EFFECT OF RAINFALL VARIABILITY ON CROP PRODUCTIVITY IN IDOFIAN, KWARA STATE, NIGERIA

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ABSTRACT

Rainfall data for Idofian were analyzed for monthly and weekly rainfall probabilities at various thresholds and correlated with yield. The mean annual rainfall is 1195 mm with a coefficient of variation (CV) of 19.6% while the mean weekly rainfall is 21.5 mm with a CV of 56% indicating very high weekly rainfall variability. 40% of the years received rainfall above annual mean value which was distributed unevenly during the cropping season. The months of May to September had high probabilities of occurrence with September having the highest for the thresholds considered. Positive correlation between yield and rainfall was recorded for cowpea, melon, rice. The predictability of yield using rainfall was however, low.

KEYWORDS: Rainfall variability and distribution, specific rainfall threshold, yield

1. INTRODUCTION

Generally, there are many factors influencing crop production; these include soil, relief, climate and diseases among others. Hence, precipitation, solar radiation, wind, temperature, relative humidity and other climatic parameters determine the global distribution of crops and livestock as well as their productivity. Agriculture largely depends on climate to function; it is one of the most weather-dependent of all human activities. In relation to climate, rainfall is the dominant controlling variable in tropical agriculture since it supplies soil moisture for crops and grasses for animals. Rainfall is a key factor in shaping the vegetation, hydrology, and water quality throughout the earth. Along with temperature, the occurrence and variability of precipitation, to a large extent determine which crops can be grown in different regions throughout the world. Rainfall is particularly critical to agriculture. Thus, any changes occurring in climatic conditions affecting rainfall patterns will have an adverse impact on agriculture and eventually affect the economic well-being of the people (Dahal, 2009). As weather pattern changes, the economy of farmers, which depends on traditional subsistence-based agriculture, becomes more vulnerable and difficult.

IPCC (2001) gives a clear difference between climate variability and climate change. Climate variability is the fluctuations of climate naturally on a time scale ranging from days, weeks and years to few decades, including altered frequencies of extreme events while climate change is a longer term fluctuation from decades to centuries. As additional insight into precision farming is gained, the importance of rainfall variability becomes more apparent. An accurate understanding of precipitation characteristics and soil variability is critical to optimizing farm production and to precision farming. The ability to make informed decisions regarding precision farm management depends upon an understanding of seasonal and spatial variability of rainfall. Rainfall studies particularly probability analysis are of great help in selection of crops and varieties, crop management practices, contingent crop planning, plant protection measures and related farm operations for sustaining crop production in an area (Mehta *et al*., 2002).

Rainfall has now become very unreliable in terms of commencement, distribution and quantity (Audu *et al.,* 2010). Annual rainfall records at a single station have large variations that are sometimes larger than the mean annual rainfall. Sumner (1988) observed that the large variability, asymmetry, and non-normal distribution of rainfall over several decades completely mask any long-term trend that might exist in that record. Rainfall variability, a major index of climate change, affects cropping activities such as land preparation and sowing, particularly in rain-fed agricultural systems. Rainfall variability is one of the main determinants of agricultural production in both developing and developed countries (FAO, 2001). It is an important characteristic of climate in SSA that imposes crop production risks, especially on rain-fed subsistence cultivation systems on marginal land (Koo, 2010). Inter-annual rainfall variation, defined as the annual deviation from long-term averages or the differences in rainfall between years, has been the key climatic element that determines the success of agriculture in a region (Ayanlade *et al*., 2009). High inter-annual rainfall variability, coupled with increase in temperature, portends serious implications for African soils.

