also been on the increase. Moreover, the average adaptive capacity of the respondent was moderate (2.92), but majority of the respondents were highly adaptive to some individual adaptation strategies which are positively reflecting the trend of tuber crop yield in the area which shows an increasing trend. In conclusion, although there is a gradual decreasing in length of raining season over the last forty years, however, Kwara State is becoming wetter especially from 2003 to 2014.

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LIST OF ABBREVIATIONS AND ACRONYMS

ADF	Augmented Dickey-Fuller
BNARDA	Benue State Agricultural and Rural Development Authority
CBN	Central Bank of Nigeria
GDP	Gross Domestic Product
GIS	Geographical Information System
IDW	Inverse Distance Weighting
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
KWADP	Kwara State Agricultural Development project
FAO	Food and Agricultural Organization
NBS	National Bureau of Statistics
NIMET	Nigeria Meteorological Agency
NRCRI	National Root Crops Research Institute
VECM	Vector Error Correction Model
UNFCC	United Nation Framework of Climate Change
UNMP	United Nation Millennium Project
SSA	Sub Sahara Africa

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Agricultural is a major source of living for most rural communities in Nigeria in particular with a contribution of about 30% of the country's Gross Domestic Product (GDP) (Kadlinker and Risbey, 2000). In Sub Saharan Africa, root and tuber crops form a major part of the staple food consumed by the populace. Historically and currently, more than 90% of root and tuber crops namely Cassava (*Manihot esculenta*), Yam (*Dioscorea* spp.) and Sweet potato (*Ipomoea batatas*) are mainly used as food (Quin, 2001).

According to Intergovernmental Panel on Climate Change (IPCC, 2007), climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. These changes can be caused by dynamic processes on earth, external forces including variations in sunlight intensity and, more recently by human beings. Globally, the earth has over the years observed an increase in temperature but decreased precipitation (Fancherean, Trzaska, Rouault and Richard, 2003). Impacts have been witnessed in several areas due to change in precipitation and temperature. The areas affected include agriculture, forestry, water resources, biodiversity, human health, and ecosystems goods and services globally (Khanal, 2009; Rosegrant, Ewing, Yohe, Burton, Huq and Valmonte-Santos, 2008). Although the impact of climate change is global, for various reasons including the state of preparedness of the continent, it has been estimated that Africa will be most vulnerable to climate change (Arnell, 2004; IPCC, 2007).

Climate change resulting from human activity has the potential to substantially affect agricultural systems (IPCC, 2001). It affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce. The greatest damage from climate change is predicted to be in the agricultural sector in Sub-Saharan Africa. The reasons are that, the region already endures high heat and low precipitation, a significant number of the agricultural population relies on relatively basic technologies, which leads to low per capita food production in most African countries and limits the capacity of farmers to embrace adaptive measures to mitigate the adverse effects of climate changes (United Nation Millennium Project, UNMP, 2005).

The IPCC (2007) report predicted that by 2020 between 75 and 250 million people in Africa will be exposed to increased water stress caused by climate change, hence agricultural production and access to food in many African countries may be further threatened. This will adversely affect food security, aggravate malnutrition and increase diseases on the continent. Within Africa, Nigeria is particularly vulnerable to climate change. According to International Fund for Agricultural Development (IFAD, 2009) most agricultural practices in Nigeria rely on rainfall and over 70% of the country's population relies directly or indirectly on rain-fed. Crop production is dependent on climatic environment and the yield of crop is determined more by prevailing weather conditions than by any other factors or combination of factors (Kowal and Knabe, 1992).

Tuber crops production in Nigeria like in other developing countries in sub-Sahara Africa is highly vulnerable to variations in climatic parameters due to its dependent on rainfall. Recent studies by various researchers have shown that most of the recent problems of food security have resulted from weather related hazards and extreme weather events such as drought and flood (McCarthy, Canziani and Dokken, 2001). Temperature alters precipitation patterns, triggers extreme weather conditions which could alter crop yields, and water supplies, as well as disrupt farming, fishing, and many other industries reliant on weather and the natural world (IPCC, 1990; Downing, 1992). According to Nyong (2005), farmers in Sub-Saharan African countries are vulnerable to climate change because they lack the capacity to adapt. The agricultural sector in Kwara State, Nigeria is therefore likely to suffer, most adversely, from climate change because of its high dependence on rainfall and temperature. Therefore, increased knowledge on effects of climate change on tuber crop yield will ensure that appropriate management practices are adopted to cope with the problem of climate change.

1.2 Problem Statement

Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops, but food production is low and has not kept pace with population increase (Federal Office of Statistics, 2009). Although Nigeria is witnessing an increase in tuber crop production yet not all tuber crop producing areas in Nigeria have recorded the upward trend in tuber production (Central Bank of Nigeria, CBN, 2008). Climate variability and change have significant impacts on food production, particularly the common staple food crops performance in tropical sub-humid climatic zone (Oluwasegun and Olaniran, 2010), however, the extent and nature of these impacts still remain uncertain.

Many farmers in Kwara State of Nigeria rely on tuber crop production for their livelihood and food security. With the increasing rate of extreme weather events, the productivity of tuber crops are unstable, which leads to crop failure. Also, there are a lot of studies on the impact of climate change on tuber crop yield in many parts of Nigeria, but there is little on long term effect of climate on tuber crop yield in Kwara state, Nigeria.

1.3 Justification

Agriculture largely depends on climate to function, hence precipitation, solar radiation, temperature, and other climatic parameters affect and determine the global distribution of crops as well as their productivity (Ayoade, 2004). Food crop is particularly sensitive to climate change because crop yields depend largely on prevailing climate conditions (temperature and rainfall patterns) (Palatnik and Roson, 2009). Moreover, there is a growing evidence that climate change, specifically higher temperatures and changes in rainfall patterns are likely to depress crop yields and increase production risks in many regions around the world (IPCC, 2001). Several research works have been conducted in many parts of Nigeria on crop-climate relation and the results indicate that climatic effects vary among crops and regions in Nigeria. According to Oluwasegun and Olaniran (2010), there is high inter-annual rainfall variability in the tropical sub-humid Nigeria and may often result in climate hazards, especially floods, with devastating effects on food production. Moreover, Challinor, Wheeler, Craufurd, Slingo, and Grimes (2004), revealed that crop productivity in tropical regions is highly vulnerable to inter-annual and sub-seasonal climate variability hence any change in temperature and precipitation may have positive and negative impacts on the crop yield.

Furthermore, tuber crop is a major food sources for the larger populace and plays a major role in the diet of Nigerians. Efforts are therefore made by farmers to increase the productivity of tuber crops through the use of various adaptation strategies as a result of the changing climatic conditions. The farmers' adaptation to climate change in tuber crop production is essential in order to ensure food security in Kwara State and Nigeria. Moreover, in a large country like Nigeria with different climatic regions, studies of crop-climate relations are important towards government's programmes on revitalizing the agricultural sector of the economy. It is therefore important to assess how root and tuber crops productivity vary with the changing climatic condition and the various adaptation strategies used by farmers as a result of changing climatic conditions using a case study of one of Zone C, Kwara State, Nigeria.

1.4 Scope and Limitation of the Study

Kwara State is divided into four agricultural zones (Zones A-D) by the Kwara State Agricultural Development Project (KWADP) based on the agro-ecological and cultural characteristics of the state. This study concentrated only on the effect of climate on yam and cassava produced from Zone C, Kwara State which comprises of Ilorin East, Ilorin South, Asa, Moro and Ilorin West Local Government areas in Kwara state Nigeria. 150 tuber crops farmers only were sampled from Ilorin East, Asa and Moro Local Government areas for the questionnaire administration. With respect to climate parameters, only observed daily rainfall and temperature were considered. Inadequate cassava and yam yield data was one of the greatest challenge encountered. As a result of this, only twenty years (1995 to 2014) crop yield data was obtained from KWADP office. Also, Language barrier was another limitation of the study as a result of this, an assistance from a translator was required to translate from the local dialect to English when administering the questionnaire which resulted in the denial of first-hand information.

1.5 Aim and Objectives

The aim of this study is to evaluate root and tuber crops productivity under the changing climatic conditions in Zone C, Kwara State, Nigeria. The specific objectives are to:

(i) examine the pattern of rainfall and temperature in the study area over the last forty years.

(ii) examine the effects of rainfall, temperature and Length of raining season on cassava and yam yield.

(iii) determine the adaptive capacities of cassava and yam farmers under the changing climatic conditions.

1.6.1 Research Questions

(i) What are the nature and trend of rainfall and temperature from 1975-2014?

(ii) What is the effect of rainfall, temperature and length of raining season on cassava and yam yield?

(iii) What is the level of cassava and yam famers' adaptive capacity to climate change?

1.7 Study Area

1.7.1 Location

The study was conducted in Zone C of KWADP, Kwara State, which falls under the southern Guinea Savanna agro-ecological zone of Nigeria (Figure 1.1).Geotropically, Kwara state is located between latitudes 8° 05' N to 10° 05' N and longitudes 2° 50' E to 6° 05' E with an area of about 32,500 km^2 . The State has River Niger as its natural boundary along its northern and eastern margins and shares a common internal boundary with Niger State in the north, Kogi State in the east, Oyo, Ekiti and Osun States in the south and an international border with the Republic of Benin along its north-western part (KSMI, 2002). The study area (Zone C) which consist of Asa, Moro, Ilorin East, Ilorin west and Ilorin south extends from latitude 8° 05ʹ N to 9° 05ʹ N and longitudes 4° 20ʹ E to 5° 5ʹ E, covering an area of about 4978.44 km^2 (Figure 1.2). The socio-economic phase of the study was carried out in Asa, Ilorin East and Moro local government areas located in Zone C of Kwara State, and the climatic data was collected from Nigeria Meteorology Agency (NIMET-Abuja) and Lower Niger River Basin and Rural Development Authority Hydrology Section, Ilorin.

1.7.2 Climate

Kwara state lies within a region described as tropical climate and are characterized by double rainfall maxima and has tropical wet and dry climate (Olanrewaju, 2009). Both seasons last for about six months. Kwara State is a summer rainfall area, with an annual rainfall range of 1000 mm to 1500 mm. The wet season begins towards the end of March and ends in October. A dry season in the town begins with the onset of tropical continental air mas commonly called Harmattan. The wind is usually predominant between the months of November and February (Olaniran, 2000). Temperature is uniformly high and ranges between 25°C and 30°C in the wet season throughout the season except in July – August when the clouding of the sky prevents direct insolation while in the dry season it ranges between 33°C to 34°C. Relative humidity at Ilorin in the wet season is between 75% and 80% while in the dry season it is about 65%. The daytimes are sunny and the sun shines brightly for about 6.5 to 7.7 hours daily from November to May (National Bureau of Statistics, NBS, 2009).

1.7.3 Soil and Vegetation

The vegetation of the study area is characterized by scattered tall tree shrubs between the height of 10-12ft. Oyegun (1993) described the vegetation to be predominantly covered by derived savannah found in East and West and are noted for their dry lowland rain forest vegetal cover. The climate of Kwara state supports tall grass interspersed with short scattered trees. This attribute predisposes the people of Kwara State to make farming their major occupation. Food crops produced in the state are mostly maize, sorghum, yam, cassava, water yam and sweet potato which constitute the main staple food aside cereals (Ajadi, Adeniyi and Afolabi, 2011). Soil formation processes are strongly influenced by geology, geomorphology process and vegetation. Oyegun (1993) identified terrasols soils, ferruginous red and brown soil, hydromorphic and organic soil and rogosols and brown soil as the four main soil types in Ilorin. The dominance soil found in most parts of Ilorin are Sandy-loam soil which are easy to farm. However, low fertility is observed due to leaching of minerals and nutrients because of the high seasonal rainfall coupled with the high temperature.

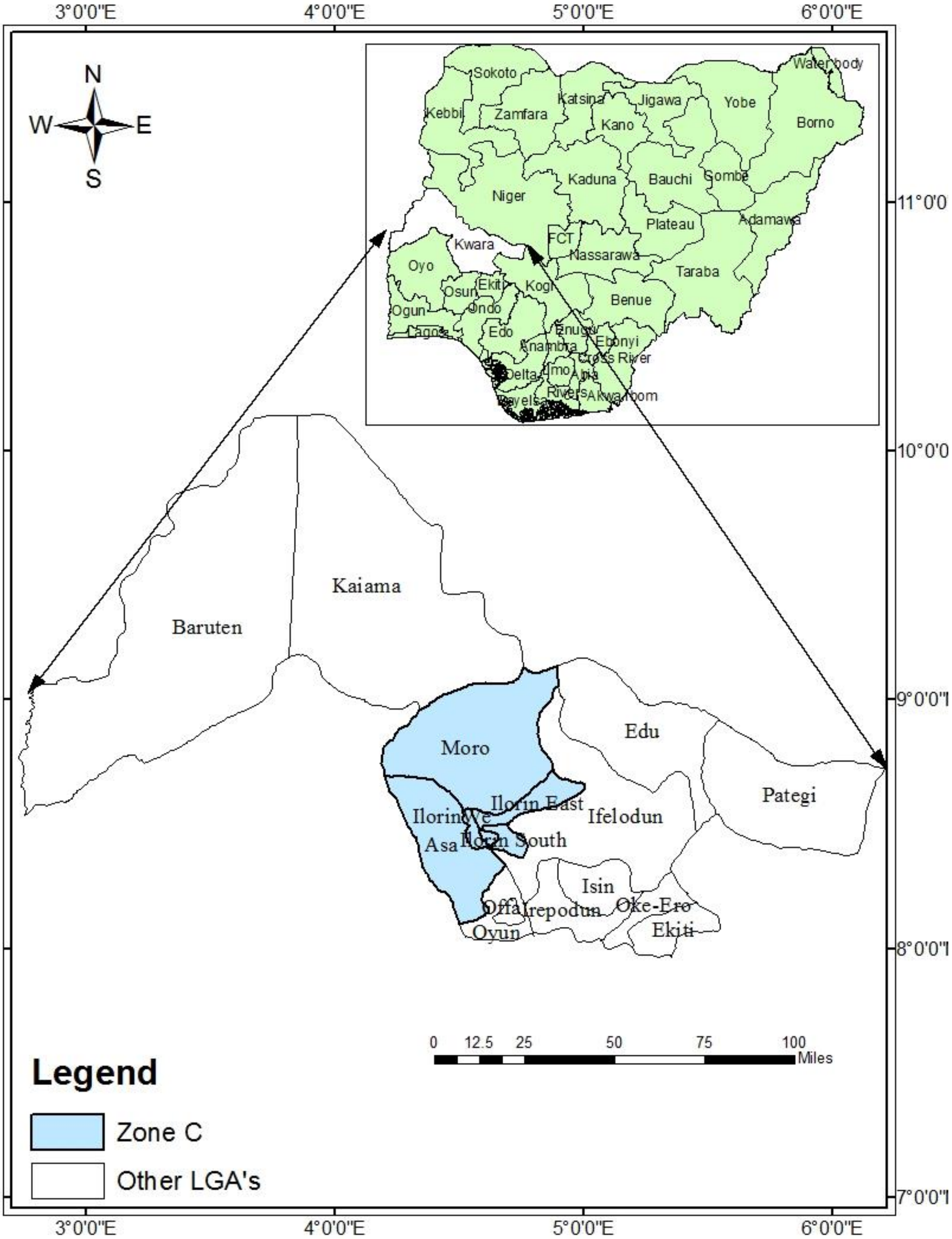

Figure 1.1: Kwara State showing Zone C Area

Source: Author, 2015

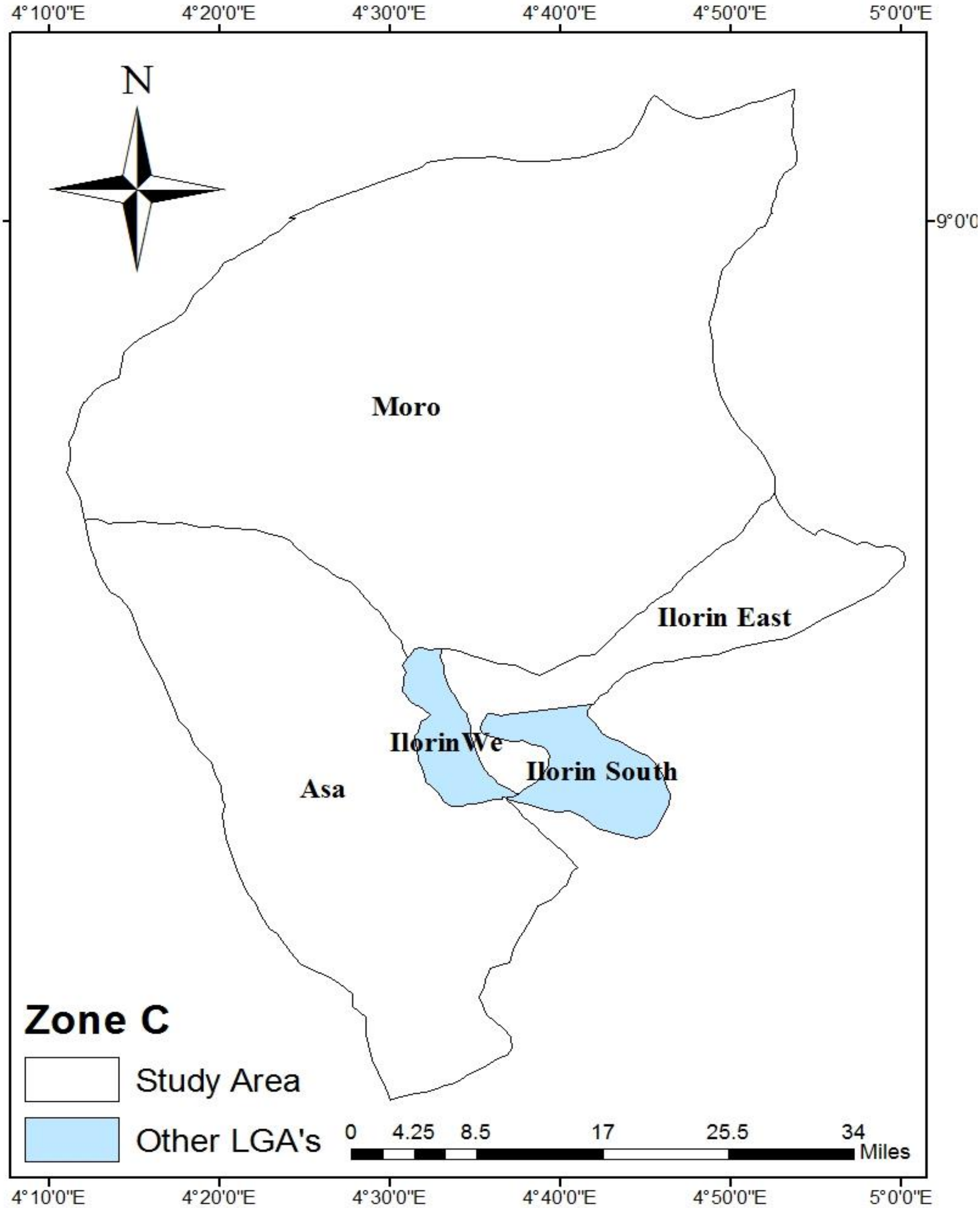

Figure 1.2: Zone C showing the Study area

Source: Author, 2015

CHAPTER TWO

2.0 LITERATURE REVIEW

The variability of the climate has been a topical issue in a sustainable environment as the crop yield and production is very important to the economy and livelihood of the people of Nigeria and the world at large. Root and tuber crops production in Nigeria like in other developing countries in sub-Sahara Africa is highly vulnerable to variations in climatic parameters due to its dependence on rainfall. This chapter reviews concepts of climate change and variability, root and tuber crops productivity and various literature within the scope of the study which helped in the development of the methodology that was used for the study.

