

Impacts of Climate Variability on Food Security in Northern Ghana

Raymond Abudu Kasei^{1,2}, Boateng Ampadu¹ and Sem Yalevu¹

Abstract

The problem of climate variability and its impact on food security in terms of agricultural productivity continues to attract scientific research in many parts of the tropics. Temporal variability of rainfall is associated with the yields of rainfed crops. In the North of Ghana perennial food shortage has been of major concern. The paper present an overview level analysis of the major climate variability factors in two districts (Bawku and Yendi) and to identify areas and periods with high levels of climate variability that have the potential to limit or adversely affect crop or livestock production. Analyses with regards to some aspects of rainfall management of the two districts were carried out using INSTAT. Participatory Rapid Rural Appraisal surveys were conducted on some selected communities of the two Districts for information on farming systems, vulnerability to climate variability and their coping strategies. Climate variability factors that have the potential for climatic stress on food security and the lack of environmental consciousness resulting in poor land and water management were contributed to seasonal food deficits in both areas. The two Districts of Yendi and Bawku are seasonally faced with problems of food deficits, probably due to lack of environmental consciousness resulting in poor land and water management.

Keywords: Cereals, Climate, Food Security, Ghana, Moisture Availability, Rainfall.

1 Introduction

Some attempts are being made to use seasonal rainfall in the management of agricultural activities (Stewart and Hash, 1982; Sivakumar, 1988) whilst little attention is being paid to the within season distribution of rainfall and its effects on crop growth, livestock and productivity. Past Governments in Ghana have tried to minimise the direct dependence of crops particularly and livestock on rainfall by establishing irrigation systems to overcome the effect of water deficits on crop, animals and other production systems. An alternative

¹University for Development Studies -Earth and Environmental Science Department (EES), Faculty of Applied Sciences (FAS), University for Development Studies (UDS), P. O. Box 24, Navrongo, Upper East Region, Ghana, Telephone: +233 547076073.

²University of Bonn, Germany.

approach seeks to gain advance information on the potential of the coming rainy season, so as to devise appropriate farming strategies that can be used to derive maximum benefits of the season. Sivakumar and others (1988) describe this method as "weather-response crop management tactics".

Climate variability, according to the IPCC (2007) is Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Climate variability is therefore used to denote the statistical deviations of individual weather events over a given period of time (e.g. a month, season or year) from the long-term statistics relating to the corresponding calendar period.

On the other hand, food security according to the World Food Summit of 1996 is defined as existing "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life". Food security according to the Summit is built on three pillars:

- Food availability: sufficient quantities of food available on a consistent basis.
- Food access: having sufficient resources to obtain appropriate foods for a nutritious diet.
- Food use: appropriate use based on knowledge of basic nutrition and care, as well as adequate water and sanitation.

The two selected districts are differentiated by their locations in the Sudan Savanna ecology (Bawku District) and Guinea Savanna ecology (Yendi District). Rainfall in the area is dependent on the seasonal northward movement of the Inter-Tropical Convergence Zone (ITCZ) and reaching its peak on many occasions in August in the Sudan ecological zone and September in the Guinea Savanna zone. The moisture situation reduces with increasing latitude therefore the Sudan ecology receives less rainfall than the Guinea Savanna ecology and it is punctuated with dry spells of different durations. Small scale peasant farming is the main occupation of the people in the two districts with small holdings of livestock. The Sudan ecology has a population of about 200 persons per square kilometer and the Guinea ecology has a population of 17 persons per square kilometer. Cereals are the staple food of the communities in the Savanna area. The main food crops cultivated in the area are rice, yams, groundnut, cassava, maize, sorghum, late millet, cowpea, pigeon pea, cotton in the Guinea Savanna and late millet, early millet, cowpea, groundnut, sorghum, early maize, rice in the Sudan ecology (Kasei *et al.*, 1995). Cereal production is the dominant agricultural activity in this semiarid environment. Cropping patterns in the two districts differ and the most notable difference being the increasing dominance of millet and sorghum over maize and root crops as soil fertility and rainfall decreases from the Yendi District in the south to Bawku in the North.

