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Application of Geographic Information System To The Effects of Climatic Variability on Sustainable Agricultural Production in Kwara State of Nigeria

By Dr. Jimoh H. Isah, A. O Adeoye
University of Ilorin, Nigeria.

Abstract - This research endeavour is on the application of Geographic Information System (GIS) as a tool for analysing the roles of microclimatological characteristics of the study area on the production rates of some selected agricultural products. In the process, specific climatic parameters were used so as to observe the climatic trends over a decade with that of agricultural production rates. Essentially, the required datasets were sourced from the Nigerian Meteorological Agency, Kwara Agricultural Development Project Office and Survey Department of Kwara State Ministry of Lands and Housing, Ilorin. The climatic data were later analysed through condesctriptive statistical techniques and the use of charts to show the rates of variation among the parameters used. Also, the selected crops were shown on charts too so as to reveal the trends of variation between the rates of crop production too. Finally, the climatic data were drawn against the crop production rates to indicate concisely the trends of climatic variation especially as it affects the crop production rates over the decade. Essentially, the following constitute as the major observations from the analysis of the datsets: First, most of the crops had the highest yield for the decade in 2008. And in year 2001 the highest value of temperature was recorded while relative humidity and rainfall had second to the lowest values. Further, Year 2004 had the highest rainfall value, temperature and relative humidity were moderate where maize, cassava and rice recorded below average yields. Then, sorghum had its second to the lowest yield value. In essence, the climatic parameters have been found to play crucial roles in the productivity rates for all the crops tested or investigated, meaning that clear understanding about the relevancies of these climatic parameters should be understood before engaging in agricultural activities so as to avert the incidence of crop failures.

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Dr. Jimoh H. Isah[α], A. O Adeoye[Ω]

Abstract - This research endeavour is on the application of Geographic Information System (GIS) as a tool for analysing the roles of microclimatological characteristics of the study area on the production rates of some selected agricultural products. In the process, specific climatic parameters were used so as to observe the climatic trends over a decade with that of agricultural production rates. Essentially, the required datasets were sourced from the Nigerian Meteorological Agency, Kwara Agricultural Development Project Office and Survey Department of Kwara State Ministry of Lands and Housing, Ilorin. The climatic data were later analysed through condesctriptive statistical techniques and the use of charts to show the rates of variation among the parameters used. Also, the selected crops were shown on charts too so as to reveal the trends of variation between the rates of crop production too. Finally, the climatic data were drawn against the crop production rates to indicate concisely the trends of climatic variation especially as it affects the crop production rates over the decade. Essentially, the following constitute as the major observations from the analysis of the datsets: First, most of the crops had the highest yield for the decade in 2008. And in year 2001 the highest value of temperature was recorded while relative humidity and rainfall had second to the lowest values. Further, Year 2004 had the highest rainfall value, temperature and relative humidity were moderate where maize, cassava and rice recorded below average yields. Then, sorghum had its second to the lowest yield value. In essence, the climatic parameters have been found to play crucial roles in the productivity rates for all the crops tested or investigated, meaning that clear understanding about the relevancies of these climatic parameters should be understood before engaging in agricultural activities so as to avert the incidence of crop failures.

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I. Introduction

Climate variability is rapidly becoming the most important environmental challenge facing mankind. Small temperature changes may seem inconsequential to the unwary, but only because small temperature shifts are often inconspicuous to people. A small temperature change to the vast volume of oceans covering the earth represents immense changes in the energy system. These energy changes can become concentrated and focused, resulting in massive hurricanes and storms. The slightest temperature change at the right moment can trigger outbreaks of insect pests or disease vectors, which can destroy entire landscapes, forest or croplands. Everything in nature is related, so outbreaks or changes in one area trigger changes in other areas. For example; the immediate survival of many coastal areas, populations, forests and wildlife may now depend on our ability to study, understand and share the small changes we observe in the environments and ecosystems around man.

