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Making effective use of climate information by small scale farmer in managing rain-fed maize production. A case study in Bole, Ghana

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Abstract

Crop production under rain-fed conditions largely depends on rainfall for moisture supply to crops. The rainfall received is unevenly distributed both geographically and seasonally and sets limits on crop production, leading to high risk and low yield of crops due to water stress. However, with proper understanding of the major or important climatic factors such as rainfall, water and humid periods, important decisions for planning and management of rain-fed maize production can be made in Bole. In this study, the mean monthly historic rainfall and evapo-transpiration data covering the period of 1961 - 2002 for Bole were used to obtain the rainfall amount and its expected pattern and distribution, standard deviation, coefficient of variation of each month, aridity indices, risk factors, length of growing and humid periods. The results from the analyses showed that the growing period for Bole is 214 days, implying that it has a higher agricultural potential and a longer drying period. The coefficient of variation and standard deviation indicated the dependability of rainfall in each month. The information developed could serve as a useful tool for a small scale rain-fed maize farmer during crop selection, timing of farming activities (supply of labour, land preparation, time of planting, harvesting and drying of crops) and also for agricultural entrepreneurs who are new to this particular environment.

Key words: Aridity indices, climate, cropping calendar, evapo-transpiration, rainfall, risk factor.

INTRODUCTION

Agriculture which is man's oldest occupation started when man found that the food around his dwelling place had become exhausted and therefore he had to travel a long distance to satisfy his needs. It is the most important of all primary activities that is pursued throughout the world and the most dependant on atmospheric conditions (Smith, 1975). Climate largely controls the vegetation cover and sets limits for crop production and pastoral activities (Ofori, 2004). Agriculture is predominantly on a smallholder basis in Ghana. The main system of farming is traditional; there is little mechanized farming, but bullock farming is practiced in some places especially in the northern parts of the country. Agricultural production varies with the amount and distribution of rainfall (MOFA, 2006).

Maize (*Zea mays* L.) is a major staple cereal crop of great importance in many countries of sub-Saharan Africa. It is known as 'Indian corn' and in America simply as 'corn' (Perseglove, 1972). Maize is used for three main purposes: (i) as a staple for human food; (ii) as feed for livestock and (iii) as a raw material for many industrial products. It also has a number of subsidiary uses (Perseglove, 1972). Maize is essentially a crop of warm countries and requires a good distribution of rainfall. In the early stage, sufficient water in the soil allows the plant to develop a healthy root system. This protects the plant against temporary periods of water stress. The optimum temperature for germination is 18 to 21°C. Rainfall during the growing season should not fall below 200 mm and in the tropics does best with 600 to 900 mm of rain during the growing season (Leornard et al., 1963). Under rain-fed agriculture, the rainfall is the primary supplier of water buts its amount is unevenly distributed both geographically and seasonally. The start of the rain is often marked by considerable day to day variability, making the actual planting time uncertain. The nature of rainfall constraint lies in the variability and the apparent unpredictability of rainfall amount and duration. Farmers have very little control over the natural source of water and therefore rain-fed agriculture is a risky occupation (Stewart, 1988).

Maize production in the Bole district is mainly rain-fed and is sensitive to climatic conditions. Irrigation and drainage facilities call for heavy capital investment and production expenses which act as constraint to their development (Bole District Assembly, 2008). The district lies in the Guinea Savannah zone which occupies most of the northern part of the country and it experiences only a single raining season (http://bole.ghanadistricts.gov.gh). Therefore, soil water management is very important and a key factor in achieving agricultural production. Thus, information on availability of water is of necessity in agriculture for effective management of farm activities, which helps prevent pre-harvest losses in crop production (FAO/UNESCO, 1973). The growing importance of maize is attributed to its staple and industrial values, as well as its adaptability to different ecological zones. The bulk of its production is done by small-scale producers who live mainly in rural areas and operate under limited capital.

Objectives of the study

The objective of the study was to help in developing the best management practices for rain-fed maize production for Bole. The sub-objectives are:
(i) To determine the period during which there is favourable moisture environment for maize production.
(ii) To establish the expected rainfall distribution and patterns, and
(iii) To develop a cropping calendar for maize production.

Even though, farmers operating in a particular area might have acquired a wealth of information and knowledge about the climate of the area they operate in, it is important to have a scientific and technological interpretation and understanding of their activities. It is extremely difficult to tell the exact time of the onset of the rains but this work would enable us to understand the moisture dynamics, expected pattern of the rains and climate once the rain starts to fall.

