EVALUATION OF AGRO-CLIMATOLOGICAL CONSTRAINTS TO COTTON PRODUCTION IN MAKARFI AND ZARIA, KADUNA STATE, NIGERIA

BY

AHMAD, Maryam Muhammad
MTech/SPS/2017/7312

DEPARTMENT OF GEOGRAPHY
FEDERAL UNIVERSITY OF TECHNOLOGY
MINNA

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ABSTRACT

Knowing and understanding the key agro-climatological variables, which affect cotton production, is of great importance for designing agricultural policies to enhance cotton production in the study area and the country at large. Little published thesis and journal have covered the research topic which has created paucity of knowledge and this study has filled such gap. The aim of this study is to assess agro-climatological constraints to low cotton production in Makarfi and Zaria, Kaduna State, Nigeria. The primary data used were those that were collected directly from the field survey, oral interview and questionnaire. Secondary data used were those data that were obtained from Kaduna State Agricultural and Rural Development Authority (KDARDA) for a period of twenty years (1998 to 2017), Nigerian Meteorological Agency (NIMET), previous researches, journals, textbooks, newspapers, magazines and encyclopedia. The methods of data analysis include mean, mean deviation, frequency percentage and multiple linear regression. The result revealed that annual rainfall tend to be decreasing in the study area despite the fluctuation in some years (2007, 2013 and 2015). The highest annual rainfall was in the year 1999 with 2272.4 mm and the lowest was in the year 2008 with 848.5 mm. The study also revealed that mean annual relative humidity tend to be decreasing despite the fluctuation. The highest mean annual relative humidity was recorded in the year 2013 with 56.4 percent and the least was recorded in the year 2010 with 47.4 percent. The finding revealed that the agro-constraints faced by cotton growers in the study area include inadequate fertilizer, inadequate pesticides, inadequate market opportunities, late planting, inadequate storage facilities after harvest and increased cotton diseases. As indicated in the result, R^2 was 0.552 for annual rainfall, thus, rainfall account for 55.2percent of the explained variance between annual rainfall and cotton yield in the study area. This shows that other climatic variables like relative humidity and temperature too play significant role in cotton yield since the remaining 44.8percent is left unexplained. As shown in the study, R^2 was 0.22 for relative humidity, thus, relative humidity account for 22.0percent of the explained variance between relative humidity and cotton yield in the study area. It’s therefore recommended that the Kaduna State Agricultural Development Programme (KSADP) should device way to motivate its agricultural extension workers to be able to assist the rural cotton growers on enhanced productivity and to guide them on new agricultural innovations.

TABLE OF CONTENTS

Contents **Page**

Pages

CHAPTER TWO

CHAPTER THREE

Pages

LIST OF FIGURES

LIST OF TABLES

Table **Page**

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Agriculture constitutes one of the most important sectors of Nigeria economy. The sector is particularly important in terms of employment generations and its contribution to the Gross Domestic Product (GDP) and export earning. However, the sector has been characterized since 1970s by declining productivity and increase dependence on import of food and raw materials (Manyong *et al*., 2015). Efforts have been made by various tiers of government to reverse the trend by diversification of the productive base through increased production of cash crops like cotton, rubber, palm oil and ground nut as they were the main export crops of the country where large revenue have been generated in the 1960s (Idem, 2009).

The major consequence of neglect of the agricultural sector in Nigeria during the oil boom years (1970-1980s) was the decline in total food and fibre production and the astronomical rise in input prices. These general problems of agricultural sector also affect the cotton industries which has hitherto played an important role in the economy.

Cotton production is done by many countries in the world, but countries in the Northern Hemisphere accounted for more than 90 per cent of world output. Developing countries account for more than two-thirds of world cotton production (Baffes, 2014). The period

1960-2001 saw global cotton output doubling from 10.2 million to 20 million tonnes (Baffes, 2014). Notably, the countries that contributed much to this growth are China and India, which tripled and doubled their production respectively. Other countries that significantly increased their share of world output were Turkey, Greece, and Pakistan. New entrants included Australia, which produced only 2000 tonnes of cotton in 1960 and averaged 650000 tonnes a year during the late 1990s.Another important new entrant in cotton production Francophone Africa, which produced less than 100000 tonnes in the 1960s, now produces almost 1 million tonnes (Baffes, 2014).

Cotton production has a relatively long history in Nigeria. The cultivation of the crop started well before the colonial era even though it was not produced in commercial quantities until the onset of the activities of the British Growing Association in 1903, since then considerable attention and resources have been devoted to the improvement of cotton production and utilization by both the public and the private organisations. Cotton is grown as a cash crop by about 0.8 million farmers on a total estimated area ranging from 0.6-08 million hectares. The major feature of cotton production in Nigeria is that about 80percent of total production is by peasant farmers under rainfed conditions with simple tools and animal drawn implements (Onu and Atala, 2012; Adeniji, 2012).

Cotton (*Gossypium hirsutum* L.) is an important cash crop in Nigeria which produces lint and seed that serve as raw materials for the local textiles and seed crushing industries. In addition, cotton seed provides edible oil for human consumption while cotton seed cake are used as raw materials for livestock feeds due to high protein content. Until recently, cotton was the fifth most important export crop and a major source of foreign exchange for the country. Unfortunately, total production remains far below the national requirements of the textile and the oil mills. This is as a result of low average yield of the crop on farmers plot of about 400-500 kg seed cotton per hectare which is below the genetic yield potential (2.5-3.0) tons seed cotton/ha, of the varieties being grown and yield that are obtainable on research plots (1.5-2.5 tons ha^{-1}) (Ogunlela, 2014).

A review by Traoré *et al.,* (2017) of current knowledge on the regional climate in Sudano-Sahelian West Africa revealed that rainfall as well as other agro-climatological variables remains unpredictable. This agro-climatological unpredictability is a major constraint for cotton farmers who have to plan the start of the cropping season (Piéri, 2009). The first rains are not always followed by the full start of the monsoon (Sultan and Janicot, 2013), dry spells can occur afterwards, i.e. during the early stages of the crop growth so that seeds may not germinate properly or germinated plants may die off. However, if sowing is delayed, the land may be too wet to till.

1.2 Statement of the Research Problem

Several authors both nationally and internationally have studied agro-climatological constraints and they include Ramasundaram (2011); Adeniyi (2012); Gohil *et al.,* (2016); Thomson *et al.,* (2014); Dalberg (2011); Kabwe (2013); Tschirley and Kabwe, (2017). Little published thesis and journal have covered the research topic which has created paucity of knowledge and this study have filled the gap.

Gohil *et al.,* (2016) assessed constraints faced by cotton growers in crisis management of cotton cultivation in Gujarat, India. The study was carried out in Amreli and Bhavnagar District of South Saurashtra Agro-Climatic Zone of Gujarat State, India to identify the various constraints faced by cotton growers in cotton cultivation. A random sample of 200 cotton growers was selected from Amreli and Bhavnagar District and the constraints faced by cotton growers in cotton cultivation were to non-remunerative price, high price of soil reclamation materials, non-availability of information about future aberrant weather conditions including cyclone, high price of insecticides/ pesticides & fungicides, insufficient demonstration of improved technologies on farmers' field, high price of chemical fertilizers, high price of organic manures, irregular supply of electricity and lack of knowledge to diagnose the pests and diseases in the crop. The important suggestions offered by the respondents were: quality seed supply should be ensured, effective insect-pest control methods should be developed, input should be supplied at subsidized rate, village level workers should frequently contact the farmers to make them aware about new technologies, crop insurance should be made available for all the farmers at cheaper rate, provision of sufficient and timely credit facilities, remunerative price of farm produce and sufficient electricity should be provided.

Agro-climatological constraints in the study area identify include multiplicity of genotypes, use of non-certified seeds, non-adoption of proper spacing, more than recommended number of insecticide sprays, less/more than recommended quantity of fertilizer use, tied up credit and unscientific plant protection. Cotton yield in the study area are on the decrease because of competition among crops for land and labour, leading to lack of timeliness in field operations and to difficulties in weed control, insect control and picking. Failure to increase the supply of this crop is likely to result in higher prices for the finished good derived from cotton, putting the country textile security at risk. The vulnerability of the country textile industry was highlighted between the years 2002 and 2013, in which prices for agricultural commodities derived from cotton elevated rapidly. During this period, average prices of textile commodities gotten from cotton increased by over 50percent (Tadesse *et al.*, 2014). These price increases were particularly steep for a number of the aforementioned crop.

1.3 Aim and Objectives

The aim of this study is to assess agro-climatological constraints to low cotton production in Makarfi and Zaria, Kaduna State, Nigeria. The objectives for this study include:

i. Examine rainfall and relative humidity trends in the study area;
ii. Analyse agro-constraints faced by cotton growers in the study area;
iii. Examine the relationship between climate variables and cotton production in the study area.

1.4 Research Questions

The research questions for this study include the followings:-

i. What are the rainfall and relative humidity trends in the study area?
ii. What are the agro-constraints faced by cotton growers in the study area?
iii. What is the relationship between climate variables and cotton production in the study area?

1.5 Justification for the Study

Knowing and understanding the key agro-climatological variables, which affect cotton production, is of great importance for designing agricultural policies to enhance cotton production in the study area and the country at large. Explanations of cotton production differences between years may include weather variability, input quantities decline and loss of cotton production efficiency. Identifying the reasons for differences in cotton production in the study area is not only important from a historical perspective, but also useful to evaluate the effects of existing and new policies. There have been changes in agricultural policies in the study area since a noticeable decline in cotton production. Policies were mainly put in place to improve cotton productivity of smallholder farmers and therefore improve livelihoods. Liberalisation policies were put in place to improve the functioning of the market system and remove state intervention in agricultural markets. But results of the policies were not fruitful as nothing changed and poverty increased mainly in cotton grown areas. Empirical studies in these areas are rare and they have not been sufficiently recognized and articulated by researchers. There is therefore need to conduct a study exploring these issues. A deeper understanding of various agro-climatological constraints which reduced cotton production is crucial for economic policy making in the study area as well as textile industry in Nigeria. Not much is known about the importance of agro-constraints faced by cotton growers in the study area. The study is expected to document the adaptation strategies put in place by cotton growers to enhance cotton production in the study area.

