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Full length Research paper

Influences of rainfall on crop production and suggestions for adaptation

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In recent years, rainfall anomalies have led to numerous incidences of droughts in the Lawra district of the Upper West Region of Ghana. These anomalies have the potential to cause undesirable effects on crop production and food security. This study analyzed annual and seasonal rainfall variability and their relationships with crop production. The adaptation techniques required to mitigate the effects of rainfall anomalies were also suggested. Monthly rainfall data for 33 years available at the Babile weather station was used. Seasonal and annual rainfall variability and concentration were analyzed using the coefficient of variation and the precipitation concentration index respectively. Available data on annual production volumes of major crops produced between 1992 and 2012 was used. Correlation analysis was used to assess the influence of rainfall on crop production. The results revealed moderate seasonal and irregular annual rainfall concentration. Generally, rainfall in the district starts in May. However, the number of rain days and volume (mm) tend to decrease in June before peaking up in July and August. Correlation between annual rainfall and crop production were negative for all the crops studied. At seasonal level only sorghum, millet and groundnut were negatively correlated with rainfall. Based on the results obtained, this study concluded that identifying and implementing appropriate adaptation techniques through effective stakeholder collaboration was essential in boosting the production of sorghum, millet and groundnut.

Key Words: Precipitation, concentration, rainfall variability, crop production, farmers, adaptation techniques, stakeholders.

INTRODUCTION

Rainfall uncertainty remains a critical challenge confronting smallholder farmers in Sub-Sahara Africa. In the Upper West Region of Ghana, where crop production is solely dependent on highly unpredictable and sporadic seasonal rainfall (Ndamani 2008), the volume, timeliness, distribution and duration of rainfall in each season are major concerns to farmers. The practice of irrigation is still minimal due to inadequate or absence of irrigation facilities in many locations in the area. This notwithstanding, the agricultural sector remains the single largest employer in the region.Majority of people in the area depend on crop and livestock production for their food needs and household incomes. Agriculture production in the region is characterized by low use of modern agricultural inputs and low productivity.

In earlier studies, Bewket (2009),has noted that in Sub-Sahara Africa, rainfall is the most important climatic factor influencing the growth characteristics of crops. This finding is collaborated by earlier works (Befekadu and Berhanu, 2000; Stern et al.,1981). Rainfall provides the water that serves as a medium through which nutrients are transported for crop development. In view of this significant role, clearly, inadequate water supply has adverse effects on efficient crop growth, resulting in low productivity. von Braun (1991), has observed that a 10% decrease in seasonal rainfall from the long-term average generally translates into a 4.4% decrease in food production. Also, Wood (1977), and Pankhurst and Johnson (1988), have observed that food shortages and famines in sub-Saharan Africa are mostly a result of rainfall uncertainties and associated drought.

Considering that the farmers in the Upper West Region rely solely on rain-fed agriculture, crop production is vulnerable to rainfall variability. Extreme variations to

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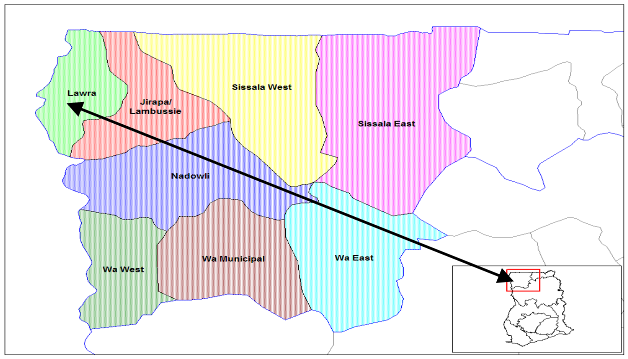

Figure 1: Source: Google images, 2014

Table 1: Cropped area (Ha) and crop production (Mt) 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
Yield					
Mean	0.83	0.97	0.83	1.40	0.70
Min.	0.33	0.90	0.70	0.83	0
Max.	1.19	1.10	1.40	1.54	0.11
CV (%)	161	99	164	101	126

agro-climatic conditions, such as droughts and floods could directly affect the livelihood of the people in the region. This notwithstanding, the relationship between rainfall variability and crop production appears not to have been adequately investigated in the region. Although data on crop yield, production and rainfall are collected and documented on regular basis, statistical analysis has not been conducted to ascertain the influences of rainfall on crop production. Also, till now, it appears conscious efforts have not been made to identify and document adaptation techniques required to address the effects of rainfall uncertainties; droughts and floods. In view of the critical importance of rainfall, a comprehensive understanding of its trends, patterns, duration and volumes is crucial for efficient crop production planning and management.

