Journal of Occupational Safety and Environmental Health
A Publication of the Society for Occupational Safety and Environmental Health

RAINFALL VARIABILITY AND AGRICULTURAL DROUGHT AT SAMARU, NORTHERN NIGERIA

[1]Idris, U. D., [1]Muhammed, F. I., [2]Yamusa, A. M and [3]Bashir, M
[1]College of Agricultural, Ahmadu Bello University (ABU) Zaria
[2]Department of Soil Science, Institute for Agricultural Research, ABU Zaria
[3]Department of Agricultural Engineering, Ahmadu Bello University, Zaria
Corresponding author's e- mail: udidris11@gmail.com; +234 802 525 9761

Abstract
Rain-fed agriculture is the most weather dependent of all human activities in Nigeria. This paper outlines implications of the reduced and erratic rainfall pattern to agricultural productivity and, suggests science-based mitigation and adaptation strategies based on rainfall prediction. There are various methods for predicting the occurrence of dry spells, all based on the statistical processing of rainfall event in the past. The more simple methods identifies the occurrence of dry spells of a certain length (5 days, 10 days) over a certain period (one or two months or more) at the start of the rainy season and statistically assess the chance that such dry spell would materialize. Forty-nine years of daily rainfall data were collected from IAR Meteorological data pool and thirty-five years data were processed using two programmes VISUAL-BASIC.NET and INSTAT**+.** The probabilities of rainfall occurrences at different levels were determined which are represented as P_0, P_1, and P_2 at zero, first and second orders of Markov chain. The rainfall data were analyzed for weekly, monthly, yearly rainfall averages and rainy days. The concept of "onset of effective monsoon and dry spells" was adopted in the present study. This information regarding the period of occurrence of dry spells in a particular location is valuable in selecting crops and their varieties to obtain the required level of drought tolerance. Prior knowledge of dry spells also helps in planning for the protective irrigations at appropriate times. From this information based on the knowledge of mean date of wet and dry spells at any location, the intercultural operations like hoeing, weeding, spraying, fertilizer application etc. can be well planned in advance.

Keywords: drought, rainfall, variability, prediction, mitigation

Introduction
Success or failure of crops particularly under rain-fed conditions is closely linked with rainfall uncertainties. The important characteristics of rainfall influencing production from rain-fed farming are the probabilities of rainfall and its amount at certain period of the growing season, the date of onset of effective rainfall, the duration of wet spells, the dates of occurrence and durations of intervening dry spells and the distribution of weekly minimum rainfall amount. Agriculture in Nigeria in general is predominantly rain-fed. Consequently farmers suffer tremendous crop failure whenever there are significant changes in rainfall pattern. It was observed that in most parts of the country, rainfall is unreliable and frequently less than that required for good crop production especially in the savanna zone which accounts for 76% of maize produced. In the Northern guinea savanna, instability or late establishment of the rains, on-season and terminal drought conditions frequently occur. As the facilities for increasing irrigation are limited, rain-fed agriculture is the only alternative for majority of the farmers. The importance of this research cannot be over-emphasized as water increasingly becomes a precious resource on which the well-being of people depends. Issues of water quality, quantity, management and planning are essential to the future of

the world population. Rain-fed agriculture, which forms the main economic base of the population of Sub-Saharan region of Nigeria is always at risk from the unreliable nature of the region's rainfall. It is likely to remain so for the foreseeable future, since more than 95% of the Agricultural farm-land is under rain-fed agriculture, Igbadun *et al*., (2005). Knowledge of the information about dates of on-set of rainfall, distribution and occurrence of rainfall during the growing season is therefore of fundamental importance in planning Agricultural operations. It is therefore necessary to give adequate attention to rain fed agriculture as a key element for food security in the study area (Idris, 2011). The objective of this research is to determine the variability of rainfall occurrence using probability distributions.

