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RAINFALL VARIABILITY AND CROP PRODUCTION IN NORTHERN GHANA: THE CASE OF LAWRA DISTRICT

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***ABSTRACT*:** Though agriculture is the predominant occupation in Northern Ghana, the relationship between rainfall variability and crop production appears not to have been adequately investigated in the area. Crop production is largely characterized by smallholder subsistence farmers who depend solely on highly unpredictable and irregular seasonal rainfall. In recent times, rainfall variability has led to numerous incidences of drought and floods. This phenomenon has the potential to adversely affect crop production and food security in the area. This study analyses inter- and intra-annual variability of rainfall so as to identify the relationship between rainfall variability and crop production in a representative district of Northern Ghana. Available monthly rainfall data for 33 years (1980 - 2012) recorded at Babile station of the district was analyzed for seasonal and annual variability using the coefficient of variation (CV) and the precipitation concentration index (PCI). Total annual quantity of crop production data on main crops (i.e. maize, millet, sorghum, groundnut and cowpea) was used. The available data covered a period of 21 years (1992 - 2012). To verify the influence of rainfall variability on crop production, correlation analysis was conducted. Although the results showed moderate seasonal rainfall distribution, (i.e. PCI>11), the inter-seasonal and inter-annual rainfall variability (CV=0.19 and C=0.18 respectively) were moderate/less erratic. The results point to a negative correlation between annual rainfall and crop production for maize, millet, sorghum, groundnut and cowpea. At seasonal level sorghum, millet and groundnut showed negative correlation while maize and cowpea showed positive correlation. These results also point to a need for further studies to determine the influence of rainfall on arable land use and the periods of occurrence of drought in the study area. The results of this study would enable farmers to improve their crop production strategies.

KEYWORDS: rainfall variability, agriculture, precipitation concentration

1. INTRODUCTION

A typical farmer in Lawra district in northern Ghana usually starts to make preparations for planting his crops with the onset of the rainy season. After months of drought the soil is dry and hard. In the month of May, the farmer starts to look into the sky every day expecting the first rain clouds to appear, which would indicate the beginning of the major/production season. When the rain finally starts, he takes his bullocks to plough his farmland and plant his crops. But his mind is filled with worry. How much rain will there be this year? Will there be another dry spell shortly after the first rain, which could destroy the seedlings, as in the previous year? Would it be better to wait and start the seeding in June? But he recalls that two years ago there was no dry period in May and a heavy rain washed away the seeds that he had planted too late, as it turned out.

These are the uncertainties a common farmer faces every year in Northern Ghana.

Agriculture plays a crucial role in the overall growth and development of Sub-Saharan Africa. In Ghana for instance, the agriculture sector is the largest employer in the country. It contributes 38 percent of GDP, accounts for about 75 percent of the export earnings, and provides over 90 percent of the food needs of the country. However, available data suggest that the Ghanaian agriculture sector growth rate has declined considerably over the years. Agriculture in Ghana is characterized by low use of modern agricultural inputs and low productivity. Crop production is largely dependent on seasonal rainfall. Although the concept of irrigation is not new, its patronage is still surprisingly low.

Previous studies have observed that rainfall is the most important climate parameter which influences the growth characteristics of crops (Bewket 2009; Befekadu and Berhanu 2000). Water serves as a carrier of nutrients and energy exchanger in crop development. Considering these critical role, clearly, inadequacy of water supply hampers efficient crop growth, resulting in low productivity. According to von Braun (1991), for instance, a 10% decrease in seasonal rainfall from the long-term average generally translates into a 4.4% decrease in food production. Rainfall variability and associated droughts have been observed to be major causes of food shortages and famines (Wood, 1977; Pankhurst and Johnson, 1988) in sub-Saharan countries of Africa.

The mono-modal pattern of rainfall in Northern Ghana and the exclusive dependence of farmers on rain-fed agriculture make crop production vulnerable to rainfall variability. Agriculture production is largely undertaken by smallholder subsistence farmers who rely solely on high unpredictable and sporadic seasonal rainfall (Ndamani 2008). The majority of people in the area rely on crop and livestock production for their livelihood. Therefore extreme variations to agro-climatic conditions (e.g. rainfall) in the area could directly affect the survival of the people.

In view of the critical importance of rainfall, a comprehensive knowledge of its patterns, duration and amounts is essential for crop production planning and management. This notwithstanding, associations between crop production and rainfall characteristics in Ghana have not been thoroughly investigated. Although the relationship between low yield and droughts has been documented in various annual reports, statistical analysis of crop yields and rainfall at regional and district levels has not been conducted.

