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Research Article

Rainfall Characteristics and Maize Yield in Kwara State, Nigeria

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ABSTRACT
Rainfall within the tropics is highly variable and it is the most important variable affecting crop yield. This present study attempts a study of the impact of rainfall characteristics on maize yield in Kwara state. Using correlation and regression analysis, the effects of some rainfall indices (monthly and annual rainfall, raindays, rainfall onset and rainfall cessation) on maize yield in Kwara State were examined. The results of the correlation statistics showed that rain days has the strongest association (r=- 0.55) with maize yield. It was also observed that early maize and late maize suffer moisture deficiency in March and November respectively while excessive rainfall of June/July and September also have implication for maize yield. The paper further derived 5 Rainfall-Yield Models for predicting maize yield in Kwara stat, Nigeria.

***Key Words**:* Maize Yield, Rainfall Onset, Rainfall Cessation, Raindays, Annual Rainfall, Rainfall-Yield Model

INTRODUCTION
Historically, West Africa is characterized by annual and diurnal variability in rainfall; this variability has been a decreasing trend and also a trend of a decrease of rainfall amount from the coast to inland. In the past three decades, rainfall in the region has been decreasing, more importantly, this trend is getting more complex (Ojo, et al, 2001). Recent studies in Nigeria clearly support this. A recent data released in Nigeria showed increasing cases of food importation and undernourishment (Federal Bureau of Statistics, 2009). In addition, the percentage of Nigerians living in urban area is also increasing by the day, a scenario that has implication for food security. Meanwhile, agriculture in Nigeria is mostly rain-fed; hence, with the decreasing rainfall across Nigeria many rural dwellers are left with no other option than to migrate to cities for unavailable jobs; a condition which is having its tolls on Nigerian cities. Indeed, many Nigerian cities are now going through a process of urban decay due to the menace of overcrowding.

The effects of climate on agriculture are obvious. According to Ayoade (2004), water in all its forms play a vital role in the growth of plants and the production of all crops. It provides the medium by which food and nutrients are carried through the plant. Ezedimma (1986) reported that water is the main constituents of the physiological plant tissue and a reagent in photosynthesis. Water is required for all metabolic reactions in plant. The concept of climate and agriculture has been extensively discussed. For example, Lema (1978), Oguntoyinbo (1986), Hartley (1999), Ayoade (2002; 2004) and Cicek and Turkogu, (2005) have all confirmed that climatic parameters (i:e rainfall, sunshine, temperature, evaporation, etc) are closely interrelated in their influence on crops . However, of all the climatic parameters affecting crop production and yield, moisture is the most important (Hodder, 1980). Moisture is primarily gotten from rainfall which in the tropics is cyclic and fairly dependable, (Ezedinma, 1986). Oguntoyinbo (1986) affirmed that in the tropical environment, temperature is not a limiting factor to plant growth and that the seasonal activities of rainfall coupled with crop husbandry seems to be the issue. In Nigeria for example, distribution of crops is dependent largely on rainfall pattern. For instance, tree crop (like cocoa) is confirmed to the high rainfall region of the south while grain crops are cultivated predominantly in the low rainfall region of the north, Hence, the type of plants / crops cultivated in any area with the tropics is related to the rainfall pattern. In fact, in Nigeria climate vagaries disrupt efficient practice of agriculture while climatic fluctuations create significant changes for agriculture production (Efe and Awaritefe, 2003). Maize cultivation is found in areas with adequate moisture. The bulk of the crop is grown in the warmer parts of the temperate regions and in the humid subtropics. It requires a frost-free growing period and does best with 600-900mm of rain during the growing season. The optimum temperature for germination is 18-21^0 C. Maize performs best in well well-drained, well

aerated, deep, warm loamy and silt loamy soils containing adequate organic matter and well supplied with available nutrients (Purseglore, 1992). In view of the length of the growing season in south-western Nigeria, it is possible to cultivate maize twice, the early maize between March and July and the late maize between July and November.

This present paper, studies the influence of rainfall characteristics on the yield of maize in Ilorin, Nigeria.