Materials and Methods

Study area: The research was carried out at Samaru which is located at 11^o11'N, 7^o38'E on an altitude of about 686m above sea level. The area is situated in the Northern Guinea Savannah ecological zone of Nigeria. It has three distinct seasons; namely the hot dry season from March to May, the warm rainy season from June to September, and a cool dry season from November to February. The area has an average relative humidity of 36.0% during the dry season and 78.5% for the wet season. The average minimum and maximum temperatures recorded in the area are 15.6^oC and 38.5^oC respectively (NCAT, 2008). Kowal and Knabe (1972) observed that precipitation of 1118mm per year occurs in Samaru with a peak in August. Climatic data were obtained from Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU), Zaria data pool. Fourty-nine years (1959-2007) of daily data were available for Samaru. Data available include rainfall, Evaporation, temperature (minimum and maximum), relative humidity, vapour pressure, sunshine hours, wind speed and radiation. Daily rainfall data for Samaru were obtained from the Institute of Agricultural Research (IAR) data pool. This station was chosen because of the availability of good and continuous rainfall records for a period of at least fourty nine (49) years between the years (1959-2007). Then (35) years data were selected at random for this work. The remaining 14 years were used for testing the models. The daily rainfall amounts were summarized into monthly averages to examine the trend of rainfall for the years in Samaru. The general trend of rainfall amount in August was observed.

***Data analysis: Initial and conditional estimation of rainfall probabilities*:** The concept of estimating probabilities with respect to a given amount of rainfall is extremely useful for planning agricultural operations. In a given cropping season, often decisions have to be taken based on the probability of receiving a certain amount of rainfall during a given day of the year $P_0(W_t)$ termed initial probabilities. It is also possible to examine the probability of rain the next day if there is rain today P_1 (W_t/W_{t-1}); and the probabilities of rain today if the previous two days were wet P_2 $(W/W_{t-1}, Wt_{-2})$. Thus the probability of occurrence of rain in a particular day depends on whether the day before was wet or dry. These probabilities are referred to as "conditional probabilities." In this study, daily rainfall data were processed using the VISUAL-BASIC (developed for the purpose) and INSTAT programme. Data analysis and the Markov chain probabilities based on daily basis were adopted (Bekele, 2000). The Markov chain is defined as a stochastic process, in which the knowledge about the state of the process at a given time, t_2, can be deduced from the knowledge of its state at an earlier time t_1 and is independent of the history of the system before t_1 (Gabriel and Neumann, 1962). Estimation of the initial and conditional probabilities of rainfall was done in two ways: The first was by using a written programme in VISUAL-BASIC with a module for precipitation occurrence, usually formulated as a Markov process. A simple point estimate for the probability of occurrence of a particular sequence of wet and dry days was given by Feyerherm *et al*. (1965) as the ratio of the number of years in which the sequence occurred to the number of years of record.

$$P_0(D_t) = \frac{no.of\ \ years\ \ that\ the\ (t)th\ day\ was\ dry}{no.of\ \ years\ of\ \ record} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

Where,

$P_0(D_t)$ indicates the initial probability for the sequence of dry days. Other conditional probabilities could be estimated by similar ratios.

The second was estimated by the INSTAT+ 3.36 statistical package, is a simple general statistics package that also includes a range of special facilities to simplify the processing of climatic data. The expected amount of rainfall at specified probability levels were computed by fitting rainfall data with a complete Gamma distribution. This is a special case of Pearson type III distribution and has been found to fit rainfall data closely (Owonubi, 1992). The density function is given as:

$$g(x) = \frac{1x^{r-1}e^{-x/\beta}}{\beta^r\Gamma(r)} \quad \beta > 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

Where,

x is a random variable (in this case rainfall amount). β is the scale parameter, r describes the shape of the distribution and Γ (r) the ordinary gamma function.

Results and Discussion

Table 1presents the mean monthly rainfall records for every five years over the 49 years. It can be clearly seen that the highest rainfall received was in August and July. Also it could be seen from the table that only in the first five year average (1959-1963) that the rainfall amount in June is more than that of July. The September also exceeded the August rainfall amount. In the years (1974-1978) the average rainfall amount in September is 210.44mm and this is greater than that of July with 202.64mm. Apart from these variations, all the other five years August averages seen to be the highest measured rainfall amount in Samaru. This is an indication that all water harvesting structures should be well fixed before the end of June for collecting large amount of runoff. It is also a good time for erosion control.