2.1 Root and Tuber Crops Production

Tuber crops are those crops in which the edible carbohydrate-rich storage organs develop wholly or partly from underground stems (Okigbo, 1989). Root and tuber crops are important in the sub-Saharan Africa especially in Nigeria as they form a major part of the staple food consumed by the populace. According to Food and Agriculture Organization (FAO, 1997), tuber crops play an important role as a substantial actor in the world food supplies.

Cassava ranks highly as a major staple food crop particularly for the low income earners and resource poor farmers in the developing economies of Sub-Saharan Africa (SSA) (Hahn, Isoba, and Ikotun, 1989). The crop's production is generally thought to require less labour per unit of output than other major staples and is able to grow and give reasonable yields in low fertile soils. Fresh cassava root contains starch that can be transformed into several end products such as pellets, chips, flour, sweetener, etc. used in food industries (Ratanawaraha, 2001). Its stems and leaves can be used as raw material for bio-ethanol in non-food industries (Sriroth *et al.*, 2003). Because it has broad uses in many industries, cassava has become an economic crop in increasing demand worldwide (Rijks, 2003). Cassava recently has become the magic crop as a result of the Presidential initiative on Cassava production few years back with good export potential. It is a good staple whose cultivation if encouraged can provide the nationally required food security minimum of 2400 calories per person per day (FAO, 2000).

Sweet potato has a long history to stave off famine especially as a cheap source of calories (Adam, 2005). It feeds millions of people in the developing world and it is especially popular among farmers with limited resources. The production, marketing and utilization of sweet potato have expanded in the last decade to almost all ecological zones in Nigeria (National Root Crops Research Institute, NRCRI, 2009). Presently, 381,000 – 510,000 ha of land are subjected to sweet potato cultivation in Nigeria with an annual production figure of 3.46 million metric tons (NRCRI, 2009). Estimated yields of sweet potatoes in the research fields varied from 40 to 70 t/ha for improved varieties, while in multi-locational trials yields averaged 23.5t/ha across seasons and locations (Tewe, Ojeniyi and Abu, 2003). In Benue State, Nigeria, approximately 212,840 ha was subjected to sweet potato production with a mean yield of 9.80 t/ ha in 2008 (BNARDA: Benue State Agricultural and Rural Development Authority, 2008).

Yams are agronomically, annual rain-fed crops which grow for 6-12 months depending on the cultivar, ecology and soil properties in the production area (NRCRI, 1998). It is an important tuber crop in Nigeria and the entire West African region which serve as staple food in many tropical and even sub-tropical countries. Although yams are produced throughout Africa, according to FAO (2000), Nigeria is said to be the largest producer of yams accounting for more than 76% of Africa total output. In all, sub-Saharan African produces about 20% of the world's total production of root and tuber crops, for about 10% of the world's total human population (Quin, 2001).

2.2 Climate Change and Climate Variability

Climate is "average" weather (current atmospheric condition) for a given place or a region over a long period of time say 30 years or longer. It defines typical weather conditions for a given area based on long-term averages. Average weather may include average temperature, precipitation, relative humidity, evaporation and wind patterns among others (Welbergen, Klose, Mark and Eby, 2008). According to United Nation Framework of Climate Change, UNFCC (2007), climate change is any long-term significant changes in the 'average weather' of a region or the earth as a whole and is attributed directly or indirectly to human activity that alters the composition of the global atmosphere. The issues of climate change have become very threatening, not only to the sustainable development of socio-economic and agricultural activities of a nation, but also to the totality of human existence (Adejuwon, 2004). Many countries in tropical and sub-tropical regions, of which Nigeria is included, are expected to be more vulnerable to warming because of additional temperature increase that consequently affects marginal water balance and harm agricultural sector (Mendelsohn *et al.,* 2000).

It is widely known that there has been a detectable rise in global temperature during the last forty years, and this rise cannot be explained without taking into account the role of human activities (IPCC, 2007). However, the global distribution of temperature increase is not uniform. Some regions experience greater change than others, especially the interior of continental regions such as the Sahel in West Africa. The current signs of global climate change have resulted from an average increase in the world temperature of just 0.7 ˚C since 1900 (Nkemdirim, 2003). Changes in rainfall levels are also typically harder to detect due to greater variability in both time and space. Even so, changing rainfall patterns have been detected for many parts of the globe and recent studies have shown that Africa has been drier in the last few decades (Oguntunde, Abiodun and Gunnar, 2006).

Climate variability and change may result in irreparable damage to arable land and water resources in some regions with serious local consequences for food production. These losses will be experienced most seriously in developing countries with low capacity to adapt (Owusu-Sekyere, Alhassan and Nyarko, 2011). This is becoming worrisome due to the region high dependence on rain- fed agriculture. Changes in temperature and precipitation directly affect crop production and can even alter the distribution of agro-ecological zones. Based on this, the temperature of Nigeria is projected to increase by about 0.02˚C/decade, a rate that is lower than the present 0.06 ˚C/decade (Maikasuwa and Ango, 2013). Olanrewaju (2010) reported that there is a downward trend in rainfall amount and number of rainy days, and air temperature was constantly high making the climate of Kwara state turn toward aridity.

2.3 Rainfall Onset, Cessation and Length of Raining Season

In Nigeria, rainfall is by far the most decisive climate variable affecting the lives of people and can therefore be regarded as the most appropriate indicator to characterize climate change (Abdou, 2010). Research has shown that changes in temperature, precipitation, water availability and shortening of the length of growing season have major implications for sustainable development (Edoga, 2007; Tadross *et al.*, 2009). Observed meteorological records now agree with farmer's perceptions that the onset and cession of the rain season seem to have shifted and will shift even further from their normal calendar dates (Hansen, Sato and Ruedy, 2012; Mubvuma, 2012). The length of the growing season can be determined in a diversity of ways. Thornthwaite and Mather (1955), Cocheme and Fraquin (1967) and Benoit (1977), have all employed rainfall–evapotranspiration relation model to determine the onset and cessation of the growing season. However, most studies (Walter, 1968; Kowal and Adrews, 1973; Olaniran, 1983) have employed rainfall alone to determine the onset and cessation of the growing season. Rainfall totals are more widely used mainly because they are more readily available (Olaniran, 1983). Also, this author believes that the use of rainfall data is a more direct approach rather than the use of some other related factors from which to make inferences.

For West Africa, Omotosho, Balogun and Ogunjobi (2000) defined the onset as the beginning of the first 2 rains totalling 20 mm or more, within 7 days, followed by 2–3 weeks, with at least 50% of weekly crop water requirement. In Nigeria, Walter (1968) defined onset date of rainfall as the month with accumulated rainfall total of 51mm or more in which the onset date is not followed by more than five days dry spells. The cessation date has been marked by the month with accumulated rainfall total of more than 51mm from December (Olaniran 1988: Olarewaju, 2013). Cessation dates is also defined as the first date on which soil water is exhausted (Stern, Dennett and Garbutt, 1981) or the soil water content down to 60 mm depth with a daily potential evapo–transpiration of 5 mm (Maikano, 2006).

2.4 Climate Change and Crop Yield

Climate affects crop production through direct impact on the biophysical factors such as plant and animal growth and the physical infrastructure associated with food processing and distribution (Schmidhuber and Tubiello, 2007). Climate change is expected to result in long-term water and other resource shortages, worsening soil conditions, drought, flood and desertification, disease and pest outbreaks on crops and livestock. Vulnerable areas are expected to experience losses in agricultural productivity, primarily due to reductions in crop yields (Apata, Samuel and Adeola, 2009). Crop production in SSA is directly affected by many aspect of climate change such as average temperature increase, change in rainfall pattern and amount, rising atmospheric carbon dioxide concentration and sea level rise. Abdrabbo, Khalil, Hassanien and Abou-Hadid (2010) evaluated the potential impact of climate change on potato yield by simulating two cultivar and irrigation requirements level on simulated potato production with climate change output models (CSIRO, and HadCM3) and the results indicated that the potato yield decrease from 11 to 13% under climate change and the climate change data output from HadCM3 model gave the highest value of potato yield comparing with CSIRO model.

According to IPCC (2007a), a temperature change in tropical areas has in general had a negative impact on food production. Temperatures throughout Nigeria are generally high with annual mean of about 27°C while diurnal variations are more pronounced than seasonal differences (Salami and Matthew, 2009). Temperature and moisture supply have a dominant influence on crop growth. The diurnal and day-to-day variability for temperature and moisture supply along with mean values are important climatic factors for plants because of the negative impact of extreme conditions (WMO: World Meteorological Organization, 2002). Warmer conditions can reduce yields of crops and pastures by preventing pollination. For example, rice yields decrease by 10% for every 1^{o}C increase in minimum temperature during the growing season (Johnston, Hoanh, Lacombe, Noble, Smakhtin and Suhardiman, 2009). Temperature affects sprouting, life size, leaf formation, storage root formation and consequently, general plant growth. The behaviour of tuber crop (cassava and yam) under the temperature variations that usually occur where the crop is normally cultivated, indicates that its growth is favoured under annual mean temperature ranging from 25 ^{o}C to 29 ^{o}C (Concelego, 1997), but it can tolerate from 16 to 30 ^{o}C (Cock,1984).

Rainfall regime is another most important climatic factor influencing crop cultivation activities particularly in tropical regions of Nigeria (Ayanlade, Odekunle and Orimoogunje, 2010). Rainfall can vary considerably even within few distance and different time scale. This implies that crop yield is exceedingly variable over space and time which will have a big effect in determining the kind of crop to be grown, farming system to be adopted and the sequence of farm operations (Adejuwon, 2005). It is expected that countries in tropical and sub-tropical regions where there is low availability of water, would generally be at risk of decrease crop yield at even 1 to 2^{o}C warming (Parry, *et al.,* 2007; FAO, 2008b). According to FAO (2008b), it is expected that as a result of climate change, the temperate region (wet areas) could become wetter and the dry areas of the tropics could become drier. Rainstorm intensity could increase in some areas and precipitation could become more variable and unpredictable. The change in rainfall can affect soil erosion rate and soil moisture, both of which are important for crop yield.

2.6 Empirical Review

Owusu-Sekyere *et al.* (2011) assessed the variability and trend of major climatic elements and the possible impact of these changes on the yield of major crops produced in the Cape Coast metropolis in the central region of Ghana. Climatic data (temperature, precipitation, relative humidity and evaporation) covering a period of period of sixteen years (1993-2008) and crop yield data (cassava, yam, cocoyam, plantain and maize) covering a period of eight years (2000-2008) were used for the assessment. Probability analysis of rainfall data was used to predict the probability of occurrence of rainfall of a certain amount in the future as well as the return period.

The study revealed that over the period under scrutiny, temperature and evaporation have been increasing gradually. It was also discovered that peak monthly rainfall is also declining and there is a higher probability of lower amount of rainfall occurring in the future. The conclusion drawn from the study was that, onset of the rainy seasons fluctuates between March and April and the frequency of rainfall has been declining over the years. The gradual decrease in peak monthly rainfall and relative humidity as well as increase in temperature and evaporation is a clear indication of a changing climate. Yields of all major crops in the metropolis have been declining gradually over the past 16 years due to the gradual change in the pattern of the major climatic elements. Although it was revealed that the yields of the various crops were declining in the period under study but there were no correlation and regression analysis made to find out the relationship between the crop yield and the climatic parameters and how each of the climatic parameters affects the crop yield.

Although the study revealed that the yields of the various crops were declining in the period under study but there were no correlation and regression analysis made to find out the relationship between the crop yield and the climatic parameters and how each of the climatic parameters affects the crop yield.

In a similar study, Adamgbe and Ujoh (2012) examined the patterns and trends of the variations in the climatic parameters and the implications of such variations on efficient yield rates of some food crops (Cassava, yam, Sorghum and groundnut) in Benue State using data on climatic variables (rainfall, temperature, sunshine) and the yield of some crops per hectare for 25 years (1986-2010). Modified Walter's method was used to determine the onset and cessation of rainfall. Duration of rainy season, number of rain days, mean monthly temperature and mean monthly Sunshine were determined. Time series analysis was used to determine the trend in the climatic parameters and yield of crops. Multiple and partial correlation analyses were employed to establish the relationship between the climatic parameters and crop yield; and also show the joint and single contribution of the climatic parameters in the yield of food crops.

The study revealed that the earliest date of onset of the rainy season was 2nd April of the year 1999, while the latest date was 2nd May of the year 1987, the earliest date of cessation of the rainy season was 1st September of the year 2001 while the latest date was 16th October of 1987, highest duration of the rainy season was 194 days (2008) while the lowest duration was 139 days (2001) and the highest number of rain days was 95 days (1999) while lowest was 59 days. Also, the climatic parameters and food crops were characterized by high inter-annual variability. All the climatic parameters except rainfall amount, temperature and sunshine were on downward trend together with rice and maize.

The joint effect of the climatic parameters on the yield of all the crops varies between 78% (Yam) and 36% (Groundnut). Among the seven climatic parameters, sunshine and rain days have the highest influence on the yield of all the seven crops while dates of onset and duration have the least influence.

Ayanlade *et al.* (2010) worked on the impact of climate variability on tuber crops in the Guinea savanna zone of Nigeria using a Geographical information system (GIS) approach by developing a GIS database and mapping inter-annual changes in tuber crop yield as a response to inter-annual rainfall variability. Tuber crops (Cassava and yam) and rainfall data for thirty years (1970-2000) were collected from nine (9) different states in the Guinea savanna zone of Nigeria. Three spatial interpolation methods namely Inverse Distance Weighting (IDW) method, Spline as the determinist methods and Ordinary Kriging were used to estimate the missing rainfall values on the basis of the remaining observed ones on each station. Co-efficient of variation, multiple correlation, regression and z-distribution chart where used to examine both the rainfall variability and the sensitivity or response of the crop yields to the variability of rainfall.

The study found out that rainfall variability is very high in most parts of Northern Guinea Savanna (Yola, Minna, and Kaduna) except Jos which has a unique pattern. There was an increased in both cassava and yam yields from 1970-1979 especially in the southern sector compared to the Northern sector. However, Cassava and yam yield were very bad from 1980-1989 but the yield from 1990-2000 appeared better compared to that of 1980-1989. It was concluded that based on the results obtained, GIS techniques proved efficient in assessing rainfall variability. Also cumulative variation in rainfall truly influences yam and cassava yields during the second decade (1980-1989) leading to momentous reduction in the crop yield. The increase in yield recorded in 1990-2000 decade may perhaps be attributed to the increase in rainfall during the planting and growing seasons within the periods. But 1980-1989 experienced a very low rainfall during planting and growing seasons that had been due to a greater number of drought episodes.