Study Area

Kwara State (figure 2) is located between parallels $11^0 71$ and 11^0 45' and 6^0 40' East longitude, covering 32.560Km^2. It lies exclusively within a tropical hinterland. The state experiences both the wet and dry seasons each lasting for about six months. The raining season starts from March and end in October while the dry season begins in November and ends in early March. The total annual rainfall in the state ranges from 800mm to 1,200mm in the northwest and 1,000mm to 1,500mm in the southeast. The state has a mean annual temperature ranging between 30^0 - 35^0C and a relative humidity of 60% on the average. The area is located within the Guinea Savanna. The average height is about 20-40. Finger like extension of the tropical rainforest occurs in the state and this is called Gallery forest (Emielu, 1991).

Climatic conditions of tropical wet and dry climate permits the growth of export tree crops (like cocoa, oil palm, etc), root crops (like yam, cassava, and cocoyam) and grain crops (like maize, rice, sorghum, etc). Maize particularly is grown twice a year in the area (Oyebanji 1993). The study area has some Agricultural Development Projects such as: National Centre for Agriculture Mechanization, Kwara State Agricultural Development Project, among others. These centers are committed to agricultural researches by keeping weather records and various crop yield records.

The soil is ferruginous tropical soils on crystalline acid rocks. The landscape consists of a relatively flat and undulating land with interspersed hills and valleys in parts of Baruten, Kaiama and Moro Local Government areas. With the availability of large arable farmland in the state most people embark on small and large scale farming. A number government farm projects are also within the state, they include : Molete farm project, Tsada-Shonga project and the Shonga farm project a number of Zimbabwe white farmers are operating. The major crops produced in some of these projects are rice and maize.

MATERIALS AND METHODS

The rainfall data used in this study were obtained from the achieves of Nigeria Meteorological Agency (NIMET), Ilorin International Airport; National Centre for Agricultural Mechanization (NCAM), Idofian, Kwara State; Kwara State Agricultural Development Project, Ilorin and Lower Niger River Basin Development Authority (LNRBDA). Maize yield data were obtained from the Kwara State Agricultural Development Project, Ilorin. The data spanned a period of fourteen (14) years (1991-2004). The choice of 14 years was based on availability and consistency of data from the four (4) weather stations mentioned earlier.

The rainfall data from the four (4) stations were summarized to get the average which was used to represent the rainfall data for the state as a whole. The monthly water consumptive use of maize within its growing season as given by Lema (1978) were compared with average monthly rainfall obtainable in the study area during the growing season to bring out the suitability of the study area for maize production.

Furthermore, relationships between each of the rainfall indices and maize yield were analyzed through the use of product moment correlation method, while linear and multiple regression analyses were used in writing models for predicting annual maize yield based on the studied rainfall characteristics.

Rainfall onset and cessation dates on the other hand were arrived at by using a modified version of Walter (1967)'s formula as used by Olaniran (1984).

RESULTS AND DISCUSSION

The data collected from the study area is presented in Table 1.

Maize Yield

According to Table 1 the mean annual maize yield is 1.22 tons/ha. The annual maize yield seems to be homogeneous across the studied period. The highest yield was recorded in 1994 with figure reaching 1.55 ton/ha and the lowest yield of 0.88 ton/ha was recorded in 1997. Thus, with the range of 0.67, mean of 1.22, standard deviation of 0.16 and coefficient of variance of 12.8% maize yield was homogenous in the period under study.

Table 1: Characteristics of Maize Yield and Climatic Parameters.