The current talk about climatic variability has been correlated with the activities of man which have in turn generated microclimate variations, pollution of environment by forest fuels burnt daily from industries and automobiles all of which generate heat, there by altering the heat balance. Specifically, urbanization has been found to modify the city climate (Bryson and Ross, 1972). And this include the effects of the changes in physical land surface, which increases in roughness and wind speed. Further, several human activities generate enormous particles into space that are capable of greatly modifying the solar energy incident on the earth surface (Landsberg 1970).

Abnormal changes in temperature and rainfall, increasing frequency, intensity of droughts and floods have long-time implications for the viability and productivity of world agro-systems. Essentially, agriculture is the sector most affected by changes in climate patterns and will be increasingly vulnerable in the future. Especially at risk are developing countries, which are highly dependent on agriculture and have fewer resources and options to combat damages from climatic variation. Agriculture is the production, processing, marketing and use of foods and bye products from plants and animals. As a matter of fact, agriculture was the key development that led to the rise of human civilization, with the husbandry of domesticated animals and plants (i.e crops) creating food surplus that enabled the development of more densely populated and stratified societies. The major agricultural products can be broadly grouped into foods, fibres, fuels and raw materials. Specifically, in the 21st

Author α : Department of Geography & Environmental Management, University of Ilorin, Nigeria. E-mail : drhijpapa@yahoo.com

century, plants have been used to grow biofuels, biopharmaceuticals, bioplastics etc. specific foods include; cereals, vegetables, fruits and meat. Fibres include; cotton, wool, hemp, silk and flax. Raw materials include; lumber and bamboo, other useful materials produced by plants are resins. Biofuels include; methane from biomass, ethanol and biodiesel. Cut flowers, nursery plants, tropical fish and birds for the pet trade are some of the ornamental products too. To appreciate the relevancies of GIS in all of these discussions, the basic components of a GIS are the computer system, geospatial data and users. To this end, a GIS will permit the performance of three fundamental stages of work namely;

i. Data Entry:- early stage in which data about the studied phenomena is entered into the GIS and representations are built.
ii. Data Analysis:- middle stage in which representations are manipulated and studied to gain (new) insight.
iii. Data presentation:- final stage in which the results of analysis are presented in maps or otherwise. With GIS, we operate on and manipulate a representation of real world phenomena (model of it).

Man has for ages been interested in climate and the study of climate is as ancient as man's curiosity about his environment. This is hardly surprising since climate influences man and his diverse activities in numerous ways. The air that man breathes, the food he eats are weather related, even his occupation, clothing and forms of shelter are to a large extent determined by the micro climatic condition of his area. Modern man not willing to live at the mercy of weather like his primitive ancestors wants to study, understand, manage and even control weather especially for his immediate locality in order to predict, modify or control it where possible. Some areas of man's life where weather and climate is posing serious challenges is largely on agriculture.

II. Aim and Objectives of the Study

The main focus of this work is to examine the climatic characteristics and the trends in relation to agricultural production. To achieve this, the following specific objectives are have being focused as follows:

i. To study and present some climatic parameters in relation to agricultural production,.
ii. To determine the trends of agricultural productivity over a decade; and
iii. To forecast the possible climatic conditions as it may affect agricultural production.

III. Literature Review

The atmosphere is not static, rather it is in constant turmoil. Its characteristics change from place to place and over time at any given place on time scales ranging from microseconds to hundreds of years. There are important interactions within the atmosphere causing such changes. Thus, the changes within the atmosphere may be internally induced within the earth atmosphere system of externally induced by extraterrestrial factors. Essentially, weather variations and climatic variations. Weather is extremely variable particularly in the temperate region. But whether in the tropics or in the temperate region the existence of diurnal and seasonal weather changes cannot be denied. The weather changes collectively make up climate. There are variations in climate itself. When these fluctuations follow a trend we talk of climatic trends. Over a long period of time, climatic fluctuations may be such that, a shift in type of climate prevailing over a given area takes place. In that case, we talk of a change in climate or climatic change. Importantly, the components of climate that seriously influence agricultural productivity levels are temperature, humidity and rainfall, others are air pressure, sunshine rate, cloudiness, nature of surfaces among others (see tables 1 and 2).