The study analyses annual and seasonal rainfall variability and identifies the relationship between rainfall and crop production in the Lawra district of Ghana. It also suggests adaptation techniques/measures to mitigate the effects of rainfall uncertainties.

MATERIALS AND METHODS

Description of the study area

Figure 1 shows the location of Lawra district of the Upper

Table 3.Statistics of annual and seasonal rainfall (mm), coefficient of variation (CV) and precipitation concentration index (PCI); (1980 – 2012).

Time/Indicator	Annual	Seasonal
Mean	1,080	914
Standard Deviation	187	175
Min.	463	436
Max.	1,644	1,583
Coefficient of Variation	0.18	0.19
PCI (%)	19	11

Table 4.Statistics of seasonal rainfall; 1980-2012.

Indicator/Month	May	June	July	August	September	October
Rainfall volume (mm)						
Mean	111.10	117.95	181.25	245.10	190.97	73.79
Minimum	34.80	0.00	10.20	72.70	78.20	0.00
Maximum	204.20	257.50	380.50	369.90	396.00	763.80
CV	0.40	0.49	0.37	0.27	0.33	1.76
Rainfall (no. of days)						
Mean	8.36	9.63	12.52	15.12	14.36	5.36
Minimum	3	5	7	10	9	0
Maximum	18	14	18	23	22	17
CV	0.35	0.26	0.21	0.19	0.21	0.68

West region of Ghana where the study was conducted. The district lies between longitude 10°30 N and latitudes2°35 W. According to the Ghana Statistical Service (2012), over 80% of the population resides in rural areas with rain-fed agriculture as their main source of livelihood. Although crop production is the principal source of income and food, cattle, sheep, goats, pigs and fowls are also reared (Ndamani, 2008).The main crops cultivated are maize, groundnut, cowpea, millet, sorghum, soybean and vegetables.

Statistics of the main crops cultivated in Lawra districts during the years 1992 to 2012 are shown in Table 1. While maize, sorghum and millet are mainly staple crops, groundnut and cowpea are produced as cash crops. Sorghum is the most widely and intensively cultivated crop. Cowpea and maize are cropped on smaller scales.

The relatively fertile soils of Lawra district are concentrated in the top 5 cm and hence, can easily be rendered infertile or washed away. The vegetation is made up of grasses, shrubs and stunted trees. The mean annual rainfall ranges from 900 to 1,200 mm. The rainfall pattern is mono-modal and last from May to October. Land preparation takes place between May and June while harvesting takes place between October and December.

The key challenges to agriculture in the district are soil degradation and persistent droughts and floods. The main causes of land/soil degradation in the area include intense livestock grazing, deforestation and extensive bush burning which usually occur within the period of November to April. The recurrent agricultural droughts and floods are said to be the reason why Lawra district has higher levels of poverty and famine.

Data and analytical methods

Monthly rainfall data for the period from 1980 to 2012 is provided by the Ghana Meteorological Agency. Available agricultural data on annual cropped area, production and yield is obtained from the Regional Agricultural Developm-