Table 1: Mean monthly rainfalls (mm) for every five years

Years/Months	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1959-1963	0.00	32.05	57.86	160.29	146.63	203.33	230.16	53.68
1964-1968	4.83	47.55	89.25	177.19	221.38	273.20	206.83	35.63
1969-1973	0.15	25.21	102.95	128.05	218.80	274.20	171.12	36.44
1974-1978	0.80	67.00	100.44	155.42	202.64	226.78	210.44	48.50
1979-1983	10.40	40.35	76.18	145.10	218.94	256.28	136.67	34.30
1984-1988	5.20	15.67	93.12	120.60	235.48	279.38	168.50	93.13
1989-1993	44.70	25.85	122.14	121.68	227.48	260.30	151.48	39.65
1994-1998	0.00	78.60	91.92	156.88	176.14	263.39	164.78	58.88
1999-2003	0.00	58.53	79.30	162.80	240.26	272.24	233.06	79.78
2004-2007	13.60	22.23	146.05	156.85	240.95	286.45	140.70	22.72

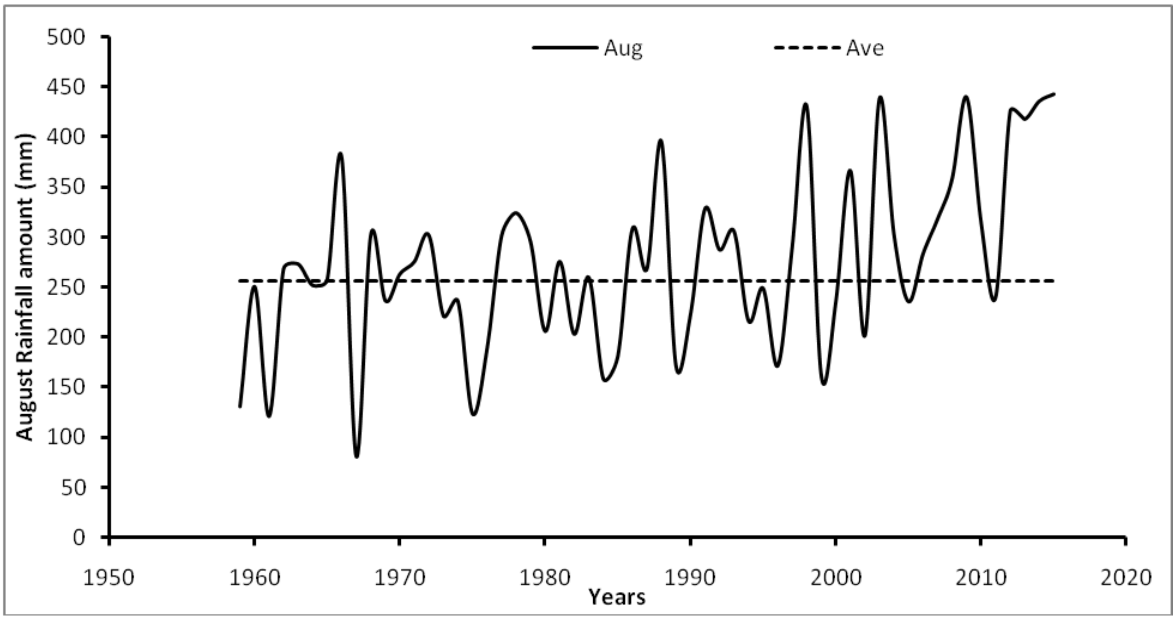

Figure 1: Fluctuation of August rainfall (mm)

***Variability of rainfall*:** The highest amount of rainfall occurs in August, but it is not always constant it varies after certain number of years as seen from Figure1. In 1959 the total August rainfall in Samaru was 130mm. After 7 years the trend changed to 379mm in 1965 and subsequently fells to 81mm in 1967. A series of systematic trend is observed from the year 1978, 1988, and 1998 with constant rise and fall in the rainfall received during the August period with 10 years interval. Finally from the last three years, there is an indication that rainfall to be expected from this chart indicates perhaps a tendency towards a higher monthly total in the later years during the period of 2005 to 2015 in August. This is as a result of having the following rainfall amount of 235mm, 283mm and 318mm during the years 2005, 2006 and 2007 respectively. So proper planning should be made to protect reservoirs around Samaru for anticipated flood incidence, protection of soil surface to prevent erosion and construct water harvesting structures to mitigate the effects against shortages. Increasing trend in rainfall totals in the month of August in Zaria may pose significant danger to areas that are prone to flooding as reservoirs could easily overflow leading to loss of life and property.