In Nigeria, an agrarian country, agricultural productivity is strongly linked to rainfall variability because farmers rely on rain-fed agriculture. Nigeria's wide range of climate variation allows it to produce a wide variety of food and cash crops. However, food production is grossly below the rate of population growth. Ideally, crop cultivations should be situated in areas with high rainfall with low variability; however, subsistence farming can be found in a wide range of environmental conditions from very suitable to marginal lands. Food shortage is therefore linked with climate change (Adefolalu, 2004). Rainfall variability from season to season greatly affects soil water availability to crops, and thus poses crop production risks. Variability in the onset of the rainy season has lead to variation in the start of the planting season of varied crops.

Various studies have revealed that rise in temperature and changes in the amount of rainfall and its distribution have altered availability of water resources consequently affecting the productivity of crops grown in the different parts of the country. Tunde *et al.* (2011) studied the impacts of temperature, relative humidity, rainfall and number of rainy days on food production and found that maize production correlated highly with rainfall amount (0.73) while other variables were very weak. Transpiration through plant parts utilizes a lot of moisture from the soil. The amount of rainfall received during the life period of crop, therefore, plays an important role in the yield of the crop. The distribution of rainfall within the crop period is however, more important than the total amount of rainfall in a season. It is, thus, possible to estimate crop yields from total rainfall received during crop period.

The objective of this study therefore was to statistically analyze rainfall variability and develop yield prediction models using rainfall and yield data available in the region. This will reveal whether or not changes in climatic variables have positive or negative effect on crop yield in the study area. It will also reveal the pattern of crop production to be adopted within the study area.

2. METHODOLOGY

Rainfall data for Idofian, Kwara State, Nigeria, covering the period from 1990 to 2004 (15 years) obtained from the NCAM Meteorological Station was used in this study. The data was subjected to statistical tests for trends, inconsistency and stability. The mean, standard deviation (SD) and coefficient of variation (CV %) of weekly and seasonal rainfall (for the cropping period) was calculated using SPSS 20.0 statistical packages. The probability of getting more than 1mm, 5mm, 10 mm, and 20mm was obtained by simple probability method. This is expressed as:

$$Probability\ (\%) = \frac{m}{n} \times 100$$

where m = total frequency of rainfall at specific threshold, n = number of days in the month

The regional average yield data for selected crops for the years under review was obtained from Kwara State Agricultural Development Project (KWADP). The regression was performed using rainfall (X) as independent variable and yield (Y) as dependent variable and a correlation between rainfall and yield was established. Yield prediction models for important crops such as maize, sorghum, melon, cowpea, millet, rice, yam and cassava were developed.

3. RESULTS AND DISCUSSION

3.1 Statistics of Mean Annual Rainfall of Idofian

The annual rainfall of Idofian for the period under review (Fig. 1) varied from 872.40 mm (1992) to 1595.10 mm (1998) with a mean seasonal value of 1195.45mm and a standard deviation of 239.42. The number of rainy days, set as days with ≥0.3mm rainfall event, also varied from 19 to 84 days. From the available record, excess rainfall above the mean value was received in 6 years (40%). About 95 % of the mean annual rainfall occurred between the months of April – October while the months of November – March contributed just 5 % of the mean annual rainfall.

Rainfall usually determines the type of crop to be grown in different environment as well as the type of agricultural system to be practiced in different parts of the country. Thus, it directly affects crop production and can alter the distribution of agro-ecological zones. In this region the dominant crops produced are maize, sorghum, melon, cowpea, millet, rice, yam and cassava.