MATERIALS AND METHODS

Historic weather data (mean monthly rainfall and mean monthly evapo-transpiration) for Bole from 1961 to 2002 were obtained from the Ghana Meteorological Service Department (2009), Accra. The station measures daily and hourly data on rainfall amount, solar radiation, wind speed, relative humidity, evapo-transpiration and maximum and minimum air temperatures. The data of maize varieties and their maturation periods were provided by the Grains and Legumes Development Board, Kumasi (2000).

Statistical analysis

In order to determine the expected rainfall and evapo-transpiration values, probability distribution based on the Weibull method was used. This is given as:

$$\mathrm{P} = \frac{\mathrm{r}}{\mathrm{n+1}} \text{ x } 100\%$$

Where P is the frequency of exceedance, r is the highest rank number and n is the lowest rank number. The aridity index was also calculated as follows:

$$\text{Aridity index(for a period)} = \frac{\text{Rainfall in that period}}{\text{Evapo}-\text{transpiration in that period}}$$

Furthermore the risk factor was calculated as:

$$\text{Risk factor} = \frac{(\mathrm{ETo}-\mathrm{P80})}{\mathrm{ETo}}$$

Where ETo is the evapo-transpiration and P80 is the probability of rainfall at 80%. In addition, the standard deviation was calculated as:

$$SD = \frac{\sqrt{(X-x)^2}}{n}$$

Where SD refers to standard deviation, X is the individual values or samples, x is the mean, and n is the total number of values or samples. Finally, the coefficient of variation was calculated as:

$$\mathrm{CV} = \frac{\mathrm{SD}}{\mathrm{Mean(x)}} \text{ x } 100\%$$

Statistical functionality of Microsoft Excel was used to calculate the above mention terms and to plot the graphs.

Agro-climatic Indices

The following are some of agro-climatic indices that are important in agriculture:
(1) Humid period: This is the period in which rainfall exceeds potential evapo-transpiration – that is Pe >ETo (FAO, 1981). This is the period of higher rainy days, higher rainfall amounts and days between rainfall events are shorter and rainfall dependency also high.

(2) Length of growing period (LGP): According to (FAO/IIASA, 2000), it is the period during the year when both moisture availability and temperature are conducive for crop growth.
(3) Effective rainfall: Rainfall must be considered when determining crop water needs that must be supplied by irrigation. Not all rainfall is effective, but only the portion that contributes to evapo-transpiration. Effective rainfall estimates should consider local conditions. Rainfall on a wet soil profile is ineffective in meeting evapo-transpiration demand, but may contribute to leaching requirement. Rainfall that produces run off has reduced effectiveness (Schwab et al., 1993).
(4) Dependable rainfall: This is a rainfall, which has the probability of occurring in either four out of five years or three out of four years. The concept of rainfall frequency analysis gives dependable rainfall amount which are usually measured in millimetre (mm) (Schwab et al., 1993).
(5) Crop evapo-transpiration (ETc): This is the amount of water used up by crops and its surroundings. Its value is normally expressed as the product of crop co-efficient (Kc) of the reference crop and the potential evaporation; that is ETc = Kc × ETo. The value of the Etc is largely determined by factors such as solar radiation, air temperature and humidity (Tanu, 1991).
(6) Potential evapo-transpiration (ETo): It is the rate of evapo-transpiration from a short green crop, fully covering the ground and fully supplied with water. Potential evapo-transpiration is now being widely used in the study of water from the surface into the atmosphere (Tanu, 1999).
(7) Evapo-transpiration (ET): Evapo-transpiration, also known as consumptive use is the form of two terms, evaporation and transpiration. Evaporation is the physical process by which water is transferred to the atmosphere from surface of water bodies, soil and wet vegetation and precipitation (which is the water released from the leaves of plants into the atmosphere). Consumptive use can be assessed with regards to its potential rate and water uses by a crop, hence the term potential evapo-transpiration and crop evapo-transpiration, respectively. Potential evapo-transpiration, evapo-transpiration and evaporation accounts for about 10% and plant transpiration for the remaining 90% (Hanson, 1991).