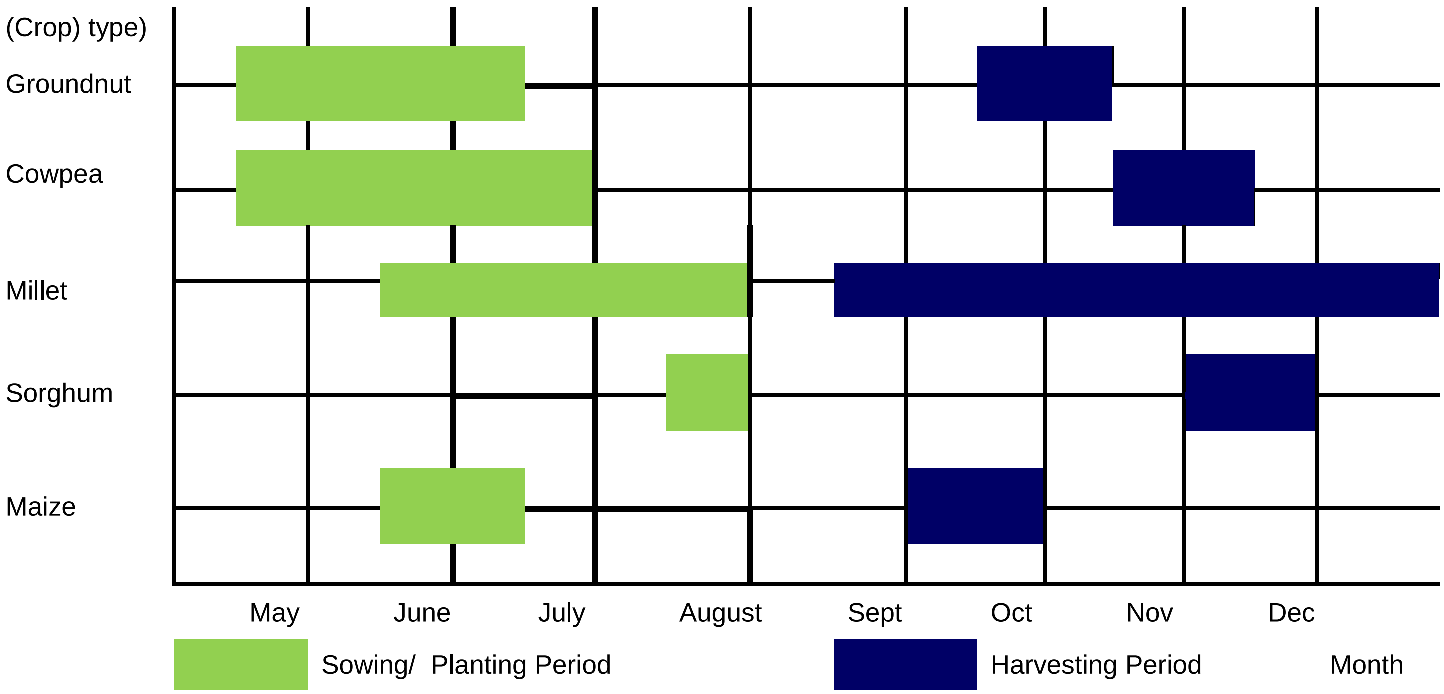

Figure 2.Crop calendar; Guinea Savannah/Northern Ghana (FAO).

