The International Journal Of Engineering And Science (IJES)
||Volume||2 ||Issue|| 5 ||Pages|| 42-48||2013||
ISSN(e): 2319 – 1813 ISSN(p): 2319 – 1805

A Stochastic Investigation Of Rainfall Variability In Relation To Legume Production In Benue State-Nigeria

[1]Enokela, O. S. and [2]Seini, S. A
[1,]Department of Agricultural and Environmental Engineering, University of Agriculture Makurdi Nigeria,
[2,]Defence Health Club Mogadishu Cantonment Abuja Nigeria,

ABSTRACT

Production of legumes in relation to variability in rainfall in Benue State was investigated for period of twenty one years between 1988 and 2008. Rainfall data and annual Legumes production output were generated from metrological unit of Nigeria Air Force Makurdi and Benue Agricultural and Rural Development Authority respectively. Statistical tool of correlation and regression were used to investigate the possible relationship between the two variables. A low correlation and regression coefficients of 0.0332 and 0.1375 were recorded respectively. The assumption of the parabolic relationship between rainfall and legume output recorded 86.25% of unexplained variation. The unexplained variation is largely due to influencing factors of production such as abiotic, farm management practices, land development, socioeconomic and catastrophic factors.

KEY WORDS ; *Stochastic, Rainfall variability, Legume Production, Benue state.*

Date Of Submission: 22 April 2013 Date Of Publication: 20,May.2013

I. INTRODUCTION.

Rainfall is a key factor shaping the vegetation and hydrology throughout the earth. It is particularly critical to agriculture, along with other factors. The occurrence and variability of precipitation to a large extent determine which crops can be grown in different regions of the world. It is one of the most important factors determining variability in agricultural production. Rainfall occurrence and distribution are however dependent on two air masses that prevail over a region. Their influences are directly linked to the movement of the Inter-Tropical Convergence Zone (ITCZ) on north and south of the equator (Olaniran, 1989). The two air masses are the tropical maritime (TM) and the tropical continental (TC). The former is associated with the moisture – laden south – west winds (south westerly's) which blow from the Atlantic Ocean, while the latter is associated with the dry and north-east winds (easterlies) which blow from the Sahara Desert. When the ITCZ is to the south of the equator, the north-east winds prevail over Nigeria, thus producing the dry-season conditions (NEST, 2003). Conversely, with the movement of the ITCZ into the Northern Hemisphere, the rain-bearing south westerly's prevail as far inland as possible to bring rainfall during the wet season. The implication is that there is a prolonged rainy season in the far south, while the far north undergoes long dry periods annually. Nigeria, therefore, has two major seasons, the dry season and the wet season, the lengths of which vary from north to south. The seasonal pattern of climatic conditions over Nigeria gives rise to four seasons in the south and two in the north. This is the result of annual total rainfall occurrence and distribution, which is more predominant in the south than in the north.

Crop Water Requirement

Discussion of water uptakes by plants and movement through plants was presented by (Kirgmer, 1983), the term crop water use includes all the evaporation from the area considered (i.e. evaporation from the soil and vegetation surfaces and plant transpiration). The proportion of the total water loss from the area means that transpiration will vary considerably, particularly in response to the proportion of the ground cover by the crop.
Since crop-water use vary from place to place in response to changing evaporative demand, it is possible however to express the requirement as a proportion of potential evaporation (Ep). The ratios of crop-water use represent "potential" values which assume water to be freely available-under many circumstances may not be true. A major complication is that water between field capacity and permanent wilting point, technically referred to as "available" may not be equally available. When soil moisture drops below field capacity, plants may experience difficulty in obtaining water (Jackson, 1989). The minimum amount of water required by legum crop with respect to evapotranspiration (ET) may be evaluated as the relationship between potential evaporation (Ep) in mm during the rainy season (X) and is described by equation 1

Ep = 61.0 – 2.86 x ---------------------- (1)
The average water requirement of 120days drop on legumes measured by a weighing lysimeter by Inserting equation (2) into equation (1) gives
ET = 45.75 – 2.14x------------------------ (3)
Equation (3) describes the relationship between water use by legume crops and evapotranspiration (Gibbon, 1985.). Since the management of drought requires many types and varieties of crops to a given rainfall regime. Institute of Agricultural Research (IAR) Zaria has over the years, carried out investigations designed to evaluate how much water (and by implication rainfall) is required to satisfy the needs of various crops, from planting to maturity. So far the water requirement of such crops of the savanna as cotton, cowpea, groundnut, maize, millet, sorghum and wheat have been determined (Fadiji, 1985).
According to FOA, the rainfall requirements of some food and commercial crops widely grown in West Africa are shown below in table 3.
Ayoade, (1983) also pointed out that, in examining some of the ways in which the major climatic elements influence crop growth and yield, two most important points must be emphasized at the onset.