Another important difference among farmers of the two districts in terms of food security comes from the constraints peculiar to the region and not from differences in farmer aspiration and these include higher incomes, effort reduction and risk avoidance. This means that enough grains be harvested by November to feed their families until the beginning of the July/August early millet or maize harvest that provides food to fill the "hunger - gap" and that is the period most farmers have no cereal stock.

The problem of rainfall variability and its impact on food security in terms of agricultural productivity continues to attract scientific research in many parts of the tropics (Sivakumar *et al.*, 1979; Dennett, 1982; Dennett *et al.*, 1985; Sivakumar 1988). Temporal variability of rainfall is associated with the yields of rainfed crops. In the North of Ghana, perennial food shortage has been of major concern. Many reports concerning strategies to

combat food shortage in the West Africa sub region have been embarked upon (Ohm and Nagy, 1985; Mokwunye and Vlek, 1986). Farmers at subsistence level in unfavourable environments are often interested in risk avoidance instead of maximizing yield (Mashall, 1987).

Analysed temperature shows that qualitatively the occurrence of certain threshold temperatures may influence crop development. In the North of Ghana maximum temperatures normally occur towards the end of the dry season (March to April) with minimum temperatures being recorded in December and January. The Lowest minimum temperatures are invariably associated with the harmattan winds in January.

The aim of this study was to collect climate data and prepare an overview level analysis of the major climate variability factors in the two districts and also identify areas and periods with high levels of climate variability that have the potential to limit or adversely affect crop or livestock production

In environments where temporal variation in the climate is large, as is the case in these two districts in a semi-arid environment, an analysis of long-term meteorological data particularly rainfall is necessary in order to obtain reliable estimates of probabilities of occurrence of certain stress patterns that affect crops and animals. This will also serve as an early warning for climatic variability stress, on food security planning.

2 Study Area

The two districts, Yendi and Bawku are located between Latitude 09° 27'N and longitude 00° 01'E, and Latitude 11° 01'N and Longitude 00° 16'W, respectively. The area is mostly semiarid with annual precipitation between 900 - 1000 mm (Kasei, 1988). Changes in the physical environment of these areas are anthropogenically and edaphically induced. In these districts there is a suspicion that environmental factors such as temperature, relative humidity and particularly rainfall have influenced the farming systems (Kasei, 1988). This area experiences a uni-modal pattern of rainfall with one farming season.

The two districts are in the North of Ghana (Fig. 1) which covers a land area of about 97,699 km² being 41% of the land area of Ghana comprising of the Northern Region 70,380 km² being 29.5%, Upper West Region 8,840 km² being 3.7% and Upper West Region 18,480 km² being 7.8%.

The two districts, Bawku and Yendi are located in the potentially dry area of Ghana. In the dry land areas of West Africa and particularly those that are semiarid. Seasonal rainfall is often variable between the seasons and within the season (Adiku *et al.*, 1997). In the two districts rainfall during the season is usually punctuated by long dry spells (Kasei, 1995). In areas such as Yendi District where rainfall is relatively higher, severe storms are common with an associated loss of water through runoff.