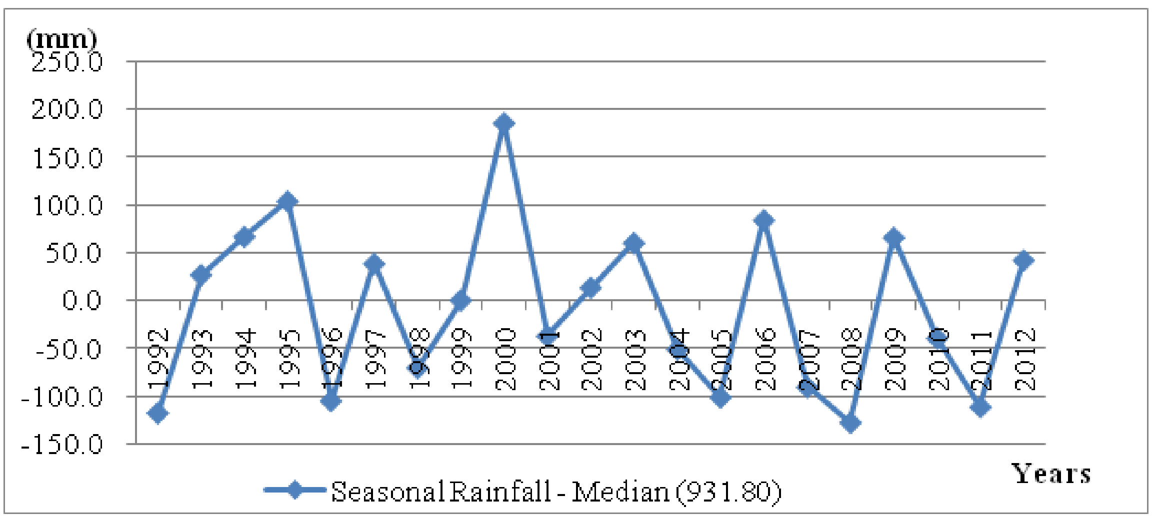

Figure 3.Seasonal rainfall compared with the median (1992 - 2012).

ent Unit (RADU).

The Coefficient of Variation and the Precipitation Concentration Index are used as statistical measures of rainfall variability and rainfall distribution respectively. The mean and standard deviation of monthly, seasonal and annual rainfall are calculated.

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

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

$PCI_{supraseasonal} = 50*[\sum Pi^2/(\sum Pi)^2]$

Pi = rainfall amount of the i^{t}month and ∑ = summation over the number of months being assessed. While PCI_{annual} denote twelve months, $PCI_{supra\ seasonal}$ denotes six months of rainfall. In this study, supra seasonal is defined as seasonal (May-October). Table 2 shows the interpretation of PCI values.

Correlation analysis is employed to assess the association between rainfall and crop production for maize, millet, sorghum, groundnut and cowpea. Rainfall (X) is used as an independent variable and crop production (Y) as a dependent variable. According to

Table 5. Correlation between crop production and annual and seasonal rainfall; 1992-2012.

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

Bewket (2009), in investigating the influences of rainfall variability, it is more significant to consider crop production than yield. That is because a focus on yield tends to gloss over impact of extreme climatic conditions involving severe droughts that could result in abandonment of planted areas prior to harvest. That is to say, total crop production combines the impact of climate on harvested area, yield and production and hence has greater economic significance than yield.

RESULTS AND DISCUSSION

Seasonal and annual rainfall patterns

The results reveal a total rainfall volume of 33,799mm recorded on 2,420 rain days within the 33 years studied. Annual rainfall ranges from 463mm to 1,643mm. Seasonal rainfall accounts for approximately 90% of total annual rainfall (see Table 3). Total annual rainfall volumes exceed 1,200mm in 1980 and 2000 and fall below 1,000mm in 1990 and 2010.

The seasonal rainfall ranges from 436mm to 1,583mm per year. A separate view of the average monthly rainfall totals over the 33 year period reveals that rainfall is generally highest in the month of August (see Table 4). Most of the seasonal rainfall occurs between July and September. This situation has the potential of causing water logging of fields. The rainfall distribution in the month of June is very erratic and could pose dangers of dry spells. Using seasonal precipitation median of 931.80mm, the results reveal a highly erratic rainfall pattern from year to year (see Figure 3). In no particular order, ten years of below median, one year (1999) of within median and another ten years of above median precipitation is observed (see Figure 3).

As noted by Ravindran (2013),when physically based seasonal forecasts are not available, crop management strategies and planning should be based on statistical assessment of historical rainfall records. It can be observed from Table4that rainfall variability in June is high (CV=53%). Also, as shown in Figure 2, the production season starts with land preparation and crop planting activities in May and June. It can therefore be inferred that the erratic rainfall pattern in June could affect crop development at the early stages if farmers attempt to delay crop planting. Thus, it is important that farmers adjust their land preparation and crop planting dates to avoid periods of dry spell and drought in the production season.

Annual and seasonal rainfall distribution and variability

The calculated coefficients of variation for annual and seasonal rainfall are 0.18 and 0.19 respectively (see Table 3).These results suggest that rainfall variability across the years and seasons is generally moderate. Nonetheless, the computed PCI annual value of 19% indicates that, on yearly basis, rainfall concentration/distribution across months is irregular (PCI=19%). The results also suggest that monthly rainfall concentration in years of low annual rainfall volume is generally erratic. On the other hand, the PCI seasonal value of 11 suggests moderate monthly rainfall concentration. It must be stated that the period of production of the crops investigated generally coincides with the yearly rainfall season of May to October. Thus, seasonal rainfall distribution is more important than annual rainfall in respect of crop production in Lawra district.

