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Effect of Climatic Variability on Maize Production in Nigeria

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Abstract: The study examines the changes in climatic elements and agronomic parameter (maize hectarage and output) for maize production in different ecological zones of Nigeria from 1980 - 2002. The study also evaluated the degree of variability in these parameters. To achieve these objectives, secondary data on climatic elements and agronomic parameters for 22years were analysed using two – way Analysis of Variance (ANOVA) and Coefficient of Variation. The result revealed significant differences in average annual rainfall, temperature, maize hectarage and output in the seven identified ecological zones ($p<0.05$). Less variability was shown by annual temperature and rainfall over the years. Annual maize hectarage and output exhibited high variability in the ecological zones. Development of irrigation facilities and adoption of cultivation method that will reduce exposure of soil to flood and erosion among others are recommended for savannah and forest zones respectively.

Key words: Analysis of variance, coefficient of variation, climatic element, ecological zones, erosion, irrigation, maize, montane and unimodal rainfall

INTRODUCTION

Climate variability and change have a direct, often adverse, influence on the quantity and quality of agricultural production. The climate of an area is highly correlated to the vegetation and by extension the type of crop that can be cultivated. Temperature, rainfall, humidity, sunshine (day length) are the important climatic elements that influence cropping production. The overall predictability of these climatic elements is imperative for the day-to-day and medium term planning of farm operations.

According to federal government of Nigeria report on drought management (FGN,1999), the Nigeria landmass of 923,766 km^2 is divided into seven ecological zones. This classification is based on the similarity of climatic elements and the type of vegetation that can be supported. These ecological zones are the mangrove swamp, rainforest, montane forest/grassland, derived savannah, guinea savannah, Sudan savannah and the Sahel savannah. The mangrove swamp and rainforest zones, and part of derived savannah zone are found in the southern part of the country. These zones are characterized by high rainfall intensity, long wet season, dense vegetation, rugged topography and temperature range of 26 – 28ºC and small farm holdings. Flood and water erosion are the major problem of crop production in these zones. A sizeable hectare of agricultural land and farmer's properties are lost yearly to water erosion in the eastern part of the country. Maize, cassava, yam and vegetables are the major crops grown in these zones.

Conversely, the savannah zone (Derived, Guinea, Sudan and Sahel savannah) is located in the northern part of the country. This region is characterized by short wet season and long dry season, high annual temperature (average) of the range 28 – 32ºC, few scattered trees and grasses, gentle slope and large farm holdings. Maize, sorghum, millet, wheat, rice, cowpea, pepper and onion are the major crops that thrive in savannah. The limiting factor to crop production in this region is water; this is because of short wet season that often commences in June and ends in September.

The montane forest/grassland zone is located in the high altitude areas of the country. This zone includes Jos Plateau, Adamawa and Obudu mountains. The zone is known for low average annual temperature (20 – 23ºC) all year round, moderately high rainfall and rugged topography. Montane forest/grassland is exceptionally suitable for maize, exotic vegetables (carrot, cabbage, cucumber and lettuce among others). The mountainous nature of this zone, cold weather and low concentration of oxygen are the obstacles to crop production. From the foregoing, all these ecological zones support maize cultivation.

Virtually all tribes in Nigeria consume maize, either fresh or processed. It is consumed as pap (*Ogi*) and *Tuwo* in virtually all parts of the country. Maize is a major ingredient in infant food brewery and poultry feed industries. It is also fermented to produce hydrolyzed to dextrins, sugars, and syrup

Specifically, maize is a hot season crop and is grown principally in areas with temperatures range of 21 - 30ºC

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Fig. 1: Source: Climate – Nigeria (2005)

(70 - 86 F), though seeds germinate best at a lower temperature range of 18 - 21ºC (64 - 58 F). Adequate rainfall or water is very important during germination and the first month of growth

It is argued that this study is of relevance because it indicates the differences in climatic elements (average annual temperature and rainfall) and agronomic factors required for maize production (maize hectarage and output) in different ecological zones of Nigeria. Also the need to establish the degree of variability in the climatic elements and agronomic data in the different ecological zones makes the study imperative.

Nigeria Ecological Zones: The total land area of Nigeria (923,766km^2) is divided into seven broad ecological or land resource zones. The categorization is based on the similarity of climate and vegetation cover as well as the type of crops that are adapted to each land area. With the exception of the montane region, the length of wet season (days) and temperature increase from the coast to the hitherland. In this categorization no state of the federation can boast of one ecological zone. A state may have up to three ecological zones. All these zones support maize production. The seven ecological zones are explained below:

Mangrove Swamp Forest: This zone is characterized by a bimodal rainfall distribution. The zone has an average annual temperature and rainfall of 26ºC and 2503mm respectively. There is hardly a month without rainfall. The mangrove swamp vegetation is a hydromorphic forest type characterized by an entangled dense growth of stems and aerial roots. The most common specie of this vegetation is the raffia palm. The better drain areas support maize oil palm trees and big trees like Iroko (*Chlorophora Exceisa*). Limiting factors to agricultural production include waterlogged soil, rugged topography and leaching as a result of excessive rainfall. A substantial land area of states such as Lagos, Delta, Rivers, Cross River, Akwa Ibom and Calabar are within this zone. The Fig. 1 shows the vegetation map of Nigeria.

Tropical Rainforest: This zone like the mangrove swamp zone has a bimodal rainfall distribution but with less intensity. There is a distinct dry and rainy seasons. The zone has an average annual rainfall and temperature of 1489mm and 26.5ºC respectively. Tropical rainforest zone accounts for a great number of plant species. The lower layer vegetation is most dense with abundance of herbs, shrubs and some grasses. The top layer accounts for valuable economic trees such as Mahogany, Iroko, Obeche among others. The zone has a high density of human population with agriculture as primary occupation of the people. The zone is known for the cultivation of maize, cassava, vegetables, yam, oil palm etc. Problem of agriculture in the zone are rugged topography and bush burning which predisposes soil to erosion.