Table 1;Approximate values of seasonal crop water needs

Crop	Crop water need (mm/total growing period)
Beans	300 – 500
Citrus	900 – 1200
Cotton	700 – 1300
Groundnut	500 – 700
Maize	500 – 800
Sorghum/millet	450 – 650
Soybean	450 – 700
Sunflower	600 – 1000

FAO; Crop water requirement, Irrigation Water Management Training Manual No. 3.

The first point is that climatic variable is modified by the others. Also, daily, seasonal, or annual variations in the values of the climatic elements are of greater importance in determining the efficiency of crop growth. The second point is that in considering the climatic environment in which crops grow, the micro-climate immediately around the crop is of vital importance. However, precipitation has becomes more important than other factors for monitoring crop yields but an intricate because it is the soil moisture, and not precipitation, that ultimately contributes to crop growth and crop yield.

The Legumes crops and water needs

Leguminous crop can be annual, biennial or perennial which refer to as their life cycles. An annual legume like Soyabean germinates from seed, flowers, sets seed and dies within one growing season. In contrast, once established, perennial plants like alfalfa and Kura clover live for three or more years, and have potential to set seed each year. An intermediate group of legumes, biennials such as sweet clover, live for two years. They grow vegetatively the first year, flowered and die in the second year.
Of the three life cycle types of legumes, perennials are considered to be the most valuable for the environment. They provide continuous ground cover, recycling of nutrients, and long-term carbon storage. The use of perennials also eliminates the need for annual reseeding. Edible legume grains have been domesticated and use by civilizations for centuries as dietary source of protein 5000 years ago. (Rachie, 1974).
Forage legumes continue to be valuable crop throughout the world as integral components of sustainable agricultural systems, providing high quality livestock feed, nectar, seed, green manure, and soil cover (Summerfield, 1980).

Legumes are also well known as soil building plants, as they enhance soil quality by adding organic matter, and improve soil structure and water infiltration.
Grain legumes are important in human nutrition in the less humid parts of the tropics, where they contribute substantially to total protein intake, particularly in those less arid parts where the main energy sources are starchy roots and tubers which contain little protein (Smart, 1983). Grain legumes are useful sources of thiamine (Vitamin B, colarbony lase), macin (Vitamin B6) and of Calcium.

Table 2: World Production of Leguminous Food Crops

Crops	Area Ha x 1000	Production Mt x 1000
Soybeans	76,542	172,621
Groundnuts in shell	25,144	35,030
Beans, Dry	24,109	17,307
Peas, Dry	5,878	10,222
Chick-Peas	9,822	7,543
Broad Beans, Dry	2,451	3,674
Cow Peas, Dry	8,965	3,200
Lentils	3,805	3,085
Pigeon Peas	3,930	3,029
Lupins	1,236	985
Bambara Beans	70	55
Pulses, Total	66,498	53,878

Summerfield, 1980

II. RAINFALL VARIABILITY IN BENUE

A major factor in rainfall variability over Sahelian West African is the latitude location of the tropical rain belt. When it is displaced abnormally far northward, the sahel experiences a wet year, according to (Sharon and Peter, 2005) an anomalous southward displacement results in drought. Important factors include sea surface temperatures, (SSTs) in the equatorial Atlantic and pressure in the South Atlantic. The first of these factors suggests a link with the Atlantic Ni˜no mode of tropical Atlantic variability, while the second suggests a possible link with the pacific and the extra tropical South Atlantic.

The Relationship of the EL NIN˜0 – Southern Oscillation (ENSO) and Rainfall is probably responsible for many of the well-established rainfall tele-connections over West Africa, including the strong tendency, for opposite anomalies, in equatorial and Southern African. There is strong tendency for positive anomalies to occur during the first half of the ENSO cycle and negative during the second half corresponding to 'cold' and 'warm' phases in the adjacent Atlantic and Indian Oceans; continentally, rainfall tends to be enhanced during the cold phase, reduced during the warm phase. The northward propagation is most pronounced during the cold phase; a similar propagation and phase shift occurs at this time in the Atlantic. The rainfall anomalies of the warm phase are nearly constant in phase, as are the SST anomalies in the Indian Ocean. This suggests that, in general, the Atlantic Ocean controls rainfall during the cold phase, the Indian Oceans during the warm phase (Sharon and Jeeyoung, 1998). Temie and Tor (2006) examined some characteristics of rainfall in Benue (Makurdi) and concluded that year-to-year correlation of rainfall and flood events was not possible because flood records were not defined in precise terms as peak over a constant threshold. Therefore, from the analysis of rainfall magnitudes and estimated recurrence interval, it was found that available records of flood events corresponded to rainfall events of high recurrence intervals. Although annual rainfall fluctuation in Benue (Makurdi) was found to be in progressive decline (table 1), the period 1996 to 2001 was marked by positive deviation from the mean. Major floods were mostly associated with high recurrence interval storms.