Akpenpum and Busari (2013) evaluated the impact of climate on the cultivation of cassava, yam and sweet potato in Kwara state, Nigeria using multiple regression, trend analysis and correlation analytical technique. They used climatic data on rainfall, evaporation, relative humidity, temperature and sunshine hours and tuber crop yield data covering a period of ten years (2002-2011). They employed simple correlation and multiple regressions to show the relationship between climatic parameters and crop yield and also to show the trend and variation in crop yield over the ten years in the study area. The authors discovered that, out of the three selected tuber crops, cassava had the highest mean value (699.34), followed by yam (732.35) while sweet potato had the lowest mean value (67.83). Similarly, the highest deviation was obtained in cassava production (359.98). This shows that the dispersion characteristic of cassava is low in Kwara state. The coefficient of variation, which shows the relative deviation between crop yields, indicates that all the tuber crops (yam, cassava and sweet potato) are heterogeneous.

The result of the regression analysis showed 99.8%, 99.9% and 82.4% of variation in yam, cassava and sweet potato respectively and these variations according to the researcher could largely be attributed to climate. Also, the correlation coefficient between the climatic parameters and the selected crop yield showed that all the climatic parameters apart from temperature had strong correlation coefficient with the selected crops. In case of cassava, evaporation and soil temperature had values greater 0.5 while for sweet potato, it is maximum atmospheric temperature and soil temperature that have values greater than 0.5. This implies that there is an average linear relationship between these climatic parameters and sweet potato yield in the study area. However, there is a weak relationship between sweet potato yield and rainfall, minimum temperature, evaporation, relative humidity and sunshine hours.

Oluwasegun and Olaniran (2010) assessed how temporal changes in climate variables affect crop production in South-western Nigeria. They used crop yield (tuber crop, grains and legumes) and climatic variables (rainfall, temperature and relative humidity) covering a period of seventeen years (1990-2006) to examine the response of the different classes of food crops under the varying climatic conditions. The study revealed that the amount of rainfall and number of wet days varied appreciably from year to year and the region shows an increase in rainfall. Mean temperature appeared to vary with the tuber crop production compared with other food crops. They concluded that, the low computed correlation coefficient ($r \leq 0.4$) for all crops yields with climatic variables implies that crop production may largely depend on combinations of number of interacting factors which are of both climatic and non-climatic components.

CHAPTER THREE

3.0 MATERIALS AND METHODS

This chapter explains in details the various ways by which data were collected and the procedure that was used in data analysis to find out how changes in climatic conditions (temperature and rainfall) affect the yield of root and tuber crops (yam and cassava) and the adaptive capacities of tuber crop farmers to climate change.

3.1 Data Collection

3.1.1 Climatic Data

Climate data used in this study were daily rainfall (mm) from 1975 to 2014 and maximum and minimum temperatures (^oC) covering a period of thirty years (1985-2014). These data were collected from Lower Niger River Basin and Rural Development Authority, Hydrology Section, Ilorin, Kwara state and Nigerian Meteorology Agency (NiMet), Abuja. These climate parameters were selected based on their importance in determining the time of farm preparations and planting, growth, development and yield of crops in West Africa. Also, according to Nwaiwu, Ohajianya, Orebiyi, Ibekwe and Eze (2013), rainfall and temperature are the two major climate parameters that significantly affect the growth and productivity of most food crops.

3.1.2 Crop Yield Data

The data on cassava and yam yields were collected from the Kwara State Agricultural and Rural Development Office, Ilorin. The values obtained were average yields of cassava and yam in tons per hectare spanning a period of twenty years (1995-2014).

3.1.3 Survey of Farmers’ Adaptive Capacity and Climate Change Perception

(a) Target Areas and Sampling Procedure

A multi-stage sampling technique was employed in the selection of respondents (tuber crop farmers) in this study. Kwara State is divided into four agricultural zones (Zones A-D) by the Kwara State Agricultural Development Project (KWADP). Firstly, out of the five Local Governments Areas (L.G.As) under Zone C in Kwara State, three of them were selected. The selection of Asa, Moro and Ilorin East Local Government Areas was based on the population of Cassava and yam farmers in each of the five (5) Local Government Areas. Secondly, Four (4) communities were randomly selected from each of the three Local Government Areas making a total of 12 communities. Cassava and yam farmers were purposively selected since they were the target group. Lastly, a total of one hundred and fifty (150) farming households (cassava and Yam) out of 750 farmers were selected, and the head of each selected household was considered as the respondent (Table 3.1). From the sampling frame, sample units that are aged 40 years and above and have lived in the community within the last 30 years were purposively selected. This was done to sample only respondents that will be able to recall temperature and rainfall patterns in their communities. The main tool for data collection was a well-structured questionnaire. The questionnaire was formulated to collect information on Socio-economic characteristics of farmers, farmer’s awareness and Perception of climate change and farmers’ adaptation strategies to climate change. The adaptation strategies considered in this study are presented in Table 3.2.

Table 3.1: Summary of the Study Location and the Sample Chosen

Local Government Areas	Community	Number of respondents
ASA	Eiyenkorin	15
	Pampo	15
	Afon	15
	Sapati-lle	15
MORO	Olooru	15
	Malete	15
	Shao	10
	Kanbi	10
ILORIN EAST	Lajolo	10
	Oke-Oyi	10
	Alapo	10
	Oke –Ose	10

Source: Field Survey (2015)

Table 3.2: Farmers Adaptations Strategies to Climate Change Considered

S/N	ADAPTATIONS STRATEGIES
1	Planting of early maturing yam varieties
2	Mulching
3	Drought tolerant yam varieties
4	Use of weather forecast
5	Application of farm yard manure
6	Changing planting date
7	Planting of higher yielding yam varieties
8	Drought tolerant cassava varieties
9	Early maturing cassava varieties
10	Multiple cropping

Source: Field Survey (2015)

3.2 Data Analysis

3.2.1 Climatic Data Analysis

(a) Onset, Cessation and Length of Raining Season

Several models have been proposed for determining the date of onset and cessation of the rainy season. These range from traditional to semi-empirical and scientific techniques. Among the existing techniques for estimating onset and cessation dates, the use of cumulative rainfall amount appears to be one of the most frequently used methods in the Guinea Savana Zone of Nigeria (Olaniran, 1983; Adejuwon, 1988; Bello, 1995). This method is mostly used because it estimates the mean rainfall onset date which does not differ much from the mean start of the growing season in Nigeria (Olaniran, 1983). The onset and cessation dates of rainfall were computed using Walter's (1967) method as modified by Olaniran (1988) because of the existence of shorter changes that are characteristic of tropical climates. It defines the dates of onset and cessation of rainfall as that of Walter's onset or cessation date which is not immediately followed or proceeded by dry spells of five or more duration.

The method is expressed as:

$$\text{Onset/Cessation} = \frac{\mathbf{DM}\,(\mathbf{51-AR})}{\mathbf{TR}} \quad - \qquad (3.1)$$

Where:

DM = Number of days in the first month containing accumulated rainfall of more than 51mm

AR = Accumulated total rainfall of the previous months;

TR = total rainfall for the month in which 51mm or more is reached and 51 is the threshold of rainfall for both Onset/Cessation month.

The rainfall cessation is calculated by accumulating monthly rainfall value from December backward. The month that the accumulated total exceeds 51mm becomes the end of the rainy season. The difference in onset and cessation dates of the rain was employed in the estimation of the effective length of the rainy season (LRS) as discussed by Adefolalu (1990) is expressed in the form:

$$LRS = Y - X \qquad - \qquad (3.2)$$

Where:

LRS = the length of raining season

Y= cessation date

X= Onset of rain

(b) Rainfall and Temperature Trend Analysis

A simple linear regression model was applied to show the long-term annual trends of rainfall and temperature over the study period and its statistical significance. To examine the nature of the trends, Standardized anomaly index which is a measure of distance, in standard units, between a data value and its mean was used. According to the World Meteorological Organisation (WMO, 2012), the index is used as a descriptor of rainfall variability and it indicates the number of standard deviations that a rainfall event deviates from average of the years considered. Standardized anomaly index is given as:

$$\mathbf{Z = \frac{X-Y}{SD}} \qquad - \qquad (3.3)$$

Where:

Z = Standardized anomaly index

X= Annual total rainfall or mean annual temperature for the year

Y = Overall mean temperature or rainfall

SD = Standard deviation of the temperature.

The standardized anomalies for rainfall and temperature were then finally plotted using Excel version 2013 in order to sub-set the study time period into phases. Based on the Nigerian Meteorological Agency (NiMet) rainfall departure classification key, Rainfall anomaly was classified as:

- less than -0.5 drier than Normal
- between -0.5 and +0.5 Normal
- Greater than +0.5: Wetter than Normal (NIMET, 2010).

Analysis of variance (ANOVA) was then used to verify the significant difference between the phases identified.

3.2.2 Crop Yield Analysis

(a) Unit Root Test

The first step in carrying out a time series analysis is to check for stationarity of the variables. A series is said to be stationary if the means and variances remain constant over time. It is referred as I (0), denoting integrated of order zero. A variable that is non-stationary is said to be integrated of order *d*, written *I (d)*, if it must be differenced *d* times to be made stationary. The Augmented Dickey Fuller (ADF) approach tests the null hypothesis that a series contain a unit root against the alternative of stationarity. If the ADF test shows that the variable is stationary in level, the variable is said to be integrated of order zero [I (0)]. If stationarity is confirmed when the variable is in first difference, then the variable is said to be integrated of order one [I (l)]; in second difference, the variable is integrated of order two [I (2)]. Since the data used is time series, unit root tests were performed using both Augmented Dickey-Fuller (ADF) (Dickey and Fuller, 1981) and Philips-Perron test to determine if the data is stationary or not.

The augmented Dickey-Fuller (ADF) test is expressed as:

$$\Delta X_t = \alpha + \alpha_1 t + \alpha_2 X_{t-1} + \sum_{i=1}^{p} b_i \, \Delta X_{t-1} + e_t \qquad - \qquad (3.4)$$

where:

X_t = the variable under consideration

Δ = First difference operator

ΔX_{t-1} = the lagged difference of X_t

t = time or trend variable, 1995-2014

a_1, a_2 and a_3 = coefficients

p = Lag number and e_t is the error term

These operations were also carried out on Annual rainfall, Temperature and length of raining season to investigate for their order of integration. The Philips-Perron test was performed to validate the results of the ADF test.

(b) Co-integration and Error Correction Model Test

Two or more variables are said to be co- integrated if each is individually non-stationary (has one or more unit roots) but there exists a linear combination of the variables that is stationary. Co-integration of two or more time series suggests that there is a long-run or equilibrium relationship between them. Two conditions must be satisfied for variables to be co-integrated. First, the series for the individual variables must be non-stationary. Second, a linear combination of the non-stationary variables from a static regression involving levels of the variables must be stationary. Although co-integration is a relationship between two non-stationary, I (1), variables, it is also possible to have a mixture of different order series when there are three or more time series variables in the model. For example, it is possible that co-integration can be present when there is a mix of *I (0)*, *I(1)* and *I(2)* variables in a model (Harris, 1995). Johanssen (1985) also found some mathematically exact and attractive results for the general case which do not rely on the assumption that all variables must be integrated of the same order before co-integration can exits. The study points out that, if X_{1t} is *I(*1) and X_{2t} is *I(0)*, then X_{1t}t and the mean of X_{2t} could be cointegrated; thus, expanding the class of variables that might be tested. The Johansen procedure was used to test for the number of co-integration vectors in the model. Johansen technique was used not only because it is vector auto-regressive based but because it performs better in multivariate model (Maddala, 2001). The co-integration model was specified as follows:

$$Y_t = \alpha + \beta_1 R + \beta_2 T + \beta_3 LRS + e_t \qquad - \qquad (3.5)$$

Where:

Y_t = cassava or yam yield in time

R = Annual rainfall (mm)

T = Mean Annual Temperature

LRS = Length of raining season

β_1, β_2 and β_3 are coefficients

If two variables are co-integrated, then their short-run dynamics can be described by Error Correction Model (ECM). The ECM developed by Engle and Granger is a means of reconciling the short run behaviour of an economic variable with its long-run behaviour (Gujarati, 1995). Granger and Engle (1985) proved that co-integrated series have an ECM representation and conversely, that ECMs generate co-integrated series, thus reconciling the two approaches as well as clarifying when levels information could be legitimately retained in econometric equations. A good time series modelling should clearly describe both short-run dynamics and the long-run equilibrium simultaneously. Komolafe, 1996; Greene, 2003; Dolado, Gonzalo and Marmol, 1999, have all shown that the existence of co-integration is an adequate condition for the incorporation of an Error Correction Term (ECT). The inclusion of ECT in a model ensures that the long run relationship is preserved. In this study, the Error Correction Model (ECM) is specified as:

$$\Delta Y_t = a_0 + a_1 \Delta R_t + a_2 \Delta T_t + a_3 \Delta LRS_t + a_4 ECt + U_t \qquad - \qquad (3.6)$$

Where:

Y_t = cassava or yam yield in time t

a_1, a_2 and a_3 = short-run effects

R_t = rainfall in time t

T_t = Temperature in time t

ECt = Error correction term

LRS_t= Length of raining season in time t

U_t = Stochastic Error term assumed to be normally distributed with zero mean and constant variance.

3.2.3 Analysis of Survey Data

Data collected from sampling survey using questionnaires were coded and statistically analysed to interpret the results using Microsoft Excel version 2013. Descriptive statistics (tables and figures) were used to characterize the farmers' socio-economic characteristics, farmers' perceptions and awareness on climate change and the factors affecting farmers' adaptation to climate change. The adaptive capacities of tuber crop farmers to climate change were estimated and categorized into high, moderate and low adaptive capacities.

A four point Likert type scale was used to determine the score levels of attributes on the farmers' adaptation strategies. Table 3.3 shows how each of the attributes was measured. The highest degree of attainment of each of the attributes affecting adaptive capacities was scored 4 whereas the lowest degree was scored 1.

Table 3.3: Score levels of attributes used to measure farmer's adaptation strategies

SCORES	ATTRIBUTES				
	Use	Knowledge	Accessibility	Availability	Consultation
4	Several	Very well	Easily accessible	Very regular	Several
3	Twice	Well	accessible	Regular	Twice
2	Once	Fairly well	Not easily accessible	Occasionally	Once
1	Never	Not well	Not accessible	Never	Never

Source: Modified from Mabe *et al*., (2012)

(a) Calculation of Adaptive Capacities of Farmers

The adaptive capacity of an ith farmer to jth adaptation strategy was calculated using Mabe *et al*., (2012) as:

$$Adap\ Cap_{ij} = \frac{K_{ij}+U_{ij}+V_{ij}+A_{ij}+C_{ij}}{N_A} \quad - \quad (3.7)$$

where;

$Adap\ Cap_{ij}$ = the adaptive capacity of an *i*th farmer to a *j*th adaptation strategy

K_{ij} = the knowledge of the *i*th farmer on *j*th adaptation strategy

U_{ij}= *the* level of usage of *j*th adaptation strategy by *i*th farmer

V_{ij} = the availability of innovations on *j*th adaptation strategy to *i*th farmer

A_{ij}= accessibility of innovations on *j*th adaptation strategy to *i*th farmer

C_{ij}= level of consultation on *j*th adaptation strategy by *i*th farmer

N_A = the sum of applicable attributes.

The average adaptive capacity of farmers to *j*th adaptation strategy was calculated as:

$$Average\ Adap\ Cap_{ij} = \frac{\sum_{\mathrm{i}}^{150}\sum_{\mathrm{j}}^{5}\mathrm{Adap\ Cap_{ij}}}{\mathrm{N}} \quad - \quad (3.7)$$

where N is the number of observation.

Based on the adaptive capacities of the attributes, three indices were established. Table 3.4 shows the categories of adaptive capacities (low, moderate and high) to which each farmer falls within. It also shows the categories of average adaptive capacities (low, moderate and high) of each adaptation technology. A farmer is lowly adaptive to adaptation strategy if the adaptive capacity calculated falls in the range of $0 < Adap\ Cap \leq 2$. The range for moderate and high adaptive capacities are $2 < \mathrm{Adap\ Cap} < 3$ and $3 \leq \mathrm{Adap\ Cap} \leq 4$ respectively.

Table 3.4: Degree of Adaptive capacities of Farmers

Degree of Adaptive Capacity	Range of Indices for Adaptive capacity	Range of Indices for Average Adaptive capacity
High	$3 \leq$ Adap Cap ≤ 4	$3 \leq$ Av. Adap Cap ≤ 4
Moderate	$2 <$ Adap Cap < 3	$2 <$ Adap Cap < 3
Low	$0 <$ Adap Cap ≤ 2	$0 <$ Adap Cap ≤ 2

Source: Modified from Mabe *et al*., (2012)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter focuses on the presentation and discussions of the results obtained from the analyses of climate, crop yield and sampling survey data which is categorised into three parts, namely, the variations in the climatic parameter, the effects of climatic parameters on tuber crop yield and farmers' adaptive capacities to climate change.

4.1 Variations in the Climatic Parameters

4.1.1 Rainfall Trend Analysis

The annual rainfall trend from 1975 to 2014 is shown in Figure 4.1. The highest rainfall amount of 1580.1mm was observed in 2014 whereas 2001 was a year of extremely low rainfall (697.7mm). It could be observed that the annual rainfall from 1978 to 1986 were below the mean annual rainfall of 1175.06mm/yr. The inter-annual rainfall variability was high from 1987 to 2003, and this may often result in climate hazards, such as drought and floods, with devastating effects on food production. These results are in line with Ayanlade *et al.* (2010) who worked on impacts of climate variability on tuber crops in Guinea Savannah part of Nigeria and reported that there is high rainfall variability in the Guinea Savannah zone of Nigeria from 1970 to 2000. From 2004 to 2014, the rainfall was generally on an increase with a mean value of 1298.16mm/yr which was above the long term mean annual rainfall value (1175.06mm/yr.), although the year 2010 and 2013 recorded a decrease in rainfall. The linear regression model showed a slight increase in the rainfall amount, depicting a positive trend with an R^2 value of 4%. This is in line with Yahaya (2012) who found out that there was an upward trend in the mean annual rainfall amount for Ilorin from 1979 to 2008 with an R value of 1.5%, 2% and 4.4% for Ilorin East, Ilorin West and Ilorin south respectively.