The Montane Forest/Grassland: The montane zone is located in the high altitude areas of the country like Jos Plateau, Mandara, Adamawa Mountain and Obudu Plateau. The zone is characterized by low average annual temperature (21.5ºC). The average annual rainfall is 1450mm. The montane zone vegetation is covered with grass at the top and base, while forests cover the slopes, favoured by moisture-laden wind. The zone has a great potential for the cultivation of maize, wheat, carrot, cabbage and other exotic vegetables but the mountainous nature of the zone prevents commercial farming.

Derived Savannah: This zone is found immediately after the tropical rainforest zone. It is the transition between the tropical rainforest and guinea savannah zones. The average annual rainfall and temperature are 1314mm and 26.5ºC respectively. The zone is covered with scattered trees and tall grasses. Maize, cassava, yam and rice are the major crops grown in this zone. The savannah in general has an enormous potential for food production in the country. Bush burning and erosion as a result of over grazing by animal especially cattle constitute a major problem to agricultural production in the zone.

Guinea Savannah: The Guinea Savannah, located in the middle of the country, is the most extensive ecological zone in Nigeria, covering near half of the country. Guinea savannah zone has a unimodal rainfall distribution with the average annual temperature and rainfall of 27.3ºC and 1051.7mm respectively. It extends from Ondo, Edo, Anambra and Enugu States in the south, through Oyo State to beyond Zaria in Kaduna State. It is a belt of mixture of trees and tall grasses in the south, with shorter grasses and less trees in the north. The Guinea savannah, with its typically short trees and tall grasses, is the most luxuriant of the savannah vegetation belts in Nigeria. The zone is characterized by low rainfall and long dry period, which call for alternative water supply (irrigation) to enhance full utilization of the zone potential in agricultural production.

Sudan Savannah: The Sudan savannah zone is found in the northwest stretching from the Sokoto plains in the west, through the northern sections of the central highland. It spans almost the entire northern states bordering the Niger Republic and covers over one quarter of Nigeria's total area. The low average annual rainfall of 657.3mm and the prolonged dry season (6-9 months) sustain fewer trees and shorter grasses than the Guinea savannah. It is characterized by abundant short grasses of 1.5 - 2m and few stunted trees hardly above 15m. It is by far the most densely human populated zone of northern Nigeria. Thus, the vegetation has undergone severe destruction in the process of clearing land for the cultivation of important economic crops such as cotton, millet, maize and wheat. This is in addition to devastation due to animal husbandry, especially cattle rearing, which is greatly favoured in this belt because the area is relatively free from tsetse fly. The trees of the Sudan savannah include the acacia, the sheabutter, baobab and the silk cotton. Fig. 2 show the rainfall distribution map.

Sahel Savannah: This is the last ecological zone that supports maize cultivation with proximity to the fringes of the fast-encroaching Sahara desert. It is located in the extreme northeastern part of the country, close to Lake Chad, where the dry season lasts for up to 9 months and the total average annual rainfall is hardly up to 700mm. It is characterized by very short grasses of not more than one metre high located in-between sand dunes. The area is dominated by several varieties of the acacia and date-palms. The Lake Chad basin, with its seasonally flooded undulating plains, supports a few tall trees. At the same time, the drainage system of rivers and streams into the Lake Chad basin has favoured irrigation, without which cultivation would be virtually impossible. The increasing aridity in the area accounts for the progressive drying up of the Lake Chad.

Literature Review: Agricultural production in Nigeria is at the mercy of weather. Extreme variations in rainfall, temperature and heat waves affect food production. Droughts, floods, and tropical rainstorms create food scarcity problems and mass movement/immigration of people. Considerable research works have been carried out on the effects of weather/climate on agricultural production, but few works have been specific on the effects of climate change on maize production. These are reviewed below:

According to Adeleke and Goh (1980), climate is the average atmospheric conditions of an area over a considerable time. It involves systematic observation, recording and processing of the various elements of climate such as rainfall, temperature, humidity, air pressure, winds, clouds and sunshine before standardization of the climatic means or averages can be arrived at. In a study on crop yield variability as influenced by climate, Chi-Chung *et al*. (2004) submitted that precipitation and temperature are found to have opposite effects on yield levels and variability of corn (maize). Furthermore, they reasoned that more rainfall can cause yield levels to rise, while decreasing yield variance and that temperature has a reverse effect on maize production. Bancy (2000) study on the influence of climate change on maize production in semi-humid and semi-arid areas of Kenya explained that in order to counter the adverse effects of climate change in maize production, it might be necessary to use early maturing cultivars and practice early planting.

Petit-Maire (1992) predicted more favourable rainfall conditions in the present day Sahel zone. He opined that if the increase in precipitation should be associated with increased rainfall intensity, then a quality and quantity of soil and water resources would decline, for instance through increased run off and erosion, increased land degradation processes and a higher frequency of floods and possibly droughts. Drought is one of the side effects of climate variability. According to Ake *et al*. (2001) it is a creeping phenomenon, characterized by extended period with rainfall below average, prolonged periods of dryness, high temperature and evapotranspiration, very low humidity, and reduced stream flow as well as reservoir water level. Kebbi, Sokoto, Katsina, Kano, Jigawa, Borno, Gombe, Adamawa and Niger are the states prone to drought in Nigeria.

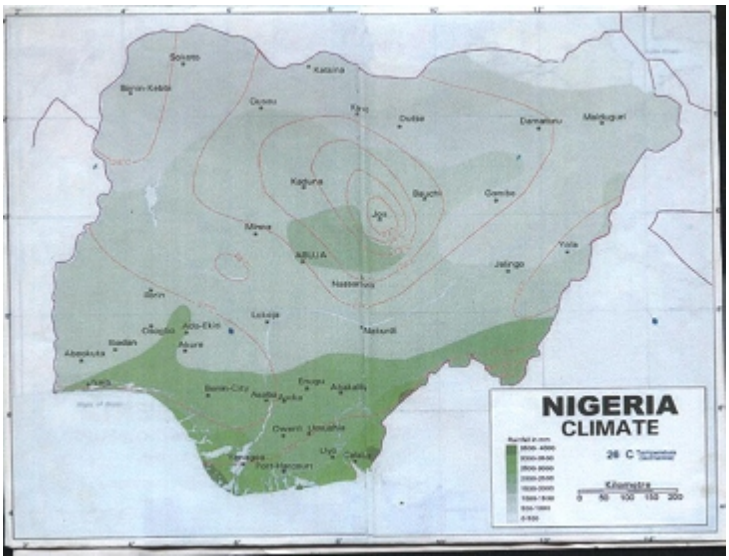

Fig. 2: Source: Climate – Nigeria (2005)

Madiyazhagan *et al.* (2004) carried out a study on water and high temperature stress effects on maize production in Australia, they observed that high temperature (greater than 38º C) compounded by water stress occurring at the same time decrease kernel set under dry land environments.

