Global Scientific JOURNALS

GSJ: Volume 6, Issue 4, April 2018, Online: ISSN 2320-9186
www.globalscientificjournal.com

ESTIMATING DEPENDABLE RAINFALL FOR IMPROVED CROP PRODUCTION IN IDOFIAN, NIGERIA

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ABSTRACT
The minimum water requirement for an agricultural region is needed for proper planning to ensure high crop productivity is achieved. Estimation of the dependable rainfall is required to design appropriately for sustainable agricultural practices particularly in line with the changing climate witnessed globally. The Dependable Rainfall Index (DRI) has been shown to be capable of determining and specifying dry and wet years. This will help to reduce the effects and losses caused by drought to man and his environment. DRI for Idofian was calculated to be 940.96 and was used as base value to classify the rainfall levels in the years available for this study. The dependable rainfall probability P80 obtained was 965mm. This value ensures that on average, there will be enough water to meet the crop's need at Idofian, four out of every five years. It was however observed that the dry months could not sustain the water requirement of most crops, hence emphasizing the need for employing irrigation in our farming practice to intensive efforts to meet the provision of food for the teeming population of the country.

KEYWORDS:

variability, dependable rainfall, exceedance probabilities.

INTRODUCTION

The rainfall received in an area is an important factor in determining the amount of water available to meet various demands, such as agricultural, industrial, domestic water supply and for hydroelectric power generation. Rainfall is the most important climatic variable as it has far-reaching influence on agricultural crop production. The amount, incidence, variation and reliability of rainfall determine differences in cropping pattern in various ecological zones. Rainfall variability is one of the main determinants of agricultural production in both developing and developed countries (FAO, 2001).

In Nigeria, agricultural productivity is strongly linked to rainfall variability because farmers rely on rain-fed agriculture. Rainfall variability from season to season greatly affects soil water availability to crops posing crop production risks. Since water need of a crop varies within the growing season, it is not always sufficient to have probability estimates for the whole season or even for a particular part of it (Jensen, 1974). Therefore, it becomes important to have a probability estimate for the occurrence of a particular sequence of rainfall throughout the season. Ideally, crop cultivations should be situated in areas with high rainfall with low variability; however, subsistence farming can be found in environmental conditions ranging from very suitable to marginal lands. Investigation of climatic trend will help to safeguard farmers as it will adequately project anticipated responses. It also further stresses the need for intensification on irrigation farming as rainfall becomes more erratic and less dependable.

For management and planning purposes the information on the amount of rainfall which one can expect in a specific period such as a week, a decade, month or year under dry, normal and wet conditions is important. The planner needs to know the amount of rainfall, which can be depended upon with a certain degree of probability (Doorenbos and Pruitt, 1977; Aminul, 2005). Knowledge about dependable rainfall will ensure that the irrigation schedule is planned in such a way as to make optimum use of rainfall and thus avoid over irrigation, water logging and salinity problems which has destroyed many agricultural lands in the past decades through rising water tables.

Aminul (2005) defined dependable rainfall as the rainfall, which can be expected in a set number of years out of a total number of years. FAO (1998) defined it as the amount of rainfall which can be depended upon in 1 out of 4 or 5 years corresponding to a 75 or 80% probability of exceedance and representing a dry year. The dependable rainfall (80%) is normally used for the calculation of storage reservoir capacity and main irrigation canals. This value ensures that on average, there will be enough water to meet the crop's need four out of every five years. If the mean value (50%) is used in the design of an irrigation system then on average, in one out of every two years there will not be enough water to meet the demands of the crop and yield will be reduced. For drainage projects, the 20% dependable rainfall is normally adopted. If the mean is used in drainage design, then one out of every two years the crops will be flooded. Thus, it is better to use design values with lower associated risk.

Rainfall values occurring at different probability levels are however, not readily available especially in developing countries, rather mean monthly values for individual stations are available. Utilizing mean monthly rainfall which has high variability instead of the dependable rainfall may result to insufficient water provision for crops. Therefore, it is important to evaluate the statistical specifications and estimate the dependable rainfall in order to design appropriately for sustainable agricultural practices particularly in line with the changing climate witnessed globally. This study therefore estimates the dependable rainfall probabilities for Idofian, Kwara State.