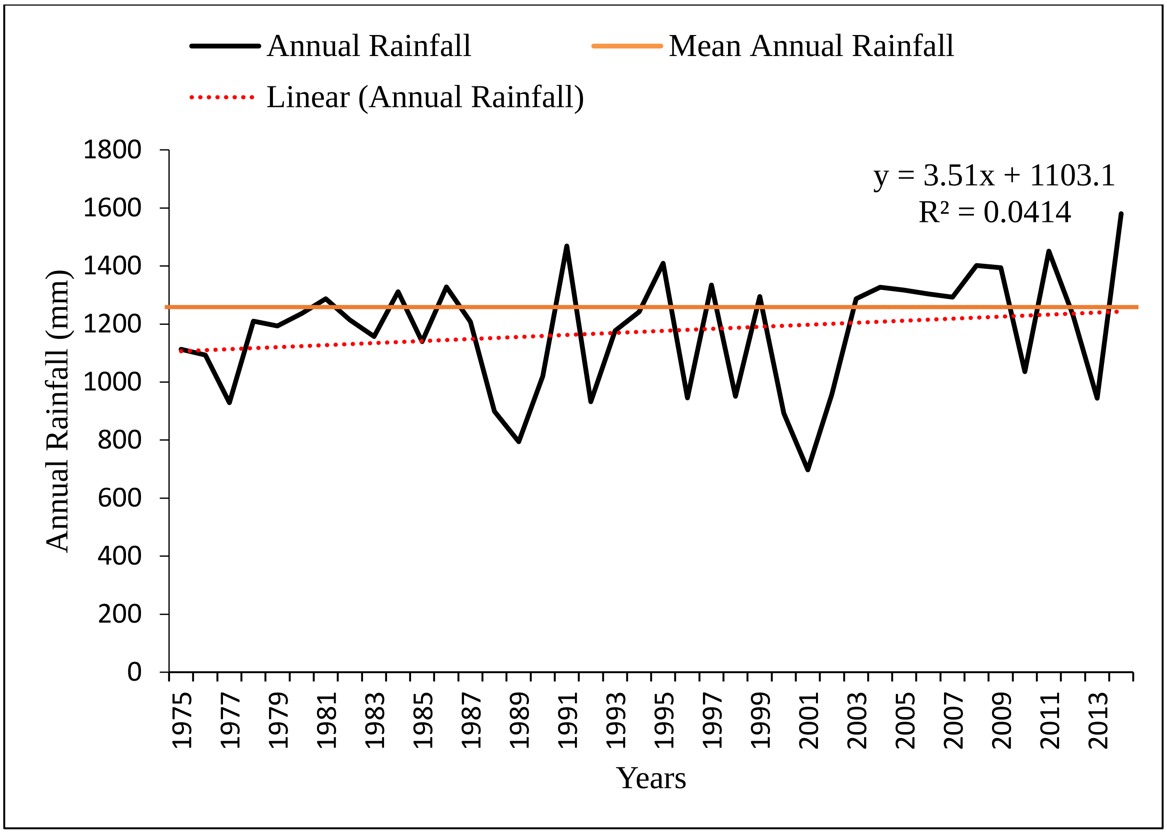

Figure 4.1: Annual rainfall series and trend line from 1975 to 2014

Adefolalu (2004) noted that the geographical location, size and shape allow West Africa to experience most of the types of weather and climate in the region. The climate of Zone C, Kwara State may also be regarded as microscopic of that of Nigeria. The total annual rainfall varied from year to year with rainfall deviation from the mean also varying from year to year.

The results of the annual rainfall anomaly for the period of study (1975 to 2014) clearly showed that there is a variability in annual rainfall (Figure 4.2). Based on Nigerian Meteorological Agency standards for classification of rainfall anomaly, the study time period was divided into three phases. Phase one (1975 to 1987) of normal years with 1186.15mm/yr of rainfall, although the year 1977 recorded a low rainfall of 928.9mm. The second phase (1988 to 2002) of drier than normal years have mean total rainfall amount of 1067.66mm/yr. However, there are exceptional individual years within the second phase that recorded high amount of rainfall such as the year 1991, 1995, 1997 and 1999. The third phase (2003 to 2014) of wetter than normal years have mean total rainfall amount of 1297.21mm/yr., though there were exceptional years like the year 2010 and 2013 with very low amount of rainfall. In general, total rainfall amount in Ilorin, Kwara State has an increasing trend. The analysis of variance (Appendix H) which compares the means of observations, shows that there is a statistical difference ($P<0.05$) between the three phases that were identified. In addition, for the period between 1975 and 2014, negative anomalies occurred 17 times indicating 42.5% of the time and positive anomalies occurred 23 times which indicates 57.5% of the time. This implies that there were more wet years than dry years.

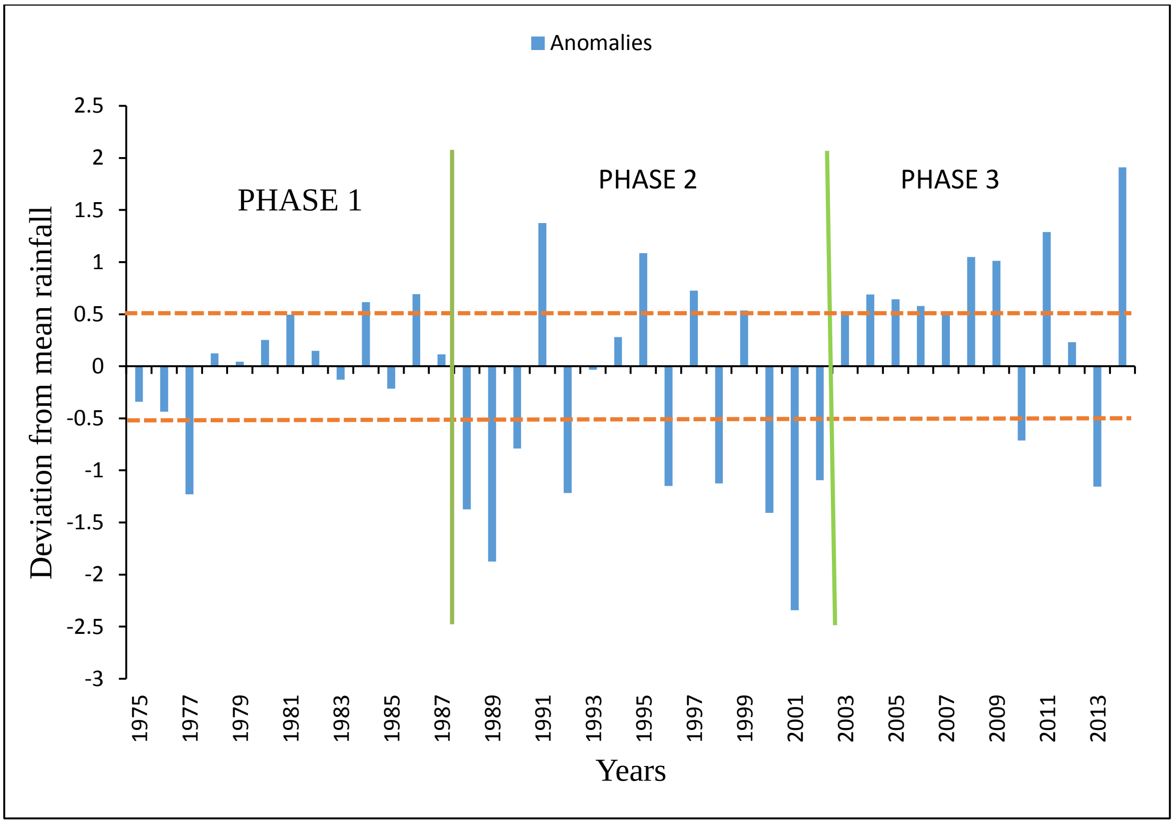

Figure 4.2: Standardized Annual Rainfall anomalies for Ilorin from 1975 to 2014

4.1.2 Variability of Onset, Cessation and Length of Raining Season

The linear trend for rainfall onset is shown in Figure 4.3. It can be seen that there is variability in the onset dates from year to year and an increasing in trend line with a positive linear trend equation (y = 0.1933x+42086). There are three types of rainfall onset as recognized by Bello (1995) and confirmed by Olanrewaju (2003) for Guinea ecological zone of Nigeria. These are; March ending downward as early onset, the periods between early and mid-April as normal onset, and late April upward as late onset. Based on this description of rainfall onset, a high frequency in early rainfall onset (19 times) was recorded from 1975 to 2014, followed by normal onset (13 times) and then late onset (8 times).

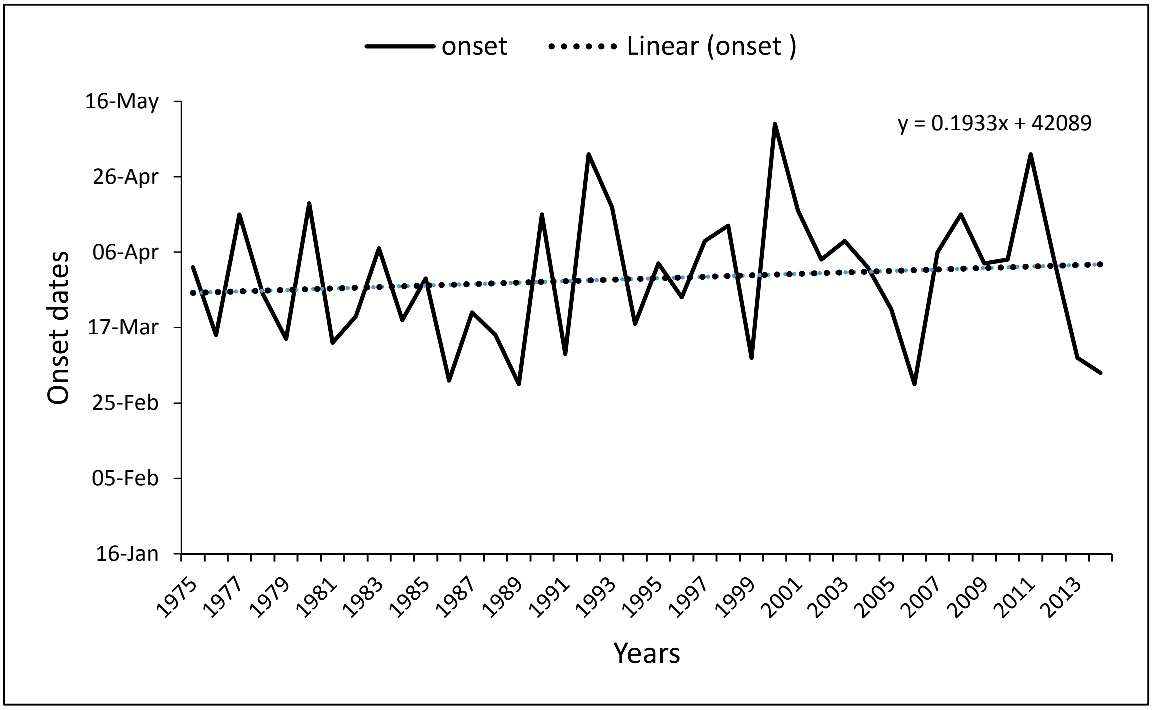

Figure 4.3: Trends in rainfall onset date from 1975 to 2014

In Agriculture, two of the most important phonological aspects of rainfall which are useful in decision making are the onset and cessation of rains. The difference between these two gives the length of the raining season (Yahaya, 2012). Table 4.1 shows rainfall characteristics for the trends of onset, cessation and length of raining season from 1975 to 2014. The earliest onset date occurred in 1989 (2nd March) while the most delayed onset date was 10th May, 2000. The mean onset date of rainfall is on 30th March. This results agrees with NSB (2009) which indicated that onset of rainfall normally occurs in late March in Kwara State. The month of March is the month of transition to wet season in Ilorin. This is because by March, the ITD had moved north of the country to about latitude 11^{o} (Yahaya, 2012). Rainfall at this period was still scanty ranging from 17 mm to 109 mm with an average of 40.98mm. This suggest that even though the rain period has started, the rainy season in terms of adequate and soil moisture is not enough for cropping purposes. This is because total evaporative loss will still be to the disadvantage of the young tender plants. The preparation and clearing of land normally commences in the month of March in readiness for the growing season. Crops such as maize and cassava fully commences in most part of the study area. Akinyeye *et al*. (1997) emphasised that the focus must be on transition month as the critical period in relation to annual cropping of farmers.

Table 4.1: Rainfall characteristics for the trends of onset, cessation and length of raining season

Variable	Earliest Date	Late Date	Mean	SD
Onset	2nd March	20th May	30th March	18
Cessation	2nd September	11th December	12th October	20
LRS (days)	120	248	197	26

SD= standard Deviation, LRS = length of raining season

Figure 4.4 shows the trends in the cessation of rainfall. There is a declined in cessation dates of rainfall as observed from the trend line equation (y = -0.4189x+42299). According to Olarewaju (2003), the last week in October is described as normal rainfall cessation, September to the third week in October as early cessation and the period of November to December as late cessation. The result shows that there is a high frequency of early rainfall cessation (65%) in Kwara State from 1975 to 2014 compared to normal (27.5%) and late rainfall cessation (7.5%). The mean cessation date of rainfall is on 12th October. This indicates that the rainfall normally ends early in Kwara State as observed by Olarewaju (2010). An early cessation will affect agriculture since these periods are critical to crop production (maturity) which may lead to crop failure.

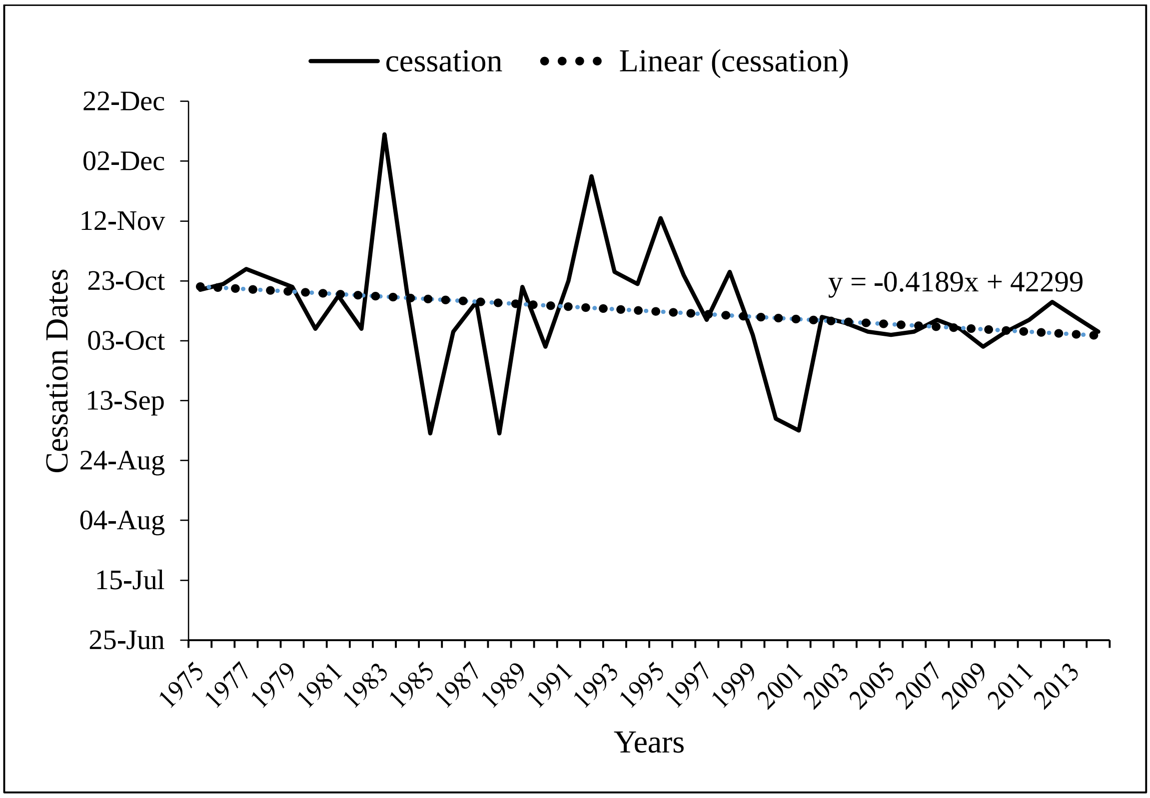

Figure 4.4: Trends in rainfall cessation from 1975 to 2014

The pattern of length of the rainy season is shown in Figure 4.5. It can be seen that there is a downward trend in length of the rainy season in the area. This is further supported by a negative trend line equation of y = -0.7338x + 211.11. This signifies that the duration of the rainy season in the study area is gradually shortening over the years. The mean length of raining season is about 197days. These findings confirmed the work of Adefolalu (2004) and Olanrewaju (2003) which indicated that there are shrinkages in the length of raining season over the study area.