In the study area, climatic parameters especially precipitation and relative humidity, are the primary control of crop yield precisely cotton production. Thus analysis of climatological conditions of Zaria and Makarfi Local Government Areas in Kaduna State will not only constitute a useful tool in planning but will also produce data in relation to other crops which will perform better in the study area.

1.6 Scope and Limitation of the Study

The scope of this study is to assess agro-climatological constraints to cotton production in Makarfi and Zaria, Kaduna State, Nigeria. This study specifically focused on rainfall and relative humidity trends in the study area, analyse agro-constraints faced by cotton growers in the study area and examining the relationship between climate variables and cotton production in the study area. The temporal scope of this study covered between 1998 and 2017 (20 years) and the geographical scope were Makarfi and Zaria Local Government Areas of Kaduna State, Nigeria.

1.7 The Study Area

1.7.1 Location of the study area

The area is bounded by latitudes 11^0 04′ 28″ N and 11^0 35′ 53″ N and Longitudes 7^0 42′ 49″ E and 7^0 70′ 00″ E. It covers an area of approximately $563km^2$, in the Basement Complex of North Central Nigeria (Figure. I.1 and 1.2). The estimated population of the selected sample points is 408,198 according to the 2018 estimation.

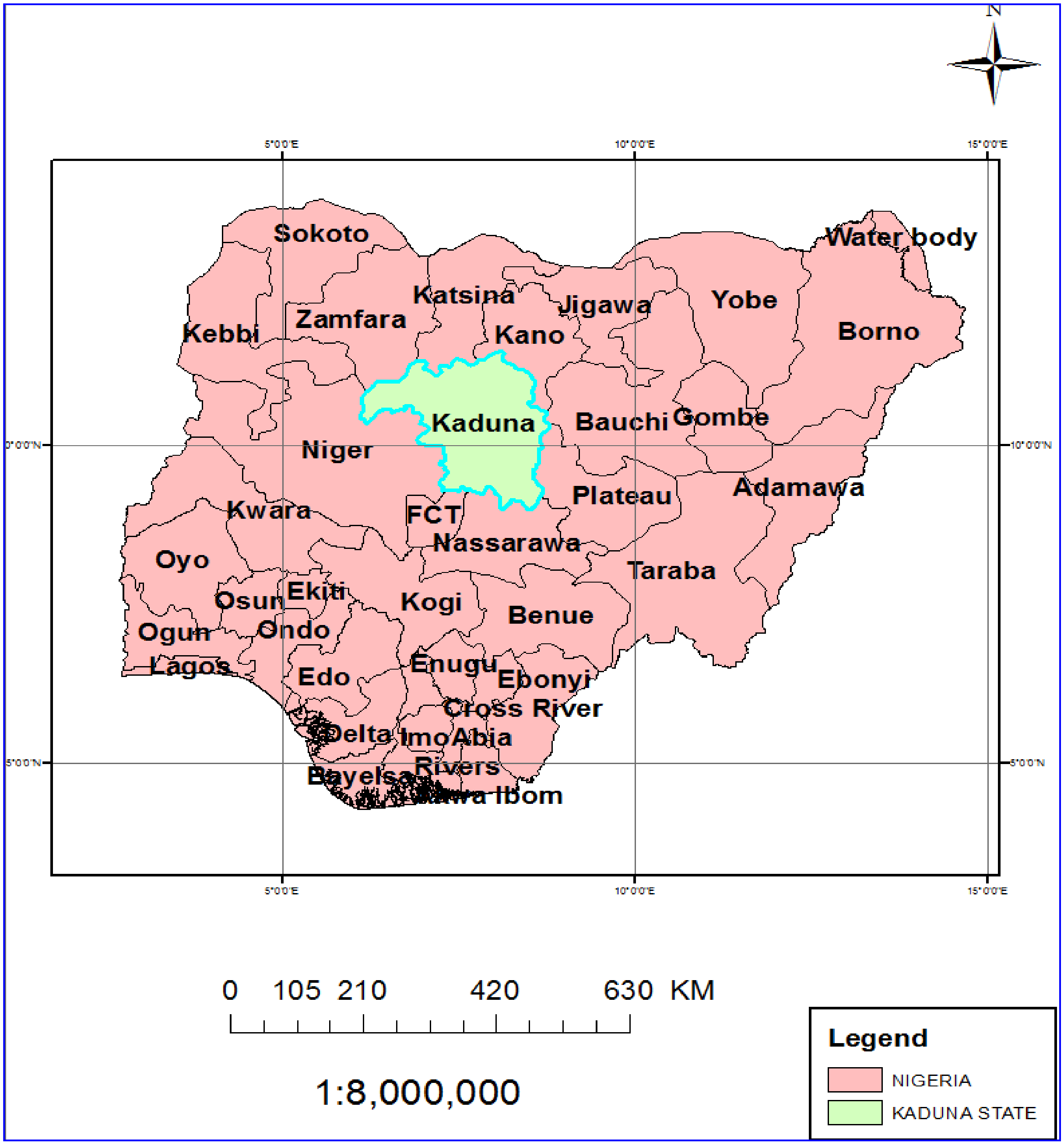

Figure 1.1: Location of Kaduna State

Source: Kaduna State Ministry of Land and Geoinformatics, 2018

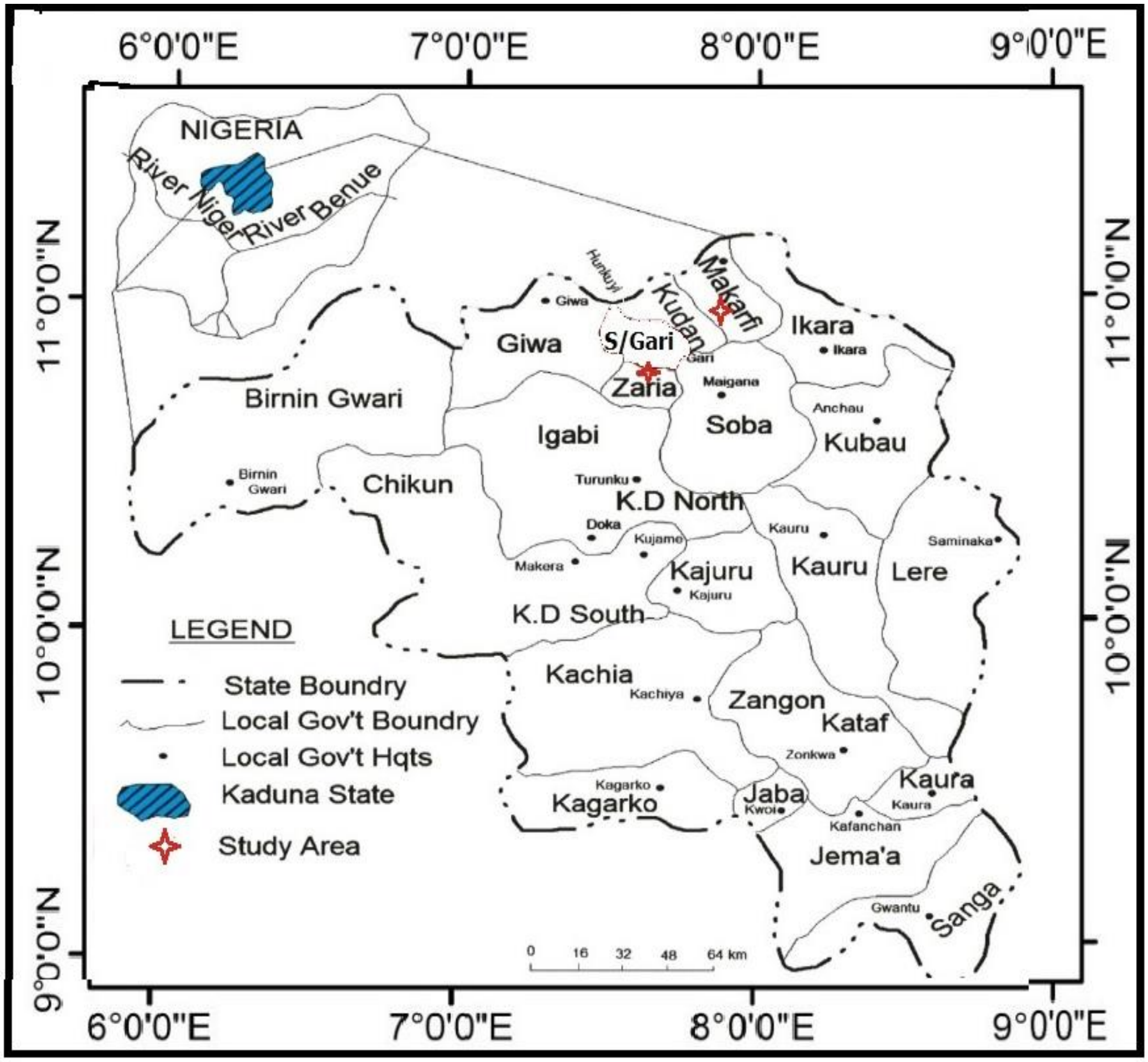

Figure 1.2: Location of Zaria and Makarfi Local Government Areas

Kaduna State Ministry of Land and Geoinformatics, 2018

1.7.2 Climate of the study area

1.7.2.1 Rainfall of the study area

Zaria and Makarfi have an average annual rainfall of 1250mm. The rains occurs between months of April – October when the South Westerly humid winds brings in rain. The dry seasons last between November and March when the prevailing North Easterly winds

(Harmattan) brings with it dusty, dry and cool air of the Sahara desert ushering in the dry season. The mean annual rainfall in the study area ranged from 1000mm to 1500mm. The month of August-September recording highest rains of 300mm (Yamusa, Abubakar and Falaki, 2015). The rainy season starts between 10^{th} of April to 20^{th} of May and extends to October.

1.7.2.2 Temperature of the study area

The temperature of the study area resembles that of the North Central Zone of the country. Temperature ranges between 25^0 C – 35^0C during the dry season. The temperature may rise to about 42^0C in March/April which is the hottest period. The coldest month is December/January. During the harmattan popularly referred to as the West Africa Doctor, temperature sometimes reaches freezing point (Record from the nearest meteorological station over a period of 15years) (Yamusa, Abubakar and Falaki, 2015).