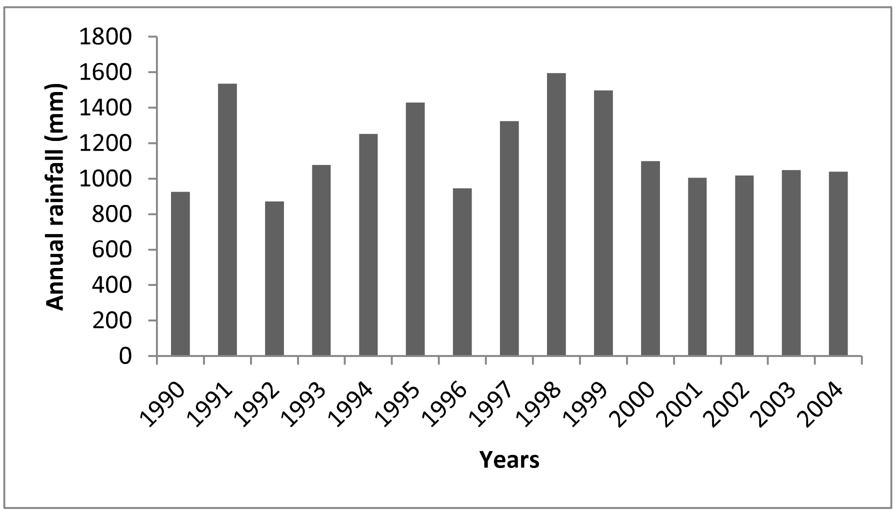


Fig. 1: Seasonal rainfall amount at Idofian (1990 – 2004)

3.2 Weekly Rainfall Analysis

The distribution of rainfall received weekly is presented in Fig. 2. Rainfall is usually well established by the month of May which is denoted as meteorological week (mw) 18 and ends by October (mw 44). The rainfall pattern in Idofian comprises of two rainfall peaks in the months of June and September, with a period of dry spell referred to as August break. This bimodal rainfall pattern is characteristic of rainfall in the south western part of Nigeria.

The analysis of weekly rainfall showed a lot of variability within the rainfall season (CV of 56%). The largest rainfall received in a single week (322 mm) was recorded in September 2001, which corresponds to meteorological week 38 (Table 1).

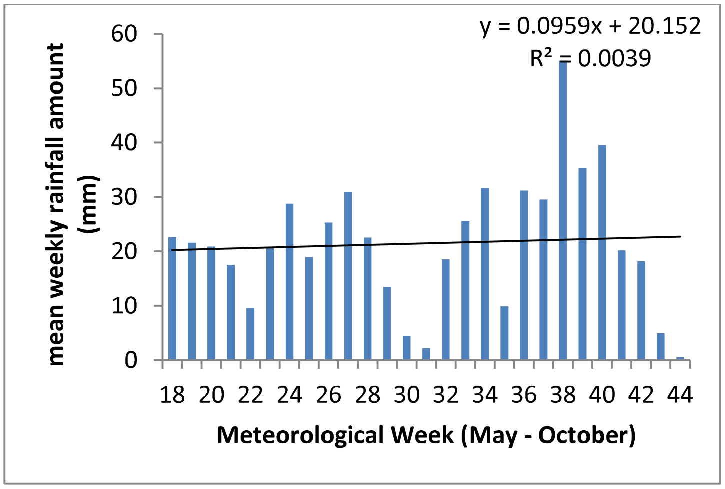


Fig. 2: Weekly rainfall distribution for the months of May to October at Idofian

Table 1. Weekly rainfall data analysis for Idofian (1991 – 2004)

Met. Week	Mean	SD	CV (%)	Maximum rainfall in a single week (mm)	Year
18	22.59	23.3204	103.2	76.9	1997
19	21.6	21.98409	101.78	75	1999
20	20.92	26.58632	127.08	89.5	1997
21	17.55	14.15	80.6	66.5	1999
22	9.6	9.266667	96.5	32	2000
23	20.76	14.50139	69.85	72	2001
24	28.78	20.3125	70.58	67	1997
25	18.97	13.96667	73.63	58.5	1999
26	25.3	20.88333	82.54	70.5	1996
27	30.96	20.41111	65.93	86.3	2002
28	22.53	23.97222	106.40	85.5	1996
29	13.49	13.60556	100.85	56.5	2002
30	4.48	5.111111	114.09	17.6	1991
31	2.21	3.680556	166.54	19.5	2001
32	18.54	18.91944	102.05	107	2002
33	25.63	24.09444	94.01	116	2002
34	31.68	32.94649	103.99	85	1991
35	9.92	13.26621	133.73	47.5	2002
36	31.23	42.8037	137.06	148.0	1997
37	29.57	23.81708	80.54	74.5	1997
38	55.08	87.83348	159.46	322.0	2001
39	35.4	27.97713	79.03	102.8	2000
40	39.58	40.11064	101.34	105.5	1991
41	20.23	24.19434	119.59	58.5	1995
42	18.23	20.2041	110.83	53.1	1995
43	4.98	11.86797	238.31	41.5	1994
44	0.54	1.37276	254.21	4.5	1991
Mean	**21.5**	**12.16**	**56.56**		