Table 1: Periods of above Average Rainfall for Benue (1927 – 2008)

Period	Duration (yrs)
1st (1928 – 1935)	7
2nd (1944 – 1955)	11
3rd (1960 – 1970)	10
4th (1966 – 1999)	3
5th (2000 – 2008)	3

This period of positive deviation from the mean corresponded to periods of increased frequency of heavy rainfalls and flooding in the series (table 2). This is in confirmation of the findings of Babatolu (1996), that heavy rainfall events are more likely to reflect annual changes than light or moderate falls. It therefore implies that it is these heavy rainfall events that result in overland flow and hence over bank flooding on River Benue.

The seasonal trend in soil moisture status in Benue indicate that, the surplus water will first be utilized in recharging the underground moisture reserve from May and should be available for rapid run-off from August to October. The month of August has been shown to be the month with the highest soil water surplus as well as having the most frequent events of extreme daily rainfall in the series. Thus, seasonality of extreme rainfall evidently had important implications for flood response. The recent flood records of 29th August 1996 and 3rd August 2000 are further indicators that floods are to be expected to occur mostly from August (Temie and Tor, 2006).

The remarkable continuous downward trend in annual rainfall amounts in Benue from 1971 to 2004, breaking only from 1996 to 2001. The period of recent upward trend (1996 – 2001) however recorded the highest frequencies of extreme rainfall events, with corresponding flood frequencies. It is therefore, not the annual rainfall total that is an important cause of increased flood frequency in Benue but the percentage of it that falls as heavy falls.

III. THE STUDY AREA

Benue has a population of 4,780,389 (2006 census) and occupies a landmass of 32,518 square kilometers. The area is within the southern Guinea Savannah Vegetation zone of Nigeria with relative humidity varies from month to month but generally ranges from 7% to 100% maximum.

The State lies within the lower river Benue trough in the middle belt region of Nigeria. Benue state is located between latitude 7^{o}30 and 7^{o}44'N of the equator and latitude 8^{o}37' and 8^{o}47'E of the Greenwich meridian, Its geographic coordinates are longitude 7° 47' and 10° 0' East. Latitude 6° 25' and 8° 8' north and shares boundaries with five other states namely: Nassarawa to the north, Taraba to the east, Cross-River to the south, Enugu to the south-west and Kogi to the west. The state also shares a common boundary with the Republic of Cameroun on the south-east.

Based on Koppen's Scheme of Classification, Benue State lies within the AW Climate and experiences two distinct seasons, the wet/rainy season and the dry/summer season. Benue state has distinct Wet and dry season, the rainy season starts in April and ends October while the dry season begins in November and ends in March.

Table 2: Extreme Rainfall Series in Makurdi (1979 – 2008)

Month	Series (years)	Series Total (mm)	Series mean (mm)
June	1983, 1996, 1998, 1999, 2004	174	43.5
July	1980, 1981, 1982, 1983, 1985, 1993,	428.7	71.45
August	1984, 1991, 1992, 1997, 1996, 2000. 2001	791.8	113.13
September	1989, 1990, 1992, 1997, 2002, 2003, 2008	445.1	89.02
October	1988, 2006, 2007	45.2	45.2

The annual rainfall ranges from 1270 – 1397mm and a mean temperature ranging from 21.6^{o}C to 32.7^{o}C, the total length of growing season is 215 days. The south-eastern part of the state adjoining the Obudu-Cameroun mountain range, however, has a cooler climate similar to that of the Jos Plateau.

Benue State is the nation's acclaimed food basket because of its rich agricultural produce which include yams, rice, beans, cassava, potatoes, maize, soya beans, sorghum, millet and cocoyam. The state also accounts for over 70% of Nigeria's soya bean production.

Agriculture is the mainstay of the economy, engaging over 75% of the state farming population. The State also boasts of one of the longest stretches of river systems in the country with great potential for a viable fishing industry, dry season farming through irrigation and for an inland water highway.