***Dry Spell lengths for crop periods* (*Agricultural Drought*):** Figure 2 shows that the probabilities of having long dry spells of 8 and 10 days from day 92 (1st April) is very high. The chance of a dry spell of more than 10 and 8 days within the 30 days has dropped to about 0.3 and 0.4 by the beginning of May and is below 0.2 by 9th May for 10 days and below 0.4 for 8 days respectively. By 1st week of June (day 159) the chances of dry spell dropped to less than 0.1 and 0.2 for 10 and 8 days respectively. This type of results can help to determine planting strategy. Sometimes dry spells are needed for drying purposes and this type of plots also allows the timing for such events to be planned. If a 120-day crop is being considered, the results indicate that the difficult time is the first 30 days after planting.

From Figure 3, there are dry spells of 8 days or more in 45 (92%) of the 49 years. In the subsequent 30 days (May) there are dry spells of 8 days or more in 30 (61%) of the 49 year. While the last 60 days of the season (June and July) has only dry spell of 8 days or more in 9 (18%) and 5 (10%) of the 49 years respectively. The first column correspond to sowing in early April, and show most of the years would have had a dry spell of more than 10 days within the following 30 days.

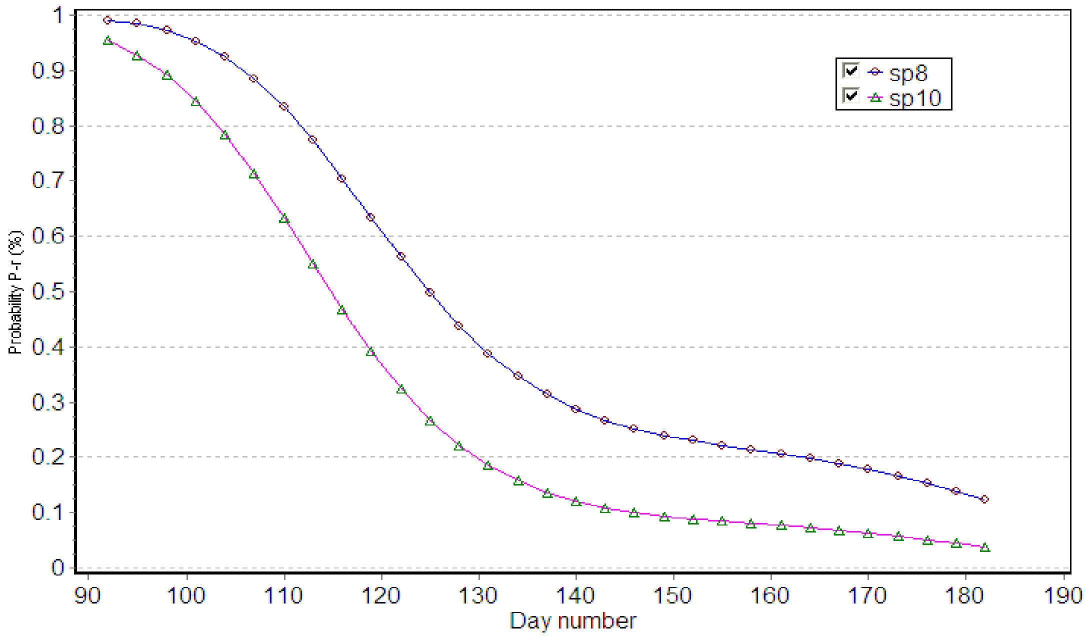

Figure 2: The risk of long dry spells after planting

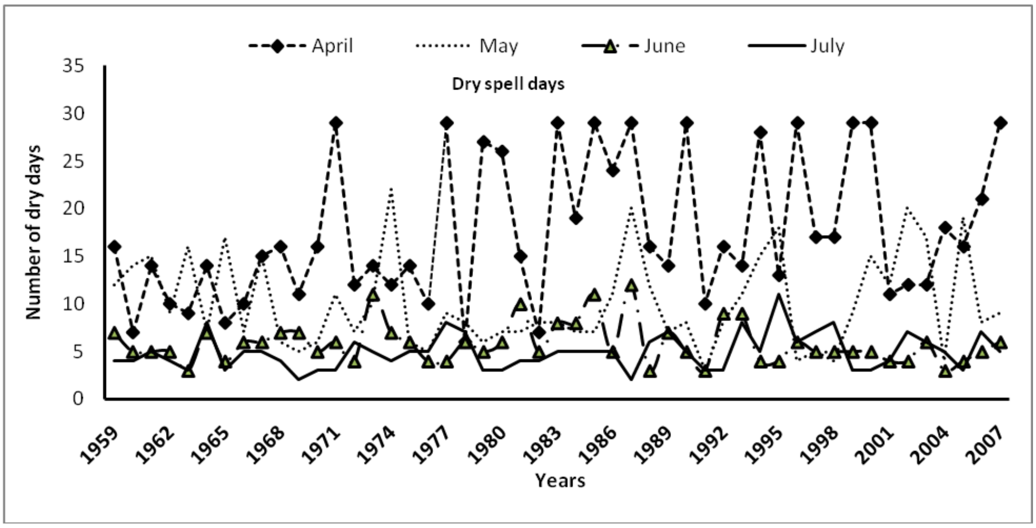

Figure 3: Number of dry spell days from April to July

In contrast, by the final two columns the longest spell in any year is 7days except 18% and 10% of the years in June and July respectively. Assume that the sowing failed if there was a 10-day dry spell; in this case the farmers has to wait till June for successful sowing to avoid the risk of planting more than one time, because is estimated as 41% and 8% in May and June respectively. This agrees with the work of Kowal and Knabe (1972) and (Edoga, 2007) for suggesting the planting date to be June in the study area. But this work is suggesting the planting date should be from third week of June to avoid the long dry spell in these range of years from 2010 to 2015 rainy season. This information regarding the period of occurrence of dry spells in a particular location is valuable in selecting crops and their varieties to obtain the required level of drought tolerance. Prior knowledge of dry spells also helps in planning for the protective irrigations at appropriate times. From this information based on the knowledge of mean date of wet and dry spells at any location, the intercultural operations like hoeing, weeding, spraying, fertilizer application etc. can be well planned in advance.