Table 2: Mean Rainfall and Probability of occurrence for Idofian (1991 – 2004)

Month	Mean Rainfall (mm)	Rainfall Threshold					
		≥ 0.3mm	≥ 1mm	≥ 5mm	≥ 10mm	≥ 15mm	≥20mm
Jan	1.5	0	0	0	0	0	0
Feb	5.4	0	0.107	0.036	0	0	0.036
Mar	36.5	0	0.193	0.032	0.129	0.0645	0.097
Apr	85.5	0.1	0.4	0.267	0.20	0.1	0.433
May	150.3	0.097	0.806	0.452	0.452	0.258	0.710
Jun	181.0	0.033	0.933	0.567	0.33	0.367	0.633
Jul	153.7	0.032	0.935	0.452	0.355	0.290	0.355
Aug	148.8	0.067	1.13	0.533	0.33	0.167	0.70
Sept	268.9	0.233	0.833	0.80	0.60	0.367	1.00
Oct	127.4	0.097	0.774	0.548	0.193	0.290	0.516
Nov	14.9	0	0.167	0.067	0	0	0.033
Dec	3.6	0	0	0	0	0	0

The probabilities of occurrence of different rainfall thresholds obtained for Idofian is presented in Table 2. The result shows that the probabilities of occurrence of rainfall of lesser threshold values are generally more than the probabilities of occurrence of rainfall of higher threshold values. The highest probabilities were recorded for receiving ≥ 1mm rainfall. There is also a trend of progressive increase and decrease of rainfall probabilities at the onset and end of the year respectively while the month of September recorded the highest probabilities of receiving rainfall at all specific thresholds considered. The months of May to September might be categorized as having high probabilities of rainfall occurrence, March, April and October as average while December, January and February were considered to be low.

Since the distribution of rainfall within the crop period is more important than the total rainfall amount in a season, presenting the various rainfall thresholds available within the season reveals the rainfall distribution pattern of the study area thus enabling the user to select values of interest to suit field operations and crop requirement. Hence management decisions can be enhanced from this information.
For effective growth to occur, the amount of rainfall available must be able to provide sufficient soil moisture after accounting for losses to runoff and evaporation. Runoff losses for Idofian has been estimated as 20% (Ahaneku, 1997) whilst the consumptive use for the crops obtained from the crop coefficients and climatic data for the region will define the need for supplemental irrigation to meet the deficiencies.

3.3 Crop Productivity Analysis

The results of regression analysis between rainfall and crop yield are as in Figures 3 – 10. The graphs show positive correlations of different percentages between rainfall and crop yield for most of the crops considered. The total rainfall amount does not always correlate with higher yield due to other factors such soil characteristics and rainfall pattern. The permeability of the soil and rainfall intensity determines how much rainfall percolates or is lost to runoff. A soil with high water holding capacity and long retention (clayey soil) will support crop production better than a porous sandy soil. Plants possess different sensitivity levels to water stress at different developmental stages. In most grain crops, flowering, pollination and grain-filling phases are especially sensitive to water stress. Crop yields are most likely to suffer if dry spells occur during critical developmental stages such as the reproductive stage. It is thus, important to know the water requirements of a crop and make provision for supplemental irrigation if rainfall becomes a limiting factor. Other contributory parameters that could affect crop productivity include; fertility of the land, seed viability and sowing time.