Year	Maize-Yield (ton/hec)	Annual Rainfall (mm)	Rain Days	Rainfall Onset	Rainfall Cessation
1991	1.22	1395.7	N.A	March 10	October 10
1992	1.10	926.2	71	April 23	October 3
1993	1.09	1761.5	74	May 2	October 8
1994	1.55	1324.4	70	Marcy 1	November 21
1995	1.19	1341.4	76	March 28	October 2
1996	1.19	1005.1	N.A	March 17	October
1997	0.88	1492.5	85	March 15	October 6
1998	1.14	1206.3	72	April 8	October 11
1999	1.25	1381.9	80	March 10	October 5
2000	1.28	980.9	56	April 15	November 1
2001	1.16	848.1	57	April 8	October 29
2002	1.30	1048.0	66	April 4	October 9
2003	1.47	1093.0	50	April 6	October 3
2004	1.25	1388.4	56	March 30	October 9
Mean	**1.22**	**1228.1**	**67.8**		
Standard Deviation	**0.16**	**19,246.6**	**10.4**		
Coefficient of Variation (%)	**12.8**	**20.1**	**15.3**		

Annual Rainfall

The highest rainfall was recorded in 1993 (1,961.5mm), while 2001 had the least rainfall (848.1 mm). The standard deviation of annual rainfall from 1994 to 2004 is 19,246.6 mm, the mean rainfall is 1,228mm and coefficient of variation is 20.1%. This suggests that annual rainfall from 1994 to 2004 is largely homogeneous.

Raindays

According to Table 1, the highest number of rain days is 85 days and was recorded in 1997, while the lowest number (50 days) of rain days occurred in 2003, with a standard deviation of 10.4 days, and coefficient of variance of 15.3% it is glaring that annual occurrences of rainy days between 1994 and 2004 is largely homogenous.

Rainfall Onset

In the same vein, Table 1 shows the pattern of variation in the rainfall onset dates and rainfall cessation dates (or otherwise known as "start of the growing season" and end of the growing season" respectively (Olaniran,

1984). For rainfall onset, years having dates between March 11 and March 20 were referred to as "wet years", while years having onsets dates exceeding April 23 are "dry years" (Olaniran, 1984). Based on this concepts, years 1992, 1995, 1998, 2000-2004 were classified as average years, and 1991, 1994, 1996-1997, 1999 were all classified as wet years; likewise, year 1993 was grouped as a dry year.

Rainfall Cessation

On the other hand, rainfall cessation was after the classification of Olaniran (1984). Years having cessation dates between October 15th and October 25th were rated as Average (Normal) years, and those years with dates between October 20th and November 1st were classified as dry years.

Considering these groupings closely, 1991, 1992, 1995, 1997-1999, 2002-2004 were average years. However, 1993 had a late start and an early cessation, and therefore it was seen as a dry year. All these scenarios have implication for bi-annual crops like maize. Table 2 shows the monthly pattern of rainfall in Kwara State over the period of study. According to Table 2, the period of minimum rainfall is from November to March with December as the driest month having mean rainfall of 1.51mm. September is the wettest often recording more than half of the total rainfall occurring during dry season.

On the whole, less than 10% of the total rainfall will fall in the dry season. On the other hand, higher rainfall starts in April to October with September being the wettest month with rainfall reaching 237.2mm. This coincides with the rainy season.

Consumptive Use

a. The analysis of maize consumptive water use is also presented in Table 3. The mean rainfall amount obtainable in March according to Table 2 is 42.1mm. This amount fell short of the 100 mm that is required at the first set of planting. Thus, early maize plants in March may experience inadequate watering due to the nature of onset.

b. A critical period during the planting season of maize is the month of November; as the minimum required (65mm) looks almost impossible to be met. In November the obtainable rainfall is only 16.8mm. This suggests a need to encourage irrigation agriculture for the purposes of food security and employment generation.

c. The possibility of having 426mm of rainfall which is the total consumptive use is possible in Kwara state as both rainfall obtainable for early maize and late maize (659.8 mm and 709.8mm respectively) are both obtainable. However, it should be noted that the pattern of rainfall distribution is also relevant to the agronomy of any crop.