1.7.3 Vegetation and Soils of the study area

The vegetation cover of the study area is uniform and monotonous typical of the Northern Guinea Savanna Zone. Green (2007) further described the vegetation as containing three vegetation sub-types viz:

1. Isoberlinia doka woodland grassland
2. Gallery or riparian vegetation
3. Shrub land composed of trees – shrub association.

Other areas of the forest are covered by Uapacamonotes Afornosia association (V-togoensis, M. Kekrstingi afzelia Africana, etc. In the low ground near Numanshi stream which stretches into the park serving as a source of water for animals during the dry season, one finds a terminalia Pseudocederela Mitrogya association with; Terminallia macrotera, Mitragyna inermis, philiostigma inermis. The presence of these vegetation types signifies clay composition in the soil.

The soil types of the study area corresponds fairly closely with the vegetation belts of the guinea savanna which extends from east to west of Kaduna metropolis. Excepts for highland areas, Kaduna metropolis has high temperature which promotes active chemical and biological changes in the soil. There are few outcrops and some fossilized literate hills in the study area. Soil types includes; sandy loams and a little clay in valleys (Oyedele, 2011). The climate, soil and hydrology supports the cultivation of most of the study area staple crops and still leaves ample scope for grazing, fresh water, fishing and forestry. Rich fertile alluvial soils are visible around the stream banks. Estimate shows that 80percent of the people in the local government area engage directly or indirectly in agricultural activities (Oyedele, 2011). Oyedele (2011) opined that the soils are yellowish to reddish, deep, well drained and fine or medium textured. Bleached layers of ferruginous tropical soils associated with ferralitic soils are also found along the River Kaduna flood plain.

1.7.4 Topography of the study area

Geologically the study area is covered by sedimentary rock formation consisting of sand stones and alluvial deposited especially around the site of the park. The area lies on a flat gently rolling land with few hills. In and around the Park, there are important land marks which are of potential interest to tourist. Some of the exquisite barren rocks make the landscape alluring and this create attractive scenery. Some of these lands are Tsunin Buffa, Kashiga Mountains, Marmara Hills, etc. the beauty of the under field land marks inhabited by both animals and birds sharing the luxury of tropical sunshine alongside meandering rivers makes the park attractive and beautiful. Most of the hills are rounded granite domes and flat topped mensas or residual hills with reddish-brown sand stones are characteristics relief features of the study area (Jatau *et al.*, 2013).

Generally the topography of the study area is that of an undulating Plateau that forms part of the rich tourist attractions in areas like Kufena in Zaria, Kagoro, Kwoi, Gwantu etc. These areas have protruding hard resistant granite rocks that are so attractive for sightseeing. Variable elevations of land topography ranging from the lowest height of 380m above sea level in river valleys and as high as 450m occurring mostly in upland areas leads to the spring up of streams arounds the study area. The Ukinkina, Kuzomani and Kuwaimbana rivers are some of the major streams that drain around the study area. Other streams include the Dagara stream, Bogoma stream and Numashi stream. Kwiambana Rivers forms quite an extensive length of the northern boundary of the study area, draining from west to east. The two streams Kuzomani and Ukinkina both drains from the centre parts of the park. Kuzomani drains to the west into the Kuwaimbana while the Ukinkina drains out from the park in the South West (Shehu, 2011). Its main rivers are River Kaduna, River Gurara, River Kogum and River Kubani (Shehu, 2011).

1.7.5 Geology of the study area

The area understudy is underlain by Precambrain rocks of the Nigerian Basement Complex. The weathering of the crystalline Basement Complex rocks under tropical condition is well known to produce a sequence of unconsolidated material whose thickness and lateral extent vary extensively. Groundwater localization within the Basement Complex occurs either in the weathered mantle or in the fracturing, fissuring and jointing systems of the bedrock (Ako and Olorunfemi, 1999). These unconsolidated materials are known to reflect some dominant hydrologic properties, and the highest groundwater yield in Basement Complex area are found in areas of thick overburden overlying fractured zones and are characterized by relatively low resistivity. The Basement Complex rocks in the areas are mostly migmatite, granite gneiss, undifferentiated schists and porphyritic biotite grantite.

1.7.6 Population and socio-economic activities

The study areas were few of the LGA in Kaduna State and could be described as a high density residential areas, which emanated as a result of cosmopolitan nature of the settlement, the presence and the relocation of the central market, some government institutions and agencies along Zaria-Kaduna road has increased the influx of people on the area. This has also given rise to buildings with no adequate set-back, grossly small green areas, absence of drainage along the access roads, narrow and untarred roads and inaccessibility of many residential buildings. These features are complemented with poor waste disposal system that turns roads and right of ways into refuse dumps. The study areas to a large extent were linear settlements, with most of the population living in standard and semi-standard structures. The houses are mostly roofed with good zinc and only few lives in traditional mud structures. The predominant commercial activity for the population is petty trading, mainly on the major road, commercial activities has increased recently and this has led to the presence of shops, super markets, along Zaria-Kaduna road Also, due to the presence of Zaria garage, there is proliferation of business within and around the garage.

Agriculture is the third most common activity in the area especially for the locals, given its multiple roles in food security and source of livelihood; there are cases of undeveloped plots of land that are also put to agricultural uses. Crops grown include; Maize, Guinea-corn, Cotton, millet and Cassava.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Cotton production

Cotton is a fiber that is most commonly used in the production of textiles. Cotton grows in a ball around the seeds of the cotton plant. The cotton plant can be found in sub tropical regions in the Americas, Africa and Asia (Joseph, 2011). Cotton has been a major cash crop in Africa, mainly in Nigeria, the areas cotton is grown in Nigeria is concentrated in the Savanna belts of the country which is the Northern and South Western Nigeria such as Kano, Kaduna, Oyo, Ondo, Kwara, Katsina, Ogun, Jigawa, Kebbi, Sokoto and Zamfara States.

Cotton belongs to the *Gossypium* family, it has a soft in texture, fluffy in nature and is a staple fibre that grows in a boll (boll tend to increase the dispersal of the seeds) around the seeds of cotton plants of the genus Gossypium in the family of Malvaceae. Cotton is one of the most important commercial crops popularly known as the "White Gold", belonging to the genus *Gossypium* under tribe *Gossypieae* of *Malvaceae* family. It is the most precious gift of nature to the mankind to cloth the people all over the world. Production of cotton in the country has been in existence since 1903, until 1974, the British Cotton Growers Association has been taking the lead. Before the oil boom in Nigeria, it has been one of the major cash crop exported to other countries, but due to the negligence of the government, the cultivation and exportation of cotton have reduced greatly (IPCC, 2014).

There are recent fears that cotton might go extinct if proper and adequate measures aren't followed because what was usually been produced from cotton are now majorly imported and not only does it affect the agricultural aspect of the country it also discourages the farmers as their hopes of livelihood tend to be closing on them. But all hopes aren't lost as the government is striving to revive back cotton seed production and in this sense, also advised farmers on quality cotton seeds, enough input, and other related vital information as it will help in generating a better outcome. The cottonseed contains oil which is extracted and processed using any suitable process, and then refined to remove unwanted materials, it can then be consumed by humans like any other vegetable oil or used as biodiesel when further processed (IPCC, 2014).

Cotton accounts more than 70 percent of the raw fibre used by the world textile industry and handlooms hence it is also called “King of fibres” (James, 2006). Cotton contributes not only fibre to the textile industry but also edible oil which plays an important role in meeting the ever increasing demand of edible oil in the country. Edible oil extracted from the cotton seed is estimated to the 5 lakh tonnes along with 30 lakh tonnes cake. In India, all the four cultivated cotton species *viz*., *Gossypium arboreum, G. herbaceum, G. hirsutum and G. barbadense* are grown on commercial scale (Singh and Kairon, 2011). Cotton is a perennial crop with an indeterminate growth habit. Wild ancestors of cotton are found in arid regions often with high temperatures and are naturally adapted to surviving long periods of dry weather. Modern cultivars have inherited these attributes, making the cotton crop well adapted to intermittent water supply that occurs with rain-fed and irrigated production. Compared with other field crops, however, its growth and development is complex (Bange, 2012). Vegetative and reproductive growth occur simultaneously making interpretation of the crop's response to climate and management difficult. Climate change impacts on cotton growth and development that influence yield and fibre quality will most likely be the result of the net effects of increases in CO_2 concentration, reduced water availability and increased atmospheric evaporative demand as a result of lower rainfall and relative humidity and increases in temperature (Bange, 2012).

2.1.2 Agro-climatic variables

In most parts of northern Nigeria, farming of cotton is basically a rural activity. About 80percent of the cotton farmers are into rain-fed and mainly at subsistence level (Inter governmental Panel on Climate Change, 2017). These farmers produce for family needs rather than for commercial purpose. Therefore, the reason for cotton production is basically to meet immediate family requirement and not for larger sale in the market for profit. Climate is vital to cotton production of most region in northern Nigeria, together with lower innovation and inflexible loyalty to customary methods for cultivating, current variation in the weather and climate have taken extreme peal production of cotton in the region. Surely, the production of cotton in most parts of the region is mostly taken as an issue of sweep stakes since precipitation differs significantly both spatiotemporally, and the inconsistency generally decides the production and yields of cotton in the region (Misselhorn, 2015).

From the mid 1970s, cotton farming in most parts of northern Nigeria was influenced by drought which generally change cotton production each year and at different places. The challenges brought about through climate change in this part of the country ranges from those environmental challenges on agribusiness to the obvious which is the seasonality of rainfall (that limits cotton growing to lower periods of 3 – 5 months) and to serious and intermittent dry seasons (that upset the typical seasonal availability of water). The drought which was experienced in the region displays such features as false and late onset of rainfall, prolong breaks (dry spell) amid the raining season, and early cessation of rainfall; prompting severe disruption in the distribution of seasonal rainfall pattern (Dai, 2014). Critical climatic restrictions are put on cotton cultivation in the region since they make the right planning for operations in the farm (that is essential for acquiring optimal yields) to be challenging. Accordingly, there have been constant failure of cotton and reduction in yields that resulted in lowering incomes generated from the cotton farms to the related issues of insufficiency of food, ailing health and general hardship by the populace (Mortimore and Adams, 2011). Hence, it is vital to investigate the effect of agro-climatic constraints to cotton production in Makarfi and Zaria, Kaduna State, Nigeria joined with an assessment of opinions of cotton farmers to its adaptation and mitigation measures.