1.1 Objectives

The aim of this study was to analyze inter-annual and seasonal variability of rainfall so as to identify the relationship between rainfall and crop production in the Lawra district of Ghana. Specifically, the study has attempted to (i) determine seasonal and annual variability of rainfall and (ii) examine the association between annual rainfall and crop production.

2. METHODOLOGY

2.1 The Study Area

This study was conducted in the Lawra district of the Upper West region of Ghana (see Figure 1). The oldest district in the region is located in the north-western corner of the country between latitudes 2°25°W and 2°45.

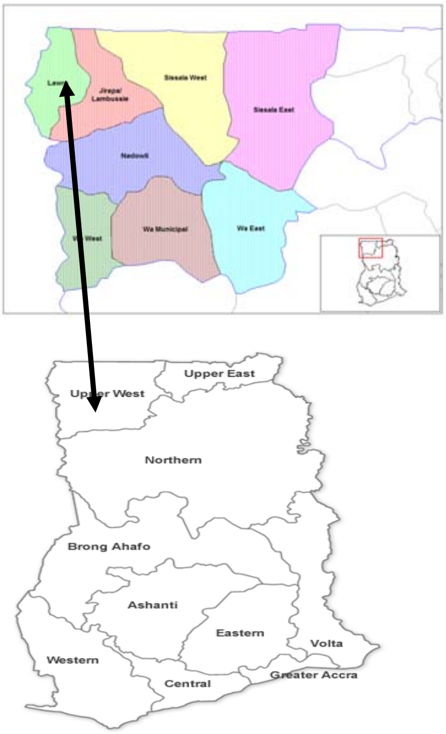

Figure 1: Source: Google images, 2013

The 2012 Population and Housing Census of Ghana reported the total population of the area as 100,929. Over 80% of the population lives in rural areas with subsistence agriculture as their principal source of livelihood (GSS 2012). Although there is small ruminants and poultry rearing, crop production is the major source of household income and food. Staple crops in the area are *Zea mays*, *Sorghum bicolor*, *Echinochloa frumentacea*, *Oryza sativa*, *Vigna unguiculata*, *Arachis hypogaea*, *Glycine max and Dioscorea rotundata*. Vegetables are cultivated on smaller scales. Groundnut and cowpea are mostly considered women's crops in the rural communities.Animals including donkeys, cattle, sheep, goats, pigs and fowls are reared (Ndamani, 2008).

The natural vegetation of the district is characterized by shrubs, stunted trees and grasses. The soil is relatively fertile, with nutrients concentrated in the top 5 cm. Hence, the soils are very fragile and can be easily rendered infertile. The mono-modal rainfall pattern of the district last from May to September. The average annual rainfall ranges from 900 to 1,200 mm. Extensive bush burning occurs during the rather protracted 7-month-long drought period of October to April leading to severe erosion the soil surface.

The main challenges to agriculture in the district are soil degradation and persistent droughts and floods. Increasing population, intense livestock grazing, bush burning and deforestation are main causes of land and soil degradation in the area. Lawra district is said to be the poorest in the Upper West region and the frequent agricultural droughts and floods are often associated with the high levels of poverty and famine in the area.

2.2 Data sources and analytical methods

The data used for this study was obtained from secondary sources. Monthly rainfall figures for the period 1980-2012, were provided by the Ghana Meteorological Agency. The agricultural data for the period 1992 – 2012 (i.e. annual crop yield), was acquired from the Regional Agricultural Development Unit (RADU).

Per standard procedure, the mean and standard deviation of monthly, seasonal and annual rainfall were calculated. The Precipitation Concentration Index (PCI) and the Coefficient of Variation (CV) were employed as statistical measures of rainfall variability.

Oliver (1980), proposed the Precipitation Concentration Index as an indicator of rainfall concentration and rainfall erosivity. Michiels *et al* (1992), evaluated the PCI and calculated its values on annual and seasonal scale through the following formulae;

$$PCI_{seasonal} = 100*[\Sigma Pi^2/(\Sigma Pi)^2]$$

$$PCI_{supra\ seasonal} = 50*[\Sigma Pi^2/(\Sigma Pi)^2]$$

Where P_i = rainfall amount of the i^{th} month and Σ = summation over the number of months being assessed.

The interpretation of PCI values is given by Table 1 below.