Table 1 : Temperature requirement for selected crops

S/N	Crops	Effective Growth Energy (EGE)
1	Swamp rice	Greater than 350°F
2	Oil palm	250-350°F
3	Rubber, cocoa, coconut	250-300°F
4	Rice, maize, beniseed	200-250°F
5	Sourghum	100-250°F
6	Cotton & groundnut	100-200°F
7	Millet	75-150°F

Source : Oshodi, (1966)

Table 2 : Rainfall requirement for selected crops.

S/N	Crops	Mean Annual Rainfall
1	Yam	At least 1250mm
2	Kolanut	At least 1250mm
3	Ground nut	500-1000mm
4	Beniseed & soya beans	1250-1500mm
5	Oil palm	1500-3000mm
6	Cocoa	1250-2000mm
7	Rubber	2000-2500mm
8	Cotton	652-1250mm

Source : Ayoade, 2004

As a matter of fact, the impact of climatic variability on agriculture in most developing countries with crop failure and livestock deaths are causing higher economic losses and thus contributing to higher food prices and under mining food security with great frequency. Also, increasing population's demand for food is rising. Below are some of the areas of agriculture that has been affected by climatic variability;

a) Soil processes

The potential of soils to support agriculture and distribution of land use will be influenced by changes in soil water balance;

- Increase in soil water deficits i.e dry soil becomes drier, therefore increased need for irrigation.
- Could improve soil workability in wetter regions and diminish poaching and erosion risks.

b) Crops

The effects of increased temperature and CO_2 levels on arable crops will be broadly neutral;

- The range of current crops will move northward.
- New crop varieties may need to be selected.
- Horticultural crops are more susceptible to changing conditions than arable crops.
- Field vegetables will be particularly affected by temperature change.
- Phaselous bean, onion and sweet corn are most likely to benefit commercially from higher temperature.
- Water deficits will directly affect fruit and vegetable production.

c) Grass lands and Livestock

- There is unlikely to be a significant change in suitability of livestock in some systems.
- Pigs and poultry could be exposed to higher incidence of heat stress, thus influencing productivity.
- Increase in disease transmission by faster growth rates of pathogens in the environment and more efficient and abundant vectors e.g insects.
- Consequences for food quality and storage.

d) Weeds, Pests and Diseases

Weeds evolve rapidly to overcome control measures, short lived weeds and those that spread vegetatively (creeping, buttercup, couch etc) evolve at the greatest rates;

- Rates of evolution will increase in hotter, drier conditions and in extreme years; could lead to some types of herbicide tolerance becoming more common.
- Possible increase in the range of many native pests and species that at present are not economically important may become so.
- Surveillance and eradication processes for other significant pests such as the colarado beetle will become increasingly important.

Essentially, the output from a GIS in the form of maps combined with satellite imagery allow researchers to view the subject in an impressive way that are also invaluable for conveying the effects of climate change to non-scientists. Prediction of impact of the variation in climate on any area of interest, especially, agriculture inherently involves many uncertainties stemming from data and models. This of course is the place GIS application in this paper and have been in part documented in the work of De Smith Goodchild, (2008).

IV. The Study Area

Kwara state lies in the middle-belt region of Nigeria and its situated between latitudes 8°-10°N and longitude 2°45'-6°4'E of the Greenwich meridian. It covers an area of about 36,825 square kilometers, with census figure of about 2,591,555people (NPC,2005) spread across the sixteen Local Government Areas including; Ilorin East, Asa, Ilorin West, Oyun, Ilorin South, Ifelodun, Offa, Moro (fig.1).

The vegetation belongs to the Tropical Savannah which comprises dense forest population in most parts of the state and derived vegetation within and around the urban centres and characterized with scattered trees among grasses that grow high such as spear grass, elephant grass and goat weed while the trees include; Baobab, Acacia, Locust-beans Shea butter trees among others. The weather type in the State belongs to the Humid tropical climate (see tables 3 and4).