The vegetation of the southern parts of the state is characterized by forests, which yield trees for timber and provide a suitable habitat for rare animals. The state thus possesses potential for the development of viable forest and wildlife reserves.

IV. MATERIALS AND METHODS

Data on crop mean yield for legumes output and rainfall for twenty one (21) years were collected from Benue state Agricultural and rural development Authority (BERNADA) and the department of metrological service, NAF Base respectively table 4. A simple and non linear correlation model was used to analyze the relationship between the crop yield output and fluctuating rainfall over the years (22yrs) to measure the goodness or fit of the model actually assumed to the data.

$$R^2 = \frac{\sum(y-y)^2}{\sum(y-\bar{y})^2} \text{-----------} 3$$

$\sum (y - y)^2 =$ Explained variation

$\sum (y - \bar{y})^2 =$ Total Variation

- The coefficient of determination is such that $0 \leq R^2 \leq 1$, and denotes the strength of the linear association between x and y.
- The model represents the percentage of the data that is the closest to the line of best fit
- R^2 gives the proportion of the variance (fluctuation) of one variable that is predictable from the other variable.
- The coefficient of determination, R^2, is a measure of how well the regression line represents the data. If the regression line passes exactly through every point on the scatter plot, it would be able to explain all of the variation. The further the line is away from the points, the less it is able to explain.

TABLE 3**.** Annual rainfall and Legume production output in Benue

Year	Annual Rainfall (mm)	Mean Yield of Groundnut ('000MT)	Mean yield of Beans ('000MT)	Mean yield of Soyabeans ('000MT)	Total yield of Legume ('000MT).
1988	841.1	0.46	0.36	0.55	1.37
1989	1346.8	1.1	0.35	1	2.45
1990	1242.6	1.4	0.45	1.3	3.15
1991	1072.6	1.5	0.55	1.5	3.55
1992	1320.2	2.48	0.46	2.32	5.26
1993	1212.9	2.38	0.41	2.43	5.22
1994	1087.4	3.77	0.73	2.7	6.10
1995	1156.7	3.07	0.9	1.3	5.27
1996	1129.2	1.67	0.6	2.76	4.49
1997	1306.8	1.67	0.75	1.51	3.93
1998	1556.4	1.66	0.75	1.5	3.81
1999	1574.4	1.74	0.8	1.9	4.44
2000	1245.6	1.75	0.81	1.95	4.51
2001	1082.4	1.75	0.78	1.95	4.48
2002	1287.6	1.8	0.81	1.96	4.57
2003	762	1.97	0.81	1.95	4.73
2004	1026	1.9	0.81	1.92	4.63
2005	871.2	1.95	0.79	1.94	4.68
2006	1395.6	1.9	0.77	1.94	4.51
2007	1338	1.95	0.8	1.96	4.71
2008	1050.5	1.87	0.81	1.95	4.63

Source: BNARDA

V. RESULTS AND DISCUSSION

The trend in rainfall and the legume production for the period under review is presented in figure 1 below. Physical appreciation of the plot indicated a sinusoidal variation in the production of legume for the period with the major decline 2000 and 2005. This period of decline correspond to a more or less stable rainfall period. The sharp decline of rainfall in 1993 however did not translate to decline in production which is an indication that it is not the amount of rainfall but the amount of soil moisture that is of importance.

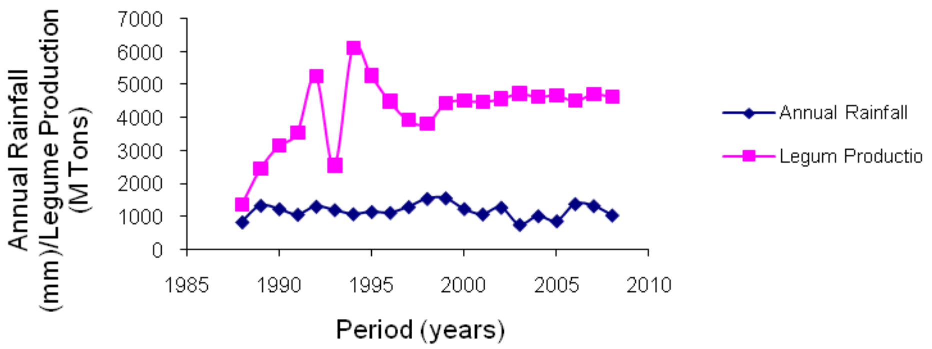

Fig. 1; Trend in annual rainfall and legume production in Benue State

In correlating the degree of the relationship between the rainfall and the output from legume production, by fitting in the observed value of the rainfall, a linear was considered from the plot in fig 2 $y_{est} = 0.1695x + 3980.7$; r^2:0.0011