RESULTS AND DISCUSSION

Standard deviation and coefficient of variation

The standard deviation and coefficient of variation for the rainfall and the ETo are presented in Table 1. The rainfall at 80% probability (P80) and potential evapo-transpiration (ET_o) for the various years for study area was used to estimate the standard deviations (SD) and coefficient of variation (CV). For a rainfall to be more reliable, its coefficient of variation must be less than 50% (Ofori, 2004). The results from the analyses showed that the months of April, May, June, July, August and September had their CV values less than 50%, and this means that the rainfall received in those months are reliable or dependable. On the other hand, the rainfall received in September (206.8mm) had the lowest CV (32.46) with SD of 67.07.

Table 1: Standard deviation and coefficient of variation for Bole for the period (1961-2002).

Month	Rainfall			Evapo-transpiration		
	Mean rainfall(mm)	SD	CV	Mean ETo(mm)	SD	CV
Jan	2.1	8.11	386.2	242.9	20.4	8.4
Feb	9.3	16.08	172.9	240.2	18.97	7.9
Mar	51.9	35.69	68.8	197.4	34.84	17.6
April	99.4	41.83	42.1	167.7	39.23	23.4
May	130.8	57.5	44.0	127	14.38	11.3
June	146.6	60.75	41.4	97.7	8.48	8.9
July	160.6	74.09	46.1	77.7	7.34	9.4
Aug	150.6	52.49	34.9	76.2	5.56	7.3
Sept	206.8	67.07	32.4	86.3	6.12	7.1
Oct	104.6	60.51	57.8	110.8	9.44	8.5
Nov	21.1	28.3	134.1	161.1	20.97	13
Dec	7.3	16.7	228.9	204.0	29.6	14.5

Aridity index, risk factor and rainfall distribution at 80% probability (expected pattern of the rain)

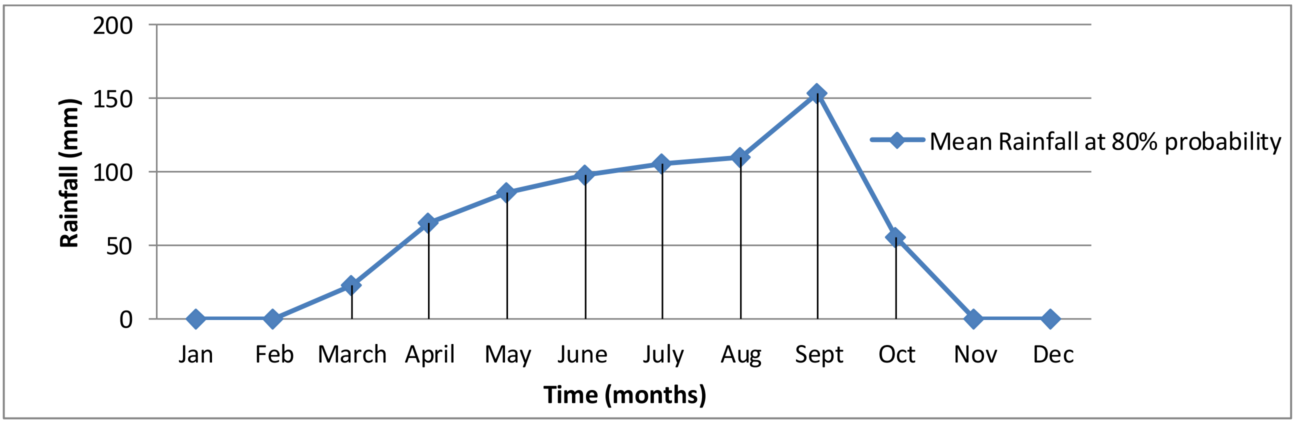
The results on aridity index and the risk factors are shown in Table 2. The rainfall at 80% probability and potential evapo-transpiration (ETo) for the various years for study area was also used to estimate aridity index, risk factors, length of humid and the growing periods. The risk of crop failure can be minimized if rainfall is greater than or equal to the potential evapo-transpiration ($P_e \geq ET_o$ or $P_e - ET_o \geq 0$) or if the aridity index (Pe/ETo) is greater than or equal to 1 for the months (AI ≥1). This is an indication of wetness period during which there is some amount of water in the soil to support crop growth. When the aridity index gives a fraction, then it is an indication of the dry period during which the rain-fed crop is most probably under stress. From the aridity indices and risk factors calculated for the study areas, the following deductions were made: based on the (1961 – 2002) data, Bole had a yearly aridity index of 0.609 and a risk factor of 0.613, but the months of May, June, July, August, and September had their aridity indexes greater than 1 with the highest value in September (2.40) implying that maize planting is suitable for the months in the year with an aridity index greater than or equal to one.