Table 3 : Average temperature values (^{0}c)(2007). Source : NIMET, Ilorin International Airport.

TEMP	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MAX^{O}C	33.4	36.4	36.9	33.9	32.2	30.7	30.0	29.0	30.1	31.4	33.8	34.3
MIN^{O}C	18.3	22.6	23.8	23.5	22.8	22.1	22.0	21.7	21.3	21.6	22.2	20.2
AVG	25.9	29.5	30.4	28.7	27.5	26.4	26.0	25.4	25.7	26.5	28.0	27.2

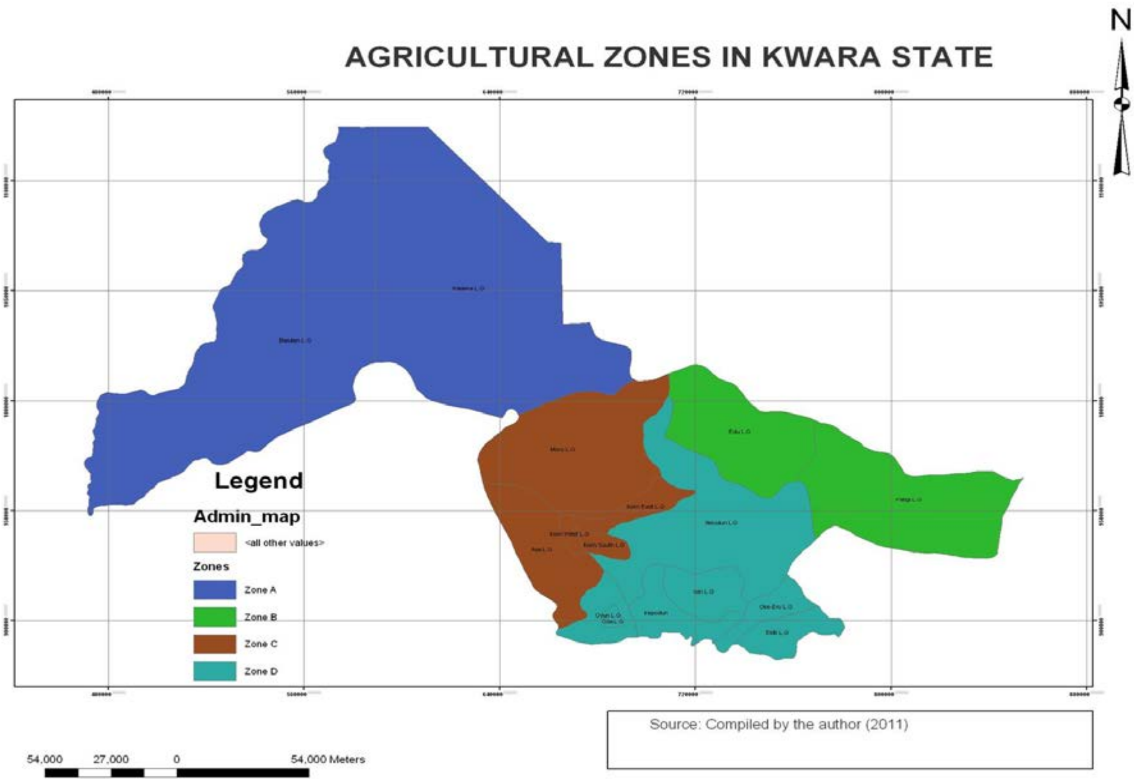

Table 4 : Monthly average rainfall values(mm) in Ilorin. Source: NIMET, Ilorin International Airport.