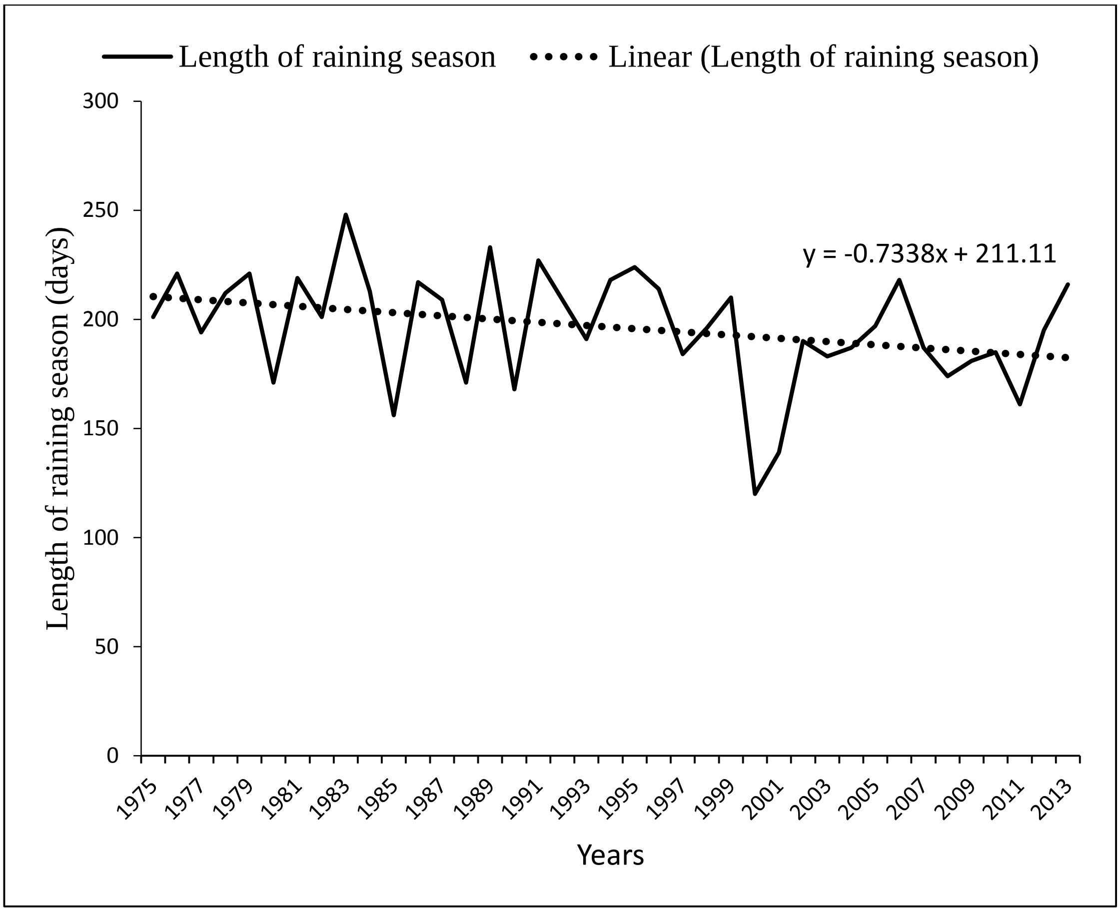

Figure 4.5: Trend in length of rainy season in Ilorin from 1975 to 2014

4.1.3 Temperature Trend Analysis

The results for temperature trend analysis for minimum and maximum temperature for Ilorin from 1985 to 2014 is presented in Figure 4.6 and Figure 4.7 respectively. The minimum temperature ranged between 21.1 ºC (1989) to 22.3 ºC (2010) with a mean value of 21.7 ºC. The lowest and highest annual maximum temperatures were 31.6ºC (1986) and 33.3ºC (2010) respectively, while the mean annual maximum temperature was found to be 32.4ºC. The results show increasing trend for both minimum and maximum temperatures with marked warming for minimum temperature. This implies that minimum temperature is increasing slightly faster than maximum temperature. From 1985 to 2014, minimum temperature had an increase of 0.0196˚C/yr in Ilorin, Kwara State, Nigeria. The minimum and maximum temperatures general upward trends observed in Ilorin, Kwara State between 1985 and 2014 corroborate the findings of Joshua *et al*. 2011, that the global trends and regional trends of the Earth temperature on average has increased.

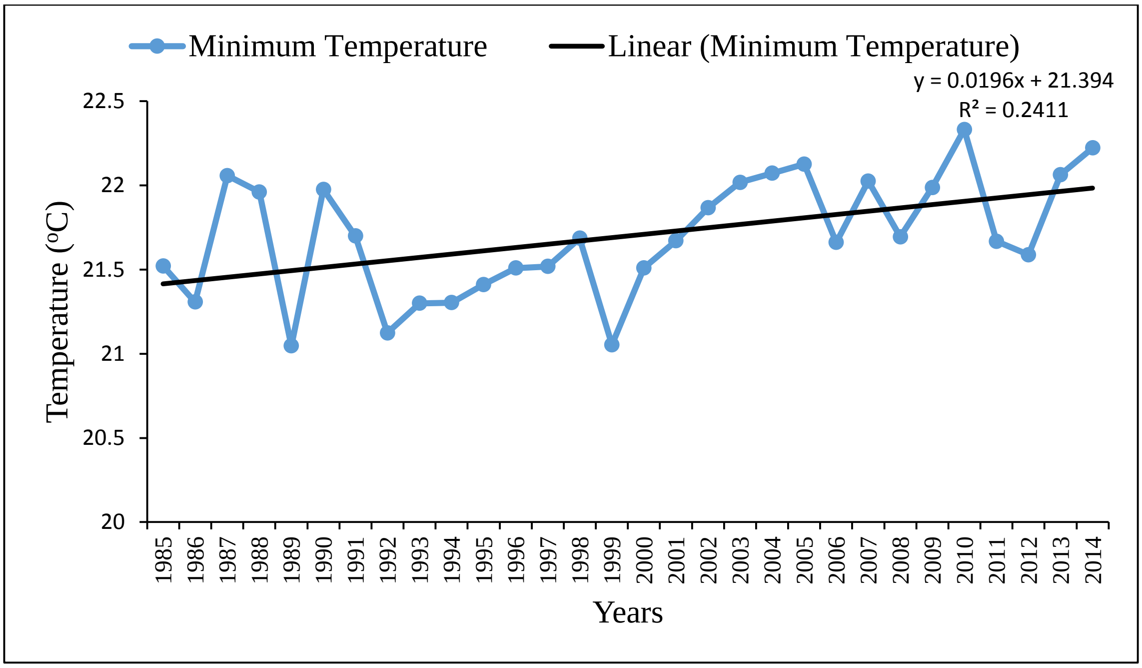

Figure 4.6: Mean Annual Minimum Temperature Trend for Ilorin from 1985 to 2014

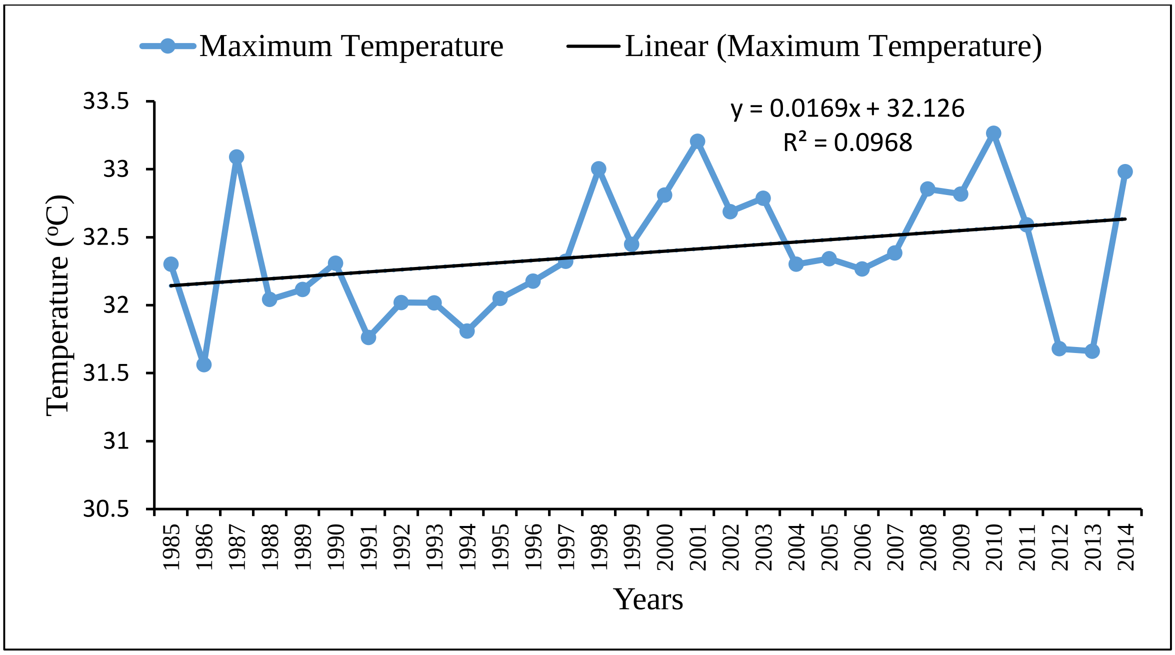

Figure 4.7: Mean Annual Maximum Temperature Trend for Ilorin from 1985 to 2014

The analyses of standardized temperature anomalies for both minimum and maximum temperatures for Ilorin from 1985 to 2014 are also presented in Figure 4.8 and Figure 4.9 respectively. Two phases were identified from the anomalies graphs for both minimum and maximum temperatures. The first phase (1985 to 2001) which shows predominantly negative anomaly in both minimum (14 times) and maximum (12 times) temperatures reflecting cooler temperatures, and second phase (2002 to 2014) which shows a predominately positive anomaly in both minimum (9 times) and maximum (7 times) temperatures indicating warming with about four years of negative anomalies period occurring within this period. Related studies in Nigeria have similarly shown different periods of warming and cooling phases over the last century (Oguntunde *et al.*, 2012). The results of ANOVA indicates that, the first phase (1985-2001) for minimum temperature having a mean value of 21.5˚C was significantly different ($P<0.05$) from the second phase (2002 to 2014) with a mean value of 22.0˚C (Appendix I). Similar observations were made for maximum temperature with the first phase (1985 to 2014) having a mean value of 32.3˚C been significantly different (P<0.05) from the second phase (2002 to 2014) with a mean value of 32.5˚C. This results confirms the findings from Falaki *et al.*, (2013), that North Central region of Nigeria is experiencing an increasing trend in temperature as well as rainfall amount. These results are also in line with a study conducted by Akinsanola and Ogunjobi (2014) on analysis of rainfall and temperature Variability over Nigeria, which revealed that there is significant increase (positive trend) in temperature in the country at 95% confidence level.

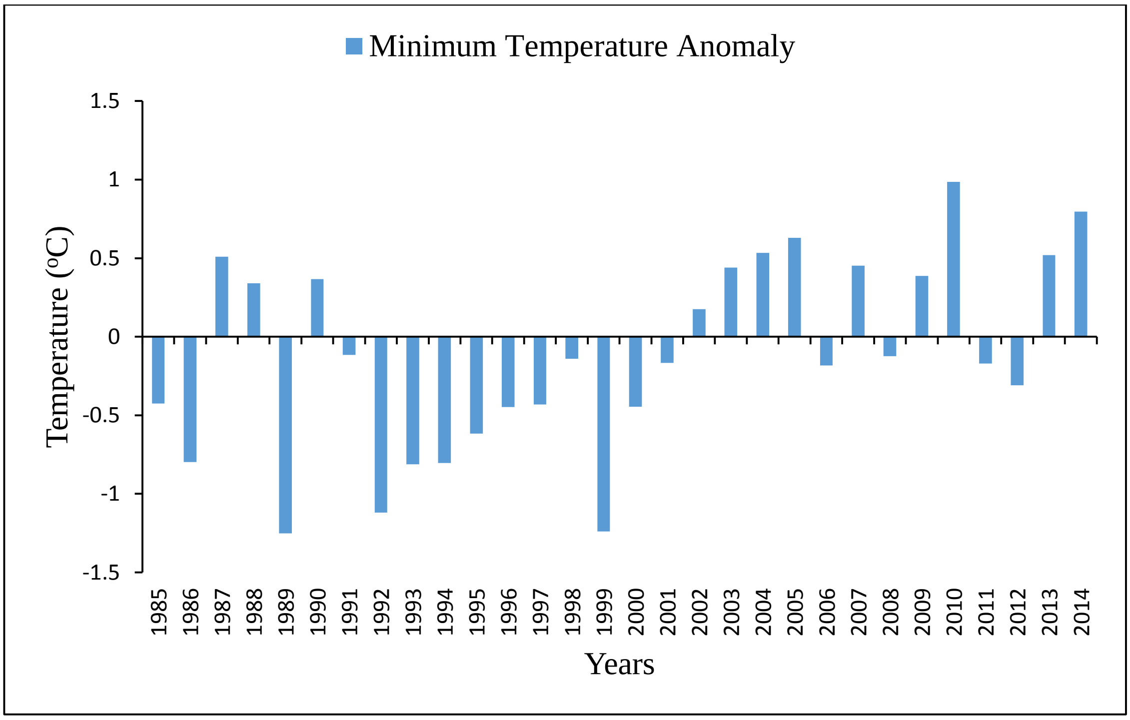

Figure 4.8: Standardized minimum annual temperature anomaly in Ilorin from 1985 to 2014

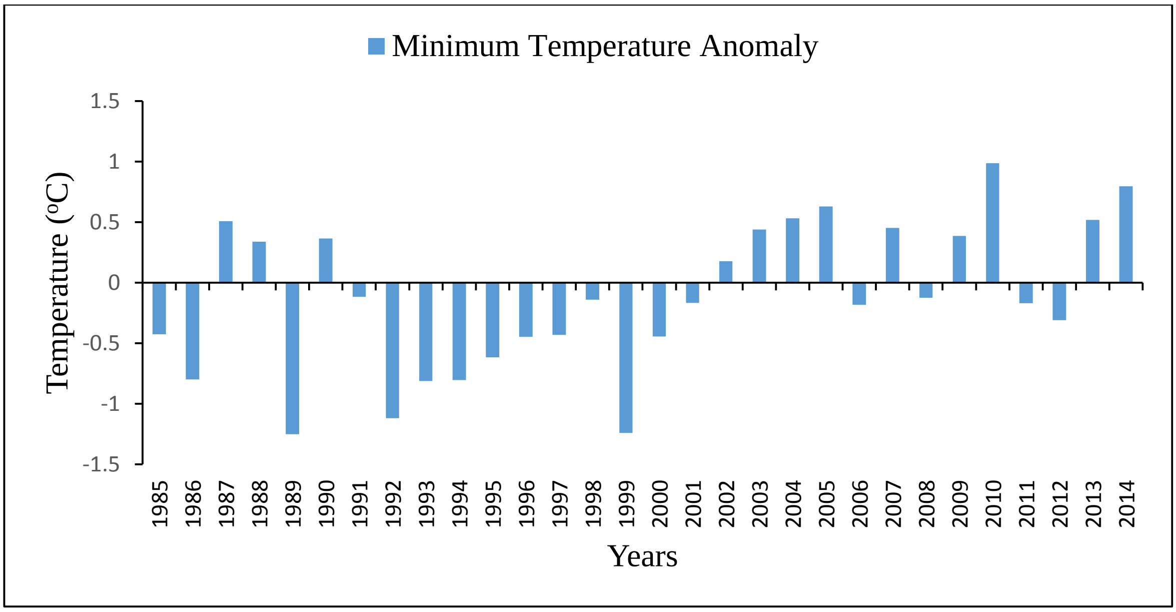

Figure 4.9: Standardized maximum annual temperature anomaly in Ilorin from 1985 to 2014

4.2 Effects of Climatic Parameters on Tuber Crop Yield

4.2.1 Tuber Crop Trend Analysis

Figure 4.10 shows the pattern and Inter-annual variations in yields of cassava and yam in Ilorin from 1995 to 2014. There is an increased in trend of both Yam and Cassava yield over the past twenty years as shown in the trend line equation. Both yam and cassava recorded their highest yield per hectare in the year 2014. The highest yield recorded by yam was 14.63 tonnes/ha and that of cassava was 17.65tonnes/ha. The lowest yield for yam (10.86tonnes/ha) was recorded in the year 2003 and the lowest yield for cassava (8.78tonnes/ha) was recorded in the year 1997.There is inter annual variation in both yam and cassava yields from 1991 to 2002 and then gradual increased in trend from 2003 to 2014. Cassava recorded a sharp increase in yield from 2005 to 2008 and then a linear trend increased from 2009 to 2014.