2.2 Review of Related Literature

Thomson and Richard (2014) studied the assessment of the growth opportunities and constraints in Zambia's cotton industry. The main objective of this study was to assess the major opportunities and constraints in Zambia's cotton industry. The study found that the cotton sector has considerable potential to contribute to growth and employment in Zambia as it currently accounts for direct and indirect employment of approximately 21percent of the population and about 19percent of agricultural Gross Domestic Product. The prominence of smallholder farmers in the sector is indicative of the income equity promotion potential of the cotton sector. However, the highly concentrated structure of the sector, with two key players currently accounting for about 80percent of the total market share in ginning; the absence of regulatory mechanisms for setting of prices; the openness of the local market to global price fluctuations and the lack of support programmes as compared to competing crops like maize are major impediments to equity promotion in the sector. Overall growth of the cotton sector is also constrained by low productivity arising mostly from poor farming practices. Furthermore, increased production in major world markets due to subsidies and use of bio-technology in cotton production undermine the competitiveness of Zambia's cotton in international markets. For Zambia to realize the potential of the cotton sector, interventions need to be targeted at raising farm level productivity. The government should also facilitate informed policy debate and development on critical issues such as biotechnology adoption as well as facilitating consensus between cotton buyers and farmers on price setting mechanisms.

Godfrey (2013) examined economic analysis of factors affecting cotton production in Zimbabwe. Improving cotton production is undoubtedly one of the greatest challenges facing the Zimbabwean government today. Since cotton is an important cash crop for the country and for individual households, it has important implications for livelihoods of rural people. In order to achieve this, several interventions in the sector were done since independence in an attempt to improve production. The main objective of this thesis was to identify factors affecting cotton production in the country during the period 1965-2005. Nerlovian supply response function was used to conduct the study. Empirical findings reveal that the major factors were government expenditure on research and extension and short-term credit extended to farmers by commercial banks and Agric bank. The elasticity of supply response with respect to research and extension was 0.17 and 0.4 in the short-run and long-run respectively. The elasticity of supply response with respect to agricultural credit was found to be 0.32 in the short-run and 0.74 in the long-run. Simulation experiments reveal that a 10 per cent increase in the provision of short-term credit will result in a 3.2 per cent increase and 7.4 per cent increase in area planted to cotton. And also it was found that a 10 per cent increase in government expenditure on research and extension will result in a 1.7 per cent increase in area planted to cotton in the short run and 4 per cent in the long run. The study also documented low elasticities of supply response with respect to own price and that of competing products (maize in this case). A comparative analysis of domestic and international cotton marketing reveal that there is some relationship between the two markets. A Spearman correlation coefficient of 0.72 was found between world price (Cotton-A Index) and the domestic lint price expressed in US dollars and was significant at 1 percent. Nominal protection coefficients were also computed for the period and it was found that the degree of protection in the domestic sector was declining over the years, but generally farmers have been taxed. Important policy messages from the empirical findings were that there is need for the government, private sector and NGOs to increase extension and training programmes to farmers and also they should continue to lobby for scrapping of policies in the developed world that depress lint prices in the world market. It was recommended that measures should be put in place that enables financial institutions to increase their provision of credit to cotton farmers. Empirical findings also reveal that in the presence of some institutional mechanisms, policies that have negative effect(producer price fall) on production, cotton production will not fall as much than in the absence of such institutional mechanisms.

Joseph (2011) studied the impacts of government maize supports on smallholder cotton production in Zambia. In Zambia, cotton has been an agricultural success story led by private cotton ginneries and smallholder production. Since liberalization in 1994, the cotton sector has seen periods of dramatic growth and two severe crashes. Production recovered well after the crash in 2000, but recovery since 2007 has not been as strong. The Zambian government has drastically increased its supports to smallholder production of maize since the 2005 harvest year through maize purchases by the Food Reserve Agency (FRA) and subsidized fertilizer targeted to maize through the Farmer Input Support Program (FISP). Because cotton is almost entirely produced in the country's main "maize belt", these maize supports in principle also affect the relative profitability of cotton, but any effects directly on smallholder cotton cropping decisions are largely unknown. This thesis attempts to move towards understanding the effects of the FRA and FISP maize supports on smallholder cotton production in Zambia. Two separate Cragg hurdle models were employed to determine the effects of the maize supports on i) smallholders" decisions whether to plant cotton, and ii) their land allocation decisions to cotton given that they decided to plant it. We also track household cotton planting decisions over a ten year period and analyze across several household indicators. We find three potential sources of dissimilarity in our results. The first potential source of variation is that our models control for time-constant unobserved effects at different levels; Model 1 controls for these effects at the household level while Model 2 controls for them at the wider, SEA level. A second potential source of discrepancy is that the models were created with different data sets and while we remained as consistent as possible in our variable definitions, the same set of variables was not available for both models. The third potentially problematic difference between our two methods is that we were unable to use the same years for both estimation procedures – Model 1 uses data from the 2003 and 2007 harvest years while Model 2 uses data from 2003 and 2006. While the results of our two models differ slightly, the results are consistent in showing no negative effects of maize supports (FRA maize purchases and FISP subsidies) on cotton planting decisions by smallholders through the 2006/07 growing season.

Gohil *et al.* (2016) examined constraints faced by cotton growers in crisis management of cotton cultivation in Gujarat, India. The study was carried out in Amreli and Bhavnagar District of South Saurashtra Agro-Climatic Zone of Gujarat State to identify the various constraints faced by cotton growers in cotton cultivation. A random sample of 200 cotton growers was selected from Amreli and Bhavnagar District and the constraints faced by cotton growers in cotton cultivation were to non-remunerative price, high price of soil reclamation materials, non-availability of information about future aberrant weather conditions including cyclone, high price of insecticides/ pesticides & fungicides, insufficient demonstration of improved technologies on farmers' field, high price of chemical fertilizers, high price of organic manures, irregular supply of electricity and lack of knowledge to diagnose the pests and diseases in the crop. The major constraints faced by the majority of respondents were: non- remunerative price (89.36 per cent), unavailability of certified seed (88.55 per cent), high price of improved seeds (83.24 per cent), high price of insecticides/pesticides & fungicides (81.44 per cent), lack of knowledge to diagnose the pests and diseases in the crop (80.40 per cent), irregular supply of electricity (79.39 per cent), high price of chemical fertilizers (78.12 per cent), high price of organic manure (74.42 per cent), non-availability of information about future aberrant weather conditions including cyclone (69.31 per cent), non-availability of implements for sowing proper seed rate and depth (68.33 per cent) and insufficient demonstration of improved technologies on farmers' field (65.56 per cent). The important suggestions offered by the respondents were: quality seed supply should be ensured, effective insect-pest control methods should be developed, input should be supplied at subsidized rate, village level workers should frequently contact the farmers to make them aware about new technologies, crop insurance should be made available for all the farmers at cheaper rate, provision of sufficient and timely credit facilities, remunerative price of farm produce and sufficient electricity should be provided.

Patrick and Tanyaradzwa (2010) assessed impact of climate change on cotton production under rainfed conditions: case of Gokwe, Ethiopia. Climate variability and change is a major threat to cotton production in Gokwe, which is largely dependent on rain fed. Cotton is the driving force for the district and changes in its levels, impact negatively farmers livelihood. This paper is a review of the farmers' vulnerability to climate change and the role adaptation in enhancing their livelihoods. Based on a time series trend analysis and correlation statistical analysis of the relationship between the climate variation scenarios and the cotton production level output over a 25 year period, and a random sample of 50 farmers; the results show that farmers are vulnerable to climate change. The relationship between the mean annual precipitation and cotton production is shown in the study. The rainfall increase was associated with the increase in cotton production output and, similarly, a decrease in rainfall resulted in low output. These annual rainfall patterns plotted in the study indicate that of the 25 years, from 1982 to 2007, at least ten had below normal rainfall. The drought conditions of 1981-1982, 1991-1992, and 2001-2002 were the major causal factors for the declining yields. In the 1991 to 1992 season, for example, a more than

80percent decrease in precipitation resulted in a 38percent decrease in cotton production in the district. Cotton production levels declined as precipitation decreased and temperature increased across the district. Although other physical factors, such as soil fertility and farm management practices, among other factors, have an important influence on agriculture, climate remained the dominant influence on cotton production. Household revenues were also negatively affected by the decline in cotton production output. The integration of sustainable policies and adaptation against climate change into the national policies and development strategies is recommended as the way forward.

Abdoulaye *et al.* (2015) studied impact of climate change on cotton production in Burkina Faso. The study evaluated the impact of climate change on cotton production in Burkina Faso. An econometric analysis resulted in identifying the major factors influencing cotton yields and evaluating the likely effects of future climate change. The results of our study regarding the potential impact of future climate change on cotton yield indicated that further increases in global temperature would significantly reduce the yield of cotton. Increasing temperature in the two first growing stages is mostly unfavorable for cotton yield, while it is favorable in the two last ones, particularly the third stage. Too much rain in the second stage is unfavorable for cotton yield but favorable in the three other stages. The result of the relationship between rainfall and cotton yield is quite consistent with the results in Some *et al.* (2006). That study used a crop simulation model and concluded that at the end of the rainy season cotton needs irrigation to reach its potential yield. Future changes in rainfall would also affect cotton production, but compared with the effects of temperature, the effects of rainfall are relatively lesser. Therefore, strategies for reducing the impacts of climate change on cotton production should emphasize the development of heat resistant cultivars rather than drought resistant ones in order to mitigate and adapt them to the effects of climate change.

Francis and Tsunemi (2014) assessed the influences of rainfall on cotton production and suggestions for adaptation in Ghana. In recent years, rainfall anomalies have led to numerous incidences of droughts in the Lawra district of the Upper West Region of Ghana. These anomalies have the potential to cause undesirable effects on cotton production and food security. This study analyzed annual and seasonal rainfall variability and their relationships with cotton production. The adaptation techniques required to mitigate the effects of rainfall anomalies were also suggested. Monthly rainfall data for 33 years available at the Babile weather station was used. Seasonal and annual rainfall variability and concentration were analyzed using the coefficient of variation and the precipitation concentration index respectively. Available data on annual production volumes of major crops produced between 1992 and 2012 was used. Correlation analysis was used to assess the influence of rainfall on cotton as well as other crops. The results revealed moderate seasonal and irregular annual rainfall concentration. Generally, rainfall in the district starts in May. However, the number of rain days and amount (mm) tend to decrease in June before peaking up in July and August. Correlation between annual rainfall and cotton production were negative. At seasonal level only sorghum, millet and cotton were positively correlated with rainfall. Based on the results obtained, this study concluded that identifying and implementing appropriate adaptation techniques through effective stakeholder collaboration was essential in boosting the production of cotton, sorghum, millet and cotton.