Because of the insignificant correlation between the rainfall and legume

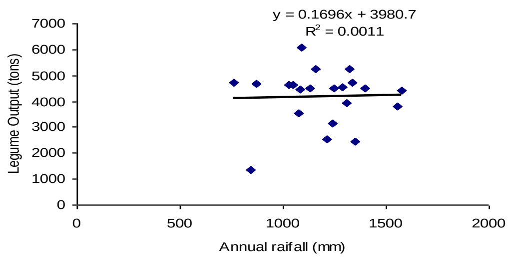

Fig2. Correlation between Legume output and rainfall

Production output. a regression was carried out on the possible relationship between the variables and a non linear second order quadratic model (polynomial) was considered from the plot in fig 3 as below.

$y_{est}=0.0026x^2+6.5596x+ 584.21$; r^2:0.0189

.

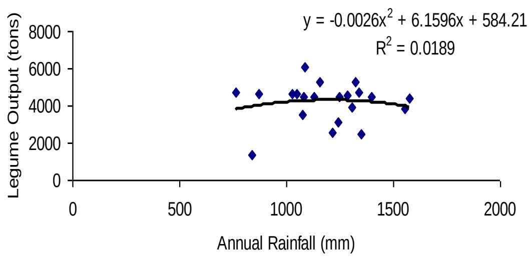

Fig 3. Regression between Legume output and rainfall

The linear correlation coefficient of r = 0.0332 is a very low linear relationship between rainfall and legume output. However there was an improvement on the part of the non linear relationship supplied by the quadratic regression model as indicated by r = 0.1375. This assumption of the parabolic relationship between rainfall and legume output introduces the concept of unexplained variation which is I – 0.1375 =0.8625 or 86.25% . The unexplained variation is largely due to influencing factors such as abiotic, farm management practices; land development, socioeconomic and catastrophic factors.

VI. CONCLUSSION

The production output of legumes in Benue is actually a function of rainfall but largely conditioned by unexplained factors earlier mentioned. From the regression analysis of best fit, 1756.7 metric tons of legumes are expected to be produced in 2012 provided the unexplained factors remain constant.

REFERENCE

[1]. Ayoade J.O.(1988). Introduction to Climatology for Tropics. Ibadan Spectron Books Limited.
[2]. Babatola, J S (1996). Recent Changes in Rainfall Patterns and its Implication for Flood Occurrence in Ondo, Nigeria. Ondo Journal of Arts and Social Sciences, 1 (1), pp. 125 – 136.
[3]. Fadiji, T.O. (1985); Institute of agricultural Research, Samaru, Ahmadu Bello University Zaria
[4]. Gibbon S.R. (1985); An Analysis of Rainfall Condition in West Africa, Including thre Rainy Seasons of the 1997 ElNino and the 1998 Lanina year. Journal of climate . 13, 2628 – 2640.
[5]. Jackson, C.R. (1989). Recent Rainfall Fluctuation in AfricaInteremispheric Teleconections. Variation in Global Water Budget.
[6]. Kirgmer, P.J. (1983). Water Transport through Soil, Plant and Atmosphere' In Agriculture in Semi-Arid Environment. Machmillan Eduction Limitd, London.
[7]. NPC (2006). National Population Census Figure for Benue State.
[8]. NEST (2003). ''Climate Change in Nigeria'' A communication guide.
[9]. Olaniran, O J (1983). Flood Generating Mechanism at Ilorin, Nigeria. GeoJournal,7.3, pp. 271 – 27.
[10]. Rachi, K.O.(1974). Grain Legumes of the Lowland Area. Advance Agronomy. 26, 1-154.
[11]. Sharon E.N and Jeeyoung K. (1998) the relationship of the el nino–southern oscillation to african rainfallsmooth. International journal of climatology, vol. 17, 117–135 (1997)
[12]. SharonE.N. and Peter J.W.(2005). A Physical Basis for the International Variability of Rainfall in the Sahel. Journal of Agro meteorology, 10, 2013 – 2410
[13]. Summerfield, R.J.(1980). Advances in Legum Science. Royal Botanic Garden Kew. England.TEMI E. OLOGUNORISA; TOR
[14]. Tersoo, E and Tor T {2006}; The Changing Rainfall Pattern and Its Implication for Flood Frequency in Makurdi, Northern Nigeria *Journal of Applied Sciences & Environmental Management, Vol. 10, No. 3, September, 2006, pp. 97-102*