Conclusion and recommendation

The information on weather's wet and dry behavior has vital importance to all allied fields like hydrology, agriculture, industry etc. It can then be used in agricultural planning, draught, soil erosion and flood estimations, impact of climate change studies, crop growth studies and other important fields in Agriculture. It is concluded that the effect of planting earlier than second week of June as a results of long dry spells of more than 8 days after planting would cause significant damage to shallow rooted crops and planting more than once. Also increasing trend in rainfall totals in the month of August as expected in the later years during the period of 2009 to 2015 may pose significant danger to areas that are prone to flooding as reservoir could easily overflow leading to loss of life and properties. Therefore this work should be extended to other drought prone areas and to all over the country at large.

References

Bekele, E (2001). Markov chain modeling and ENSO influences on the rainfall seasons of Ethiopia, National Meteorological Agency of Ethiopia, Adis Ababa.

Edoga, R.N. (2007). Determination of Length of Growing Season in Samaru Using Different Potential Evapotranspiration Models. *AU J.T.*, 11(1): 28-35.

Feyereherm, A. M. and Bark, L.D (1965). Statistical Methods for persistent precipitation patterns. *Journal of Applied Meteorology*, 4: 320-328.

Gabriel, K.R and Neumann J (1962). Markov Chain Model for daily rainfall occurrence at Tel-Aviv. *Q J R Meteorol. Soc.*, 88: 90-95.

Idris, U, D. (2011). Performance Evaluation of three probability distribution models for predicting rainfall amount in Samaru, Nigeria, Unpublished M.Sc Thesis Department of Agricultural Engineering Ahmadu Bello University Zaria.

Igbadun, H.E., Mahoo, H.F., Tarimo, A.K.P.R., and Salim, B.A. (2005). Trend of Productivity of water in rain-fed agriculture. Proceedings of the East Africa Integrated River Basin Management Conference Sokoine University of Agriculture Morogoro Tanzania.

Kowal, J.M. and Knabe, D.T (1972). An agroclimatological Atlas of the Northern states of Nigeria with explanatory notes.

Nigeria College of Aviation Technology, Zaria (2008). Meteorological station data. Nigeria College of Aviation Technology, Zaria.

Owonubi, J.J., Odiwo, A.E., Asiribo, D.E. and Abdulmumin, S (1992). Rainfall probability estimates for agricultural production in the Nigerian Savanna. *Samaru Journal of Agricultural Research*, 9: 3-18.