METHODOLOGY

Rainfall data for Idofian, Kwara State, Nigeria, covering the period from 1994 to 2014 obtained from the NCAM Meteorological Station was used in this study. The rainfall pattern was depicted using histogram, while trend line was used to depict the slope of the rainfall.

Monthly dependable rainfall, as well as rainfall in wet, normal and dry years, defined as the rainfall with a probability of exceedance of 20, 50 and 80% respectively, representing a wet, normal and dry year were evaluated. These values are useful for the design of the irrigation system capacity, programming of irrigation supply and simulation of irrigation management conditions.

To calculate rainfall probabilities, rainfall record from a range of years (15 – 30) is required. Estimates of the respective rainfall data was obtained by computing and plotting probabilities from the rainfall records using the simple ranking method as described by Doorenbos and Pruitt (1975) in the following procedure:

i. Yearly rainfall totals for a given period were tabulated.
ii. Data were arranged in descending order of magnitude.
iii. Plotting positions were tabulated from the expression:

$$F_a = \frac{100 \times m}{(N+1)} \quad (1)$$

where:

N = number of records

m = rank number

F_a = plotting position

iv. Plotting of values on log-normal scale and evaluation of the logarithmic regression equation.

v. Calculation of year values at 20, 50 and 80% probability represented as P_{wet}, P_{normal} and P_{dry} respectively.

vi. Determination of monthly values for the dry year using the relationship:

$$P_{i\,dry} = \frac{P_{i\,av} \times P_{dry}}{P_{av}} \quad (2)$$

where: $P_{i\,av}$ = average monthly rainfall for month i

$P_{i\,dry}$ = monthly rainfall dry year for month i

P_{av} = average yearly rainfall

P_{dry} = yearly rainfall at 80% probability of exceedance

Similarly values for normal and wet years were determined using:

$$P_{i\,normal} = \frac{P_{i\,av} \times P_{normal}}{P_{av}} \quad (3)$$

and

$$P_{i\,wet} = \frac{P_{i\,av} \times P_{wet}}{P_{av}} \quad (4)$$

vii. Determination and specification of dry and humid years was obtained using the dependable rainfall index (DRI). This index estimates the minimum water requirement of a region especially in terms of agriculture as well as water resources (Popov *et al*., 2002, Khoshraftar, 2009, and Bahman, 2011). The Dependable Rainfall Index (DRI) is calculated from the expression:

$$DRI = \left(\sqrt[N]{P_1 \times P_2 \times P_3 \ldots\ldots P_N}\right) \times 0.8 \quad (5)$$

where DRI is the dependable rainfall index, 0.8 is the constant coefficient, P is the given year's precipitation and N is the number of the annual precipitation observations for the statistical period considered.

The scale for classifying the intensity of rainfall and also to determine the rainfall quality through the DRI is as follows:

NP = DR ≤ P ≤ GM

D = P < DR

W = P > GM

where GM is the geometric mean, NP is the normal precipitation range, D is the drought threshold and W is the wet-year threshold.

RESULTS AND DISCUSSION

Statistics of Mean Annual Rainfall of Idofian.

The annual rainfall, averaged over the period 1994 – 2014 (21 years), and the trend line is illustrated in Figure 1. The graph shows the occurrence of inter-annual rainfall variability and a decrease in the annual average rainfall is evident, as seen in the slope of the regression line. The slope of the yearly time series is about −9 mm per year.

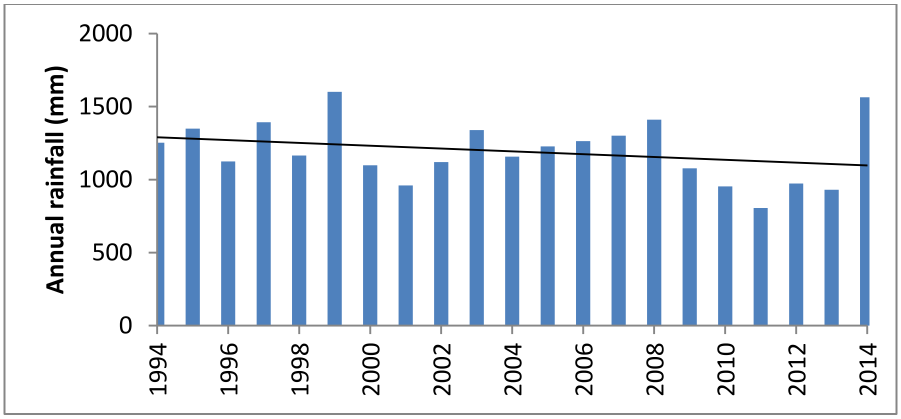

Fig. 1: Annual Rainfall for Idofian, Kwara State, Nigeria, (1990 – 2004).