Figure 1 presents the monthly rainfall distribution at 80% probability. It starts in March with a minimum value of 22 mm, and then increases rapidly to a maximum value of 152.8 mm in September and decreases to 55 mm in October until it reaches zero in both November and December. Therefore, any maize variety planted in the month of November, December, January, February will experience water stress due to low rainfall and the high evaporative losses.

Table 2: Mean monthly rainfall, 80% probability rainfall, ETo and 80% probability ETo, and aridity index and risk factor for Bole (1961-2002).

Month	Rainfall (mm)	Rainfall at 80% probability	ETo (mm)	ETo at 80% probability	Aridity index	ETo-P80 (mm)	Risk factor
Jan	2.1	0	242.9	229.5	0.01	242.9	1.00
Feb	9.3	0	240.2	226	0.04	240.2	1.00
March	51.9	22	197.4	170	0.26	175.4	0.89
April	99.4	65	167.7	135	0.59	102.7	0.61
May	130.8	86	127.0	117	1.03	41.0	0.32
June	146.6	97	97.7	92	1.50	0.7	0.01
July	160.6	105	77.7	95.9	2.07	-27.3	-0.35
Aug	150.6	109	76.2	71.8	1.98	-32.8	-0.43
Sept	206.8	153	86.3	81.2	2.40	-66.5	-0.77
Oct	104.6	55	110.8	104	0.94	55.8	0.50
Nov	21.1	0	161.1	146	0.13	161.1	1.00
Dec	7.3	0	204.2	184	0.04	204.2	1.00
Year	1091.1	691.8	1789.2	1652.4	0.61	1097.4	0.613

Figure 1: Graph of mean monthly rainfall at 80% probability against time for Bole (1961 - 2002).



Dryness or wetness period

Figure 2 presents the dryness or wetness period in Bole. The dryness or wetness period is determined using mean monthly rainfall and ETo. The dryness period starts in January at ETo value of 242.9 mm to April and continues from October to December, implying that Bole has a longer drying period. Hence, the best time for farmers in this locality to dry any harvested maize should be within this period since the atmosphere could conducive enough to facilitate the drying process. Water deficit occurs during the dryness period and this is best time to dry any harvested maize. The wetness period also starts from May to September, implying that the best time for a farmer to grow maize should fall within this period. If farmer grows maize between the months of November to April, there would be a higher probability of crop failure. The graphs of rainfall and ETo against time showing the period of dryness or wetness can serve as a guide for appropriate area for crop planting, drying and storage. The rainfall received varies both geographically and seasonally, so there is the need for scientist to analyse and evaluate the climatic information developed each year so that it could be useful for farmers engaged in rain-fed maize production.

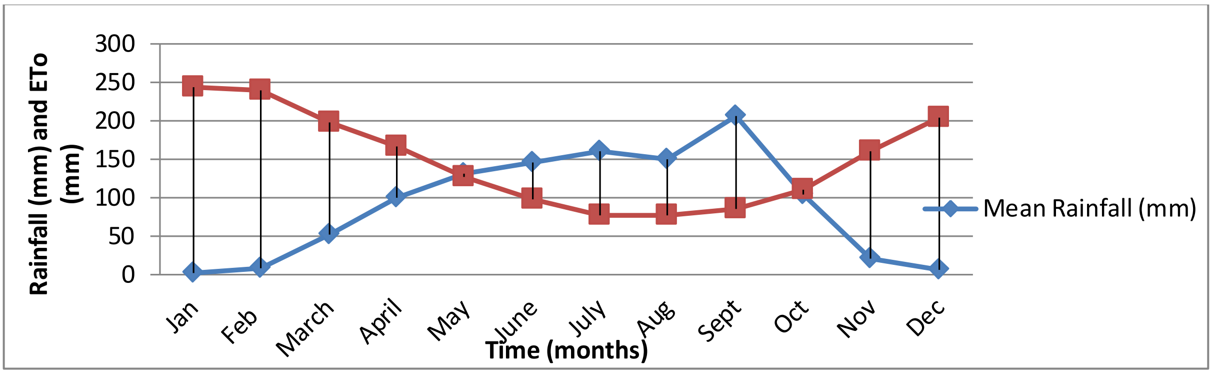
Table 3: Length of growing period and humid period at Bole.