The results shown in Table 4 reveal that rainfall volume and rain days tend to decrease in June which may result in dry spells. July and August are observed to have higher volumes of rainfall and this has high possibility of causing water logging of farm lands. According to Rugumayo et al (2003), findings on rainfall variability and its relationship with crop production should provide the basis on which agricultural policy makers can plan for irrigation facilities to respond to the incidence of recurring droughts. The findings of this study point to the need for farmers to adopt water harvesting technologies in order to deal with incidences of dry spells during the production season.

Rainfall-crop production relationship

The results of correlation analysis show that Maize, sorghum, millet, cowpea and groundnut are negatively related with annual rainfall. However, with seasonal rainfall, sorghum, millet and groundnut show negative relationships. Only maize and cowpea show positive relationships with seasonal rainfall (see Table 5).Duration of seasonal rainfall is generally same for all crops and covers the period from land preparation in May/June to

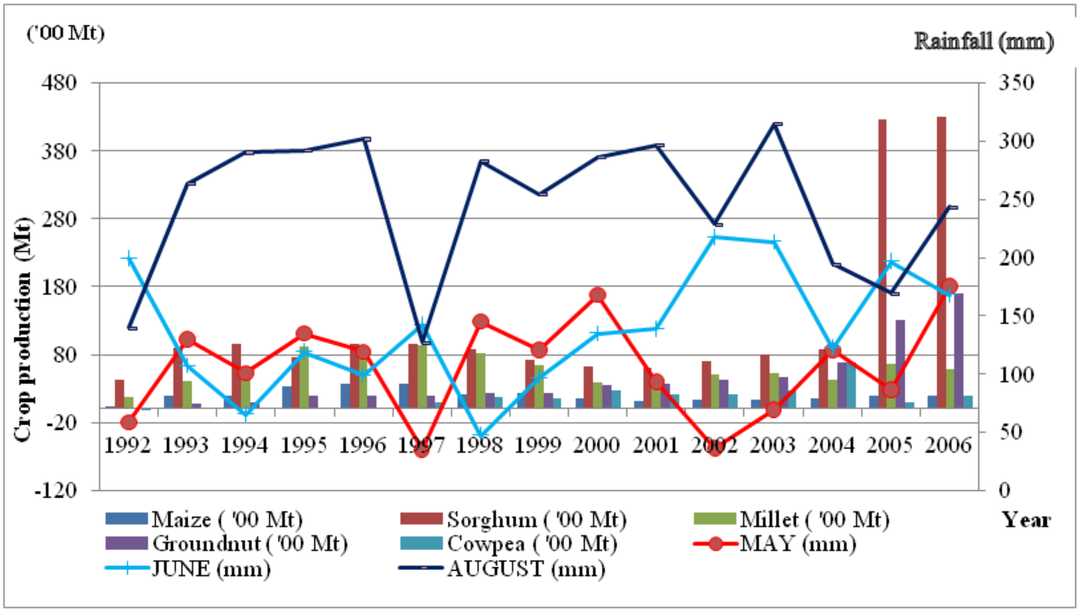

Figure 4. May/June/August rainfall pattern and crop production (1992-2006).

Table6. Correlation between May/June/August rainfall (mm) and crop production (Mt); 192-2012.

Crop/ Month	Correlation coefficients		
	May	**June**	**August**
Maize	0.47	-0.47	0.03
Sorghum	0.22	-0.09	-0.02
Millet	0.24	-0.48	0.10
Groundnut	0.15	-0.20	0.05
Cowpea	0.05	-0.17	0.00

the crop harvesting in October/December. While the correlation coefficients for sorghum and groundnut are statistically significant, those for maize, millet and cowpea are not. These results reveal the importance of other factors (e.g. labor, fertilizer, insecticides) influencing annual crop production volumes of maize, millet and cowpea.

The coefficients of variation of cropped area (see Table 1) 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. Similarly, the 970mm total annual rainfall volume observed that same year is the lowest recorded within the 33 years investigated. Consequently, the crop production volumes for same year (i.e. 1992) are lowest. The results also reveal that the large area of cropped land and high production volumes of crops recorded in 1995, 2000 and 2005 are directly related to the annual rainfall volumes recorded in those same years.

