Paper:

Dry Spells Occurrence in Tamale, Northern Ghana – Review of Available Information

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Sustainable crop production is important for food security in Northern Ghana, where highly variable rainfall coupled with high evaporation rates and soils prone to degradation combine to produce low crop yields of main staple crops that are vital for local people's livelihoods. Rainfall in this region generally ranges between 800 mm and 1200 mm per annum, falling within a single rainy season from April to October, with a peak in late August-September. This amount is adequate for most arable crops such as maize, rainfed rice, soybeans, and yams. Intermittent dry spells occur, however, at critical crop growth stages, resulting in significant yield reductions. Several studies conducted in this area show that dry spells can be expected during each annual rain season, with a high level of certainty and duration from two to three days up to four weeks. This paper reviews both available literature on dry spell incidence and rainfall prediction in the West African region, with a particular focus on northern Ghana. Available daily rainfall data for 52 consecutive years are analyzed to determine dry spell duration and occurrence in northern Ghana.

Keywords: northern Ghana, drought, dry spells

1. Introduction

Rainfed farming systems dominate Ghanaian agriculture, particularly regarding the cultivation of major staples, such as maize, yams, cassava, and rainfed rice. Climate in the country is suitable for this mode of production because rainfall ranges from 750 mm/annum in the coastal savannah of the Greater Accra Region to approximately 2200 mm/annum in the western region. Temperatures are within the 25-40°C range, which is typical for tropical conditions.

Northern Ghana produces a variety of crops within a single rainy season, from May to October. In northern Ghana, the rainfall amount range is 1100-950 mm/annum, whereas the temperature maximum reaches above 42°C in the dry period of the year (Ghana Meteorological Agency, G-Met, 2013).

In this environment, farmers depend strongly on seasonal rain; any alteration in precipitation distribution affects their livelihoods. Recent threats in climate change aggravate the already delicate balance of food production and security.

To develop strategies for enhancing the livelihoods of smallholder farmers affected by drought or flood risks and to improve existing practices and methods in managing these natural phenomena, several initiatives have addressed the issues of resilience in existing farming systems in two regions of Northern Ghana. These institutions include the Climate and Ecosystem Change Adaptation and Resilience Research in Africa (CECAR-Africa) 2011-2016 project, which is supported by the Japan Science and Technology Agency (JST) / Japan International Cooperation Agency (JICA), the Science and Technology Research Partnership for Sustainable Development (SATREPS), the Government of Japan, and the Government of Ghana (GoG). Of major concern to the farmers in study area are the occurrence and duration of dry spells during rainy seasons, which considerably affect crop performance during crucial stages of development and reduce crop yields.

This paper reviews previously available information on dry spells and presents the results of our analysis of the length and the probability of occurrence of these dry spells based on the daily climatic data available from G-Met, a partner institution of the CECAR-Africa Project. The main objectives are to confirm and provide detailed information on the dry spells that occur during rainy season, which can be used by farmers as guidance for timing the cultivation of major crops.

2. Literature Review

Problems of precipitation probability and dry spell occurrence in tropical regions, particularly in West Africa, have been studied extensively due to their effects on rainfed agriculture. Projected changes to the dry spell characteristics in Africa for the 2041-2070 and 2071-2100 periods, with respect to the 1981-2010 period, suggest significant changes, with increasing mean numbers of dry days and five-year return levels of maximum dry spell durations, whereas the mean number of dry spell days is decreasing [1]. In this study, dry spell is defined as an extended period of dry days, including those of one day duration, while a dry day is defined as a day with a precipitation amount less than a predefined threshold, usually 0.5 mm.

A study in Senegal [2], showed that severe drought years and extreme dry spell events are interrelated. The same authors in a different study [3] also observed irregular dry spells of longer than two weeks, which are associated with intermittent rain events at the beginning of the rainy season, and less frequent 8-14 day-long dry spells, which are lethal to crops when they occur at the core of the rainy season.