Thakare *et al* (2014) analysed the impact of weather parameters on cotton productivity at Surat (Gujarat), India. Global warming is casting its shadow in the form of climatic changes that is affecting the local weather conditions which has its bearing on crop production and water availability, the basic necessities for survival of life on the planet. In the present study, an attempt was made to investigate the cause of poor production of cotton in 2011-12 in Surat, Gujarat as compared to 2012-13 and 2013-14. Weather data since 2000 was analyzed and compared with the data of 2011-12 and comparison was made to find the abnormality in cotton crop productivity. It was found that during 2011-12, there was delayed monsoon, as well as during squaring and flowering stage (*i.e*. in August 2011) there was high rainfall (595.6 mm), maximum and minimum temperatures were above normal, during development (June-August) and flowering stage of crop (October-December) which disturbed the crop physiology indirectly affecting the yield of cotton. The combined effect of rainfall and temperature was on relative humidity that created conducive atmosphere for insect and pest attacks on crops. Due to changes in temperature and relative humidity, evaporative water demands would have further aggravated the watering needs of crop. The study concludes that erratic monsoon or delayed monsoon hampers crop physiology ultimately yield due to erratic weather conditions. Further, such changes in cotton growing areas could form the basis of planning and decisions on pricing, crop insurance, export and import policies of cotton crop.

2.3 Assessing the Constraints to Agriculture

Increasing amounts of scholarly attention has already been devoted to bringing attention to the evolving constraints that will be important for determining the production of food (cotton) in the future (Tilman *et al.*, 2012). Although the exact nature of these constraints depends on the context in question and will later be explored in the main body of the thesis, a number of these constraints are common across much of the world's agricultural sector. For instance, one way to increase production in future will be to increase the amount of land that is cultivated.

Historically, increases in area cultivated have been important for increasing the supply of agricultural goods. For example, between 1970 and 2005, cultivated area for the ten major global crops, which make up nearly 60percent of cultivated area, increased by 26percent (Tilman *et al.*, 2012). The prospects for continuing to increase cultivated area appear to be very limited, however. A primary issue is that there is increasing international recognition of the threat posed by agricultural land expansion to biodiversity, such as the encroachment of agriculture into fragile ecosystems, including forests. Similarly, increased land use competition from biofuels and other non-food crops is also predicted to restrict the amount of land that can be devoted to food crops. Expanding cultivatable area is therefore unlikely to be the solution to increasing the supply of agricultural production in the future. This means that increases in yield will form the basis for increasing the supply of crops (Bulte and Engel, 2016).

Past experience has highlighted agriculture's ability to substantially increase the productivity of land. For instance, sustained rates of yield growth for a number of staple crops were characteristic of the sector in many parts of the world during the twentieth century. Key to this was the increased use of a range of modern agricultural technologies. These technologies transformed land previously farmed using more traditional methods, into land that delivered much greater output per acre in many areas of the world. The utilisation of improved crop varieties and the use of modern farm inputs, such as fertiliser and irrigation, were integral to increasing the productivity of land in most areas of the world. For example, across developing countries yields for wheat increased by over 200percent and yields for rice increased by over 100percent (Pingali, 2012). The increased supply of staple crops has had very substantial effects on the real price of food, which showed trend rates of decline in the latter part of the twentieth century. Pingali (2012) estimate that rice prices would have been 80- 124percent higher and wheat prices 29-61percent higher without the productive gains spurred by crop genetic improvement programmes that occurred as part of the Green Revolution. Global food challenges in the present day are in many ways comparable to those fifty years ago. For example, between 1970 and 2005, total production of staple crops increased by 123percent. Concerns about an impending Malthusian crisis due to rapid and concentrated population growth were thus successfully averted.

Despite previous success in increasing the productivity of agriculture, a crucial issue pertains to whether rates of productivity growth in agriculture will be sustained in the future. There is increasing evidence that the productivity gains made from switching to modern farming techniques are slowing. A number of studies have noted a slowdown and even stagnation in the rate of yield growth for key staple crops in recent decades. Pingali (2012) estimate that globally, 24-39percent of areas growing cereals such as rice, wheat, maize and soybeans display non-increasing trends in yield growth. In addition, Lin and Huybers (2012) show that 50percent of major wheat growing areas show stagnant growth rates. Levels of public R&D in agriculture have also fallen over time, meaning that research into maintaining and improving the yield potential of cultivars has decreased (Lin and Huybers, 2012). In light of this, the primary challenge facing agriculture in the coming decades will be to maintain the productive success of the past and continue to increase the supply of these crops to meet future demand. In order to do this, agriculture will have to increasingly confront constraints to productivity on existing cultivated land (Tilman *et al.*, 2012). How significant these constraints are for current productivity and whether these constraints are likely to evolve in future is thus a first order concern for research on food security in the twenty-first century.

Given the importance of continuing to increase the productivity of agriculture in the coming years, it is crucial to understand the evolving constraints the sector could be exposed to. In recent years, increasing amounts of research effort has been devoted to understanding the interaction between environmental features and economic production systems in general. Much of this research has been motivated by overwhelming evidence that human induced emissions of greenhouse gases, such as carbon dioxide, are contributing to rising global temperatures (Tilman *et al.*, 2012).

According to the IPCC (2014), average surface temperatures around the world have increased by 0.85°C between 1880 and 2012. For example, previous work has shown that since 1980 yields of major cereals across the world have already reduced due to temperature increases, offsetting some of the gains made by technological improvements over this period (Lin *et al.*, 2012). Projections of future warming, although suffering from significant uncertainties about the sensitivity of the climate system to changes in greenhouse gas emissions and the uncertain nature of future emissions trajectories, indicate substantial increases in global temperatures. Warming by the end of the century is likely to exceed 2°C and in extreme cases could amount to 5°C. These projected increases in temperature have been predicted to substantially lower the productivity of agriculture in the future owing to the harmful effect of heat on crop growth. Moreover, climate change is also likely to affect other climatic inputs integral to agriculture, such as rainfall patterns and extreme heat, which could influence the probability of events generally considered harmful for agriculture, like drought and floods (IPCC, 2017).

How resilient the agricultural sector is to these shocks will be crucial to avoiding the adverse effect shocks to productivity for global markets and for producers and consumers more locally. The share of food traded internationally has risen steadily over time, and a range of government support schemes have been introduced aiming to stabilise the price of agricultural commodities so that local productivity shocks in agriculture tend to have less effect on local food prices (Anderson, 2010). However, the productivity of agriculture (cotton production) still remains crucial as a source of income for farmers and labourers.

Although these changes in climate present a challenge from a global food security perspective, a crucial point pertains to the expected geographical distribution of climate change impacts. For instance, growing areas in lower latitude regions (those nearer to the equator) have been identified as areas most vulnerable to the adverse effects of climate change (Anderson, 2010; Pingali, 2012). This stems from the fact that already these areas tend to be hotter and thus prone to extreme weather. Output from climate models predicts that by the end of the this century, growing season temperatures in the majority of tropical and sub-tropical areas will exceed those historically recorded as hottest more often than not. Despite this, research examining the potential economic impacts of climate change on agriculture has largely taken place in the United States and other developed countries (Anderson, 2010). Increased amounts of research are thus needed to assess exactly how agricultural production could be affected in areas of the world that may be particularly vulnerable to these changes and to understand the opportunities for reducing the adverse impacts of future changes borne by climate change.

For many countries, changes in rainfall are expected to constrain cotton production and therefore detrimentally impact cotton industry. An example of this might be a reduction in the growing season length or increased uncertainty in the start of the growing season. As consequence cotton yields in some countries are projected to fall by 50percent by 2020 and overall crop revenue might decrease by 90percent by 2100. Because of their low adaptive capacity, small-scale farmers are likely to be the worst affected by these decreases in revenue. Pingali (2012) predicted for eight contrasting sites in the Sudano-Sahelian zone of Burkina Faso, Senegal, Mali and Niger using a process- based crop model a negative impact on yields of millet and cotton of up to -41percent by the end century under an scenario with increased temperature and decreased rainfall. Pingali (2012) further predicted across West Africa crop yield decreases of up to 50percent as a result of increasing temperature. Furthermore, when warming exceeds 2^{0}C, negative impacts caused by this temperature rise cannot be counteracted by any potential positive change in rainfall.

Adaptation options based on appropriate planting dates are important for maximizing cotton yields because optimum planting dates favour the establishment of healthy and vigorous plants (Anderson, 2010). Generally, planting time in the Sudano-Sahelian zone coincides with the first substantial rains of the season in order to optimize yields of both grain and straw. However, due to the erratic rainfall pattern s, the first rain suitable for planting is often followed by several dry days that may cause the planting to fail and oblige the farmer to replant. Delayed planting can avoid this problem, but late planting results in a substantial shortening of the growing season and, consequently, in lower yields. Another constraint related to the planting date is the availability of labour, especially at the beginning of the rainy season. Lack of, or insufficient labour can hinder the capacity of the farmer to prepare the soil, thereby causing a delay in the planting date.

Rainfall is another weather parameter, which also affects the growth and development of cotton plant. Bange (2012) studied about the influences of rainfall on the yield of cotton in Madhya Pradesh, whereas, Pingali (2012) studied the same for Surat and reported negative effect of maximum and minimum rainfall on cotton crop. The study measured impact of climate change for the entire growing season of cotton and found that cotton production levels declined as precipitation decreased and temperature increased. However, the effect of climate change on cotton yields may not only depend on precipitation, but the precipitation occurring during specific growth stages (germination, fruiting, and maturity). Only few studies have focused on the relationship between the effects of early- and late-season precipitation on cotton yields. Bange, (2012) also studied the estimation of cotton yield based on weather parameters of Maharashtra.