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Table 2: Mean Monthly Pattern of Rainfall for Kwara State (1991 – 2004)

Months	Jan.	Feb.	Mar.	Apr.	May	June	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean (X)
Rainfall (mm)	5.9	9.1	42.1	91.5	161.9	195.8	168.5	152.4	237.2	134.9	16.8	1.6	101.5

Table 3: Monthly water consumptive use of maize within the growing season

Month	1st	2nd	3th	4th	5th	Total
1.Consumptive use (mm)	100	90	96	75	65	426
2. Rainfall obtainable for early maize (mm)	42.1 (March)	91.5 (April)	161.9 (May)	195.8 (June)	168.5 (July)	659.8
3. Rainfall obtainable for late Maize (mm)	168.5 (July)	152.4 (August)	237.2 (September)	134.9 (October)	16.8 (November)	709.8

**Values based on rainfall record in Table 2*

Table 4: Agro-Climate Models for maize Yield in Kwara State

1	**Annual rainfall**	**Y= 1.388 - 0.0001AR…….eq. 1**
2	**Numbers of raindays**	**Y= 1.824-0.009NRds……eq 2**
3	**Rainfall Onset:**	**Y= 1.334-0.001Ronset…….eq 3**
4	**Rainfall cessation :**	**Y= 0.342-0.005 RCess……..eq.4**
5	**Climate-Yield Model**	**Y=1.112-0.0001AR-0.0109Nrds-0.003Ronset-0037. Rcess……eq.5.**

Equations 1-5 can be used to predict maize yield in Kwara State.

Relationship between Climate and Maize Yield

The result of the moment product correlation between maize yield and consumptive use of water showed that annual rainfall has a weak and negative relationship (r= -0.22) with maize yield , the numbers of raindays has strong negative correlation (r= -0.55) with yield, rainfall onset has a weak positive correlation (r= 0.23) with maize yield, and rainfall cessation has a weak negative correlation (r= -0.02). Thus raindays has the greatest effect on annual maize yield.

The reason for this is deduced from the observation made by Ojo, *et al.* (2001) that the patterns of mean rain days generally follow the same pattern with mean rainfall amounts and that greater percentages of the raindays will be during the rainy season. Therefore, the concentration of rain days during rain season is having a great influence on maize yield annually such that the higher and less evenly distributed the number of rain days the lower the maize yield.

Rainfall cessation has the lowest influence on maize yield. This reveals that the study area is not prone to a very early cessation which can affect the yield of late maize greatly. In the study area, according to Table 2, 1997 recorded the lowest yield (0.88ton/ha) due to the high number of rain days and early cessation (October 6) of that same year, while 2003 with the lowest number of rain days has high yield of 1.47 ton/ha. The yield (1.55) experienced in 1994 is simply due to the early onset of rain and late cessation which resulted in a longer growing season for maize.

Maize Yield Models

The regression models generated for predicting maize yields otherwise known as Climate-Yield Models are presented below.

Conclusion and Recommendation

The following are the major findings and recommendation in this work:

i. The study shows that maize experience moisture deficiency at the early stages (especially early maize) and at the last month of the growing season (late maize) in the study area.

ii. In the months of June, July and September rainfall is in excess of the total amount required.

iii. Rain days have the greatest influence on maize yield (r=-0.55) in the study area. This means that despite the fact that maize plant requires a considerable amount of rainfall for effective growth and yield, it is still highly sensitive to excessive rainfall and continuous daily rainfall pattern typical of the tropics during raining season.

iv. Thus, maize requires a well-distributed, considerable amount of rainfall over an appropriate numbers of days during its growing season for optimum yield.

v. It may be argued that rainfall does not constitute the totality of the agricultural environment; it is an important factor in the rain-fed agriculture system of Kwara state.

vi. There is a need for a sustainable irrigation project this will be geared towards meeting the moisture requirement, particularly in March during the first Month of early maize and the in last month of late maize in November, if maize cultivation in Kwara state is to still be a bi-annual.

vii. Also, the intercropping of maize with other crops like cassava that can thrive under higher rainfall should be encouraged during those months of excess rainfall. This will help to reduce the impact of such excess rainfall on maize. This selection with definitely give room for maize to yield optimally and help to resolve both food need and financial needs of local farmers.

viii. Lastly, there are needs for the establishment of standard Weather

Stations especially in rural areas in the state. This will enhance climatic data collection and it will facilitate agricultural planning and sustainable development.

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