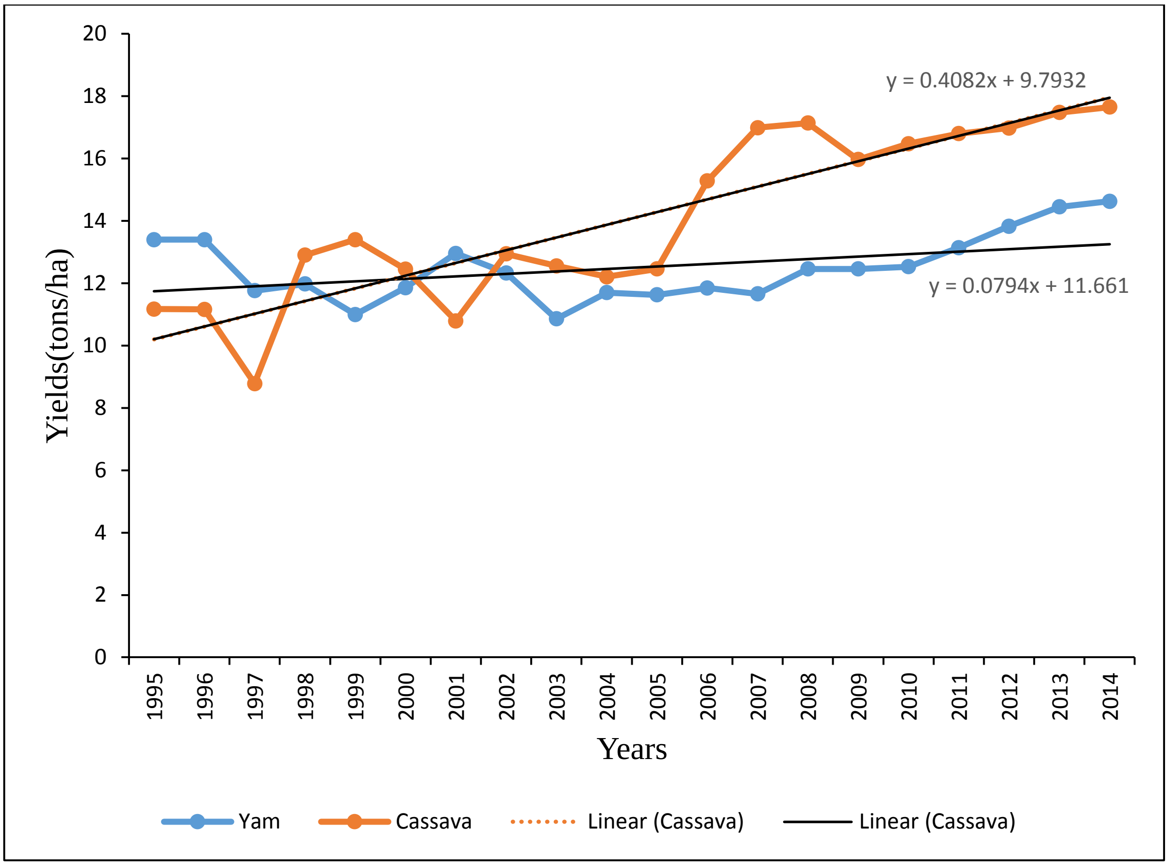

Figure 4.10: Trend of yam and cassava yield in Ilorin from 1995 to 2014

4.2.2 **Empirical Results of Stationarity Tests**

Before the econometric estimations, unit root tests using the Augmented Dickey-Fuller (ADF) (Appendix B) and Philip-Perron test (Appendix C) were conducted to find out whether the data were stationary or not stationary, and the order of integration. The two tests were performed, because they make different assumptions about the residuals from the auxiliary regression. Whereas Dickey-Fuller (1979) class of tests assumes that the residuals from the auxiliary regression are white noise, the Philips-Perron (1998) makes no assumption about these residuals.

The results of ADF test are presented in Table 4.2. Column 2 of Table 4.2 shows the type of ADF model used for each variable tested for stationarity. The Philip-Perron test was also performed to validate the Augmented Dickey-Fuller (ADF) test. The results of the Phillip-Perron test (Table 4.3) are consistent with the results of the Augmented Dickey-Fuller test. In all the tests performed, both Augmented Dickey-Fuller (ADF) and Phillip-Perron test, the null hypothesis that there is a unit root or data is not stationary were rejected for rainfall and temperature at levels, but was rejected for length of raining season, cassava and yam yield at first difference. Both Column 5 of Table 4.2 and Table 4.3 showed clearly that climate variables are integrated of order zero, I(0), while the length of raining season, yam and cassava yields are integrated of order one.

Table 4.2: Results of Unit Root Test (Augmented Dickey-Fuller) from 1995 to 2014

Variable	Model	t-statistics at Levels	t-statistics at 1st Difference	Order	Decision
Annual Rainfall	T and I	-4.453*	-------	I (0)	Stationary at levels
	I	-3.905*	--------	I (0)	Stationary at levels
Temperature	T and I	-3.692*	--------	I (0)	Stationary at levels
	I	-3.381*	---------	I (0)	Stationary at levels
Length of Raining Season	T and I	-2.884	-5.585*	I (1)	Stationary at 1st difference
	I	-3.004	-5.335*	I (1)	Stationary at 1st difference
Yam	T and I	-1.806	-5.512*	I (1)	Stationary at 1st difference
	I	-1.198	-4.320*	I (1)	Stationary at 1st difference
Cassava	T and I	-3.206	-4.932*	I (1)	Stationary at 1st difference
	I	-0.874	-5.132*	I (1)	Stationary at 1st difference

Source: Author's Computation
Mackinnon Tables were used for the rejection of critical values
T and I represents Trends and Intercept; I represent Intercept, * Represents 5% significant level

Table 4. 3: Results of Unit Root Test (Phillip-Perron) from 1995 to 2014

Variable	Model	t-statistics at Levels	t-statistics at 1st Difference	Order	Decision
Annual Rainfall	T and I	-4.453*		I (0)	Stationary at levels
	I	-3.839*		I (0)	Stationary at levels
Temperature	T and I	-3.900*		I (0)	Stationary at levels
	I	-3.473*		I (0)	Stationary at levels
Length of Raining Season	T and I	-2.987	-4.751*	I (1)	Stationary at 1st difference
	I	-3.064	-4.544*	I (1)	Stationary at 1st difference
Yam	T and I	-1.976	-4.131*	I (1)	Stationary at 1st difference
	I	-1.108	-3.586*	I (1)	Stationary at 1st difference
Cassava	T and I	-3.239	-4.780*	I (1)	Stationary at 1st difference
	I	-1.106	-4.947*	I (1)	Stationary at 1st difference

Source: extracted from Stata print out
Mackinnon Tables were used for the rejection of critical values
T and I represents Trends and Intercept
I represent Intercept only, * Represents 5% significant level

4.2.3 **Empirical Results of Co-integration Tests**

The first step of the Johansen procedure was to determine the lag number for the model. The Akaike Information Criteria (AIC), L I and HQIC recommended the number of lags for the co-integration test to be 2 (Appendix D). Table 4.4 shows the Johansen co-integration results which indicates the number of co-integrating vectors among the variables. The maximum rank (r) indicates the null hypothesis. When r = 0, it means that there is no co-integration between the variables and when r = 1, 2, 3 and 4, it means there is 1, 2, 3 and 4 co-integration between the variables respectively. When the trace statistics is more than 5% of the critical value, the Null hypothesis is rejected and the alternative hypothesis is accepted. Based on the results in Table 4.4, the null hypothesis of zero co-integrating vectors at 95-pecent level can be rejected. The trace statistics for r = 2 is 15.7447 which is greater than its 5% critical value. This means that the null hypothesis can be rejected at r =2, indicating that there exist at most 2 co-integrating vectors at 5% level. Hence there is a long run relationship between the variables.

Table 4.4: Trace Statistics Test for number of Co-integrating Vectors for Yam

Maximum rank (r)	Eigenvalue	Trace statistics	5% critical value
0	---------	54.5635	47.21
1	0.73446	32.0220	29.68
2	0.61614	15.7447	15.41
3	0.54459	2.3733*	3.76
4	0.13030	---------	------

* indicates where the null is accepted using the Pantula principle
Number of lag =2, model type: a model with unrestricted constant
Source: extracted from Stata print out

The results of trace Statistics test for number of co-integrating vectors for Cassava is presented in table 4.5. The null hypothesis was rejected for r = 0 because the value of trace statistics (53.6913) was higher than the 5% critical value (47.21). But at r =1, the trace statistics value (26.1503) was lower than the 5% critical value (29.68). Hence the null hypothesis was accepted. This means that there exist one co-integration between the variables indicating a long run relationship between the variables. The Johansen model is a form of error correction model and, where only one co-integrating vector exists, its parameters can be interpreted as estimates of the long-run co-integrating relationship between the variables concerned (Hallam and Zanoli, 1993).

Table 4.5: Trace Statistics Test for number of co-integrating vectors for Cassava

Maximum rank (r)	Eigenvalue	Trace statistics	5% critical value
0	--------	53.6913	47.21
1	0.80211	26.1503*	29.68
2	0.55607	12.3446	15.41
3	0.44476	2.3425	3.76
4	0.12872	--------	-------

* indicates where the null is accepted using the Pantula principle
Number of lag =2, model type: a model with unrestricted constant
Source: extracted from Stata print out

4.2.4 Results of Vector Error Correction Modelling

The error correction model provides a useful link between long-run equilibrium relationships and short-run (disequilibria) dynamics (Gujarati, 1995). Since the variables are co-integrated, VECM were then performed for each co-integrating vector (Appendix F). The specification of the ECM involves expressing the first difference of both yam and cassava yields as a function of the independent variables (Annual rainfall, mean annual temperature and length of raining season) in a co-integration equation, as well as the equilibrium error term called the error correction term. The error correction model estimates for yam is presented in Table 4.6. The results indicates that yam yield is affected positively by rainfall and temperature but negatively by length of raining season. The positive coefficient of rainfall (0.0004062) significant at 5% indicates a positive relationship between rainfall and yam yield. This means that an increase in rainfall during the growth period of yam tends to stimulate an increase in yam yield, whereas a reduction in rainfall will decrease yam yield in that particular year. However there was no significant relationship between temperature and yam production, which agrees with the finding of Ayende, Ajewole, Ogunlade and Adewunmi (2010), that there is no significant relationship between temperature and agricultural production in Nigeria.

Also, the negative relationship between LRS and yam yield was not significant at 5% level. The R^2 value of 0.79 indicates that the model explains 79% of variation in the yield of yam. The coefficient of the error correction term (ECt) has the expected negative sign and was significant at 5% level. This confirms that there is a long run relationship between yam yield, rainfall, temperature and length of raining season. The results of diagnostic check performed on the model indicates that there is no serial auto correlation between the variables as shown by the Lagrange multiplier test with a probability value of more than 0.05 (0.719). The residual normality was also verified for normally distribution and the probability of Jarque Bera test (0.9403) for all variables was greater than 5% level, hence the residuals are normally distributed. Therefore the model is accepted.

Table 4.6: Error correction model estimates for yam

Variable	Coefficient	Standard Error	z-Statistics	Probability
Rainfall	0.0004062*	0.000972	-0.42	0.006
Temperature	0.0282127	0.2602551	0.11	0.914
Δ LRS	-0.0057738	0.0062912	-0.92	0.359
ECt	-0.082422	0.4409185	-2.29	0.022
Constant	0.2399287	0.1743826	1.38	0.169
R^2= 0.79; Prob(Lagrange multiplier test) = 0.719 Prob(Jarque Bera test) = 0.9403				

Source: extracted from Stata print out

Δ LRS denotes Length of raining season; ECt denotes Error correction term; * denotes significant at 5% level.

The results for error correction model for that of cassava is presented in Table 4.7. The results showed that there is a long run causality between cassava yield, rainfall, temperature and length of raining season as indicated by the Error correction term (ECt) value of –0.0566743 and is significant at 5% level. The results shows a negative coefficient between rainfall (-0.0019732) and cassava but not significant at 5% level. However, the coefficient of length of raining season (0.0226374) was found to be positive and significant. This means that an increase or decrease in length of raining season would lead to an increase or decrease in the yield of Cassava by 0.023 tonnes per year. Also, the coefficient of mean annual temperature was found to be negative and significant. This means that an increase in temperature will results in a 2.359 decrease in cassava yield per year. The coefficient of determination (R^2) of cassava is 0.73, thus the independent variables explain 73% of the variations in the dependent variable. Both Lagrange multiplier test and Jarque Bera test were also performed as diagnostic check to verify the model (Appendix G) and the results indicates that there was no autocorrelation and the residuals are also normally distributed at 5% level as shown in Table 4.7.

Table 4.7: Error correction model estimates for Cassava

Variable	Coefficient	Standard Error	z-Statistics	Probability
Rainfall	-0.0019732	0.0018055	-1.09	0.27
Temperature	-2.359864*	0.5859489	-4.03	0.000
Δ LRS	0.0226374*	0.0113042	2.00	0.045
ECt	-0.0566743	0.0550128	-1.03	0.303
Constant	0.043532	0.3866241	0.11	0.910
R^2= 0.73; Prob (Lagrange multiplier test) = 0.1078 Prob(Jarque Bera test) = 0.9733				

Δ LRS denotes Length of raining season; ECt denotes Error correction term
Source: extracted from Stata print out * denotes significant at 5% level.

4.3 Farmers' Adaptive Capacity to Climate Change

4.3.1 Farmers' Socio-economic Characteristics

Table 4.8 reveals the socio-economic characteristics of cassava and yam farmers. Majority of the respondents (92%) are males. This implies that root and tuber crop production in Kwara State is mostly dominated by males due to the labour intensive nature of yam and cassava production. About 5.3 % of the respondents were above 60 years of age whiles majority of the respondents (94.7%) were within the age of 40 to 60 years. The average age of the respondents was 48 years which indicates that majority of the respondents are economically active. This means that people at the age from 40 to 60 years are more involved in farming and this explains that they would have substantial amount of knowledge and awareness of climate change. The literacy level was observed to be high, about 78% of respondents were educated while 22% had no education. The average years of schooling of the respondents as estimated by this study was about 7 years. This implies that majority of them attended Secondary schools or its equivalents.

In agricultural production, education is an important factor in adoption of improved technologies in increasing crop yield. This is to say that large proportion of the sample have the primary understanding of the climate variables in relation to agricultural production and also explains that they are aware of climate variability and change. Majority of the respondents (72%) maintain a family household size greater than 5 whiles 28 % of the respondents have household size from 1 to 5. The average household size of the respondents was about 7. The implication for the household size of more than 5 people is that, there will be more hands to help in agricultural activities which is evident from the sources of labour used in crop production that indicates that majority of respondents (65.33%) use the household (self and family) as a source of labour.

Again, 65.3% of the farmers belonged to social organization such as farmers Association, while 34.6% of them do not belong to any. Majority of the respondents (91.3%) had between 0.3 to 3 hectares of yam farm land while those that had above 3 hectares accounted for 8.7%. The result shows that many of the respondents were small scale farmers and that farm size is a critical factor influencing the output of farmers. This is in agreement with similar result obtained by Olayide, (1990) who categorized small scale farmers as ranging from 0.2 hectares to 9 hectares holding in Nigeria.

Table 4.8: Frequency Distribution of Respondents by their Socio-economic Characteristics

Variables	Frequency	Percentage
Gender		
Male	130	86.7
Female	20	13.3
Age (years)		
40-60	142	94.7
>60	8	5.3
	Mean Age = 48 years	
Level of Education		
No formal Education	33	22.0
Basic (primary- JHS)	55	36.7
Secondary/vocational	39	26.0
Tertiary	23	15.3
Household Size		
1- 5	42	28.0
Greater than 5	108	72.0
Member of Farmers Association		
membership	98	65.3
no membership	52	34.7
FARM SIZE		
0.3 -3 Hectares	137	91.3
Above 3 Hectares	13	8.7
Sources of Labour		
family and self	98	65.3
Hired	52	34.7

Source: Field Computation, 2015

4.3.2 Tuber Crop Farmers' Awareness and Perception of Climate Change

Table 4.9 shows the farmers awareness of climate change in the past 30 years. Majority of the respondents (91.3%) are aware of climate change while 8.3% are not aware of climate change in the study area. Concerning their sources of awareness, majority of the respondents (62.7%) indicated sources of awareness through their own observation, 27% were through radio and 5.1% through family and friends. However, none of the respondents reported to have access to climate change information through extension officers. Although extension officers have the vital role of advisory and technical knowledge for the development of the entire community but this role was not well played on climate change issues.

Table 4.9: Distribution of Respondents awareness and source of awareness of Climate Change

Variables	Frequency	Percentage
Awareness		
Aware	137	91.3
Not Aware	13	8.7
Sources of Awareness		
Own observation	86	62.8
Radio	37	27.0
Friends and family	7	5.1
Researches	4	2.9
NGO	3	2.2

Source: Field Computation, 2015

The farmers were asked about their perception on climate change for the past 30 years. According to Diggs (1991) and West *et al*. (2007), climate change is perceived differently at different levels of conceptualization and it varies with age, education, location and livelihood activity. Table 4.10 shows the farmers' perception of climate change. About 92% of the respondents perceived an increase in temperature over the years. This is consistent with meteorological data which showed an increase in both minimum and maximum temperature over the last thirty years. About 56.2% of the respondents observed an increased in rainfall whiles 43.8 % indicated a decreased in rainfall. The closeness of these percentages can be explained by the high inter –annual rainfall variability in the study area. Although the majority (56.2%) observation of an increase in rainfall is consistent with the meteorological data which indicated an increase in rainfall amount over the last forty years. The onset of the rainy season was perceived by 58.67% of respondents to be early, while 50% of respondents perceived cessation of the rains to be early, making the length of rainy season shorter according to 82% of respondents. Moreover, 73.3% of respondents observed an increased in occurrence of dry spells whiles 26.6% indicated a decreased in dry spells over the past years.