Relative humidity is another weather parameter which also directly and indirectly affects yield of crop. Bange, (2012) reported that the relative humidity was found to be the vital weather parameters which contributed to the infestation of sucking pests. Exports of the crop from developing countries reached US$ 2.8 billion in 2009–2010, providing incomes to millions of farmers. It is therefore important to understand the scope for cotton farmers to adapt to the changing climate and how cotton production can have a reduced emissions profile (Bange, 2012). Keeping in view, the present study will evaluate agro-climatological constraints to low cotton production in Makarfi and Zaria, Kaduna State, Nigeria.

2.4 Effect of Agro-climatic Factors on Cash Crops Production in Nigeria

The vulnerability of Nigerian agricultural sector to climate change is of particular interest to policy makers because agriculture is a key sector in the economy accounting for between 60-70percent of the labour force and contributing between 30-40percent of the nation's GDP (Ajetomobe, Abiodun and Hassan, 2011). The sector is also the source of raw materials used in several processing industries as well as a source of foreign exchange earnings for the country. How much one can hold climate responsible for changes in agricultural productivity in Nigeria will, for a long time, remain a subject of research as long as other factors are at interplay in determining agricultural productivity. It was observed that weather and climate influence most of the processes involved in crop production for example: solar radiation produces energy for warming the soil, plants and for metabolic processes, rainfall and its characteristics in terms of amount of intensity, reliability and distribution influence crop growth and soil erosion. Atmospheric evaporation determines the performance and survival of crops. Planting and dates are determines by the start of rains (Ajetomobe *et al.,* 2011).

Climate plays a dominant role in agriculture having a direct impact on the productivity of physical production factors, for example the soil's moisture and fertility. Adverse climate effects can influence farming outputs at any stage from cultivation through the final harvest. Even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the cotton crop. High temperatures and atmospheric pressure are capable of causing health hazards to cash crops production household, leading to reduced productivity of labour and consequent loses associated with neglect of farm operations. It was observed that the consequential effect of weather risks result in considerable loses in income of the farmers (Omonona and Akintunde, 2010).

The effects of agro climatic factors on some selected food crops such as cowpea, yam, rice and maize in Ibadan, Oyo state was examined. Following his correlation and regression analysis, the responsiveness of each crop yield to specific agro climatic variables (rainfall, temperature, sunshine and humidity) was determined. It was found out that rainfall, rainy days and technology have positive effects on the yield of cotton and cowpea and accounted for 56percent and 52percent variations in total yields respectively in Oyo State. The effects of agro climatic factors on food crops yield in the Eastern ecological agricultural zone of Nigeria (using cassasva, cotton, yam, maize and rice as study crops) were analyzed. It was discovered that rainfall had negative effect on cassava in Anambra and Rivers states but a positive effect in Cross River State. Total rainfall, total number of rain days and technological trend were found to have accounted for 34percent variation in cassava yield, 59percent in yam yield in Rivers State (Omonona and Akintunde, 2010).

Climate variability has been identified as one of the most crucial factors that negatively affect sustainable agricultural production and the scope for reducing poverty in Nigeria. Therefore, any change in climate is bound to impact on the agricultural sector in particular and other socio-economic activities in general. The impacts could be measured in terms of effects on crop growth, availability of soil water, health and availability of farm labour, soil fertility, soil erosion, incidents of pests and diseases, and sea level rise (Nwajiuba, 2012).

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Types of Data

Data used in this research work were generated from both primary and secondary sources as indicated in the study.

3.1.1 Primary data

The primary data used were those that were collected directly from the field survey, oral interview and questionnaire.

3.1.2 Secondary data

Secondary data used were those data that were obtained from Kaduna State Agricultural and Rural Development Authority (KDARDA) for a period of twenty years (1998 to 2017), Nigerian Meteorological Agency (NIMET), previous researches, journals, textbooks, newspapers, magazines and encyclopedia. The data collected from KDARDA and NIMET they includes cotton yield and climatic parameters data respectively. The climatic parameters include rainfall and relative humidity.

3.2 Sources of Data

The data on cotton yield was obtained from the official records of the Kaduna State Agricultural and Rural Development Authority (KDARDA) for a period of twenty years (1998 to 2017).

Rainfall and relative humidity data were obtained from the Nigerian Meteorological Agency (NIMET) of Kaduna State, the choice of the climatic parameters was based on their importance in determining the time of farm preparations and planting, growth, development and yield of cotton in the study area.

3.3 Instruments for Data Collection

The instruments for data collection of this study include questionnaire design, oral interview and field survey.

3.3.1 Questionnaire design

The structured questionnaires design is part of the instrument for data collection which is aimed at obtaining detail information on how to achieve the stated objectives of the study. Structured questionnaires were administered to the cotton farmers of Zaria and Makarfi Local Government Areas. The questionnaire was structure into three sections based on the research objectives. The sections include the followings:

Section A: Demographic characteristics of the respondents

Section B: Agro-constraints faced by cotton growers in the study area

Section C: Adaptation strategies put in place by cotton growers to enhance cotton production in the study area

3.3.2 Oral interview

An oral interview is an effective research technique which help the interviewer access his or her information needed to carry out his research effectively and efficiently. This method involved personal meetings with designated officials in adaptation strategies put in place by cotton growers to enhance cotton production in the study area, cotton farmers and stakeholders that are into cotton production in the study areas. This information derived from the oral interview was integrated into that of questionnaire analysis during results and discussion.

3.3.3 Field survey

The field survey revealed those areas within the study areas that are viable to cotton production as well as their constraints. Thus, some of the cotton farmers were selected randomly in a stratified way that adequately represents the widening of the study area. And the observations was based on the aim and objectives of the research work. This instrument was used to add value to the information generated in questionnaire and oral interview.

3.4 Sample Size and Technique

Sample size was drawn using Yamani's formula. This formula is concerned with applying a normal approximation with a confidence level of 95percent and a limit of tolerance level (error level) of 5percent.

Sample points for this study include some officials of Kaduna State Agricultural and Rural Development Authority (12 staff) and cotton farmers as well as stakeholders of the study area. To this extent the sample size was determined by

$$n = \frac{N}{1+Ne^2} \qquad (3.1)$$

Where: n = the sample size

N = population (This include cotton farmers of Zaria and Makarfi LGAs)

e = the limit of tolerance (0.05)

$$\text{Therefore, } n = \frac{408{,}198}{1 + 408{,}198\,(0.05)^2} = \frac{408{,}198}{1 + 408{,}198\,(0.0025)} = \frac{408{,}198}{1 + 1{,}020} = \frac{408{,}198}{1{,}021} = 399$$

The study respondents were 399 and simple random sampling was used to distribute the questionnaires among the respondents.

3.5 Method of Data Analysis

3.5.1 Examine rainfall and relative humidity trends in the study area

The methods employed for the data analysis for this objective were mean and mean deviation. Rainfall and relative humidity data were obtained on yearly basis for a period of twenty years (1998 – 2017). The mean annual relative humidity was computed using this statistical technique that was adopted by Li *et al.,* (2003). This Li *et al.*, statistical description was used to achieve objective one of this study.

$$\overline{X} = \frac{\Sigma x}{n} \qquad (3.2)$$

Where x = annual rainfall and relative humidity for a giving period

N = number of years

The mean deviation used in this research work was to analyzed rainfall data in relation to cotton yield. The deviation represents extends of variation of parameter from the mean value, the mean deviation is expressed as $M.D = \sum f(x-\bar{x})/N$ (3.3)

Where x = annual rainfall for a giving period

$\bar{x}$ = the average annual rainfall (yearly)

n = number of years

M.D = mean deviation

3.5.2 Agro-constraints faced by cotton growers in the study area

The agro-challenges faced by cotton growers in the study area was examined based on the respondents as well as stakeholder opinions. Their responses were analysed using frequency percentage as indicated in the equation.

Frequency percentage equation is given as follow:

$$\text{Frequency-percentage} = \frac{\text{Number of observed}}{\text{Total Number}} \times \frac{100}{1}$$

(3.4)

3.5.3 Examine the relationship between climate variables and cotton production in the study area

Multiple linear regression was used to test the relationship between rainfall, relative humidity and cotton production.

$$Y = \pm a_1 \pm b_{\underline{1}} x_1 \pm b_2 x_{\underline{2}} + b_3 \underline{x}_3 \ldots \ldots \ldots \ldots \ldots \ldots \pm b_n x_{\underline{n}} \tag{3.5}$$

Where: Y = Cotton production yield; x_1, x_2, x_3= rainfall and relative humidity

a_1, b_1, b_2, b_3……….b_n = are constant

$$b_1 = \frac{\sum(x_{2y} X^2{}_1 - \sum x_1 y . \sum x_1 x_2}{\sum x^2{}_1 . \sum x^{2\partial} - [\sum x_1 \sum x_2]^2} \; for\ 2\ variables$$

$$b_1 = \frac{\sum(x_2 - \bar{x}_2)(y - \bar{y}).\sum(X_1 - \bar{X}_1)^2 - \sum(x_1 - \bar{x}_1) \\ (y - \bar{y}).(\sum x_1 - \bar{x}_1.x_2 - \bar{x})}{\sum(x_1 - \bar{x})^2.\sum(X_2 - \bar{X}_2)^2 - [\sum(x_1 - \bar{x}_1)(x_2 - \bar{x}_2)]^2}$$

$$b_2 = \frac{\sum x_1 y . \sum x_2^2 - \sum x_2 y . \sum x_1 x_2}{\sum(X_1 - \bar{X}_1)^2 . \sum x_2^2 - (\sum x_1 x_2)^2}$$

$$b_2 = \frac{\sum(x_1 - \bar{x}_1)(y - \bar{y}).\sum(x_2 - \bar{x}_2)y - \bar{y}\sum(x_1 - \bar{x}_1)(x_2 - \bar{x}_2)}{\sum(x_1 - \bar{x}_1)^2.\sum(x_2 - \bar{x}_2)^2 - [\sum(x_1 - \bar{x}_1)(x_2 - \bar{x}_2)]^2}$$

$$a = \bar{y} - b_1\bar{X}_1 - b_2\bar{X}_2$$

X was for rainfall and relative humidity values and Y was for cotton yield values. This was used to achieve objective three of the study.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Examine Rainfall and Relative Humidity Trends in the Study Area

Rainfall in the study area is an important climatic element for cotton yield and other agricultural activities. An inter-monthly change in precipitation has been the major weather element that is responsible for the attainment of most agricultural productions in the study area. Cotton farming in the study area is often related to the variability of precipitation since there is dependence on rain fed cultivation by the farmers. Hence, water shortage becomes a great limitation to crop production, particularly cotton production in the study area. As revealed in Figure 4.1, annual rainfall tend to be decreasing in the study area despite the fluctuation in some years (2007, 2013 and 2015). The highest annual rainfall was in the year 1999 with 2272.4 mm and the lowest was in the year 2008 with 848.5 mm. This implies decrease in cotton production across the study area as a result of decrease in annual rainfall.