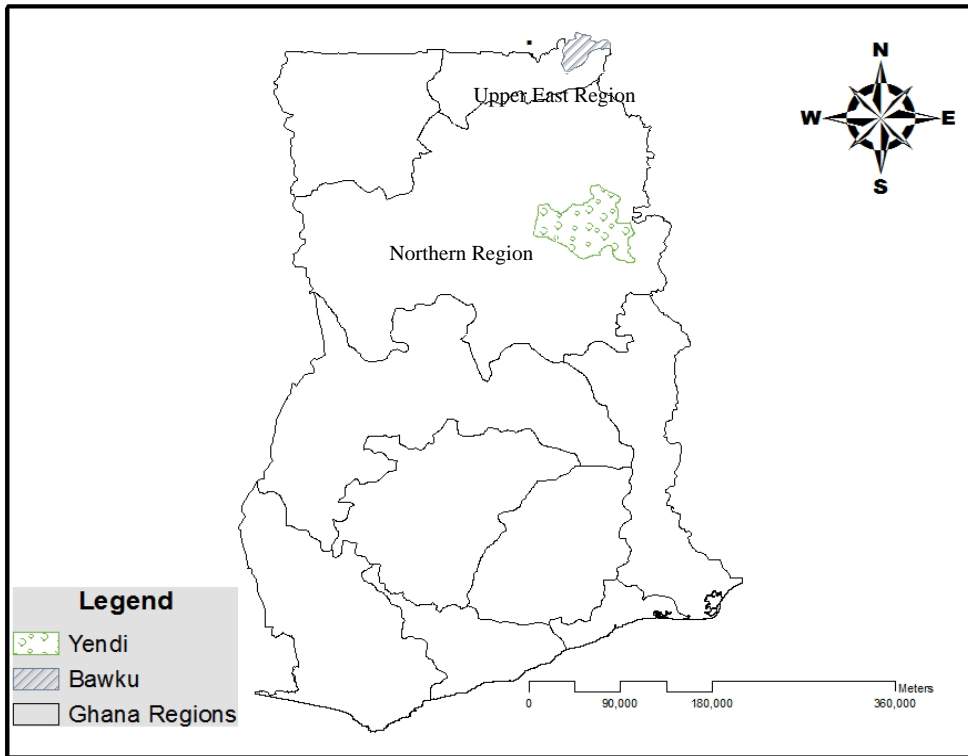


Figure 1: Map of Ghana showing Bawku and Yendi areas.

3 Methodology

Long-term mean monthly and daily rainfall for about 30 years or more for the two districts were obtained from Savanna Agricultural Research Institute (SARI) and Meteorological Services Department Headquarters of Ghana at Legon - Accra. Other complementary climatological data were obtained for sunshine, wind, temperatures and relative humidity from Bawku - SARI station and also Yendi weather station, respectively. Participatory Rapid Rural Appraisal surveys were conducted on selected communities of the two Districts for information on farming systems vulnerability to climate variability and their coping strategies.

Rainfall is the most important variable in dry land Agriculture with regard to food security in rain fed crop production. It is quite true that annual rainfall values do not indicate the dependable character of the rains but they give a useful identification of dry and wet years although a year with low rainfall could be a good agricultural year if well distributed. Therefore annual or average values of this climate parameter are also used in this analysis.

Analysis with regard to some aspects of the rainfall management of the two districts was done using INSTAT (Stern and Knock, 1999). This is an interactive statistical package developed at the University of Reading, UK for the analysis of climate data for

agricultural planning. A descriptive analysis was employed for the other climatic parameters.

4 Results and Discussions

4.1 Rainfall

In the two districts rainfall during the season is usually punctuated by long dry spells (Kasei, 1995). In areas such as Yendi District where rainfall is relatively higher severe storms are common with an associated loss of water through runoff.

Rainfall pattern for the two districts is characterised by seasonality, inconsistent intra-seasonal distribution (Figs. 2 & 3) and year to year variability. These characteristics are constraints to crop production. Specifically there is very little rainfall in the dry season (November to April). The climatic water balance for Yendi and Bawku (Figs. 2 and 3) indicates that about 90% of the total annual rainfall for both districts fall during the rainy season. Dry season rain is easily negated by evapo-transpiration.

In the Yendi area a potential start date in March is possible. During this period, there is a low probability of a short dry spell before the month of May when the rains normally stabilise (Kasei *et. al.* 1995). Risk avoidance strategies are necessary at this time. There is a low probability of a dry spell length of less than or equal to five days. There is also a higher probability of both temperature and PE becoming high with a rapid loss of soil moisture during this period.

In the Bawku district, the potential start date of the rains is March. Many false starts of the rains are characteristic of this district. There is a low probability of dry spell lengths of less than 5 days following the start of the rains in the area. Successive crop failures are associated with recurrent droughts during this period between the start and onset of rains when they are assumed to have stabilised. This has led to food scarcity in the area in recent times. The period of prolonged dry weather after the start of the rains affects the livelihoods of farmers, avoiding it depends on the timing of that period in relation to the life cycle of the crop.