The result of the majority of the respondents perceived higher temperature for the last years agrees with the findings from Otitoju (2013) who noted that majority of the respondents (92.2%) in south-western Nigeria perceived an increase in the temperature over the last two decades.

Table 4.10: Respondents Perception of Climate change

Variables	Frequency	Percentage
Increase in temperature	138	92.0
Decrease in temperature	12	8.0
Increase in rainfall amount	77	56.2
Decrease in rainfall amount	73	43.8
Early Onset of rainfall	88	58.7
Normal Onset	17	11.3
Late Onset	45	30.0
Early Cessation	75	50.0
Normal Cessation	24	16.0
Late Cessation	51	34.0
Increase in Length of raining season	27	18.0
Decrease in Length of raining season	123	82.0
Increase in dry spell	110	73.3
Decrease in dry spell	40	26.7

Source: Field Computation, 2015

A comparison of farmers' perception of climate variability and change in the three selected Local Government Areas is shown in Figure 4.11. Analysis of the graph indicates that the perceptions of respondents on certain climate parameters are slightly different. The respondents in Asa (57.63%) and Moro (60%) indicated an increase in rainfall amount whiles those from Ilorin East (65.85%) rather observed a decrease in rainfall amount. All the respondents from the three Local Government Areas reported an increase in both temperature and dry spells in the last 30 years. Whiles about 90% and 47.5% of the respondents in Moro and Asa Local Government Areas respectively indicated an early onset of rainfall, the respondents from Ilorin East (53.65%) rather believe the rain starts late. Also, whiles about 68.29% and 58% of respondents from Ilorin East and Moro respectively indicated a decrease in length of raining season, 54.24% of respondents in Asa believe that there is an increase in length of raining season. Although some climate variables were observed differently by some local governments, but in general the observations made by most of the respondents is in line with the analysis of the observed climatic data.

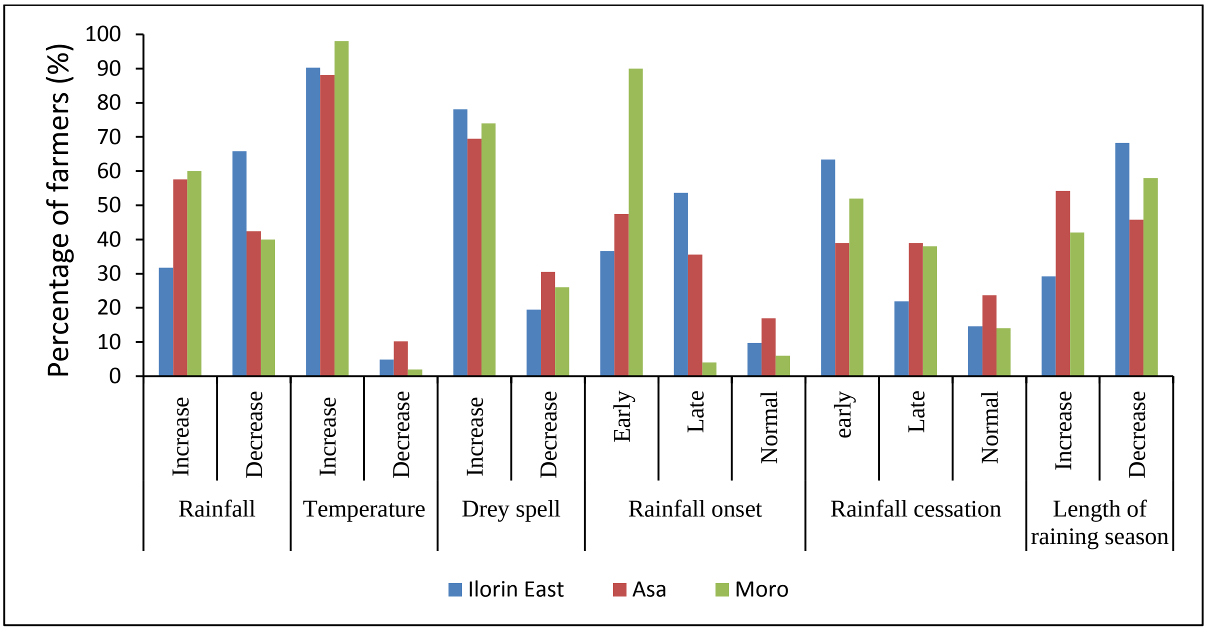

Figure 4.11 Farmers' Perception of climate variability and change for the selected Local Government Areas in Kwara State.

4.3.3 Tuber Crop Farmers' Adaptation Strategies to Climate Change Effects

Adaptation to climate change is a two-step process, which initially requires the perception that climate is changing and then responding to changes through adaptation. Therefore, after assessing farmers' perception and awareness on climate change, their adaptation strategies were also measured. In adapting to climate change and variations in agriculture, farmers were applying their own experiences, resources and information from the organizational level to cope with the effects of climate change. Table 4.4 shows that farmers in the various communities are adopting a variety of adaptation strategies in their farming practices to deal with the impact of climate change. All the adaptation strategies examined were highly practised by majority of the farmers with the exception of farm yard manure where only 40.7% of the respondents indicated its use as an adaptation strategy. Similar findings were obtained by Sangotegbe *et al.,* (2012) that the most commonly adopted adaptation measure to climate change by food crop farmers in Oke-Ogun area of South Western Nigeria are: mulching, planting different crops, changing planting dates and planting different crop varieties. It was observed that the farm practices especially planting dates were highly changing (96%) from season to season due to unreliability of rainfall. Most farmers did planting after the second rain in order to minimize risk of wasting their inputs in cases where the first rain ceases. Also, changes in temperature and rainfall may require farmers to use new varieties or alter cropping patterns (Johnston *et al*., 2009), especially if they want to continue meeting their dual objectives of output and profit maximization as indicated in table 4.4 that, majority of the respondents interviewed uses both early maturing and drought tolerant crop varieties as a result of changing climatic conditions.

This study also confirms the findings of Rudolf and Hermann (2009) and Apata *et al* (2009) that the main strategies for reducing climate risk is to diversify production and use of soil and water management measures to maintain adequate crop yields. Other attributes such as Knowledge, accessibility, availability and consultation were also assessed (Table 4.11). The results indicates that majority of the farmers had knowledge about the adaptation strategies that they were using except the use of farm yard manure were 56% indicated that they have no knowledge about it. Similar results was also noticed in terms of accessibility, availability and consultation of each of the adaptation strategies.

Table 4.11: Distribution (%) of respondents according to their adaptation strategies for each attributes (n=150)

Adaptation strategies	Use		Knowledge		Accessibility		Availability		Consultation	
	use	NU	well	NW	AC	NAC	AV	NA	Con	NC
Early maturing yam variety	88.7	11.3	86.0	14.0	84.0	16.0	85.3	14.7	80.0	20.0
Mulching	78.7	21.3	80.7	19.3	81.3	18.7	82.0	18.0	78.7	21.3
Drought tolerant yam variety	84.0	16.0	86.0	14.0	83.3	16.7	82.0	18.0	82.7	17.3
Application of farm yard manure	40.7	59.3	44.0	56.0	46.0	54.0	45.3	54.7	42.0	58.0
Weather forecast	77.3	22.7	78.7	21.3	72.7	27.3	73.3	26.7	76.7	23.3
Changing planting date	96.0	4.0	94.7	5.3	96.7	3.3	97.3	2.7	89.3	10.7
Higher yielding yam variety	82.7	17.3	85.3	14.7	86.0	14.0	88.7	11.3	80.0	20.0
Drought tolerant Cassava variety	86.0	14.0	87.3	12.7	84.7	15.3	85.3	14.7	81.3	18.7
Early maturing Cassava variety	89.3	10.7	91.3	8.7	90.7	9.3	90.0	10.0	89.3	10.7
Multiple cropping	93.3	6.7	92.7	7.3	96.7	3.3	94.0	6.0	82.7	17.3

Source: Computation from field data (2015)

NU=Not Use, NW= Not well, AC= accessible, NAC= not accessible, AV= available, NA= not available, Con= Consultation, NC= never consulted

The level of the adaptation strategies used by the farmers were also examined. The degree of adaptive capacities of tuber crop farmers to the various adaptation strategies are presented in Table 4.12. The respondents interviewed were highly adaptive to the use of multiple cropping (3.43), Changing planting date (3.25) and drought tolerant cassava variety (3.17) with their adaptive capacities falling within the within the range of $3 \leq adapCap \leq 4$. The adaptation strategies with moderate adaptive capacities are planting of early maturing yam variety, early maturing Cassava variety, planting of higher yielding yam variety and Drought tolerant yam variety. Out of the 10 adaptation strategies considered, farmers are moderately adapting to 5 of them. The respondents in the area have low adaptive capacity to the use of farm yard manure with an adaptive capacity value of 1.87. This is due to its low availability and accessibility. Generally, the average adaptive capacity of the respondents is 2.92. This implies that tuber crop farmers in the study area are moderate adapters to climate change. This study is in agreement with Mabe *et al*. (2012) who found out that rice farmers in the Northern region of Ghana are moderately adaptive to climate change.

Table 4.12: Degree of Adaptive Capacities of Tuber Crop Farmers

Adaptation strategies	Adaptive Capacity	Degree of Adaptive capacity	Rank
Multiple cropping	3.43	High	1
Changing planting date	3.25	High	2
Drought tolerant Cassava variety	3.17	High	3
Mulching	3.09	High	4
planting of early maturing yam variety	2.95	Moderate	5
Planting of early maturing Cassava variety	2.93	Moderate	6
Planting of higher yielding yam variety	2.89	Moderate	7
Drought tolerant yam variety	2.83	Moderate	8
Weather forecast	2.75	Moderate	9
Application of farm yard manure	1.87	Low	10
AVERAGE	2.92	Moderate	

Source: Computation from field data (2015)

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Crop production have been the main sustenance of Nigeria's economy before the advent of crude oil. Its importance over the sustainability of life cannot be over-emphasized. The productivity of tuber crops under the changing climatic conditions were evaluated. The statistical analysis of Annual rainfall data for the period of forty years (1975 to 2014) showed that rainfall is characterized by large inter-annual variability especially from 1987 to 2013 with a linear increase in trend ($R^2 = 4\%$), indicating that Kwara State, Zone C is becoming wetter. The findings also revealed that the mean onset date of rain occurs in 30th of March. This implies that land preparation for cassava and yam can be embarked upon and planting can also be carried out during this period. The onset and Cessation of rainfall were examined to determine the length of the raining season and the results shows that there is a gradual decrease in length of the raining season. The results of minimum and maximum temperature analysis for Ilorin from 1985 to 2014 shows a statistically increasing trend at 95% confidence level with minimum temperature increasing at a faster rate compared to maximum temperature indicating that Ilorin is becoming warmer.

The results obtained from the analysis of rainfall, temperature and length of raining season impact on tuber crop yield (cassava and yam) from 1995 to 2014 using co-integration and VECM techniques indicates that tuber crop yield (cassava and yam) and rainfall, temperature and LRS were all co-integrated and there were both short run and long run causalities running between the variables. The output of yam was found to have a significant positive relationship with the amount of rainfall which shows that the production of these commodities irrespective of their increasing output was still dependent on the amount of rainfall. However, there was a negative relationship between cassava yield and rainfall though was not significant but temperature and length of raining season were significant in cassava model. Hence, increase in temperature and shortening of length of raining season will adversely affect the yield of cassava.

Farmers' perception on climate variability were compared with the actual variations based on the scientific data obtained from the analysis of climate. The results shows that majority of the respondents (91.3%) are aware of climate change with more than 92% of farmers indicating that temperature in the area had increased and about 56.2% of the respondents indicating that rainfall has also been on an increase. Although some climate variables were observed differently by some local governments, but in general the observations made by most of the respondents such as increase in temperature and rainfall are in line with the observed climatic data. Moreover, the average adaptive capacity of the respondent was moderate (2.92), but majority of the respondents were highly adaptive to some individual adaptation strategies which are positively reflecting the trend of tuber crop yield in the area which shows an increasing trend.

5.2 RECOMMENDATION

Though the rainfall trend is increasing, the main challenge is the distribution of rainfall amount and the shortening of raining the season. These results obtained show that adaptation to climate change in Kwara State Nigeria is important if tuber crops farmers are to increase productivity. There is need for putting in place policies and programmes that will make the food crop farmers to be proactive in the use of resources and at the same time adapting to climate change. Particularly the following recommendations are proffered:

(1) The use of short duration crop varieties and drought tolerant varieties should be encourage by farmers due to the gradual decreasing in the length of raining season in Kwara State.

(2) Climate change adaptation strategies that would ensure optimal temperatures, enhanced soil moisture availability for crop use against short dry spells and ensure sustainable agricultural productivity are advocated to mitigate effect of climate change.

(3) The extension programme aspect of climate change adaptation strategies policy in Kwara State should focus much more on the bottom-up participatory approach so that the indigenous and the emerging adaptation strategies and technologies can be focused in the various agro-ecologies since climate differ across ecologies.

(4) This study assessed only the adaptive capacity of cassava and yam farmers and hence future research should consider the effects of adaptive capacities of farmers on the output of tuber crops and other food crops which are major staples produced in the region.

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APPENDICES

Appendix A: QUESTIONNAIRE OF THE SURVEY

Perceptions and Adaptive capacity of tuber crops farmers to climate change adaptation strategies in Kwara state, Nigeria

WASCAL Program, Isaac Larbi talarbi18@yahoo.com

SECTION A: SITE INFORMATION

Questionnaire ID… Date: ___/___/___

Name of the Community: ………………………..

State: ……………… Local Government Area (LGA): …..................

GPS co-ordinate point: Latitude ______ S and Longitude ______ E

SECTION B : FARMER'S PROFILE

1. Name of respondent: [...]
2. Sex of respondent [ ] 1= Male 0 = Female
3. Age of respondent: 40 – 60 [.....................................]
4. Household size: [………………………]
5. Number of years spent in formal education of respondent :

   (a) None = 0 [ ] (b) basic (primary/JSS) = 1 – 6 years [ ]

   (c) Secondary (secondary/ Vocational) = 7-9 years [ ] (d) Tertiary (Training College/ Polytechnic/ University) 10 – 15 years = [ ]

SECTION C: FARMERS' AWARENESS AND PERCEPTION OF CLIMATE CHANGE

6. Are you aware or heard that climate has changed or is changing? (a) Yes (b) No (c) Do not know
7. If yes, from where have you heard about climate change? (a) own observation (b) radio (c) NGO working in the area (d) Researchers (e) told by neighbours/friends/family (f) others specify………

8. What are your observations about the following climatic parameters for the past 20years?

Rainfall amount	Increased [ ]	Decreased [ ]	The same [ ]	Don’t know [ ]
Onset of rainfall	Early onset [ ]	Late onset [ ]	Normal [ ]	Don’t know [ ]
Cessation of rainfall	Early Cessation [ ]	Late [ ]	Normal [ ]	Don’t know[ ]
Length of growing season	Increased [ ]	Decreased	The same [ ]	Don’t know[ ]
Temperature	Increased [ ]	Decreased	The same [ ]	Don’t know [ ]
Frequency of prolonged dry spells	Increased [ ]	Decreased[ ]	Normal [ ]	Don’t know [ ]

SECTION D: TUBER CROP PRODUCTION

9. Which of the following tuber crops do you cultivate?

a) Cassava [ ] b) Yam [ ] c) Cassava and yam [ ]

10. What is the size of your farm for the crop production? [..................................... hectares]

11. How many cassava stems do you cultivate in a year? [ ]

12. How many yam seeds do you cultivate in a year? [ ]

13. How much do you invest in crop production? [ ]

14. What is your source of labor? (a) self (b) family (c) hired

15. How much do you contribute in total to cost of labor during farming? [..Naira]

16. Do you apply fertilizer on your crops (Cassava and yam)? Yes = 1 No = 0

17. How much do you spent on fertilizer? [………………………naira]

18. What is your output of tuber crop in a year? Cassava [.................] Yam [...........................]

19. How much do you gain from your tuber crops production? Cassava [.............................naira] Yam [......................................naira]

Section E: Factors Affecting Farmers' Adaptation Strategies to Climate Change

20. How long have you been in farming? ……………………………years

21. Do you belong to any farmers' association in your area? (a) Yes ( ) (b) No ( )

22. Have you receive any extension service in the past years? (a) Yes ( ) (b) No ( )

23. Do you have access to credit facilities in your area? (a) Yes ( ) (b) No ( )

24. Do you have access to weather information? (a) Yes (b) No

25. Do you have access to major market in your in your area? (a) Yes ( ) (b) No ( )

26. If yes, please state in kilometers, the distance of the market from your area…………………..km.

27. How did you acquire your farm land? (a) Inherited (b) Communal ( ) (c) Government allocation (d) Lease ( ) (e) Others (specify)……………………………………………….