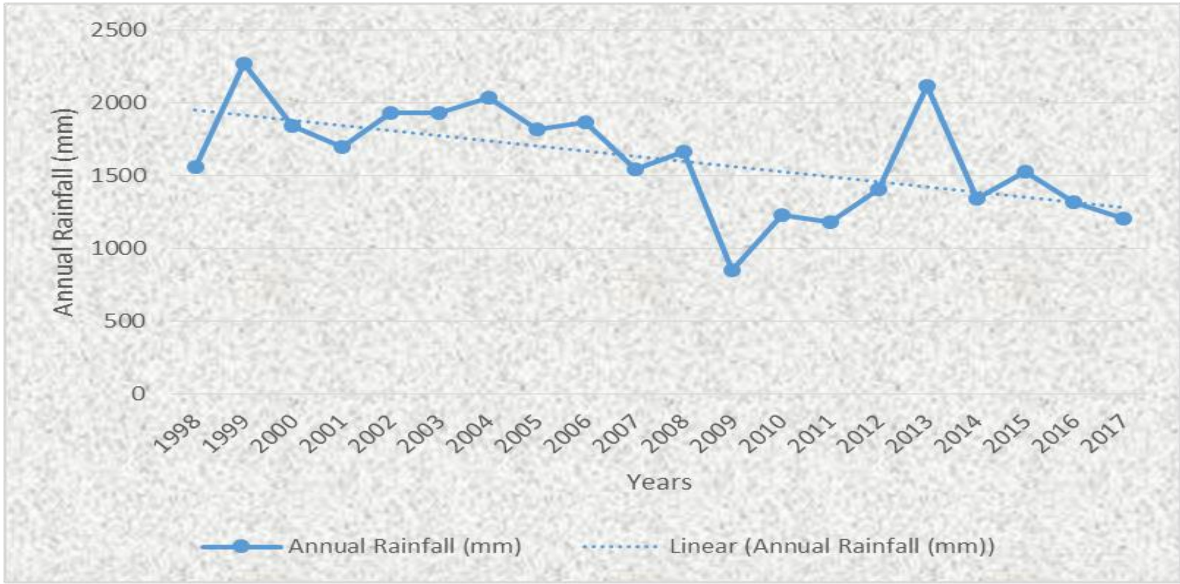

Figure 4.1: Annual Rainfall of the Study Area (1998 – 2017)

Continuous rainfall during flowering and boll opening has impaired the pollination and thus reduce fiber quality. However, increasing amount of rainfall in early growing period of cotton production in the study area has resulted in higher yield of cotton.

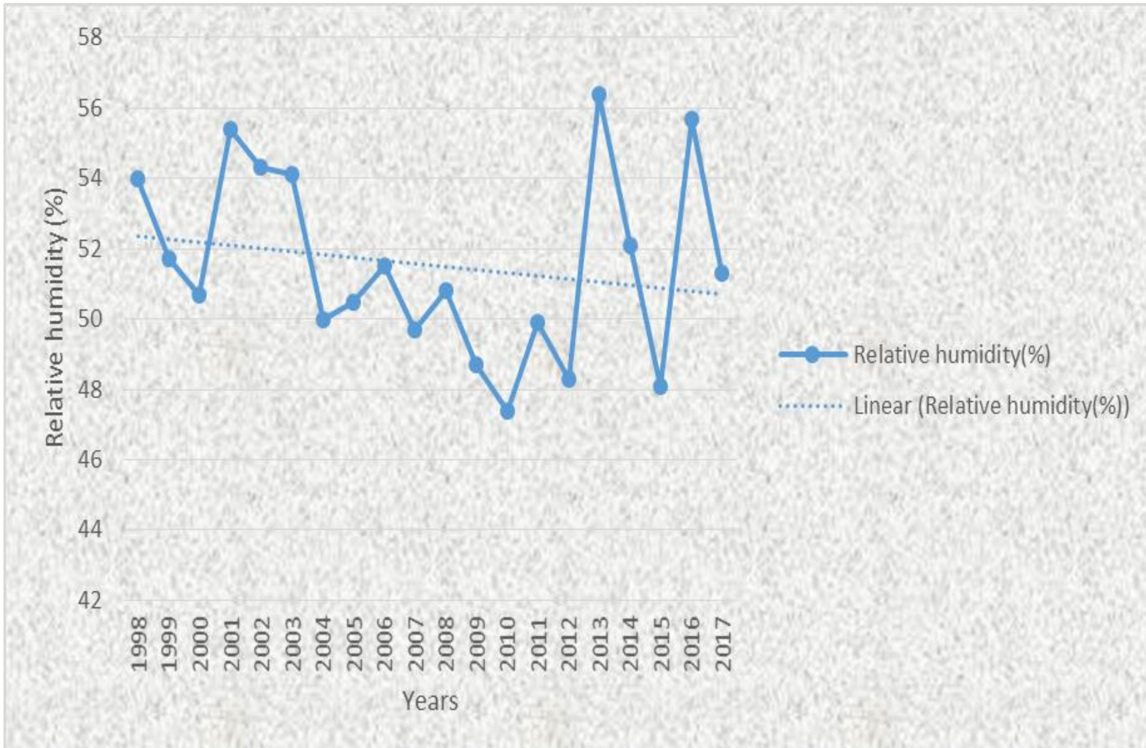

Figure 4.2: Mean Annual Relative Humidity of the Study Area (1998 – 2017)

As revealed in Figure 4.2 of the study, mean annual relative humidity tend to be decreasing despite the fluctuation. The highest mean annual relative humidity was recorded in the year 2013 with 56.4percent and the least was recorded in the year 2010 with 47.4percent. Cotton yield is a function of growth rates, flower production rates and boll retention during fruiting period depend on minimum relative humidity of 50percent. This implies that the lower the relative humidity, the lower the cotton yield in the study area. Because cotton grown at lower relative humidity had higher transpiration rates, lower leaf temperatures and lower stomata conductance.

4.2 Agro-constraints Faced by Cotton Growers in the Study Area

It is noticeable from the performance of the cotton production in the study area that since 2003/2004 cropping season, there has been a fall and fluctuating pattern in the production trends in cotton. The production trend in cotton had not witnessed remarkable improvement between 2007/2008 cropping year while the 2010 – 2012 cropping seasons experienced a decline and this agreed with the work of Baffes (2014); and Idem (2009).

As revealed in Table 4.1, 301 respondents affirmed that their exist agro-constraints faced by cotton grower in the study area and 49 respondents said they do not suffer any agro-constraints since they have available fertilizers and pesticides. The details of these agro-constraints were given in Table 4.2.

Table 4.1: Presence of Agro-constraints Faced by Cotton Growers in the Study Area

Options	Frequency	Percentage (%)
Yes	301	86.0
No	49	14.0
Total	350	100

Source: Field Survey (2020)

The agro-constraints faced by cotton growers in the study area include inadequate fertilizer, inadequate pesticides, inadequate market opportunities, late planting, inadequate storage facilities after harvest and increased cotton diseases as indicated in Table 4.2 of the study.

Table 4.2: Agro-constraints Faced by Cotton Growers in the Study Area

Options	Frequency	Percentage (%)
Inadequate fertilizers	63	20.9
Inadequate pesticides	51	16.9
Inadequate market opportunities	32	10.6
Late planting	26	8.6
Inadequate storage facilities after harvest	59	19.6
Increased cotton diseases	70	23.4
Total	301	100

Source: Field Survey (2020)

As revealed in Table 4.2, increased cotton diseases ranked the highest with 23.4percent, inadequate fertilizers ranked second with 20.9percent, inadequate storage facilities after harvest ranked third with 19.6percent, inadequate pesticides ranked fourth with 16.9percent, inadequate market opportunities ranked fifth with 10.6percent and late planting ranked the least with 8.6percent. This implies that increased cotton diseases is the major agro-constraint facing cotton growers in the study area. About 23.4percent of the respondents said their farms were attacked by aphids, bacteria blight (*Xanthmonas malvacearum*) dowson and alternaria leaf spot (A*lternaria* *Macopora* *Zim*) the spread of these two diseases is capable of destroying an entire cotton crop. Most of the cotton growers in the study area suffer in the hands of unscrupulous middle men who often exploit and rob them of benefits of their effort. The problem is compounded because of lack of interference by government on matters affecting marketing and pricing of cotton.

As indicated in Table 4.3, numbers of hectares of land used in production of cotton are within the range of one to ten.

Table 4.3 Hectares of land for cotton production

Hectares of land	Frequency	Percentage (%)
1 to 2 hectares	145	48.2
3 to 5 hectares	122	40.5
6 to 9 hectares	11	3.7
10 and above	23	7.6
Total	**301**	**100**

Table 4.3 revealed that 1 to 2 hectares ranked highest with 145 respondent's, 3 to 5 hectares ranked second with 122 respondent's, 10 and above ranked third with 23 respondent's and 6 to 9 hectares ranked least with 11 respondent's. This shows that most of the respondent's cultivate 3 to 5 hectares of land for cotton production in the study area.

Regarding the assessment of cotton yield in the study area, Table 4.4 shows that cotton yield have been decreasing over the decade with 275 respondent's as against 26 respondents who said there cotton yield is increasing in the area. This implies that cotton yield is decreasing in the study area.

Table 4.4: Perception of respondents on cotton yield

Cotton yield	Frequency	Percentage (%)
Increasing over the year	26	8.6
Reducing over the year	275	91.4
Total	**301**	**100**

Table 4.5 revealed that most of the respondent's do not use fertilizer to supplement soil nutrients in the study area and this has resulted to low cotton yield in the study area.

Table 4.5: Use of fertilizer for cotton production

Use of fertilizer	Frequency	Percentage (%)
Yes	45	15.0
No	256	85.0
Total	**301**	**100**

As depicted in Table 4.5, only 45 respondents use fertilizer to enhance their cotton yield and the remaining 256 respondents do not use fertilizer to enhance cotton yield in the study area and has led to low cotton yield. Other factors that have led to low cotton yield in the study area include poor land management, climatic factor, pest and diseases and too much reliance on small parcel of land.