Akintola (2001) in a study on the comparative analysis of the distribution of rainy days in different ecological zones observed that the rainy days in the Southern zone shows relatively less variabilities that those in the central (middle belt) and the Northern zones. Likewise, the distribution in the middle belt shows less variability than those of the Northern zone. He, however, suggested land irrigation as a solution to water inadequacies in the north while flood control measures were advocated for the Southern zone.

WMO/UNEP (1996) report, found out that overall global warming is expected to add in one way or other to the difficulties of food production and scarcity. The report also stated that reduced availability of water resources would pose one of the greatest problems to agriculture and food production, especially in the developing countries. Katz and Brown (1992) believed that climate variability is likely to increase under global warming both in absolute and relative terms. Increased intensities of rainfall and increased rainfall totals in mangrove swamp and rain forest zones would increase leaching rates in well drained soils with high infiltration rates and would cause temporary flooding and water saturation hence reduced organic matter decomposition in many soils in level or depressional sites. WMO (1996) report revealed that global rising temperature now estimated to be 0.2º C per decade or 1ºC by 2040 (Mitchell *et al.*, 1995) with smallest increase in the tropics (IPCC, 1992) would diminish the yield of some crops, especially if night temperatures are increased. The result posited that higher night temperature might increase dark respiration of plants, diminishing net biomass production.

FAO (1995) report stated that climate change may result in shift in the present (agro) ecological zone for over hundreds of kilometers horizontally, and hundreds of metres altitudinally with the hazard that some plants, especially tress and animal species cannot adjust themselves in time.

Factors other than climate are known to influence crop yield variability. Anderson *et al.* (1987) argued that adoption of common high-yielding vanities, uniform planting practices, and common timing of field operations have caused yields of many crops to become more strongly influenced by weather patterns, especially in developing countries. In order to maintain equilibrium between supply of agricultural output and the demand for food by growing population, farmers through the assistance of government will have to adjust and adapt when necessary to the possible changes imposed by changing climate. The ability to adapt to the effects of climate change will vary greatly between countries and regions.

MATERIALS AND METHODS

The study was carried out in Abeokuta, Ogun State, Nigeria. The research commenced in 2005 and ended in 2007. Secondary data (meteorological and agronomic data) collected from IITA station at `Ibadan, CBN and FAO publications were utilized for the study. The meteorological and agronomic data included average annual temperature and rainfall as well as the average

Table 1: Agro – Ecological Data Based on Ecological Zones

Zones	Mean Annual Temperature (^oC)	Mean Annual Rainfall (mm)	Type of Rainfall Distribution	Length of wet Season (days)
Mangrove Swampy Forest	26 – 26.3	1453 – 3553.6	Bimodal	300 - 360
Rainforest	25.8 – 27.3	1071.7 – 1906.5	Bimodal	200 - 250
Montane Forest/Grassland	20.3 – 22.7	108 – 1141.7	Bimodal	200 - 300
Derived Savanna	25.4 – 27.6	448.3 – 1314	Extended bimodal	200 - 250
Guinea Savanna	26.4 – 29.2	586 – 1517.5	Unimodal	150 - 200
Sudan Savanna	25.3 – 27.3	262.3 – 1052.3	Unimodal	90 - 150
Sahel Savanna	20.6 – 31.6	232 – 842.6	Unimodal	< or equal to 90

Source: Survey Data (2005)

annual output and hectarage of maize in the seven identified ecological zones of Nigeria. The time series data (1980 – 2002) covered 22years.

Nigeria lies on the southern coast of West Africa between 2º and 15º E longitude and 5º and 15º latitude. It is bordered by Republic of Benin to the west, Niger to the north, and Chad and Cameroon t the east. The southern coast faces the Gulf of Guinea. Nigeria offers an array of environment, ranging from the belt of mangrove swamps and tropical rainforest in the lower elevations along the coast, to the open woodland and savannah on the low plateau which extends through much of the central part of the country, to the plains in the north and highlands to the east. Much of the southern half of the country is characterized by a long growing period (200 – 360days) with bimodal rainfall seasons and average annual rainfall of 2000mm. The northern half of the country on the other hand has a much shorter unimodal rain distribution. The agro-ecological data based on the seven ecological zones is presented in Table 1.

Analysis of variance (ANOVA) and the coefficient of variation were used to evaluate the differences in climatic elements and agronomic factors in the seven ecological zones, and among the years under consideration. Specifically, a two – way ANOVA was adopted to determine the differences in annual rainfall, temperature, output and maize hectarage in the ecological zones, and the period of study. The following hypotheses were tested:

Meteorological Hypotheses:

(a) Average Annual Temperature (ºC)

$H_o : \mu_{MAN(T)} = \mu_{RAINFOR(T)} = \mu_{MONT(T)} = \mu_{DER(T)} = \mu_{GUI(T)} = \mu_{SUD(T)} = \mu_{SAH(T)}$

$H_I : \mu_{MAN(T)} \neq \mu_{RAINFOR(T)} \neq \mu_{MONT(T)} \neq \mu_{DER(T)} \neq \mu_{GUI(T)} \neq \mu_{SUD(T)} \neq \mu_{SAH(T)}$

(b) Average Annual Rainfall (mm)