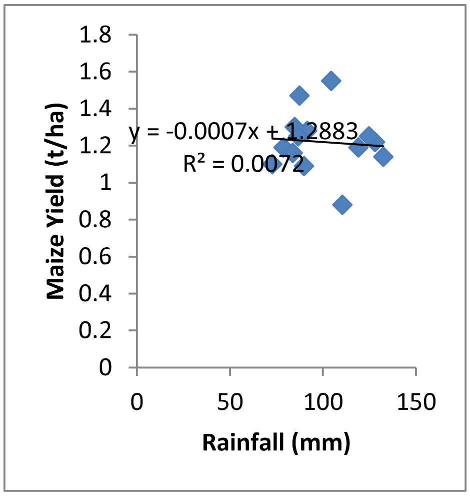


Fig. 3: Graph of Rainfall and Yield for Maize

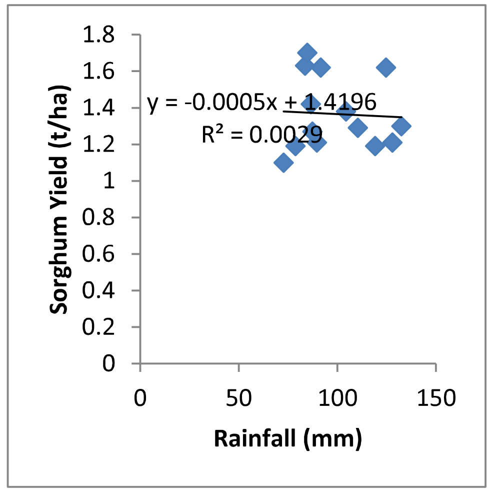


Fig. 4: Graph of Rainfall and Yield for Sorghum

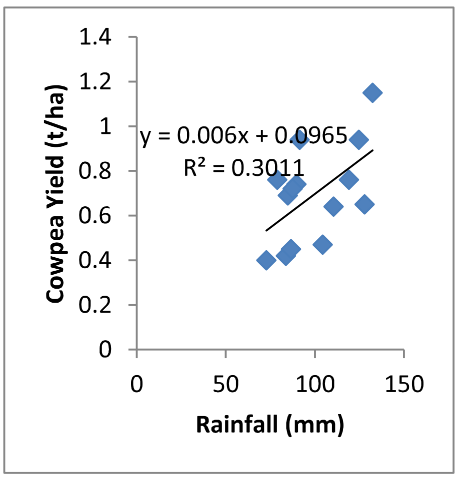


Fig. 5: Graph of Rainfall and Yield for Cowpea

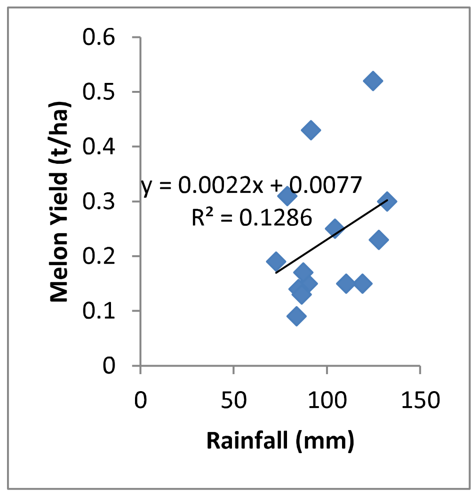


Fig. 6: Graph of Rainfall and Yield for Melon

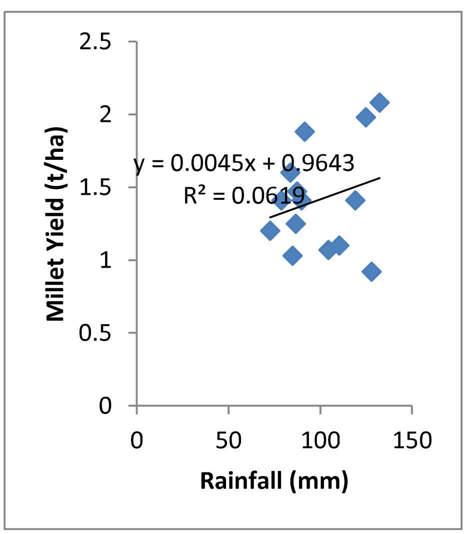


Fig. 7: Graph of Rainfall and Yield for Millet

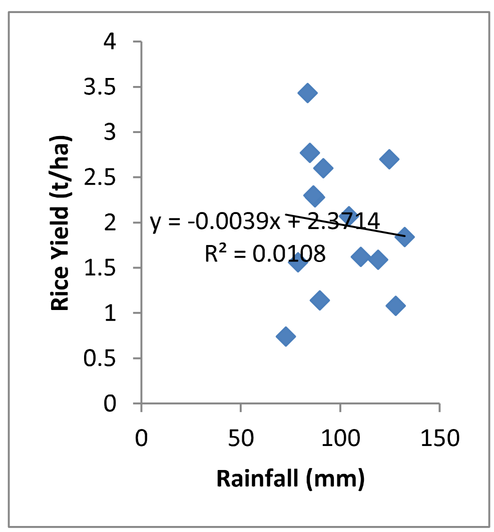
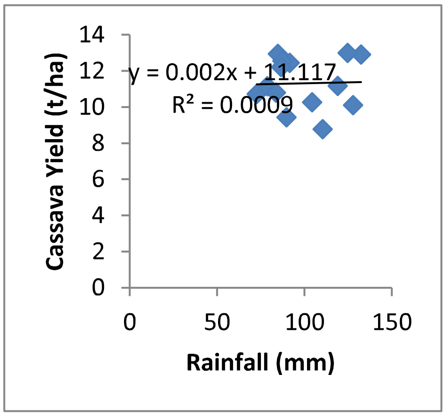


Fig. 8: Graph of Rainfall and Yield for Rice



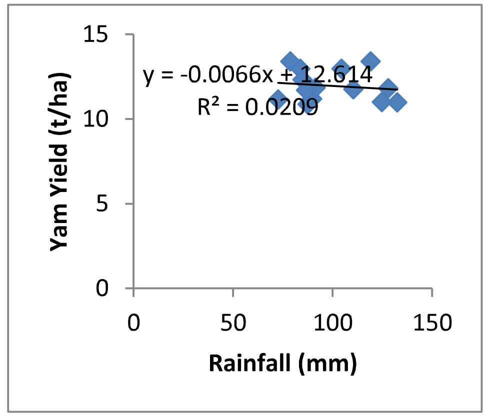


Fig. 9: Graph of Rainfall and Yield for Cassava Fig. 10: Graph of Rainfall and Yield for Yam

4. CONCLUSION

Water availability is the most critical factor for sustaining crop productivity in rain-fed agriculture. Different crop growth stages have different sensitivity levels of development to water stress; low availability of water during a critical stage can have a high impact on yield. Hence, to efficiently use water, it is important to understand when crop needs water the most and ensure that values that can be depended upon are known and available, thus stabilizing crop production.

Rainfall is the major source of water for plant use. Planning of agricultural activities is hinged on the availability of rainfall. Statistical analysis of past records was used to determine the total amount, variability and distribution. The study has shown that there is high variability (56%) in the distribution of weekly rainfall amounts during the season and the possibility of critical growth stages falling within periods of drought. This can account for the low correlation between yield and rainfall for some crops.

The result of this analysis will assist in decision making for both human and equipment input in field activities. For most crops, varieties exist with a wide range of maturities and climatic tolerances. Thus, improved cultivars need to be adopted as well as integrating supplemental irrigation to prevent adverse water stress at crucial developmental growth stages to prevent drastic yield reduction.

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