The statistical specifications of Idofian rainfall for the period under review are stated below:

Average	1194
Geometric Mean	1165
Rainfall Range	795
Standard deviation	209
Number of Dry Years	4
Number of Normal Years	13
Number of Wet Years	4

About 94% of the mean annual rainfall occurred between April and October while the months of November – March contributed only 6% of the mean annual rainfall. It was observed that there are extremities of the average annual rainfall values in the study area. The five wettest and five driest years were selected as shown in Table 1. The wettest year and driest years recorded for Idofian are 1999 and 2012 respectively. It was observed that some dry years were immediately followed by the wettest years, for instance 2013 and 2014. For the wettest years, the percentage excess of rainfall varied between 13 to 34 % while in the driest years, the percentage deficiency varied between 19 to 33 %.

Table 1: The Five Wettest and Driest Years of Idofian for the period 1994 - 2014

	Wettest Years			Driest Years		
S/N	**Year**	**Annual Rainfall (mm)**	**Percent of Mean annual**	**Year**	**Annual Rainfall (mm)**	**Percent of Mean annual**
1	1999	1601.10	134.1	2012	805.70	67.5
2	2014	1564.50	131.1	2001	930.20	77.9
3	2008	1410.10	118.1	2010	953.60	79.9
4	1997	1392.50	116.6	2013	960.20	80.4
5	1995	1349.60	113.1	2011	973.50	81.5

Computation and plotting of rainfall probabilities:

The values of the rainfall probabilities are presented in Table 2, while Table 3 shows the values of monthly wet, normal and dry rainfall probabilities. This implies that for the month considered the tabulated values of rainfall will be available for crop use 80% of the time. The rainfall in normal years (50% probability) is, in general, well approached by the average rainfall as seen in Table 3.

Table 2: Rainfall probabilities and plotting position for Idofian data

S/No	Year	Annual rainfall (mm)	Rank number (M)	Plotting position (F_a)
1	1994	1253.22	9	41
2	1995	1349.60	5	23
3	1996	1124.70	13	59
4	1997	1392.50	4	18
5	1998	1165.00	11	50
6	1999	1601.10	1	4
7	2000	1098.20	15	68
8	2001	960.20	18	82
9	2002	1119.80	14	64
10	2003	1339.20	6	27
11	2004	1157.60	12	54
12	2005	1227.80	10	45
13	2006	1264.10	8	36
14	2007	1301.20	7	32
15	2008	1410.10	3	14
16	2009	1077.50	16	73
17	2010	953.60	19	86
18	2011	805.70	21	95
19	2012	973.50	17	77
20	2013	930.20	20	91
21	2014	1564.50	2	9

Table 3: Monthly Wet, Normal and Dry Rainfall Probabilities

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
P $_{\text{Average}}$	2	8	40	101	167	181	148	147	237	144	16	1	1194
P $_{\text{Dry}}$	2	7	33	81	134	146	119	119	191	116	13	1	965
P $_{\text{Normal}}$	2	8	40	99	163	177	144	144	232	140	16	1	1165
P $_{\text{Wet}}$	3	10	48	119	196	212	173	173	279	169	19	1	1400

From the plot of rainfall probabilities, Fig. 2, the values at 80%, 50% and 20% were extracted as follows:

P80 = 965 mm = P_{dry}

P50 = 1165 mm = P_{normal}

P20 = 1400 mm = P_{wet}

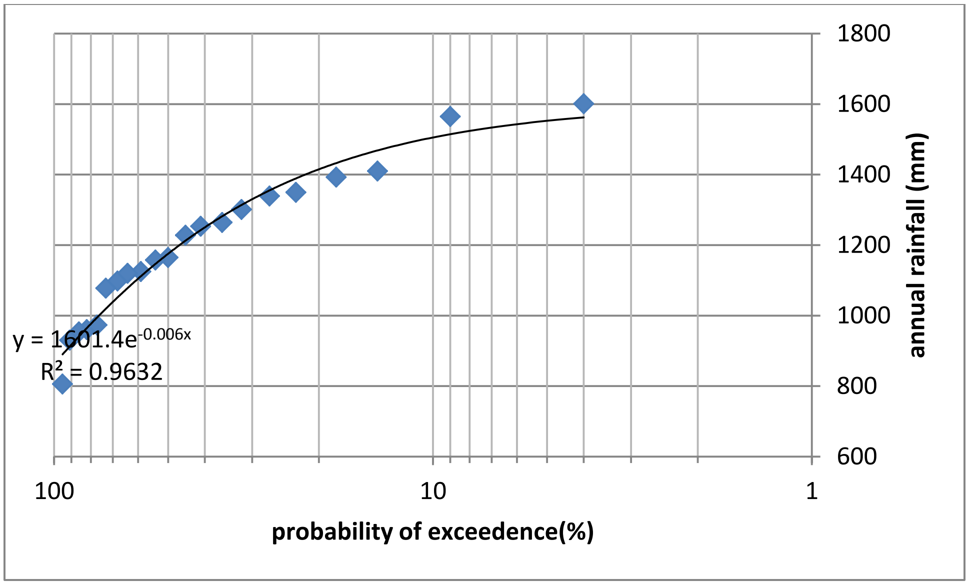

Fig. 2: Graph of Probability of Exceedence for Idofian.

Dependable Rainfall Index (DRI)

DRI is one of the hydro-climatic indices used for estimating the minimum water requirement and water resources of a region. Other indices that could be employed include the Standard Index Annual precipitation (SIAP) method (Khalili and Bazarafshan, 2003). The DRI has been adduced to be good in estimating dependable rainfall for utilization in agriculture. It is a relatively acceptable value for rainfall which could be relied on for planning.

Using equation (5), the DRI for Idofian was 940.96

The DRI was then used as base value to classify the rainfall levels using the scale:

$NP = DR \leq P \leq GM$

$D = P < DR$

$W = P > GM$

The classification revealed that for the period under study, there were two (2) years of drought, ten (10) wet years and nine (9) normal years.

In a lysimetric study carried out by Adeogun and Idike (1999), the crop coefficient of maize at the same study location, Idofian was determined. In another dry season study, Adeogun *et al*., (2004), using an indigenous drip irrigation system, obtained a cumulative water requirement of 690 mm for maize. The sum of dependable rainfall in the dry months of October – April in the present study amount to 253, 306 and 369 for the P_{dry}, P_{normal} and P_{wet} respectively. There is, therefore, a clear indication that the amount of dependable rainfall falls grossly below crop water requirement in the dry season. The implication of this is that for sustainable agriculture to be practiced there must be a drastic shift from a total rain-fed system of agriculture since the water requirement of most crops cannot be satisfied by the quantity of rainfall available within the dry months of October – April.

With the increasing population growth in the country as well as attendant high poverty level, intensive farming is needed to prevent a crisis situation. Intensification must be approached in two ways, that is not only increasing the area commanded by crop production but also, ensuring year round production. This can be actualized by providing irrigation for months below the dependable rainfall while adequate drainage is provided for excess rainfall.

CONCLUSION

Crops needs water for optimum development but with the decreasing nature of rainfall in many regions, there is tendency of crop failure, resulting in hunger and food insecurity if prompt action is not taking. 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.

In agricultural crop production, rainfall amount with 75 – 80% probability of occurrence is considered as dependable rainfall. The water requirements of most crops could however, not be met within the dry period, thus emphasizing the need to employ irrigation into our farming practice in a bid to ensure food is provided for the teeming populace.

This findings indicates the importance of agro-meteorological studies in predicting drought, how to scientifically deal with it and to avoid greater damages which would result in less economic crop production. It can be used in predicting the trend, future planning and preparing the region for intensive agricultural production.

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