$H_o : \mu_{MAN(R)} = \mu_{RAINFOR(R)} = \mu_{MONT(R)} = \mu_{DER(R)} = \mu_{GUI(T)} = \mu_{SUD(R)} = \mu_{SAH(R)}$

$H_I : \mu_{MAN(R)} \neq \mu_{RAINFOR(R)} \neq \mu_{MONT(R)} \neq \mu_{DER(R)} \neq \mu_{GUI(R)} \neq \mu_{SUD(R)} \neq \mu_{SAH(R)}$

Agronomic Hypotheses:

(a) Average annual hectarage of maize (ha)

$H_o : \mu_{MAN(Ha)} = \mu_{RAINFOR(Ha)} = \mu_{MONT(Ha)} = \mu_{DER(Ha)} = \mu_{GUI(Ha)} = \mu_{SUD(Ha)} = \mu_{SAH(Ha)}$

$H_I : \mu_{MAN(Ha)} \neq \mu_{RAINFOR(Ha)} \neq \mu_{MONT(Ha)} \neq \mu_{DER(Ha)} \neq \mu_{GUI(Ha)} \neq \mu_{SUD(Ha)} \neq \mu_{SAH(Ha)}$

(b) Average Annual Output of Maize (Tonne)

$H_o : \mu_{MAN(OT)} = \mu_{RAINFOR(OT)} = \mu_{MONT(OT)} = \mu_{DER(OT)} = \mu_{GUI(OT)} = \mu_{SUD(OT)} = \mu_{SAH(OT)}$

$H_I : \mu_{MAN(OT)} \neq \mu_{RAINFOR(OT)} \neq \mu_{MONT(OT)} \neq \mu_{DER(OT)} \neq \mu_{GUI(OT)} \neq \mu_{SUD(OT)} \neq \mu_{SAH(OT)}$

Where:

MAN is the Mangrove swamp zone
RAINFOR is the Rainforest zone
DER is the Derived savannah zone
GUIN is the Guinea savannah zone
SUD is the Sudan savannah zone
SAH is the Sahel savannah zone
T is the average annual temperature (ºC)
R is the average annual rainfall (mm)
OT is the average annual output (tonne)
Ha is the average annual maize hectarage

Coefficient of Variation (CV %) measured the degree of variabilities in temperature, rainfall, maize hectarage and output in the different ecological zones of Nigeria. Multiple bar charts were used to complement the results of the two – way ANOVA.

RESULTS AND DISCUSSION

Average Annual Temperature (ºC): The result of analysis of variance (between the column) for evaluating the differences in the average annual temperature in different ecological zones showed that there is significant difference in the average annual temperature in the different ecological zones ($p<0.05$). The study revealed that average annual temperature increases northwards. This is because vegetation (trees and shrubs) and cloud covers diminish from the coast to the hitherland of the

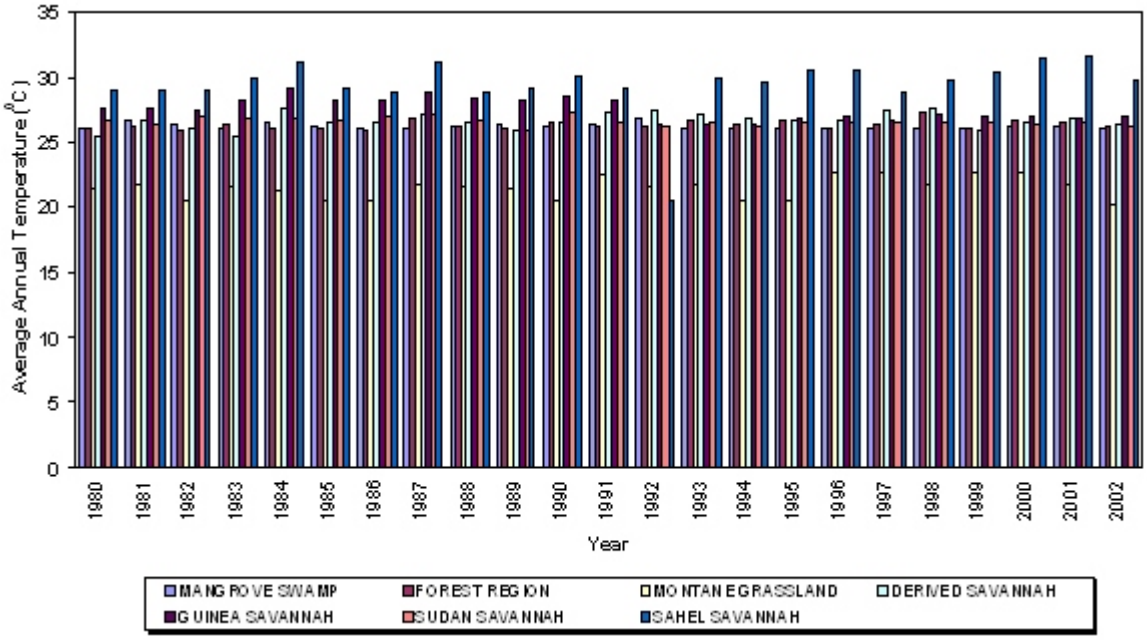

Fig. 3: Distribution of average annual temperature in different ecological zones

country. The study showed that the Mangrove zone has an average annual temperature range of 26.0 – 26.3ºC, the range of 20.3 – 22.7ºC and 20.3 – 31.6ºC were recorded for Montane and Sahel zones respectively (Table 1).

Moreover, the result of ANOVA (among the years) showed that there is no significant difference ($p>0.05$) in the average annual temperature among the years considered. This means that change in average annual temperature over the period of study (22years) is not pronounced (significant). This result is corroborated by temperature chart in Fig. 3, which shows almost identical jointed bars for all the ecological zones from 1980 to 2002.