As indicated by Bewket (2009), although the correlation coefficients may not be statistically significantly, it should be noted that any form of correlation between rainfall and crop production is indicative of the fact that farmers are vulnerable. Farmers therefore have to adopt the best possible mechanisms to mitigate the effects of rainfall uncertainty/variability. However, as observed by Bezabih et al (2011), some uncertainties will still arise if farmers decide to change crop production strategies in response to rainfall variability by adopting techniques such as using

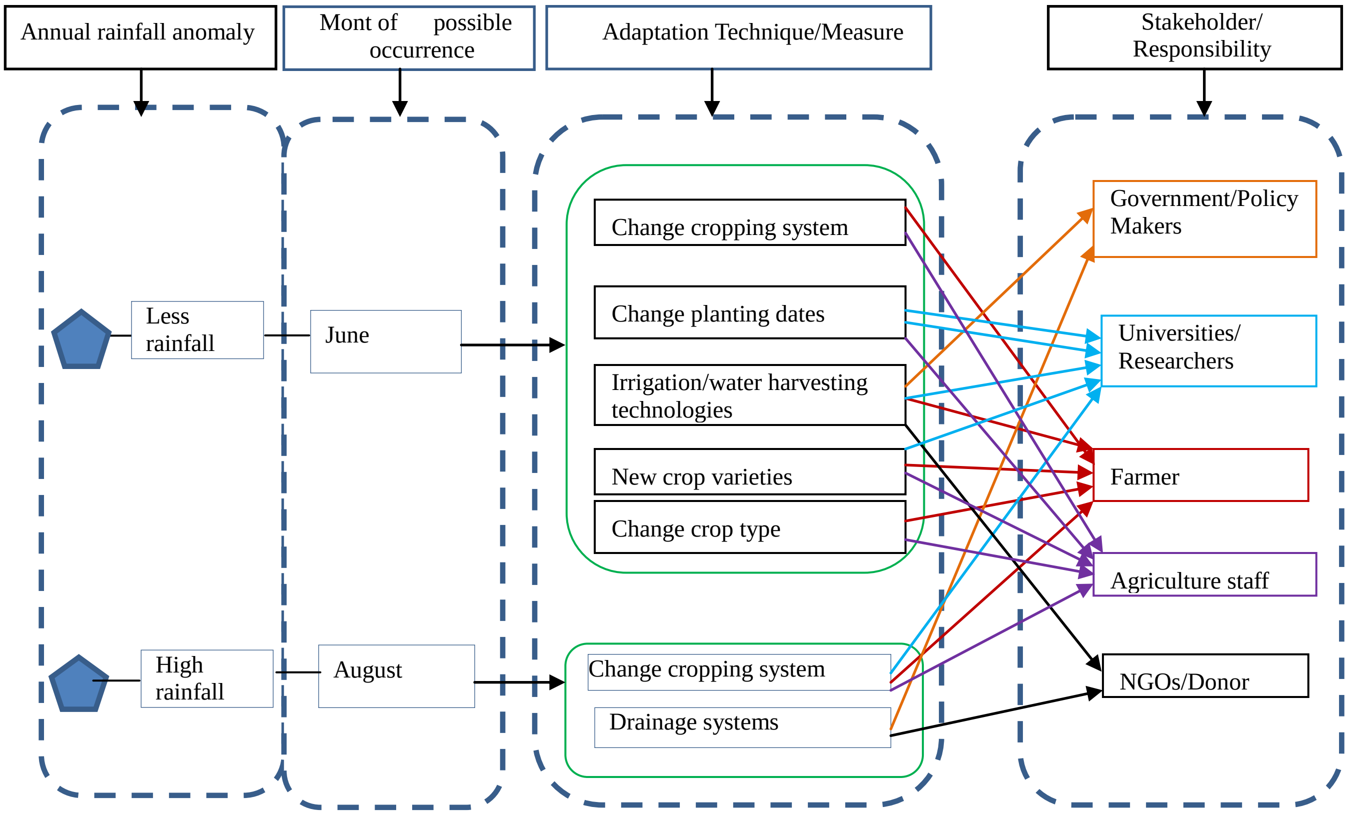

Figure 5: Representation of rainfall anomalies, adaptation measures and stakeholder responsibility.

new crop varieties, new agronomic practices, changing their planting dates, and adapting their plots and cultivation methods to new crops.