Table 4.6 revealed that 64.8percent of the respondents do not use pesticides to reduce the effects of pest on the cotton yield as against 35.2percent who uses pesticides to enhance cotton yield in the study area.

Table 4.6: Use of Pesticides for cotton production

Use of pesticide	Frequency	Percentage (%)
Yes	106	35.2
No	195	64.8
Total	**301**	**100**

4.3 Examine the Relationship between Climate Variables and Cotton Production in the Study Area

Rainfall is regarded as the most important agro-climatic element influencing cotton cultivation, about 70percent of the cultivated land area falls under semi-arid region known for lower and unreliable rainfall pattern. Reduced amount of rainfall and extended dry spells during the cotton planting season were reported as the major reason accountable for lower average yield in many parts of the study area.

Table 4.7: Descriptive Statistics for Annual Rainfall and Cotton Production

	Mean	Std. Deviation	N
Cotton Yield (tonnes)	37.218	9.0383	20
Annual Rainfall (mm)	973.44	274.554	20

Table 4.7 revealed that standard deviation of cotton yield was 9.03tonnes and that of annual rainfall was 274.55mm. The mean of cotton yield was 37.21tonnes and that of annual rainfall was 973.44mm.

Table 4.8: Regression between Annual Rainfall and Cotton Production (ANOVA)

Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	1306.680	1	1306.680	34.440	.000[b]
1	Residual	1062.329	18	37.940		
	Total	2369.010	19			

a. Dependent Variable: Cotton Yield (tonnes)

b. Predictor: (Constant), Annual Rainfall (mm)

At .05 confidence level, the significant value of F from Table 4.8 is 5.32. Hence, as value of F which is 34.44 is larger than 5.32, therefore indicates that there is a significant linear relationship between mean annual rainfall and cotton yield in the study area.

Table 4.9: Model Summary between Annual Rainfall and Cotton Yield

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.743[a]	.552	.536	6.1596

As indicated in Table 4.9, R^2 was 0.552 for annual rainfall, thus, rainfall account for 55.2percent of the explained variance between annual rainfall and cotton yield in the study area. This shows that other climatic variables like relative humidity and temperature too play significant role in cotton yield since the remaining 44.8percent is left unexplained.

Table 4.10: Correlation Coefficients between Annual Rainfall and Cotton Yield

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	13.418	4.208		3.188	.084
	Annual Rainfall (mm)	.024	.004	.743	5.869	.000

a. Predictors: (Constant), Annual Rainfall (mm)
b. Dependent Variable: Cotton yield (tonnes)

Table 4.10 revealed that annual rainfall is positively linearly linked to cotton growth in the study area with 0.84. As such, the regression equation now becomes (y'= bx + a) becomes **y' = 0.240(x) + 13.418**.

Table 4.11: Regression analysis between relative humidity and cotton yield

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	4.576	1	4.576	.054	.818[b]
	Residual	2364.434	18	84.444		
	Total	2369.010	19			

a. Dependent Variable: Cotton Yield (tonnes)

b. Predictors: (Constant), Relative Humidity (^0C)

At 0.05 confidence level, the F value from Table 4.11 is 5.32 therefore, since the F value of 0.54 is less than 5.32 indicates that a significant relationship exists between relative humidity and cotton yield within the study area.

Table 4.12: Model summary between average relative humidity and cotton yield

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change
1	.044[a]	.022	-.034	9.1893	.022

As indicated in Table 4.12, R^2 was 0.22 for relative humidity, thus, relative humidity account for 22.0percent of the explained variance between relative humidity and cotton yield in the study area.

4.4 Summary of Findings

The summary of findings for this study include

a. As revealed in Figure 4.1, annual rainfall tend to be decreasing in the study area despite the fluctuation in some years (2007, 2013 and 2015). The highest annual rainfall was in the year 1999 with 2272.4mm and the lowest was in the year 2008 with 848.5mm. This implies decrease in cotton production across the study area as a result of decrease in annual rainfall.

b. As revealed in Figure 4.2 of the study, mean annual relative humidity tend to be decreasing despite the fluctuation. The highest mean annual relative humidity was recorded in the year 2013 with 56.4percent and the least was recorded in the year 2010 with 47.4percent. Cotton yield is a function of growth rates, flower production rates and boll retention during fruiting period depend on minimum relative humidity of 50percent. This implies that the lower the relative humidity, the lower the cotton yield in the study area. Because cotton grown at lower relative humidity had higher transpiration rates, lower leaf temperatures and lower stomata conductance.

c. As revealed in Table 4.1, 301 respondents affirmed that their exist agro-constraints faced by cotton grower in the study area and 49 respondents said they do not suffer any agro-constraints since they have available fertilizers and pesticides. The details of these agro-constraints were given in Table 4.2.

d. As revealed in Table 4.2, increased cotton diseases ranked the highest with 23.4percent, inadequate fertilizers ranked second with 20.9percent, inadequate storage facilities after harvest ranked third with 19.6percent, inadequate pesticides ranked fourth with 16.9percent, inadequate market opportunities ranked fifth with 10.6percent and late planting ranked the least with 8.6percent. This implies that increased cotton diseases is the major agro-constraint facing cotton growers in the study area. About 23.4percent of the respondents said their farms were attacked by aphids, bacteria blight (*Xanthmonas malvacearum*) dowson and alternaria leaf spot (*Alternaria Macopora Zim*) the spread of these two diseases is capable of destroying an entire cotton crop. Most of the cotton growers in the study area suffer in the hands of unscrupulous middle men who often exploit and rob them of benefits of their effort. The problem is compounded because of lack of interference by government on matters affecting marketing and pricing of cotton.

e. Table 4.3 revealed that 1 to 2 hectares ranked highest with 145 respondent's, 3 to 5 hectares ranked second with 122 respondent's, 10 and above ranked third with 23 respondent's and 6 to 9 hectares ranked least with 11 respondent's. This shows that most of the respondent's cultivate 3 to 5 hectares of land for cotton production in the study area.

f. Regarding the assessment of cotton yield in the study area, Table 4.4 shows that cotton yield have been decreasing over the decade with 275 respondent's as against 26 respondents who said there cotton yield is increasing in the area. This implies that cotton yield is decreasing in the study area.

g. As depicted in Table 4.5, only 45 respondents use fertilizer to enhance their cotton yield and the remaining 256 respondents do not use fertilizer to enhance cotton yield in the study area and has led to low cotton yield. Other factors that have led to low cotton yield in the study area include poor land management, climatic factor, pest and diseases and too much reliance on small parcel of land.

h. Table 4.6 revealed that 64.8percent of the respondents do not use pesticides to reduce the effects of pest on the cotton yield as against 35.2percent who uses pesticides to enhance cotton yield in the study area.

i. Table 4.7 revealed that standard deviation of cotton yield was 9.03tonnes and that of annual rainfall was 274.55mm. The mean of cotton yield was 37.21tonnes and that of annual rainfall was 973.44mm.

j. At .05 confidence level, the significant value of F from Table 4.8 is 5.32. Hence, as value of F which is 34.44 is larger than 5.32, therefore indicates that there is a significant linear relationship between mean annual rainfall and cotton yield in the study area.

k. As indicated in Table 4.9, R^2 was 0.552 for annual rainfall, thus, rainfall account for 55.2percent of the explained variance between annual rainfall and cotton yield in the study area. This shows that other climatic variables like relative humidity and temperature too play significant role in cotton yield since the remaining 44.8percent is left unexplained.

l. At 0.05 confidence level, the F value from Table 4.11 is 5.32 therefore, since the F value of 0.54 is less than 5.32 indicates that a significant relationship exists between relative humidity and cotton yield within the study area.

m. As indicated in Table 4.12, R^2 was 0.22 for relative humidity, thus, relative humidity account for 22.0percent of the explained variance between relative humidity and cotton yield in the study area.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The two main climatic elements of important to cotton production were found to be rainfall and relative humidity. When relative humidity rises above the acceptable limit (60percent) for cotton growth, it brings about quicker development together with decreased cotton yields, consequently this discourages the farmers by lowering their morale and even their productivity. Agriculture and particularly cotton production in Zaria and Makarfi Local Government Areas is greatly sensitive to the variability in weather and climate, especially to those extreme weather phenomena like drought and severe storms.

From the foregoing findings, these conclusions may be drawn it is possible to grow cotton profitably if it is taken as a package. The study shows that yields are low due to inadequate fertilizer, inadequate pesticides, inadequate market opportunities, late planting, inadequate storage facilities after harvest and increased cotton diseases. Provision of enabling environment by government in form of regulatory measures for marketing and prices will go a long way to facilitate increased cotton production.

5.2 Recommendations

Based on summary of findings and conclusion of this study, the following recommendations were highlighted to enhance cotton production in the study area and Kaduna State in general.

(i) Government as well as stakeholders alike should endeavor to facilitate lower input cotton cultivation and to promote its sustainability. They should also promote environmentally friendly farming technologies and instill in the farmers international best practices.

(ii) The Kaduna State Agricultural Development Programme (KSADP) should device way to motivate its agricultural extension workers to be able to assist the rural cotton growers on enhanced productivity and to guide them on new agricultural innovations.

(iii) Agricultural Research Institutes should redouble their efforts and focus on improving seed varieties of cotton and other key crops in order to reverse the decline in productivity as well as to enable coping with the changes brought about by change in climate. Such work needs to pay particular attention to the development and promotion of seed varieties that are suitable for specific agroecological zones of Kaduna State.

(iv) Timely and accurate weather forecasting services should be provided to the farmer's in order to improve cotton faming activities.

(v) Farmers should be encouraged to adopt dry season cotton farming, this will ensure all year round farming and such reduce their vulnerability to changing climate.

(vi) Farmers should have access to Fertilizer, pesticide and improved groundnut seed at the beginning of every growing season.

(vii) For the last few decades, research in Africa has focused only on drought resistant cultivars of cotton. This strategy may not be sufficient according to the results of this study. Therefore, strategies for reducing the impacts of agroclimate on cotton production should emphasize on the development of heat resistant cultivars rather than drought resistant cotton cultivars in order to mitigate and adapt to the effects of climate variability.

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