Average Annual Rainfall (mm): The result of analysis (among ecological zones) showed that there is significant difference in the average annual rainfall in the different ecological zones ($p<0.05$). This finding conforms to the situation in the seven identified ecological zones. There is progressive decline in total rainfall and length of wet season from south to the northern part of the country. The range of average annual rainfall in Mangrove zone is 1453–3554mm, this reduced to 108–1142mm and 232–842.6mm in Montane forest/grassland zone and Sahel savannah respectively. The bimodal distribution of rainfall in Mangrove rainforest and montane zones allow for the cultivation of maize twice in a year. However, planting of maize takes place once in a year in the savannahs (Guinea, Sudan and Sahel) because of the unimodal rainfall distribution of these zones. The length of wet season (days) is expectedly shorter (90-200 days) in the savannah compared to Mangrove and Rainforest zones (200-360 days). Heavy rainfalls accompanied with thunderstorms are associated with Mangrove and Rainforest zones. This often leads to flooding and leaching of farmlands. The resultant effect of this is low productivity compared to savannah zones.

Furthermore, the result of the analysis (among the years) revealed that there is significant difference in the average annual rainfall among the years. F^{cal} (6.76) is greater than F^{tab} (1.79) at 5% level of significance. This result confirms the happenings across the ecological zones. In some years rain falls heavily starting early and stopping late. While in another years, rainfall with low intensity commences late and stops earlier. The lateness in rainfall often necessitates special prayers to God by farmers and concerned citizen for rain to fall most especially in the Sudan and Sahel savannah zones. In some cases rituals are performed by farmers to appease the god of rain. The consequence of late commencement and early stoppage of rain is sharp drop in maize production. The rain distribution pattern of Nigeria based on agroecological zones is shown in the Fig. 4.

Average Annual Hectarage and Output: The result revealed that there are appreciable variations in the maize hectarage and the output in the ecological zones ($p<0.05$). The Fig. 5 shows that the average maize hectarage is higher in the savannah zones; all things being equal this translates to more output. This may be attributed to progressive reduction in the cost of land preparation for farming from the coast to the hitherland as well as favourable government policies (e.g. SAP), which ban the importation of maize, thus encouraging local production.

Moreover, there is also significant difference in the average annual maize hectarage and output of maize

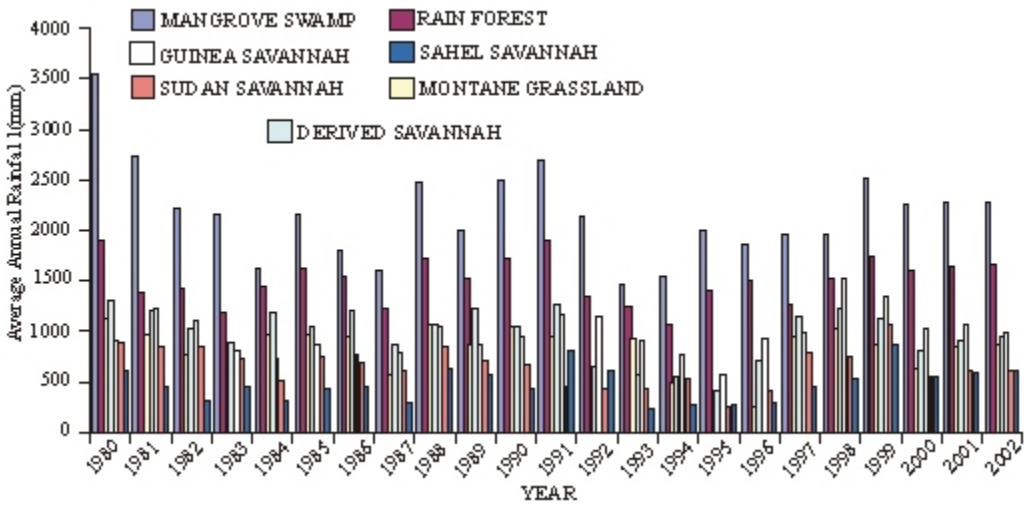

Fig. 4: Annual rainfall distribution for different ecological zones

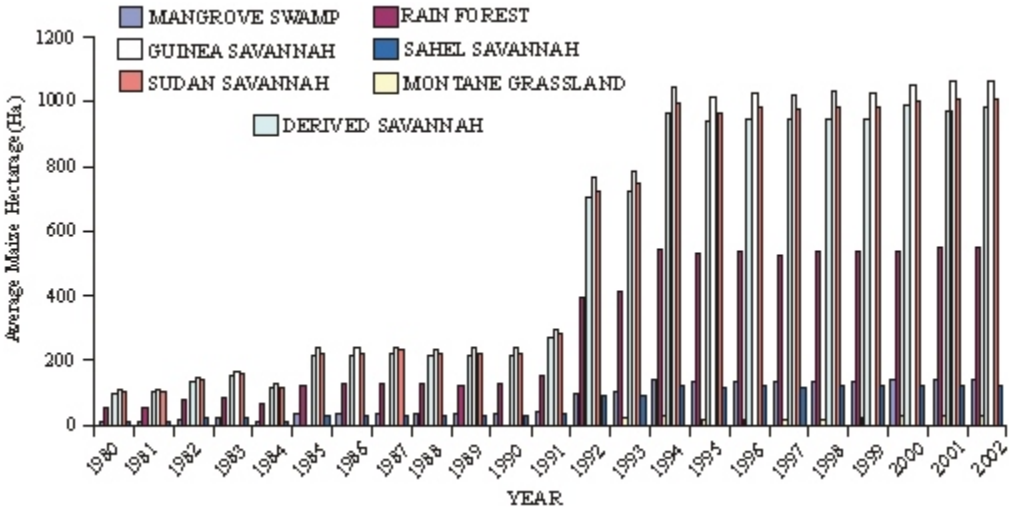

Fig. 5: Distribution of maize hectarage in different ecological zones

among the years (1980 - 2002). The F^{cal}s are greater than F^{tab}s. Fig. 6 shows an appreciable increase in maize output over the years.

Coefficient of Variation (CV): The coefficient of variation result revealed that Rainforest zone has the lowest dispersion of average annual temperature (14.84%); this is followed by Guinea savanna (21.38%) and Mangrove swamp forest (21.49%) respectively (Appendix E). This means that Rainforest zone experienced little change in average annual temperature compare to other ecological zones for the time period.