Parameter	Growing period	Humid period
No. of days at mean rainfall	214 days	150 days
80% rainfall probability	183 days	114 days
Rainfall amount	894.8mm	795.4mm

Length of growing period, humid period and the cropping calendar

Table 3 shows the length of the growing period and the humid period for Bole. The length of the growing period is about 214 days and this implies that Bole has a higher agricultural potential and a shorter humid period, which starts from mid April to mid November.

Figure 2: Graph of mean monthly rainfall and mean monthly ETo against time for Bole (1961-2002).



The rainfall within this period is 894.9 mm, which is sufficient for maize production. Moreover, the percentage of rainfall within this growing period is 82% (894.8 / 1091.1 × 100). The length of the humid period is about 150 days and this starts from third week of May to third week of October and the rainfall within the humid period is about 795.4 mm. The percentage of rainfall in the humid period is 72.9% (795.4/1091.1 × 100). However, the rainfall amount receive between January and April is not sufficient for maize production so it will therefore be important for the maize farmers in this locality to follow the cropping calendar developed in Table 4 in order to avoid any kind of water stress during the growing period. This information would be useful to farmers in Bole as well as the new farmers who have moved to the zone to engage in maize production. Table 4 also showed the maize cropping calendar for Bole; it indicates the periods in the months of which farming activities could be carried out for the different maize varieties. In addition, the best time of input supply, the best time of land preparation, the best time of planting, as well as the best time of harvesting of the different type of maize varieties within this particular locality are also indicated in the table.

Based on the results obtained herein, it is therefore recommended that the supply of farm inputs such as seeds, fertilizers, machinery, equipment's, credit facilities (loans) etc., should be made available by February prior to the onset of the rains. During the field operation stage, the demand for labour is high since a lot of farmers search for labour at this crucial period. Hence, the number of labourers required for the operations on the field should be notified so that they will know the exact time that they will be needed on the field. Moreover, field operations should be carried out during April since at this time, soil moisture level will be sufficient enough to support machinery loads. The length of land preparation could be varied between one to 3 weeks depending on the size of the land and the type of machinery or the type of labour employed for such activities. Agricultural machinery such the plough could use few days to prepare the land, while the use of human labour might take longer.

The cropping calendar was prepared based on the maturity periods of the different maize varieties and also by estimating that the planting time of each maize variety should fall within the humid period. And since the humid period is 150 days, any maize variety planted should fall under this period. The amount of rainfall received in each month was also taken into consideration; maize varieties with a longer maturity period such as La Posta, Dobidi and Okomasa should be planted earlier (first to mid week of May) so that their time of harvesting could coincide with the drying period which starts in October. If a maize farmer in this locality disregards the above cropping calendar and plant his/her maize later than the month of May, there would be a likelihood of the plant to suffer from water stress. Also, if a farmer in this locality plants his/her maize earlier than the month of May, the maturity or the harvesting period might coincide with the rain and this could affect yield. This is because maize at its harvesting period (especially when the seeds are dry) can easily germinate on the plant itself when it comes into contact with the rain and might even encourage mould growth.

Table 4: Cropping Calendar.

Maize varieties	Time of input supply	Time of land Preparation	Time of planting	Time of harvesting (days)
La Posta	By February	Early April	1st to Mid Week May	120
Dobidi	By February	Early April	1st to Mid Week May	120
Aburotia	By February	Mid April	Mid to end of May	110
Safita 2	By February	Early April	1st to 3rd Week of May	95
TEZSRW	By February	Early April	1st to 3rd Week of May	95
Okomasa	By February	Early April	1st to Mid Week of May	120
Obatampa	By February	Mid April	Mid to end of May	110
Abeleehi	By February	Mid April	Mid to end of May	110
Dorke SR	By February	Early April	1st to Mid Week of May	95
Golden Crystal	By February	Mid April	Mid to end of May	110
Kawanzie	By February	Early April	1st to Mid Week of May	95
Mamaba	By February	Mid April	Mid to end of May	110

CONCLUSION

This analysis is an essential tool for planning and management of rain-fed maize production in Bole. It has been observed through the analysis that Bole has a higher agriculture potential because the length of growing period is 214 days. The cropping calendar, as well as the data on the length of growing period, length of humid period and graphs on rainfall-ETo is an important parameter to serve as a guide for planning of most farming activities. The information on the aridity index, risk factors, coefficient of variation can be used to minimise the risk of crop failure. This work should be extended to other parts of the country and the world, as well for use by stakeholders in the agriculture industry in order to mitigate some of the impact of climate change.

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