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	Annual Avg.
2007	00.0	00.0	31.6	98.9	285.5	158.2	199.3	134.1	241.7	152.9	00.3	06.6	100.7
2006	00.6	01.0	79.4	97.5	192.4	129.7	195.4	86.0	259.0	250.7	00.0	00.0	107.4
2005	00.0	08.0	60.1	108.0	255.7	211.5	133.8	63.8	271.5	179.8	01.0	11.9	93.8
2004	02.1	00.0	45.1	77.5	210.3	310.4	192.5	156.8	187.9	104.1	09.2	00.0	182.3
2003	00.0	00.0	25.3	81.5	98.0	370.8	94.2	80.7	400.1	125.7	18.4	00.0	107.9
2002	07.4	07.6	98.4	106.7	145.8	96.8	160.0	257.9	93.3	155.1	05.9	00.0	94.5
2001	00.0	06.0	13.8	53.3	145.1	137.3	85.1	87.0	173.6	31.9	00.0	00.0	60.6
2000	04.5	00.0	19.6	45.9	105.6	194.2	81.0	185.0	279.7	142.5	00.0	00.0	72.3
1999	00.0	15.1	68.0	118.5	171.3	296.2	179.4	138.1	268.9	248.3	36.1	00.0	12.3
1998	00.0	00.3	19.0	107.4	169.2	241.6	229.0	131.6	388.1	176.3	05.0	06.0	122.3

Source : The Authors

The monthly temperature values are in Jan 25.9°c, June 26.4°c and Sept 25.7°c, while the corresponding rainfall figures are 00.0mm, 158.2mm and 241.7mm respectively with the annual rainfall value of 100.7mm for the year 2007. Annual average rainfall values in 2005, 2004 and 2002 shows a clear range of variation.

The Tropical Maritime air mass from the Atlantic Ocean is prevalent from March to Oct, while the tropical Continental air mass from the Sahara desert takes over from Nov to Feb (Olaniran, 2002). This results in two seasons; raining season (March-Oct) exhibiting double maxima rainfall pattern with peak periods in the months of June and Sept. it is succeeded by prolonged dry (harmattan) dry season between Nov- March. Humidity vary seasonally ranging from 75% to 80%.

V. Materials and Methods of Study

The study area (Kwara state) is made up of 16 Local Government Areas grouped into four (4) zones (see table 5).

Table 5 : The Zonal Divisions of Kwara Agricultural Development Project areas

ZONE A	ZONE B	ZONE C	ZONE D
Baruten LGA	Patigi LGA	Ilorin west LGA	Ifelodun LGA
Kaiama LGA	Edu LGA	Ilorin south LGA	Irepodun LGA
		Ilorin east LGA	Isin LGA
		Moro LGA	Offa LGA
		Asa LGA	Oyun LGA
			Ekiti LGA
			Oke Ero LGA

Source : Kwara Agricultural Development Project (2010)

Global Journal of Human Social Science Volume XI Issue V Version I August 2011

The data required for accomplishing the philosophy of this work have been drawn from: Primary source (geo-spatial data and the attribute data of the study area to get a digital map of Kwara), and Secondary source(the meteorological data for the climatic parameters that was obtained from the records of Nigerian Meteorological Agency), Ilorin International Airport, while information on the trends of agricultural production were collected from the records of Kwara Agricultural Development Project, Ilorin.

VI. Data Analysis and Discussion of Results

Many issues of relevance are as considered for achieving the philosophy or the central tenets of this research endeavour as follows.

a) The roles of climatic parameters on agricultural production

Table 6 : Some components of climatic parameters over a ten year period

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Temperature	34.8	37.9	40.1	36.4	34	35.7	35.9	36.8	37.1	36
Relative Humidity	69	78	76	77	83	82	83	82	79	84
Rainfall	1104.5	946.7	907.6	1028.9	893.8	1600.2	1144.5	1236.9	1481.6	1381.9

Source : Kwara Agricultural Development Project (2010).

Essentially, the rate of the variability of the climatic parameters used in this paper are as indicated by figs 1 to 4.