Also the Mangrove swamp zone has the smallest variation (0.81%) of average annual rainfall, the Sudan savanna and Rainforest zones have 1.13 and 1.25% respectively (Fig. 7). This explains why the Mangrove swamp has a small difference in average annual rainfall compare to other zones over the years.

Generally, the coefficient of variation is very high (more variability) for maize hectarage and output in all the ecological zones. The value ranges from 57.4 – 59.48% and 73.13–73.16% for maize hectarage and output respectively. However, the montane forest/grassland zone has the highest coefficient of variations results for annual maize hectarage (73.16%) while both Sudan (59.48%) and Sahel (59.48%) savannahs recorded the highest coefficient of variation for annual output. That is more variability is exhibited by maize output in both Sudan and Sahel savannahs. These results are expected bearing in mind the ban on importation of maize as well as other government policies and strategies aimed at encouraging more Nigerians to embrace agriculture. The effects are the increases in maize hectarage and output in the ecological zones over the years.

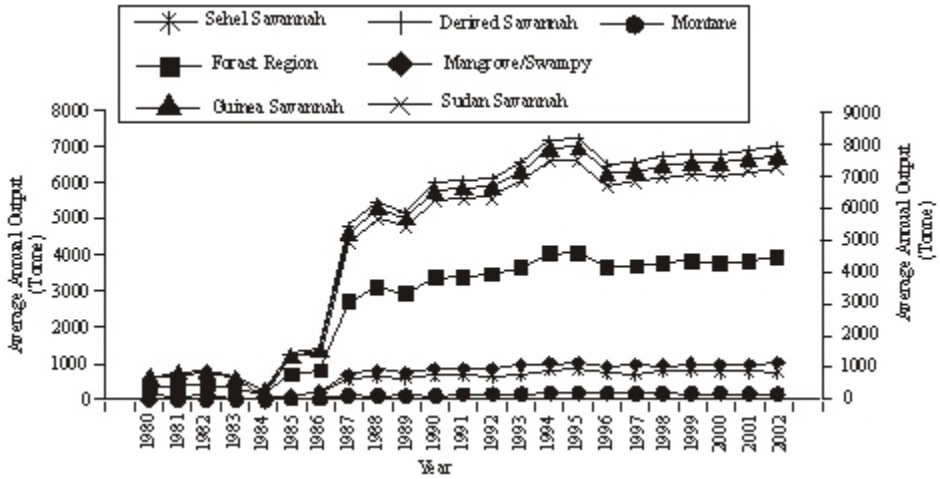

Fig. 6: Distribution of average annual output of maize in different ecological zones

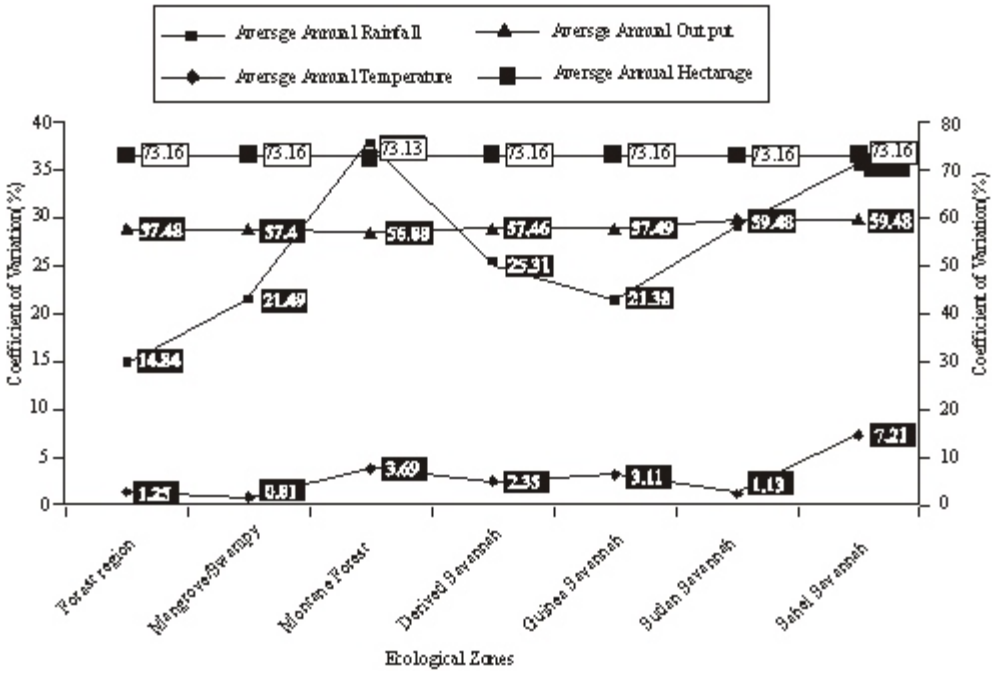

Fig 7: The Coefficient of variation results in different ecological zones

CONCLUSION AND RECOMMENDATION

Climate change, if it occurs, will definitely affect crop production. This study revealed that with the availability of enough water, maize can be grown in most part of Nigeria all round the year. This is because of the insignificant variation in average temperature in the 22 years considered for this study. However, variation in annual temperature is significant in the different ecological zones. Specifically, a very high temperature is usually experienced prior to the onset of rainfall, temperature as high as 32ºC and 39.5ºC in Rainforest and Sahel savannah zones respectively. Frequent torrential rainfall with high intensity in the Mangrove, Rainforest and Montane zones encourage the growth of dense trees, shrubs and crops. However, this heavy rainfall also predisposes soil to leaching; while the big trees and rugged topography make land clearing more difficult and expensive, hence the subsistence nature of farming in these zones.

Moreover, savannah (Derived, Guinea and Sudan) zone is found to be suitable for maize production in terms of good soil and temperature. The maize hectarage as well as the output are found to be higher in the savannah than

the Mangrove swamp, Rainforest and Montane forest/grassland zones. In general, the study showed that there is a progressive increase in the annual maize hectarage and output of maize in all the seven ecological zones over the 22years considered. The introduction of SAP in 1986, which had among its strategies the ban on importation of maize and scrapping of marketing board as well as other government economic policies aimed at encouraging maize production can be attributed to the increase in maize hectarage and output from late the late 1980's.