Rainfall variability study [4] in West Africa from 1950 to 1990, based on data from more than 300 daily rain gauges identified the occurrence of a sharp change around 1960 in Sahelian rainfall that led to drier years in general. The same author suggested that attention should to be given to the occurrence of extreme rainfall events.

Different research [5] predicted a reduction in rainfall of 15-20% and an increase in air temperatures over the 21^{st} century in the same region.

A critical review [6] reported that long dry spells result in heavy costs to the affected communities and that the success or failure of the crops under rainfed conditions is strongly related to their distribution. The definition of dry spell, as originally presented in 1919, is also given in this paper, as well as descriptions of models used in dry spell calculation and prediction. The authors indicate that the frequently used Markov chain models may overestimate very short dry sequences and underestimate very long dry sequences and that these models are location specific. They recommend the forecasting of the starting time of dry spells, as well as the gap between two consecutive critical dry spells, for future studies. Exploration of the use of the artificial neural network (ANN) to forecast dry spell properties is also recommended after statistical validation of these models.

In Ghana, [7] showed that the frequency of droughts has increased beginning in the 1970s for the Volta Basin and thus for a large part of the West African sub-region.

In other recent literature on Ghana [8] and [9], the Kwahu Plateau in central Ghana is marked as an important divide in the extent of the precipitation changes, although the researchers concluded that the reduction in rainfall is not temporally or spatially uniform. They further observed a 20% drop in mean annual precipitation in the forest region to the southwest, which is twice the amount in the savanna zones in the period 1951-2000.

Study of dry spells occurring in northern Ghana [10] using first-order Markov chain modeling showed no significant change in the onset of rain, annual rainfall amount, or maximum rainfall days was established in that study. However, a significant decrease in the number of rain days and the probability of dry spells of up 11 days in the first four weeks of the planting season was revealed. Studies conducted in 2004 [11] and 2010 [12] centered on the social aspects of the dry spells and periods. They reported that threats of drought and possible changes in climate drive the needs of farmers to diversify and reduce agricultural and non-agricultural risks. The work on social dimensions of adaptation to climate change in Ghana [12] in particular emphasized the role of the state in adapting to climate change, because community resilience is low, due to inadequate social amenities and economic infrastructure. The author further maintained that household resilience can be offset by poor community resilience and inadequate water, health, educational, and road infrastructures.

Recent study [13] confirmed that the farmers' choices of indigenous climate-related strategies are highly dependent on decreases in rainfall and increases in temperature in northern Ghana.

Table 1. Characteristics of rainfall in Tamale.

Parameter	Year	mm/annum
Highest rainfall year on record	1963	1666.4
Lowest year on record	1992	693.5
Average for 52 years		1104.5
		Years
Years above average		22
Years below average		30
		Days
Average number of rainy days/year		77
Lowest number of rainy days	1983	56
Highest number of rainy days	1968	104

(Source: G-Met, 2013)

3. Materials and Methods

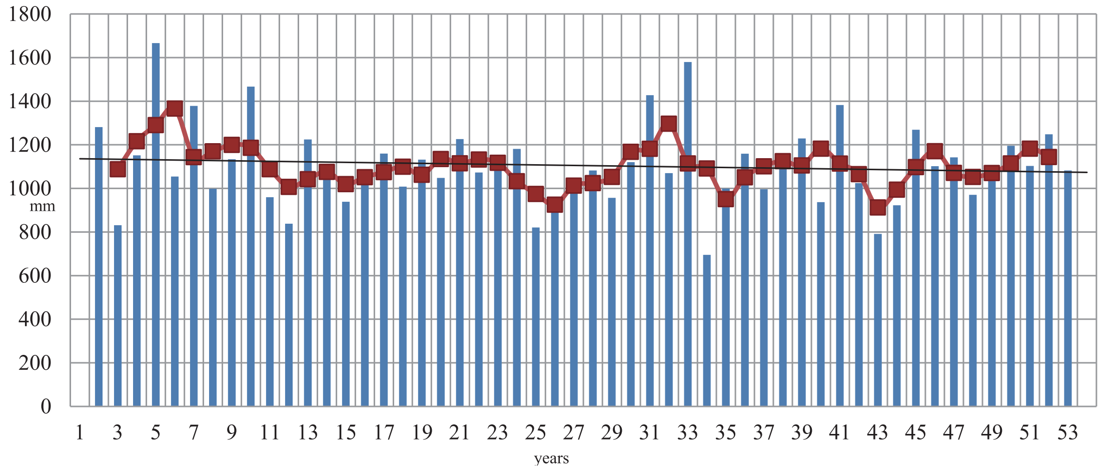
In this study, daily rainfall records were obtained from G-Met and were analyzed using INSTAT (v. 3.37) statistical package (2010 SSC, University of Reading). Basic rainfall characteristics obtained include the following characteristics:

- Average annual rainfall, minimum and maximum rainfall, three-year year moving average, and departures from the mean for 52 years of data available (1960-2011).
- Probability of occurrence for rainfall during the cultivation season (March to October) was also calculated. Other information includes duration of rainy season (days), as well as monthly distribution of rainfall (%).
- Dry spell analysis includes a review of dry spells in days for the period 1960-2011 as well as probability of occurrence of the dry spells.

4. Results and Discussion

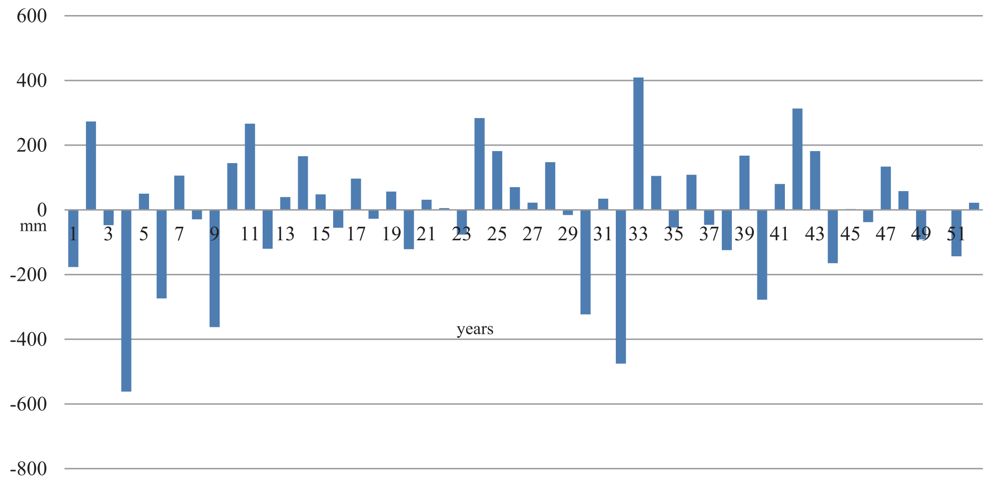
4.1. General Observations

Several characteristics of rainfall in Tamale are presented in **Table 1**. The analysis of 52 years of continu-



(Source: G-Met, 2013)

Fig. 1. Three-year moving average of rainfall in Tamale from 1960 to 2011.



(Source: G-Met, 2013)

Fig. 2. Departures from the mean rainfall amount in Tamale from 1960 to 2011.

ous daily rainfall data in Tamale showed that the average cultivation season for major staple crops lasts from May to October (approximately 153 days). The highest annual rainfall, 1666.4 mm, was observed in 1963, and the lowest, 693.5 mm, was in 1992. The average annual rainfall was 1104.5 mm. The number of rainy days averaged 77, with the highest (104) and lowest (56) recorded in 1968 and 1983, respectively. The cyclic nature of annual rainfall, with years of alternating above- and below-average rainfall, is clearly shown in **Figs. 1** and **2**.