Relationship between crop production and May, June and August rainfall

The correlation between May and June rainfall is found to be strongly negative (*Correlation coefficient* = *-0.5*). This implies that the rainfall pattern of these months tend to move in opposite direction. Similar observation could be made from Figure 4.Also,as shown in Table 6, while annual volume of production of all the crops investigated is positively correlated with May rainfall, the relationship with June rainfall was negative. Despite the high rainfall volumes in August, all the crops except sorghum and cowpea show positive correlation. While the relationship is negative for sorghum, cowpea shows no correlation at all. Sorghum, millet and groundnut are mostly long-cycle crops planted at the beginning of the rainy season in May. Compared to other crops, sorghum (Bewket 2009) and groundnuts are noted to be tolerant to end of season dry spells in September. They are rather more sensitive to early dry spells in June.

It must be stated that due to the limited amount of data used in this study, the correlation coefficients obtained were not statistically significant.

Adaptation techniques to rainfall uncertainties

Under any given agricultural production year, three types of rainfall situations may occur in Lawra district; (1) less than median rainfall, (2) more than median rainfall or (3) a normal rainfall. As shown in Table 3, lower rainfall volumes may occur in June (CV=53%) as a result of lower number of rain days. On the other hand, higher rainfall volumes may also occur in August due high volumes of rainfall.

To mitigate the effects of these rainfall anomalies on crop production, stakeholders should identify/develop reliable, resilient and sustainable adaptation techniques/measures and implement them appropriately. Previous studies have identified various adaptation and coping techniques associated with drought and floods on agriculture. As noted by Fosu-Mensah et al, 2012, such techniques and mechanisms could include crop diversification, change in crop, change in planting date and planting short duration crops. Mary and Majule, 2009, also suggested improved soil tillage practices, soil fertility improvement and mixed cropping as other adaptation techniques.

More specifically, drought or dry spell periods require farmers to implement measures such as altering cropping system (e.g. mix cropping), planting/sowing dates, crop varieties (drought-resistant species) or change crop type. Based on farmers' level of awareness and access to irrigation/water harvesting facilities, they could water crops during periods of less rain. As a long term measure, government, policy makers and NGOs/donors should develop irrigation facilities and water harvesting technologies. While research institutions and universities should develop drought-resistant and early maturing crop varieties, agriculture staff on the other hand should educate farmers on improved/modern technologies and practices. In the case of floods, medium-to-long term measures are required. Government and policy makers should design and implement effective drainage systems. Farmers on the other hand should shift their crop production activities to less flood-prone arable lands.

CONCLUSION

In this study, an attempt has been made to assess rainfall variability and its relationship with crop production in the Lawra district of Ghana. The results revealed moderate seasonal and irregular annual rainfall concentration. Generally, rainfall starts in May, but the number of rain days and precipitation volume tend to decrease in June. Consequently, the results reveal negative correlations between rainfall in June and annual crop production volumes for all the crops investigated. Since land preparation and seeding/sowing starts in May, it could be inferred that the decrease in rain days and volume usually experienced in June has adverse effects on crop development. As noted by Laux et al, 2008, prolonged dry spells of two or more weeks after sowing are disastrous for plants, because they dry top soil layers and prevent germination, which may lead to total crop failure or yield reduction. Although the number of rain days and precipitation volume were found to be highest in August, the correlation coefficients were positive for all crops studied. At seasonal level (i.e May-October), only sorghum, millet and groundnut showed negative relationships with rainfall. Per the results obtained, this study recommends that agricultural stakeholders should adopt appropriate strategies/techniques (e.g. soil tillage practices, soil fertility improvement, drought-resistant varieties, irrigation and water harvesting) to mitigate the adverse effects of dry spell (especially in June) on the production of sorghum, millet and groundnut.

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