Table 1: Interpretation of the precipitation concentration index (PCI) values

PCI Value	Interpretation
> 10	Uniform precipitation distribution
11to 16	Moderate precipitation distribution
16 to 20	Irregular distribution
>20	Strong irregularity of precipitation distribution

Correlation analysis was conducted taking rainfall (X) as an independent variable and yield (Y) as a dependent variable to estimate rainfall-crop production relationship for maize, millet, sorghum, groundnut and cowpea. In investigating the effects of rainfall variability, it is more important to consider crop production than yield. According to Bewket (2009), a focus on yield tends to gloss over impact of extreme climatic conditions involving severe droughts that could lead to the abandonment of planted areas prior to harvest. In other words, total production aggregates the impact of climate on production, yield and harvested areas and thus has greater economic importance than yield.

3. RESULTS AND DISCUSSION

3.1. Annual and Seasonal Rainfall Patterns

The rainfall pattern in Lawra district is mono-modal ranging from May to October. There was a total rainfall volume of 33,799 mm recorded on 2,420 rain days within the 33 year period. As shown in Table 2, the total annual rainfall varied from 463mm to 1643 mm. Seasonal rainfall accounts for approximately 90% of total annual rainfall. Figure 2 and 3 show the trend of annual and seasonal rainfall respectively. Considering annual rainfall totals alone, there was an observable 20 years cycle of high and low rainfall volumes. Annual rainfall totals exceeded 1200 mm in 1980 and 2000 and fell below 1000 mm in 1990 and 2010 as shown in Figure 2.

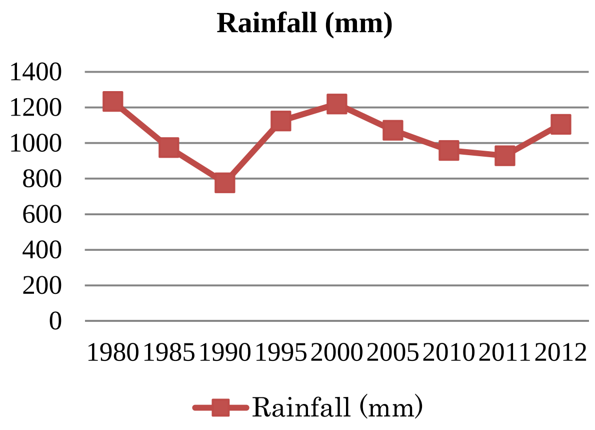

Figure 2: Annual rainfall trend

Seasonal rainfall varied from 436 mm to 1583 mm per year with a mean of 914 mm. A separate view of the average monthly rainfall totals over the 33 year period shown in Figure 3 reveals that rainfall was generally highest in the month of August. Most of the seasonal rainfall occurs within a short period, generally, July to September. This poses dangers of water logging of fields and floods. The rainfall distribution in the months of May, June and October is very erratic due to the generally low number of rain-days and rainfall volume (Figure 4). This erratic rainfall pattern invariably resulted in dry spells. Figure 3 below shows the average monthly rainfall over the 33 year period.

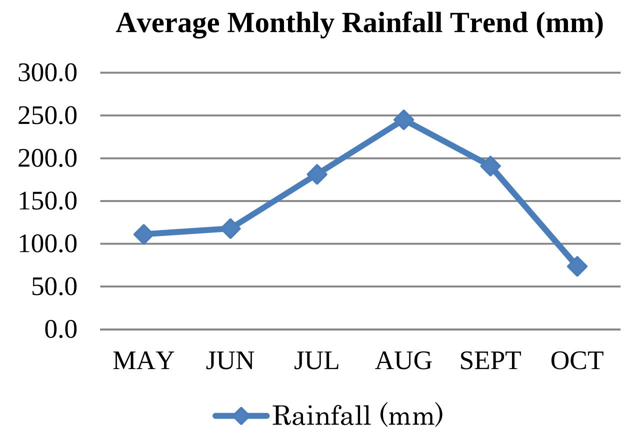

Figure 3: Seasonal rainfall trend (1980 - 2012)

3.1.1. Observation/Implication

There are various factors that could influence cropping strategies under conditions of rainfall uncertainty, For example, Ravindran (2013), postulated that when physically based seasonal forecasts are not available, crop management strategies and planning should be based on statistical assessment of historical rainfall records. Figure 5 below shows that the production season starts with land preparation and planting activities in the months of May and June. However, as shown in Figure 4, the pattern of rainfall in the months of May and June has been very erratic from year to year. Thus, the findings of this study provide the basis for farmers to adjust their land preparation and planting dates to coincide with periods/months of reliable and uniformly distributed rainfall.