Considering the wide variation of onset the rain is said to have stabilised in the Yendi area, when the mean date of onset of the rains is from 23rd May given a standard deviation of ± 9 days. The preparatory and seeding period (Fig. 2) which is the period between the start of the rains and the onset of the rains is associated with dry spells of different intensities. This period could spread over 50 days making it difficult for farmers to take a decision on whether to plant or not for fear of losing their crop due to this pre-season drought. The early onset of rains is an indication of a longer growing season and late onset may mean a shorter season.

The mean onset of rains in the Bawku District is 29th May with a standard deviation of ± 13 days. The period immediately after the start of the rains until the onset is drought prone. This is a period of persistent abnormally low rainfall over the years which make farmers to re-sow early planted crops. This period is within the preparatory and seeding phase and with duration of over 50 days. The uncertainty in the reliability of rainfall during this period imposes stresses on both the early sown crops and the farmers' livelihoods. The grass becomes dry due to the dry spell and animal feed becomes a problem.

End of rains is a potential climate variability driver that can impose stress on food security. For example the end of the rains determines the yield and quality of grains. The end of rains is defined for areas in northern Ghana as the period when a total of 10 mm of rain has been achieved within 10 days after which no rain falls for the next 10 days (Kasei and Afuakwa, 1991).

In the Yendi area, the end of rains which range from 20th September to 7th November is a wide variability and an indication of high probability of cessation of rainfall before the expected date of 28th October. This means that terminal drought could be a climate variability stress condition on late planted crops or long maturity duration crops.

The range in end of rainy season between 24th September and 29th October is quite wide in the Bawku area. The mean date of 12th October has a bearing on the moisture availability period. This would determine the type of maturity duration of crops that might be recommended in order to avoid food insecurity.

The variability of rainfall in the Yendi District is influenced by dry-spells of different duration during the rainy season. The total annual rainfall therefore varies from year to year in this location. The years from 1971 to 2001, rainfall in the area experienced a high positive mean deviation of over 50% in 1971 (Fig. 4). The highest negative departure from the long-term mean was over 30% mm in the dry year of 1983. In the period 1971 to 2001, 18 years out of the 31 years showed negative departures from normal. Only 13 years showed a positive deviation. Rainfall in this area is usually unevenly distributed during the year. The variability in the year to year rainfall particularly towards the negative trend is an indication of the stress conditions vulnerable communities are experiencing over the years.

Any discussion on rainfall variability of Bawku will keep in view crops and also livestock which are so important to rural livelihoods in the area. A high annual variability of rainfall is experienced in this location. Drought occurrence during the growing season contributes to the variable annual rainfall totals. Figure 5 shows that over 50% of the annual total rainfalls between 1971 and 1998 were below the long-term average. Only 13 years out of 28 years showed a positive departure from the long-term mean of 951 mm with the area experiencing a high mean positive deviation of a little over 400 mm. The highest negative departure was about 30% in 1983 which was a dry year affecting many areas in Ghana. This area is now a fragile environment with the onset of semi-aridity which is associated with frequent dry years.

Table 1: Long-term rainfall (mm) Pot Evapo-transpiration (PET - mm), Maximum and Minimum Temperatures (°C) and Moisture Availability Index (MAI - mm) for Bawku - Ghana

	January	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Rainfall (1931 - 1960)	0.0	4.8	13.0	48.8	101.3	115.8	165.6	242.1	212.3	58.2	6.9	1.3
PET (1931 - 1960)	144	164	176	174	169	138	123	115	119	138	133	135
Rainfall (1961 - 1960)	0.6	2.5	13.2	44.4	93.2	139.4	180.0	243.7	188.4	52.2	4.6	1.9
Maximum Temp.	35.0	38.5	40.0	39.4	36.2	33.8	32.0	31.2	32.2	34.9	37.1	36.1
Minimum Temp.	18.4	22.2	25.3	26.7	25.7	24.0	23.1	22.8	22.6	22.8	20.5	18.5
MAI	0	0	0	0.20	0.44	0.75	1.01	1.65	1.28	0.33	0.02	0

Table 2: Long-term Rainfall (mm) Pot Evapo-transpiration (PET - mm) Maximum, Minimum Temperatures (°C), Moisture Availability Index (MAI - mm/month) for Yendi - Ghana