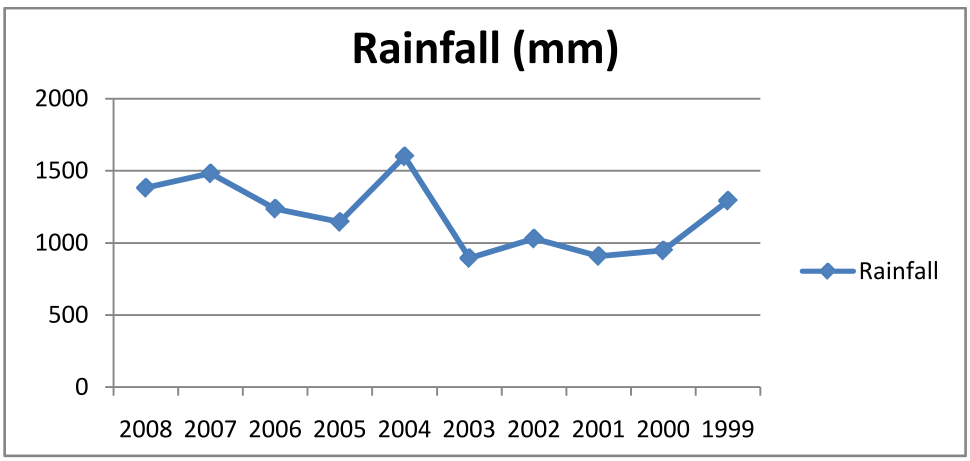

Fig 1 : Rainfall variability over the past ten years. Source : The Authors, 2011.

From fig 1 it is observed that rainfall amount fluctuates through the decade with the highest value 1600mm recorded in 2004 and the lowest value 893.8mm in 2003. Average rainfall amount for the decade is 1172.7mm, therefore the values recorded in the years 1999, 2000, 2001. 2002, 2003 and 2005 are below the average thus can be regarded as years with low rainfall amount while the values for 2004, 2006, 2007 and 2008 are above the average value and are said to have high rainfall amount.

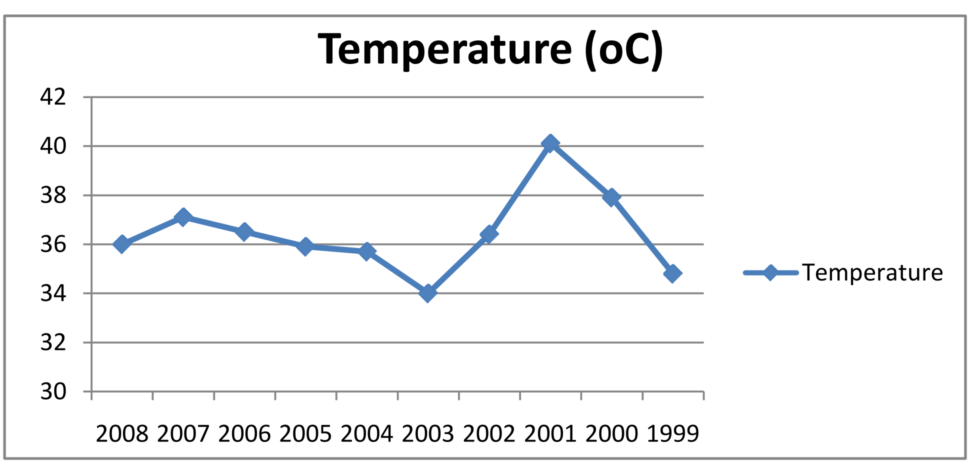

Fig 2 : Temperature variability over the past ten years. Source : The Authors, 2011.

Fig 2 shows that temperature values gently fluctuates until it suddenly escalated in Year 2001 which had the highest value of 40.1°C while the lowest value 34°C was in 2003. The average value for the decade is 36.47°C thus, years 1999, 2003, 2004, and 2005 with values lower than average can be regarded as years with low temperature while year 2000, 2001, 2006, 2007 and 2008 with values higher than average can be called hot years but year 2002 has a temperature value equal to the average therefore can be regarded as a year with moderate temperature.