The potential of savanna zones in Nigerian maize production cannot be overemphasized. The need for the development of irrigation facilities in these zones in order to make water available by augmenting the unimodal rainfall distribution of the zones is imperative. Moreover, development of short, drought resistant and early maturing variety of maize especially suitable for this zone so that the short wet season can be fully utilized.

On the other hand, control of flood, development of early maturing and disease resistant variety of maize are important consideration for increase productivity of maize in the southern zones (Mangrove swamp and rainforest zones), while early maturing and low temperature resistant maize varieties is advised for the montane forest/grassland.

Finally, a quantitative understanding of weather, climate and other related environmental factors and the manner in which they affect maize production in the country would greatly enhance the benefits achievable through the use of new agricultural food – production technologies.

Appendices

Appendix: A

Average Annual Temperature(^{O}C) of Different Ecological Zones (1980 – 2002)

Year	Forest Region	Mangrove/Swampy Forest	Montane Forest/Grassland	Derived Savannah	Guinea Savannah	Sudan Savannah	Sahel Savannah
1980	26.1	26.1	21.5	25.5	27.6	26.7	28.9
1981	26.2	26.7	21.7	26.7	27.6	26.4	28.9
1982	25.9	26.4	20.6	26.1	27.5	26.9	29.0
1983	26.4	26.0	21.6	25.4	28.2	26.8	29.9
1984	26.1	26.5	21.2	27.6	29.2	26.8	31.2
1985	26.1	26.2	20.5	26.5	28.3	26.7	29.1
1986	25.8	26.1	20.5	26.5	28.1	26.9	28.8
1987	26.8	26.1	21.8	27.1	28.8	27.0	31.0
1988	26.3	26.2	21.6	26.5	28.4	26.6	28.8
1989	26.1	26.4	21.5	25.8	28.3	25.8	29.2
1990	26.5	26.3	20.6	26.5	28.5	27.3	30.1
1991	26.3	26.4	22.5	27.3	28.2	26.5	29.2
1992	26.2	26.8	21.6	27.5	26.4	26.3	20.6
1993	26.7	26.1	21.8	27.1	26.4	26.5	29.8
1994	26.4	26.1	20.5	26.8	26.4	26.3	29.6
1995	26.7	26.1	20.4	26.6	26.8	26.5	30.5
1996	26.1	26.1	22.7	26.7	26.9	26.5	30.5
1997	26.4	26.1	22.6	27.4	26.6	26.5	28.8
1998	27.3	26.1	21.7	27.6	27.0	26.5	29.7
1999	26.1	26.1	22.6	25.9	26.9	26.5	30.4
2000	26.6	26.3	22.6	26.5	26.9	26.4	31.5
2001	26.5	26.3	21.8	26.8	26.8	26.5	31.6
2002	26.3	26.0	20.3	26.4	26.9	26.3	29.7

Sources: CBN Statistical Bulletin (2003) & FAO Publications

Appendix: B

Hectares of Land Used For Maize Production in Nigeria from Different Ecological Zones (1980 – 2002)

Year	Forest Region	Mangrove/Swampy Forest	Montane Forest/Grassland	Derived Savannah	Guinea Savannah	Sudan Savannah	Sahel Savannah
1980	55.93	14.15	2.39	99.42	108.03	102.77	12.91
1981	574.59	145.37	24.56	1021.49	1109.89	1055.87	132.60
1982	76.40	19.33	3.27	135.82	147.58	140.40	17.63
1983	87.05	22.02	3.72	154.75	168.14	159.96	20.09
1984	6.55	1.66	0.28	11.65	12.66	12.04	1.51
1985	123.79	31.32	5.29	220.06	239.11	227.47	28.57
1986	123.84	31.33	5.29	220.17	239.22	227.58	28.58
1987	123.88	31.34	5.29	220.23	239.29	227.64	28.59
1988	123.87	31.34	5.29	220.21	239.27	227.62	28.58
1989	123.87	31.34	5.29	220.21	239.27	227.62	28.58
1990	123.87	31.34	5.29	220.21	239.27	227.62	28.58
1991	153.86	38.92	6.58	273.52	297.19	282.73	35.51
1992	395.46	100.05	16.90	703.04	763.88	726.70	91.26
1993	405.52	102.59	17.33	720.93	783.32	745.19	93.58

Appendix B (continued)

1994	541.36	136.96	23.14	962.42	1045.70	994.81	124.93
1995	525.68	132.99	22.47	934.54	1015.42	966.00	121.31
1996	533.52	134.98	22.80	948.48	1030.56	980.40	123.12
1997	529.60	133.98	22.63	941.51	1022.99	973.20	122.22
1998	531.57	134.48	22.72	945.01	1026.79	976.81	122.67
1999	531.69	134.51	22.72	945.22	1027.02	977.03	122.70
2000	543.19	137.42	23.21	965.67	1049.24	998.17	125.35
2001	547.15	138.42	23.38	972.71	1056.89	1005.45	126.27
2002	549.90	139.12	23.50	977.60	1062.20	1010.50	126.90

Sources: CBN Statistical Bulletin & FAO Publications

Appendix: C

Average Annual Rainfall Distribution (mm) Of Nigeria from Different Ecological Zones (1980 – 2002)