	January	February	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.
Rainfall (1931 - 1960)	1.8	11.7	41.9	90.9	126.7	151.6	156.9	200.4	243.3	126.2	24.1	10.9
PET (1931 - 1960)	166	168	177	161	139	117	110	106	121	129	133	157
Rainfall (1961 - 1960)	1.9	7.2	58.9	76.5	133.5	169.3	198.7	222.6	251.0	105.9	8.5	9.0
Maximum Temp.	35.2	37.1	37.2	35.3	33.6	31.2	29.7	29.6	30.3	32.3	34.6	34.5
Minimum Temp.	19.7	22.4	24.2	24.4	23.4	22.2	21.9	21.8	21.5	21.6	20.0	18.9
MAI	0	0	0.34	0.40	0.76	0.97	1.21	1.46	1.57	0.56	0.06	0

Table 3: Average duration of moisture availability periods (Days)

LOCATION	PREPARATORY PERIOD	SEEDING PERIOD	RAINY PERIOD	POST RAINY PERIOD	WET PERIOD	RESIDUAL MOISTURE PERIOD	WET + RESIDUAL MOISTURE PERIOD
Yendi	56	37	136	14	187	20	207
Bawku	31	59	90	21	70	19	183

4.2 Moisture Availability Index (MAI)

The moisture availability index (MAI) proposed by Hargreaves (cited by Kasei, 1988) is used as a measure of water sufficiency. In the absence of adequate information on the type, depth, moisture-retention capacity and other characteristics of the soil the MAI would give an approximate idea of moisture available for crop growth. The MAI is the ratio of dependable rainfall to potential evapo-transpiration.

Moisture availability in Yendi area is low in March and April and somehow deficient even in May (Table 2). The moisture situation becomes adequate after June and excessive for August and September. In October moisture becomes moderately deficient while from November through February it is very deficient. This area is clearly susceptible to intra- seasonal drought conditions during the growing season. Generally, The moisture availability period for the Yendi area is greater than in the Bawku area (Table 3).

The moisture availability index values for the Bawku district are given in Table 1. The MAI could give an approximate idea of the available moisture situation for crop growth in this environment.

The values are very low early in the year with moisture from January to April being very deficient. May is moderately deficient until the moisture situation improves in June when it becomes somewhat deficient. Adequate moisture is achieved in July and excess moisture period is in August and September. From October to March the moisture situation becomes very deficient.

The variability in the moisture situation as indicated by the MAI explains the recurrence and persistent low precipitation and fluctuations over a long period. This confirms the variability stress conditions that exist during the period between the start and onset of the rains. Similar stress conditions imposed by the period before the humid phase during the post-rainy and residual moisture phase affect food security. The data for Bawku shows

that the moisture availability is below the requirement for long maturity varieties of maize. These might suffer from periods of moisture stress during the growing season.

Table 4: Assessment of Farming Systems Vulnerability to Climatic Variability: A Rapid Rural Appraisal Survey

Climate Stressors	Description	Locations	
		Yendi District	Bawku District
	Crops/ varieties abandoned due to drought	Reduced production of some sorghum varieties while other varieties have been abandoned. Late varieties cowpea and also bambara beans are abandoned.	Manipinta a late variety of groundnut, frafra potatoes
	New varieties introduced	New varieties of maize, soya beans, groundnuts and sorghum introduced between 1990 and 2004 by MOFA (Ministry of Food and Agriculture)	Capala sorghum, soya bean, maize, groundnuts (chinese). From MOFA From 1980 to 2003
	Crops now cultivated	Maize, sorghum millet, yam, cowpea, soya beans and groundnuts, cassava, vegetables (mainly by women)	Maize, sorghum cowpea, soya beans and groundnuts, vegetables (mainly by women)
	Planting period most affected by drought	First planting which is early May	First planting which is May
	Combating Practices	Making sacrifice to shrines. Cultivation near water bodies since 2001. The practice of composting to increase soil water retention capacity.	Making sacrifice to shrines by rain maker the Tindana (The land lord). Contours bunding, ridging
	Experiences of community from stressor	Adverse changes in sizes and volumes of water in river, streams and dams, dug-outs. Most water bodies dry up in the dry season Crops planted early normally suffer from drought,	Insect attack crops. Crops planted early normally suffer from drought
	Extent of Stressor	More frequent and intense	Longer and more frequently
Fluctuation in the onset of rains	Period	April/May	May to early June
	Period	October/November	October
Uncertainty in the end of rains	Period	October/November	October