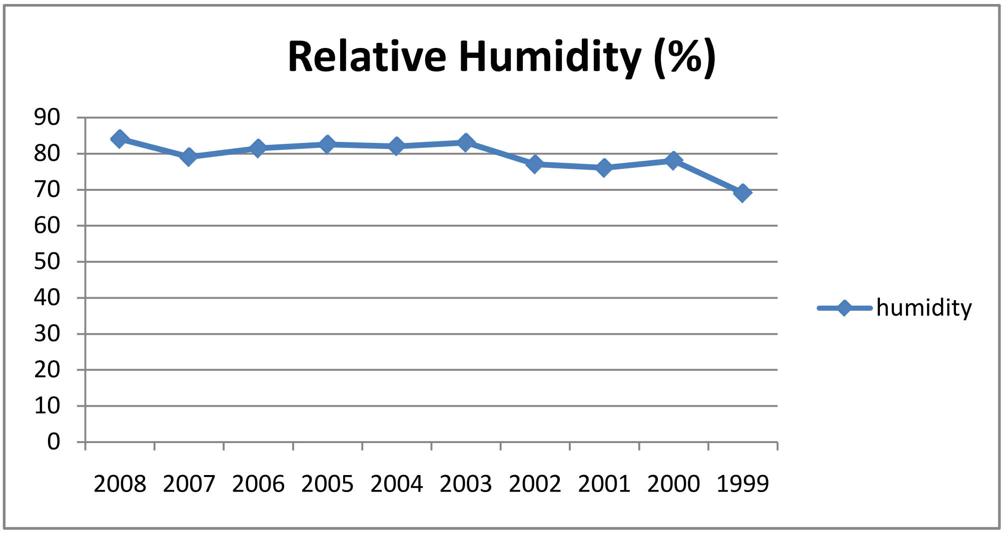

Fig 3 : The variability of Relative humidity over the past ten years. Source : The Authors, 2011

This fig 3 had values for the decade and is relatively moderate with very slight fluctuations too. The highest value is 84% in 2008 and 69% in 1999 as the lowest value. Average value for the decade is 79.3% therefore, years 1999, 2000, 2001 and 2002 can be referred to as less humid years, while year 2003, 2004, 2005, 2006 and 2008 can be regarded as very humid years, but humidity values in 2007 equals the average value.

VII. Trends of Agricultural Productions over the Years

Selected crops were used to sample agricultural production in the study area for the because of their consistency and good production rate in the various agricultural zones. Such crops includes rice, cassava, yam, sorghum and maize (fig 4).