Year	Forest Region	Mangrove/Swampy Forest	Montane Forest/Grassland	Derived Savannah	Guinea Savannah	Sudan Savannah	Sahel Savannah
1980	1906.5	3553.6	1141.7	1314.0	909.2	905.1	621.3
1981	1389.2	2736.9	985.0	1211.4	1237.9	859.9	461.5
1982	1440.3	2241.7	789.4	1011.4	1104.9	854.9	318.0
1983	1205.9	2176.5	789.4	893.7	836.5	748.1	445.4
1984	1447.7	1617.5	963.0	1184.7	732.0	514.7	314.0
1985	1615.3	2147.0	958.0	1053.7	869.5	762.7	426.0
1986	1377.2	1810.0	953.0	1190.3	798.5	697.3	461.0
1987	1232.3	1593.0	581.0	874.3	794.5	617.3	302.0
1988	1722.7	2482.5	1077.0	1078.7	1054.5	852.0	661.0
1989	1530.3	1996.3	886.0	1235.7	870.5	709.5	562.0
1990	1723.7	2490.3	1047.0	1064.0	951.0	676.0	435.0
1991	1901.0	2687.8	965.0	1269.3	1178.5	463.5	817.0
1992	1343.2	2136.5	223.0	657.7	1161.5	431.3	611.0
1993	1258.0	1453.0	934.0	587.3	895.5	426.7	232.0
1994	1071.7	1561.3	108.0	555.0	776.0	529.5	254.0
1995	1410.0	1993.8	287.0	448.3	586.0	262.3	271.0
1996	1499.8	1865.1	252.0	729.0	937.0	404.0	292.0
1997	1278.4	1965.2	963.6	1146.7	1004.5	797.3	466.2
1998	1523.3	1946.5	1044.0	1232.7	1517.5	758.0	534.0
1999	1754.2	2521.1	885.0	1143.4	1343.4	1052.2	842.6
2000	1630.1	2266.4	641.5	822.2	1032.5	576.8	573.0
2001	1672.0	2274.4	861.5	895.9	1045.1	606.5	582.0
2002	1672.1	2277.1	869.8	955.9	992.7	609.8	603.3

Sources: CBN Statistical Bulletin & FAO Publications

Appendix: D

Output of Maize ('000TONNE) From Different Ecological Zones in Nigeria

Year	Forest Region	Mangrove/Swampy Forest	Montane Forest/Grassland	Derived Savannah	Guinea Savannah	Sudan Savannah	Sahel Savannah
1980	0.358	0.09	0.02	0.64	0.69	0.66	0.08
1981	0.421	0.11	0.02	0.75	0.81	0.77	0.10
1982	0.448	0.11	0.02	0.80	0.87	0.82	0.10
1983	0.347	0.09	0.01	0.62	0.67	0.64	0.08
1984	0.12	0.03	0.01	0.21	0.23	0.22	0.03
1985	0.696	0.18	0.03	1.24	1.34	1.28	0.16
1986	0.782	0.20	0.03	1.39	1.51	1.44	0.18
1987	2.698	0.68	0.12	4.80	5.21	4.96	0.62
1988	3.082	0.78	0.13	5.48	5.95	5.66	0.71
1989	2.930	0.74	0.13	5.21	5.66	5.38	0.68
1990	3.374	0.85	0.14	6.00	6.52	6.20	0.78
1991	3.399	0.86	0.15	6.04	6.57	6.25	0.78
1992	3.416	0.86	0.15	6.07	6.60	6.28	0.79
1993	3.680	0.93	0.16	6.54	7.11	6.76	0.85
1994	4.038	1.02	0.17	7.18	7.80	7.42	0.93
1995	4.055	1.03	0.17	7.21	7.83	7.45	0.94
1996	3.637	0.92	0.16	6.47	7.03	6.68	0.84
1997	3.677	0.93	0.16	6.54	7.10	6.76	0.85
1998	3.765	0.95	0.16	6.69	7.27	6.92	0.87
1999	3.811	0.96	0.16	6.78	7.36	7.00	0.88
2000	3.797	0.96	0.16	6.75	7.33	6.98	0.88
2001	3.856	0.98	0.16	6.86	7.45	7.09	0.89
2002	3.918	0.99	0.17	6.97	7.57	7.20	0.90

Sources: CBN Statistical Bulletin & FAO Publications

Appendix: E

Coefficient Of Variation (%) Of Weather Parameters for Different Ecological Zones

ECOLOGICAL ZONES	Average Annual Rainfall(mm)	Average Annual Temperature(^{O}C)	Average Annual Output('000Tonne)	Average Annual Hectarage (Ha)
Forest Region	14.84	1.25	57.48	73.16
Mangrove/Swampy	21.49	0.81	57.40	73.16
Montane Forest	37.76	3.69	56.88	73.13
Derived Savannah	25.31	2.35	57.46	73.16
Guinea Savannah	21.38	3.11	57.49	73.16
Sudan Savannah	29.03	1.13	59.48	73.16
Sahel Savannah	35.47	7.21	59.48	73.16

Source: Result of Data Analyzed (2005)

Appendix: F

ANOVA RESULT FOR AVERAGE ANNUAL OUTPUT (TONNE)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	279081430.6	20	13954071.53	10.11402	1.69E-17	1.65868
Columns	715497323.4	6	119249553.9	86.43302	3.44E-41	2.175006
Error 165561104.6	120	1379675.872				
Total	1160139859	146				

Source: Result of Data Analyzed (2005)

Appendix: G

ANOVA RESULT FOR AVERAGE CULTIVABLE LAND (HA)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	7451521.506	22	338705.523	10.11535	4.76E-19	1.62352
Columns	9910017.584	6	1651669.597	49.32667	2.13E-31	2.167953
Error	4419928.965	132	33484.31034			
Total	21781468.06	160				

Source: Result of Data Analyzed (2005)

Appendix: H

ANOVA RESULT FOR AVERAGE ANNUAL TEMPERATURE (^{O}c)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	6154106.65	22.00	279732.12	6.76	0.00	1.62
Columns	45908784.60	6.00	7651464.10	184.78	0.00	2.17
Error	5465907.25	132.00	41408.39			
Total	57528798.50	160.00				

Source: Result of Data Analyzed (2005)

Appendix: I

ANOVA RESULT FOR AVERAGE ANNUAL RAINFALL

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	22.88	22.00	1.04	1.14	0.31	1.62
Columns	795.69	6.00	132.62	145.90	0.00	2.17
Error	119.98	132.00	0.91			
Total	938.55	160.00				

Source: Result of Data Analyzed (2005)

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