4.3 Temperature

In the Bawku area temperatures are very high with seasonal variation including two maxima and two minima. Table 1 shows that the maximum temperatures vary between 31.2°C for August and 40.0°C for March. The minimum temperatures remain between 18.4°C for January and 26.7°C for April. The diurnal range of temperature is normally higher in the dry season than in the wet season from June to September. However, crops such as cereals could be affected by extreme temperatures (Cocheme and Franquin, 1967)

but these do not occur during the humid or moist period in this location. Very high temperatures could still occur after "false starts" of the rains. These "false starts" occur in this area in 1 year out of every 4 years and gives an impression of the start of the rains followed by a rainless period for many days (Table 1) and with high temperatures resulting in low parentage germination or even, seedling mortality. The period of extremely high temperatures is in March/April and just before the onset of the rains. These extreme temperatures increase rapid drying of the soil during the pre-season drought which has serious consequences for crop development and farmers livelihoods.

In the Yendi area temperatures are high and vary seasonally including two maxima (Table 2). Maximum temperatures are achieved during the period before the first few rains in March and immediately after the cessation of the rains (Table 2). The maximum and minimum temperatures vary between 29.6°C in April and 37.2°C in March (Table 2). The minimum temperatures are between 18.9°C in December and 24.4°C in April. Base temperature for upland cereals ranges between 10 and 15°C while the ambient temperatures may be higher. Prolonged high temperatures do not occur during the humid months but could occur during the preparatory and seeding period. Stresses occur during the preparatory and seeding period and during the period of post rainy and residual moisture phase (Fig. 2) when high temperatures occur just before the onset of the harmattan. The post rainy and residual moisture phase is the time when sorghum and millet are approaching senescence.

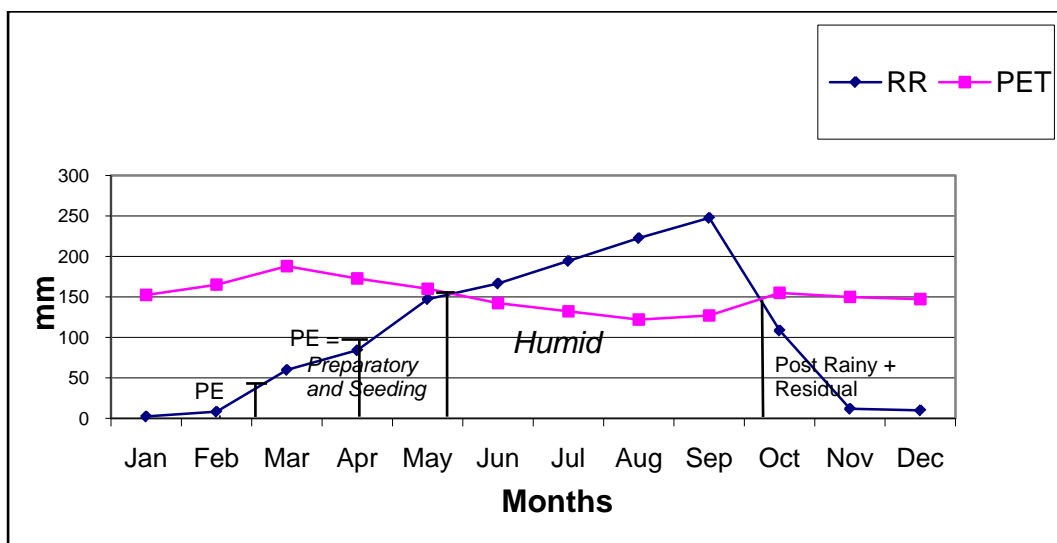


Figure 2: Annual Distribution of rainfall and Evaporation for Yendi (1957-86)