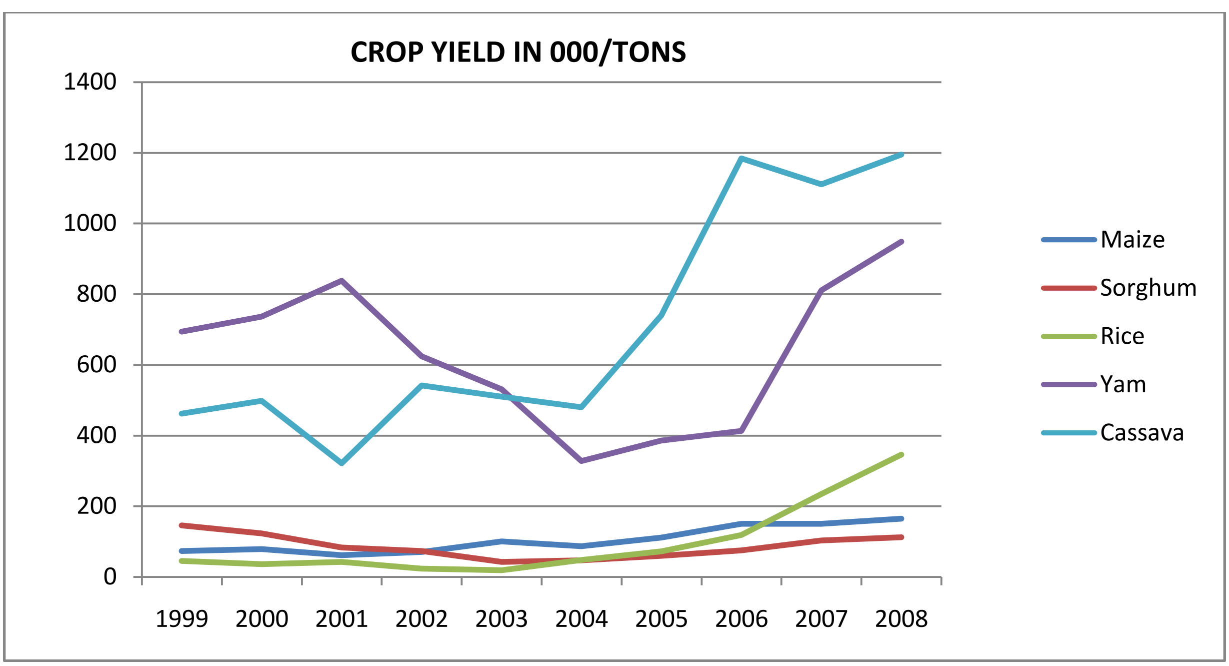

Fig 4 : chart showing the selected crops over the decade. Source : The Authors, 2011

Cassava recorded its highest yield value 1195.2 thousand tons in 2008 and its lowest value 321.8 thousand tons in 2001, with an average of 704.6 thousand tones for the decade thus 1999, 2000, 2001, 2002, 2003 and 2004 experienced low cassava yield while 2005-2008 had very high yields of cassava. Yam had its highest yield value, 948.6 thousand tons in 2008 and lowest value, 327.8 thousand tons in 2004 with an average value of 631 meaning 2002-2006 had low yam yields while other years recorded high yields. Also, Rice yields is most in 2008 and least in 2003 with average of 98.2 thousand tones to have 1995-2005 with low yields and 2006-2008 with high yield records. Further, Maize recorded highest yield values in 2008 and lowest values in 2001 with average values of 104.9 thousand tones which implies that the years 1999-2004 experienced low yields while 2005-2008 had high maize yields. Finally, Sorghum reached its peak of productions in 1999 and lowest in 2003 with average value of 86.8 thousand tones listing 2001 to 2006 with low yields while 1999, 2000, 2007 and 2008 had high sorghum yields.

Essentially, it has been observed that most of the crops had the highest yield for the decade in the year 2008.

Generally, the comparison between the rates of variability in climatic conditions and the yield rates of the selected crops covering the years under study indicates the level of influence the climatic parameters have on the rates of cop yields between the periods under study.

In year 2001 the highest value of temperature was recorded (regarded as a hot year), relative humidity and rainfall had second to the lowest values while cassava and maize recorded the lowest yield and the values for rice and sorghum were below average. In 2003, lowest values were recorded for temperature and rainfall but relative humidity had its second highest value, sorghum and rice also recorded their lowest yield while maize, cassava and yam yield values were below average value. Year 2004 had highest rainfall thus can be regarded as a "wet year", temperature and relative humidity were moderate where as maize, cassava and rice recorded below average yields then sorghum had its second to the lowest yield value. 2008 recorded the highest yield value for most of the crops except sorghum which was also above average yield, while relative humidity was highest, rainfall value was above average and temperature had the exact average value.

VIII. Forecasts on Climatic Conditions on Agricultural Production

In observing the trends of climatic variability and agricultural production as demonstrated earlier it becomes obvious that the climatic variability has been for a very long time and is still in operation in the environment. The challenges posed by climate may worsen if necessary checks are not taken and this will certainly affect agricultural production as it may drop drastically in the next few years.

VIII. Conclusion

Strong relationship has been found to exists between agricultural production and climatic variability. The trend in the climatic variables under study shows that the variability is felt where local factors of climate directly affects agricultural production. For instance, many places still depend on rain-fed crop production system and agricultural production rate is therefore easily affected by any slight adverse condition of weather. Thus, the use of GIS technology has greatly enhanced both the scope and quality of environmental management and planning, which has become more focused and goal oriented.

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