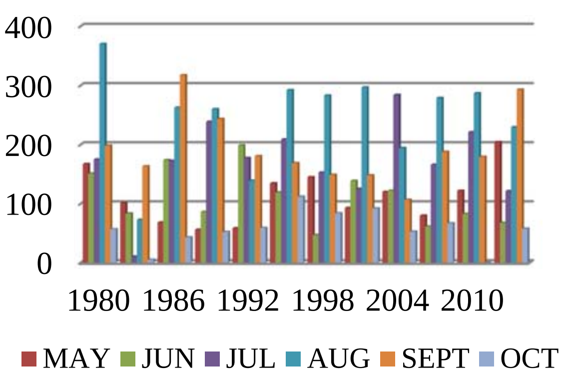

Figure 4: Monthly Rainfall Trend in Lawra District.

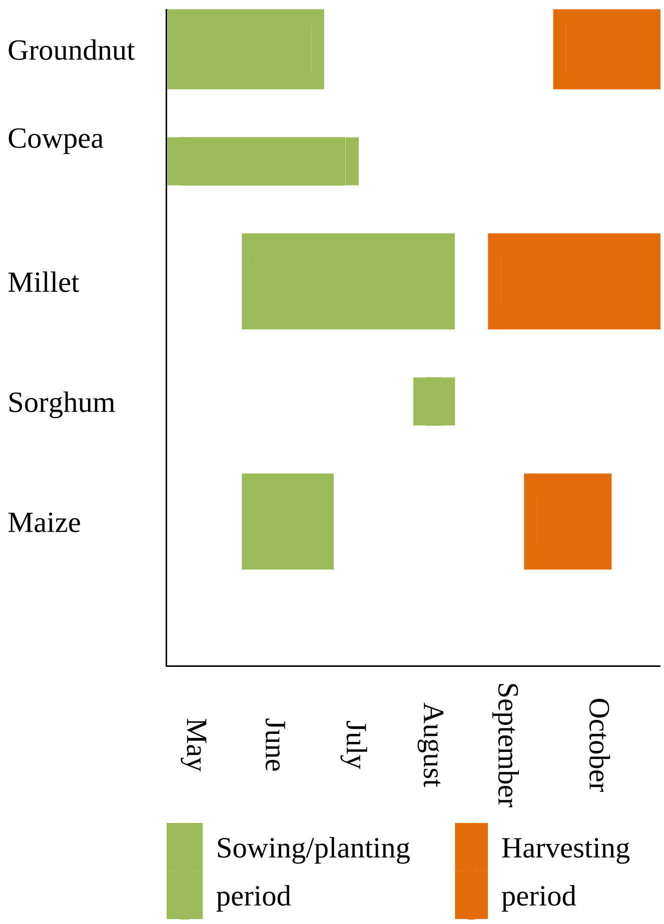

Figure 5: Crop Calendar; NorthernGhana (FAO)

3.2 Seasonal and annual rainfall variability and trends

As shown in Table 2 below, the calculated coefficient of variation for annual rainfall is 0.18, indicating that variability of rainfall across the years was generally moderate. However, the computed PCI values show that year-on-year rainfall concentration/distribution across months was irregular (PCI=19%). It can be observed that monthly rainfall distribution in years of low annual rainfall is generally erratic. The computed coefficient of variation of seasonal rainfall was 0.19, indicating a slightly higher variation in rainfall distribution than in annual rainfall. The PCI value of 11 calculated for seasonal rainfall represents moderate monthly precipitation distribution. The distribution of seasonal rainfall is most important factor for consideration since crop production in Lawra district consistently occurs only in the rainy period.

Table 2: Summary of Annual and Seasonal rainfall (mm), Coefficient of Variation (CV) and Precipitation Concentration Index (PCI); (1980 – 2012)

Time/ Indicator	Annual	Seasonal
Mean	1080	914
Standard Deviation	187	175
Min.	463	436
Max.	1644	1583
CV	0.18	0.19
PCI (%)	19	11

3.2 .1 Observation/Implication

The number of rain days and rainfall volumes tend to decrease in the months of June and October leading to dry spells. The months of July and August tend to have higher volumes of rainfall which often cause flooding (Figure 5). The findings here should provide the basis on which agricultural policy makers can plan for irrigation facilities to respond to the incidence of recurring droughts (Rugumayo et al, 2003). The findings also point to the need for farmers to be encouraged to adopt water harvesting technologies in order to deal with periods of dry spells during the production season, which normally occurs during the months of June and October. The number of rain days tends to decrease within these months resulting in wilting and drying of crop plants.