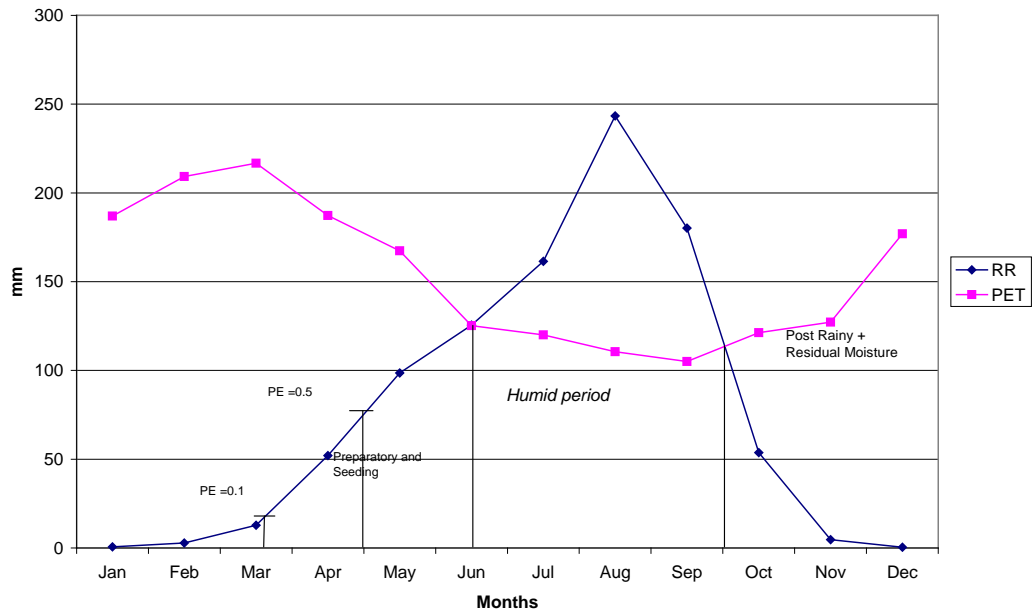


Figure 3: Annual Distribution of Rainfall and Evaporation for Bawku (1957-1986)

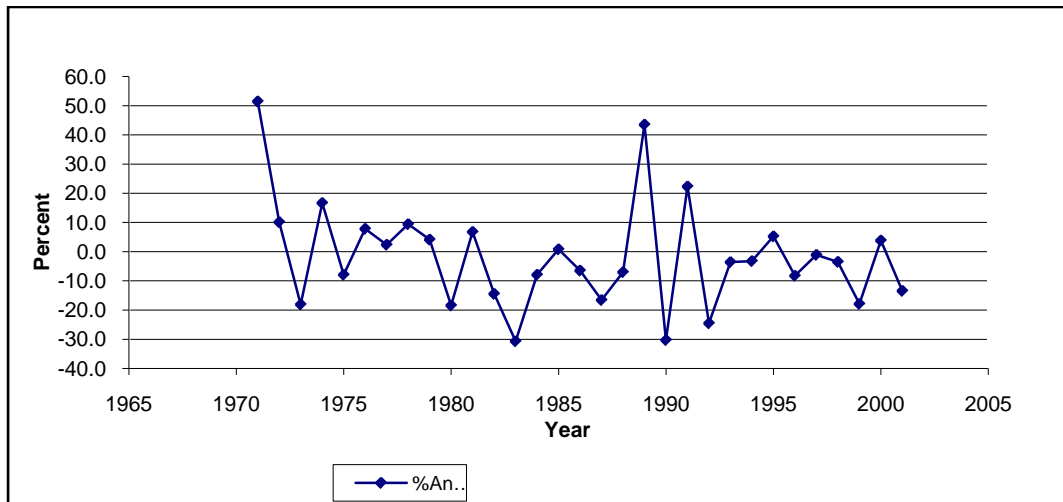


Figure 4: Maximum and Minimum Temperature for Yendi (1961- 1990)