Appendix B: Augmented Dickey-Fuller Unit root test results

ADF Test for Rainfall from 1995 - 2014

```
. dfuller annualrainfall, trend regress lags(0)

Dickey-Fuller test for unit root                   Number of obs   =        19

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -4.453            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0018

------------------------------------------------------------------------------
D.annualra~l |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
annualrain~l |
         L1. |  -1.078844   .2422628    -4.45   0.000    -1.592418   -.5652696
      _trend |   18.74061   9.569779     1.96   0.068    -1.546419    39.02763
       _cons |   1097.336   288.0078     3.81   0.002     486.7863    1707.885
------------------------------------------------------------------------------
```

ADF Test for Mean Annual Temperature from 1995-2014

```
. dfuller meantemp, trend regress lags(0)

Dickey-Fuller test for unit root                   Number of obs   =        19

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(t)             -3.900            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0121

------------------------------------------------------------------------------
  D.meantemp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    meantemp |
         L1. |  -1.272916   .3264022    -3.90   0.001    -1.964858   -.5809745
      _trend |   .0603287     .03766     1.60   0.129     -.019507    .1401645
       _cons |   34.06752   8.756759     3.89   0.001     15.50402    52.63102
------------------------------------------------------------------------------
```

ADF Test for Length of raining season

```
. dfuller lrsd1, trend regress lags(1)
```

Augmented Dickey-Fuller test for unit root Number of obs = 17

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-4.751	-4.380	-3.600	-3.240

MacKinnon approximate p-value for Z(t) = 0.0006

D.lrsd1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lrsd1						
L1.	-1.85471	.3904047	-4.75	0.000	-2.698128	-1.011291
LD.	.4620043	.2460106	1.88	0.083	-.0694693	.9934779
_trend	1.810158	1.530332	1.18	0.258	-1.495923	5.11624
_cons	-17.49057	16.9725	-1.03	0.322	-54.15742	19.17629

ADF Test for Yam

```
. dfuller yamd1, trend regress lags(1)
```

Augmented Dickey-Fuller test for unit root Number of obs = 17

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-4.131	-4.380	-3.600	-3.240

MacKinnon approximate p-value for Z(t) = 0.0057

D.yamd1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
yamd1						
L1.	-1.593679	.3857478	-4.13	0.001	-2.427037	-.7603217
LD.	.288339	.2383486	1.21	0.248	-.2265818	.8032598
_trend	.0740339	.0422504	1.75	0.103	-.0172426	.1653105
_cons	-.5453634	.4447979	-1.23	0.242	-1.506291	.4155642

ADF Test for Cassava

```
. dfuller cassavad1, trend regress lags(1)
```

Augmented Dickey-Fuller test for unit root Number of obs = 17

	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
		Interpolated Dickey-Fuller		
Z(t)	-4.780	-4.380	-3.600	-3.240

MacKinnon approximate p-value for Z(t) = 0.0005

D.cassavad1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
cassavad1						
L1.	-1.634514	.3419535	-4.78	0.000	-2.37326	-.8957686
LD.	.3615944	.2218079	1.63	0.127	-.1175924	.8407812
_trend	-.0429822	.0701328	-0.61	0.551	-.194495	.1085306
_cons	1.176629	.7823776	1.50	0.157	-.513595	2.866853

Appendix C: Phillip-Perron Unit root test results for Rainfall, Temperature, length of raining season, Cassava and yam yield from 1995 to 2014.

1. Phillip-Perron Unit root test at Levels

```
. pperron annualrainfall, trend regress

Phillips-Perron test for unit root                 Number of obs   =        19
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -20.538           -22.500           -17.900           -15.600
 Z(t)            -4.453            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0018

------------------------------------------------------------------------------
annualrain~l |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
annualrain~l |
         L1. |  -.0788438   .2422628    -0.33   0.749    -.5924179    .4347304
      _trend |   18.74061   9.569779     1.96   0.068    -1.546419    39.02763
       _cons |   1097.336   288.0078     3.81   0.002     486.7863    1707.885
------------------------------------------------------------------------------
```

```
. pperron meantemp, trend regress

Phillips-Perron test for unit root                 Number of obs   =        19
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -20.335           -22.500           -17.900           -15.600
 Z(t)            -3.692            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0229

------------------------------------------------------------------------------
meantemp     |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    meantemp |
         L1. |  -.2729162   .3264022    -0.84   0.415    -.9648579    .4190255
      _trend |   .0603287     .03766     1.60   0.129     -.019507    .1401645
       _cons |   34.06752   8.756759     3.89   0.001     15.50402    52.63102
------------------------------------------------------------------------------
```

```
. pperron lengthofrainingseason, trend regress

Phillips-Perron test for unit root                 Number of obs   =        19
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)         -10.992           -22.500           -17.900           -15.600
 Z(t)            -2.884            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.1677

------------------------------------------------------------------------------
lengthofra~n |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
lengthofra~n |
         L1. |   .3239473   .2262969     1.43   0.172    -.1557806    .8036753
      _trend |   .9063019   1.052465     0.86   0.402    -1.324825    3.137429
       _cons |   117.0275   44.59997     2.62   0.018     22.47976    211.5752
------------------------------------------------------------------------------
```

```
. pperron yam, regress

Phillips-Perron test for unit root                 Number of obs   =        19
                                                   Newey-West lags =         2

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)           -4.490           -17.200           -12.500           -10.200
 Z(t)             -1.198            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.6746

------------------------------------------------------------------------------
         yam |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         yam |
         L1. |   .7881929   .1910796     4.12   0.001     .3850502    1.191336
             |
       _cons |   2.687354   2.372567     1.13   0.273    -2.318325    7.693034
------------------------------------------------------------------------------
```

```
. pperron cassava, trend regress

Phillips-Perron test for unit root                 Number of obs   =        19
                                                   Newey-West lags =         2

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -14.045           -22.500           -17.900           -15.600
 Z(t)             -3.206            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0833

------------------------------------------------------------------------------
cassava      |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
     cassava |
         L1. |   .2269751   .2386682     0.95   0.356    -.2789789     .732929
      _trend |   .3313304   .1119673     2.96   0.009     .0939704    .5686905
       _cons |   7.766285   2.404987     3.23   0.005     2.667939    12.86463
------------------------------------------------------------------------------
```

2. Phillip-Perron Unit root test at First Difference

```
. pperron lrsd1, regress

Phillips-Perron test for unit root                 Number of obs   =        18
                                                   Newey-West lags =         2

                              ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic          Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -18.807           -17.200           -12.500           -10.200
 Z(t)             -5.335            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
       lrsd1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       lrsd1 |
         L1. |  -.2175018   .2432661    -0.89   0.385    -.7332029    .2981993
             |
       _cons |  -.0411119   7.333934    -0.01   0.996    -15.58836    15.50613
------------------------------------------------------------------------------
```

```
. pperron lrsd1, trend regress
```

Phillips-Perron test for unit root — Number of obs = 18; Newey-West lags = 2

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-19.286	-22.500	-17.900	-15.600
Z(t)	-5.585	-4.380	-3.600	-3.240

MacKinnon approximate p-value for Z(t) = 0.0000

lrsd1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
lrsd1 L1.	-.272308	.2495713	-1.09	0.292	-.8042567	.2596406
_trend	1.438902	1.450081	0.99	0.337	-1.651872	4.529676
_cons	-13.73504	15.62968	-0.88	0.393	-47.04892	19.57884

```
. pperron yamd1, trend regress
```

Phillips-Perron test for unit root — Number of obs = 18; Newey-West lags = 2

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-20.819	-22.500	-17.900	-15.600
Z(t)	-5.512	-4.380	-3.600	-3.240

MacKinnon approximate p-value for Z(t) = 0.0000

yamd1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
yamd1 L1.	-.289099	.2464424	-1.17	0.259	-.8143785	.2361805
_trend	.0789885	.0368233	2.15	0.049	.0005015	.1574756
_cons	-.6651935	.3860337	-1.72	0.105	-1.488005	.1576179

```
. pperron yamd1, regress
```

Phillips-Perron test for unit root — Number of obs = 18; Newey-West lags = 2

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(rho)	-18.485	-17.200	-12.500	-10.200
Z(t)	-4.320	-3.750	-3.000	-2.630

MacKinnon approximate p-value for Z(t) = 0.0004

yamd1	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
yamd1 L1.	-.0750343	.2494065	-0.30	0.767	-.6037524	.4536838
_cons	.0727103	.1938885	0.38	0.713	-.3383148	.4837355

```
. pperron cassavad1, trend regress

Phillips-Perron test for unit root                 Number of obs   =        18
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -18.117           -22.500           -17.900           -15.600
 Z(t)             -4.932            -4.380            -3.600            -3.240
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0003

------------------------------------------------------------------------------
cassavad1    |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   cassavad1 |
         L1. |  -.1874423   .2536807    -0.74   0.471    -.7281499    .3532653
      _trend |   .0099455   .0748678     0.13   0.896    -.1496315    .1695225
       _cons |   .3317824   .8104715     0.41   0.688    -1.395697    2.059261
------------------------------------------------------------------------------
```

```
. pperron cassavad1, regress

Phillips-Perron test for unit root                 Number of obs   =        18
                                                   Newey-West lags =         2

                               ---------- Interpolated Dickey-Fuller ---------
                  Test         1% Critical       5% Critical      10% Critical
               Statistic           Value             Value             Value
------------------------------------------------------------------------------
 Z(rho)          -18.041           -17.200           -12.500           -10.200
 Z(t)             -5.132            -3.750            -3.000            -2.630
------------------------------------------------------------------------------
MacKinnon approximate p-value for Z(t) = 0.0000

------------------------------------------------------------------------------
   cassavad1 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
   cassavad1 |
         L1. |  -.1855015   .2453618    -0.76   0.461    -.7056452    .3346423
             |
       _cons |   .4255841   .3854068     1.10   0.286    -.3914418     1.24261
------------------------------------------------------------------------------
```

Appendix D: Selection Criteria for Co-integration test

```
. varsoc yamd1 annualrainfall meantemp lrsd1, maxlag(3)

   Selection-order criteria
   Sample:  1999 - 2014                          Number of obs      =        16
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-220.693				1.9e+07	28.0866	28.0965	28.2798*
1	-207.864	25.658	16	0.059	3.0e+07	28.483	28.5324	29.4487
2	-183.453	48.821*	16	0.000	1.7e+07	27.4317*	27.5207*	29.17
3	.	.	16	.	-2.6e-09*	.	.	.

```
   Endogenous:  yamd1 annualrainfall meantemp lrsd1
    Exogenous:  _cons
```

```
. varsoc cassavad1 annualrainfall meantemp lrsd1, maxlag(3)

   Selection-order criteria
   Sample:  1999 - 2014                          Number of obs      =        16
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-228.011				4.6e+07	29.0014	29.0113	29.1945*
1	-212.851	30.321	16	0.016	5.6e+07	29.1064	29.1558	30.0721
2	-189.759	46.184*	16	0.000	3.8e+07	28.2199*	28.3089*	29.9582
3	.	.	16	.	-2.0e-09*	.	.	.

```
   Endogenous:  cassavad1 annualrainfall meantemp lrsd1
    Exogenous:  _cons
```

Appendix E: Johansen Co-integration Test

1. Cointegration test results for Yam

```
. vecrank yamd1 annualrainfall meantemp lrsd1, trend(constant)

                      Johansen tests for cointegration
Trend: constant                                        Number of obs =      17
Sample:  1998 - 2014                                            Lags =       2
-------------------------------------------------------------------------------
                                                        5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0      20    -232.49073         .       54.5635     47.21
    1      27    -221.21996     0.73446     32.0220     29.68
    2      32    -213.08141     0.61614     15.7449     15.41
    3      35    -206.39561     0.54459      2.3733*     3.76
    4      36    -205.20896     0.13030
```

2. Cointegration Test results for Cassava

```
. vecrank cassavad1 annualrainfall meantemp lrsd1, trend(constant)

                      Johansen tests for cointegration
Trend: constant                                        Number of obs =      17
Sample:  1998 - 2014                                            Lags =       2
-------------------------------------------------------------------------------
                                                        5%
maximum                                      trace    critical
  rank    parms       LL       eigenvalue  statistic    value
    0      20    -245.17463         .       53.6913     47.21
    1      27    -231.40414     0.80211     26.1503*    29.68
    2      32    -224.50131     0.55607     12.3446     15.41
    3      35    -219.50027     0.44476      2.3425      3.76
    4      36      -218.329     0.12872
-------------------------------------------------------------------------------
```

Appendix F: Vector Error Correction Model Results

1. Yam

Variable	Coefficient	Standard Error	z-Statistics	Probability
Rainfall	0.0004062*	0.000972	-0.42	0.006
Temperature	0.0282127	0.2602551	0.11	0.914
Δ LRS	-0.0057738	0.0062912	-0.92	0.359
ECt	-0.082422	0.4409185	-2.29	0.022
Constant	0.2399287	0.1743826	1.38	0.169

2. Vector Error Correction Model Results for Cassava

Variable	Coefficient	Standard Error	z-Statistics	Probability
Rainfall	-0.0019732	0.0018055	-1.09	0.27
Temperature	-2.359864*	0.5859489	-4.03	0.000
Δ LRS	0.0226374*	0.0113042	2.00	0.045
ECt	-0.0566743	0.0550128	-1.03	0.303
Constant	0.043532	0.3866241	0.11	0.910

Appendix G: Diagnostic Test for the Model

1. Diagnostic test for cassava model

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	3	39.67524	0.0000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
cassavad1	1	.	.	.	.	.
annualrain~l	.0005181	.0062343	0.08	0.934	-.0117009	.012737
meantemp	-9.591058	2.490453	-3.85	0.000	-14.47226	-4.70986
lrsd1	.3166304	.0625083	5.07	0.000	.1941164	.4391444
_cons	260.7744	.	.	.	.	.

2. Diagnostic test for cassava model

Cointegrating equations

Equation	Parms	chi2	P>chi2
_ce1	2	21.81192	0.0000
_ce2	2	24.94117	0.0000

Identification: beta is exactly identified

Johansen normalization restrictions imposed

beta	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
_ce1						
yamd1	1	.	.	.	.	.
annualrain~l	(omitted)					
meantemp	3.140258	1.600617	1.96	0.050	.0031062	6.277409
lrsd1	-.1597337	.0406305	-3.93	0.000	-.2393681	-.0800993
_cons	-85.43136	.	.	.	.	.
_ce2						
yamd1	1.14e-13	.	.	.	.	.
annualrain~l	1	.	.	.	.	.
meantemp	4010.24	1697.19	2.36	0.018	683.8082	7336.671
lrsd1	-173.9107	43.08199	-4.04	0.000	-258.3498	-89.47152
_cons	-110245.2	.	.	.	.	.

Appendix H: ANOVA of the phase one (1975-1987), phase two (1988-2003) and phase three (2004-2014) of Annual rainfall in Ilorin

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Phase 1 (1975-1987)	13	15420	1186.154	11133.83
Phase 2 (1988-2003)	15	16014.95	1067.663	55398.36
Phase 3 (2004-2014)	12	15566.5	1297.208	29301.78

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	353653.176	2	176826.6	5.312684	0.00937	3.251924
Within Groups	1231502.61	37	33283.85			
Total	1585155.79	39				

Appendix I: ANOVA of the phase one (1985-2001) and phase two (2002-2014) of Minimum and maximum Temperature in Ilorin

Anova: Single Factor :
Minimum Temperature

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Phase 1(1985 to 2001)	17	365.646	21.50859	0.09517
Phase 2(2002 to 2014)	13	285.3182	21.94755	0.054734

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.41948605	1	1.419486	18.23593	0.000203	4.195972
Within Groups	2.17952211	28	0.07784			
Total	3.59900816	29				

ANOVA of Maximum Temperature in Ilorin

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Phase 1(1985 to 2001)	17	549.0401	32.29648	0.227197943
Phase 2(2002 to 2014)	13	422.6178	32.50906	0.222986296

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.332916308	1	0.332916	4.477048445	0.234385579	1.195972
Within Groups	6.311002639	28	0.225393			
Total	6.643918947	29				

Appendix J: Onset, Cessation and Length of raining season from 1975 to 2014

YEARS	ONSET DATE	CESSATION DATE	LENGTH OF RAINING SEASON
1975	02-Apr	20-Oct	201
1976	15-Mar	22-Oct	221
1977	16-Apr	27-Oct	194
1978	26-Mar	24-Oct	212
1979	14-Mar	21-Oct	221
1980	19-Apr	07-Oct	171
1981	13-Mar	18-Oct	219
1982	20-Mar	07-Oct	201
1983	07-Apr	11-Dec	248
1984	19-Mar	18-Oct	213
1985	30-Mar	02-Sep	156
1986	03-Mar	06-Oct	217
1987	21-Mar	16-Oct	209
1988	15-Mar	02-Sep	171
1989	02-Mar	21-Oct	233
1990	16-Apr	01-Oct	168
1991	10-Mar	23-Oct	227
1992	02-May	27-Nov	209
1993	18-Apr	26-Oct	191
1994	18-Mar	22-Oct	218
1995	03-Apr	13-Nov	224
1996	25-Mar	25-Oct	214
1997	09-Apr	10-Oct	184
1998	13-Apr	26-Oct	196
1999	09-Mar	05-Oct	210
2000	10-May	07-Sep	120
2001	17-Apr	03-Sep	139
2002	04-Apr	11-Oct	190
2003	09-Apr	09-Oct	183
2004	02-Apr	06-Oct	187

2005	22-Mar	05-Oct	197
2006	02-Mar	06-Oct	218
2007	06-Apr	10-Oct	187
2008	16-Apr	07-Oct	174
2009	03-Apr	01-Oct	181
2010	04-Apr	06-Oct	185
2011	02-May	10-Oct	161
2012	04-Apr	16-Oct	195
2013	09-Mar	11-Oct	216
2014	05-Mar	06-Oct	215
mean	30-Mar	12-Oct	196.9