3.3 Relationship between rainfall and crop production

The coefficients of correlation of seasonal and annual rainfall for production volumes of each main crop are given in Table 3. Maize, sorghum, millet, cowpea and groundnut showed negative correlations with annual rainfall. However, with seasonal rainfall, sorghum, millet and groundnut show negative correlations. Only maize and cowpea showed positive correlations with seasonal rainfall. The seasonal rainfall covers the period from field/land preparation in May/June to the crop maturity/harvesting in October/December.

Correlations for sorghum and groundnut were found to be statistically significant while that for maize, millet and cowpea were not significant. These indicate the importance of other factors such as agricultural inputs (e.g. labor, fertilizer, insecticides) in determining production/yield. The coefficients were mostly not significant at 0.01 and 0.05 level.

Table 3: Correlation between Crop Production and Annual and Seasonal Rainfall

Crop/Season	Annual	Seasonal
Maize	-0.056	0.097
Sorghum	-0.046	-0.149*
Millet	-0.304	-0.130
Cowpea	-0.100	0.021
Groundnut	-0.138	-0.156*

***Significant at 0.1 level

Table 4 shows the main crops cultivated in Lawra districts during the years 1992 to 2012. Maize, sorghum and millet are mainly staple crops while groundnut and cowpea are cash crops. Sorghum is the most widely and intensively cultivated. Maize and cowpea are mostly cropped on a smaller scale.

The high coefficients of variation of cropped area (see Table 4.) appear to be closely related to total annual rainfall volumes. For instance, in 1992, cropped area of maize, groundnut and cowpea reached a lowest level at 856 ha, 187 ha and 63 ha respectively. The total annual rainfall volume of 970 mm observed that year was the lowest recorded within the 33 year period studied. Similarly, the production volumes of crops during that year were low. Also, it was observed that the high volumes of crop production and cropped area data recorded in 1995, 2000 and 2005 were positively related to those of annual rainfall volumes recorded in those years.

Table 4: Cropped Area (ha), Crop Production (Mt) and Yield (Mt/ha) of Main Crops; (1992 – 2012)

Indicator	Maize	Sorghum	Millet	Groundnut	Cowpea
Area					
Mean	2,933	21,658	8,766	5,942	2,922
Min.	856	4,645	2,495	187	0
Max.	5,380	54,300	12,800	15,790	61,359
CV (%)	36	88	32	96	74
Production					
Mean	2,421	21,065	7,281	8,337	2,034
Min.	282	4,180	1,747	155	0
Max.	6,411	59,730	17,920	24,288	6,797
CV (%)	58	87	53	97	94

3.3.1 Observations/Implications

Previous studies have noted that effectively measuring the extent to which rainfall variability affects crop production requires further analysis. Uncertainties are set to arise if farmers decide to change crop production strategies in response to rainfall variability by adopting techniques such as using new crop varieties, use new agronomic practices, changing their planting dates, and adapting their plots and cultivation methods to new crops (Bezabih et al, 2011). Though this study found most of the coefficients of correlation not to be significant, it should be borne in mind that any form of correlation between crop production and rainfall is indicative of the fact that farmers are vulnerable to famine (Bewket 2009). Farmers therefore have to adopt the best possible strategies to mitigate the effects of rainfall uncertainty/variability

4. CONCLUSION

This study determined statistical distributions of annual and seasonal rainfall and associations between rainfall variability and crop production in the Lawra district of Ghana during the period of 1980 to 2012. Data used include rainfall, cropped area and crop production figures obtained from the Lawra district. Moderate inter-annual and seasonal rainfall variability were observed across years and months. Inter-annual rainfall distribution was irregular while the seasonal rainfall was moderately distributed. Annual rainfall totals exceeded 1200 mm and fell below 1000 mm within every ten year period. The mean seasonal and annual rainfall was 914 mm and 1018 mm respectively. Seasonal rainfall variability has a direct influence on production volume of the main crops cultivated in the area. There was a negative correlation between crop production and seasonal rainfall for sorghum, millet and groundnut. The correlation for maize and cowpea was observed to be positive. The inter-annual variability of production volume of the crops investigated was high, largely as a result of the irregular/erratic inter-annual rainfall distribution. Sorghum and millet exhibited the highest variability because their cultivation period is of longer duration (June to December). Within this period, rainfall variability is high.

To provide a complete understanding of the influence of rainfall uncertainty on crop production, additional studies need to investigate the relationship between rainfall variability and arable land use and the periods of occurrence of droughts and floods. The authors are currently investigating the effects of rainfall on cropping area and periods of droughts in Northern Ghana.

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