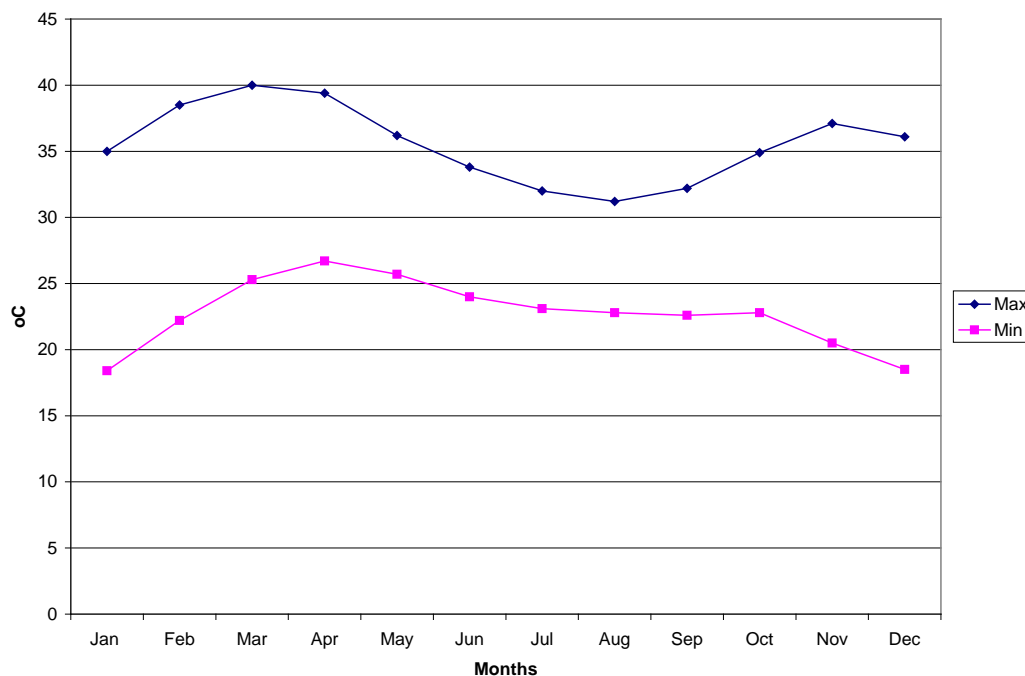


Figure 5: Max and Min Temp for Bawku (1961- 1990)

4.4 Length of growing Season

When the rainy season is short, or when sowing is late, crops rely on residual moisture in the soil for maturation. The duration of the growing season is therefore related to the crops grown in the area. The length of the growing season for any location can be obtained by subtracting the onset date from the end date of the rains for each year.

In the Yendi area rainfall and evapotranspiration are the major factors in determining the length of the growing season. When the rainy season is short, or when sowing is late, crops rely on residual moisture in the soil for maturation. The duration of the growing season is therefore related to the crops grown in this area. The length of the growing season in Yendi area is 132 - 200 days with a mean of 167 has implications on the period between planting and harvesting

The length of the growing season in the Bawku area varies from 113 to 173 days. The length of the growing season is adequate to support the major crops of the area. The duration could be sometimes shorter although for most of the years minimum duration is always greater than 100 days. Late onset of rains and an early cessation are the main causes of reduction in the total length of the season. False starts of the rains, late stabilization of the rains and also early truncation of the rains are major stresses in the Bawku environment resulting in subsequent yield loss due to soil water shortage and inadequate water to fill dams for watering animals and irrigation.

4.5 Vulnerability to Climatic Variability

Table 4 shows periods and practices that put stress on farming systems in the two districts (Yendi and Bawku). The table indicates some of the activities of the communities that make them susceptible to climatic variability in their agricultural practices. Responses found in the table expose some of these vulnerabilities, for instance the making of sacrifices to shrines to combat drought.

5 Conclusion

Climate variability factors that have the potential for climatic stress on food security have been identified. Some aspects have been assessed with local participation to understand vulnerabilities of the farming systems. Basic meteorological information and local knowledge on climate variability in relation to the Farming System of the Yendi and Bawku Districts formed the basis for the information on the effect of these stressors and the coping strategies of the communities. However, from the perspective of agricultural production in the north of Ghana, or the two Districts to be precise are seasonally faced with problems of food deficits, probably due to lack of environmental consciousness resulting in poor land and water management.

Policies should therefore be directed toward interventions to improve agriculture by addressing issues concerning some aspects of these climate variability stresses that constantly affect food security in these areas.

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