4.2. Average Monthly Rainfall Distribution in 1960-2011 and Number of Rain Days

The results of the average monthly distribution and rain days are presented in **Fig. 3**. Monthly rainfall increased gradually from the start of the year, with a peak in September (221.6), followed by a sharp decline to 88.4 mm in October. A comparison of rainfall between the periods of 1960-1991 (30 years) and 1992-2011 (22 years) and the overall monthly rainfall (52 years) did not show a marked difference in the pattern of distribution.

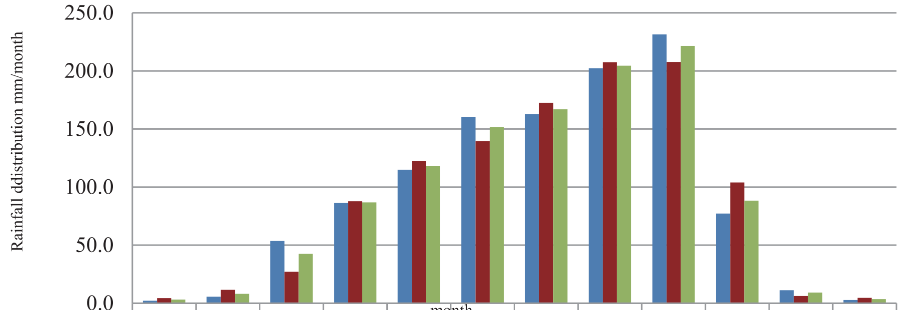
The distribution of rain days (**Table 2**) shows that of annual total of 77, the highest numbers, 14 and 16, occurred in August and September, respectively.

The percentage of rainfall in each month is presented in **Fig. 4**. Approximately 86% of the total rain was recorded in the months of May to October, indicating the duration of the main rainy season.

4.3. Dry Spell Analysis

The results of the dry spell analysis are presented in **Table 3**. In this paper, a dry spell is defined as a period in which the weather has been dry for an abnormally long time but is shorter and less severe than a drought [6, 14].

The average duration of dry spells in the rainy season (May-October) in the peak rainfall period was shortest in September (4) and August (6). At the start of the season, dry spells lasted two or more weeks (17 and 13 days for March and April, respectively), which agrees with data obtained by [3] and [10] and is comparable with informa-



	1	2	3	4	5	6	7	8	9	10	11	12
avg-1960-1990	2.1	5.6	53.6	86.3	115.0	160.5	163.0	202.3	231.5	77.3	11.2	2.8
avg-1991-2011	4.4	11.6	27.0	87.8	122.3	139.5	172.6	207.6	207.7	104.0	6.3	4.7
overal avg	3.1	8.1	42.5	86.9	118.0	151.8	167.0	204.5	221.6	88.4	9.1	3.6

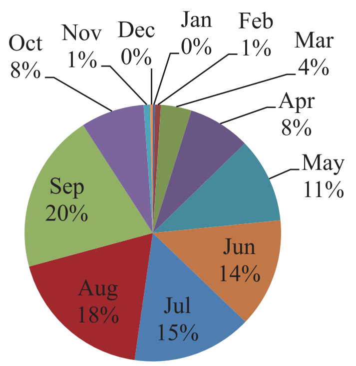
(Source: G-Met, 2013)

Fig. 3. Monthly rainfall distribution in Tamale.

Table 2. Number of rain days/month (≥0.5 mm).

Month	Number of rain days
January	0
February	1
March	3
April	5
May	8
June	11
July	11
August	14
September	16
October	8
Total	77

(Source: G-Met, 2013)



(Source: G-Met, 2013)

Fig. 4. Monthly rainfall in Tamale during 1960-1991, expressed in percentages.

tion from [15], working in Senegal. The longest dry spell in September was eight days, a month with the largest share of annual rainfall, whereas in August, the length was 19 days for the entire period of 52 years. At the start (May) and the end of growing season (October), spells of 14, 26, and up to 34 days occurred (**Table 3**), giving validity to the farmers' complaints recorded in the field (**Table 3**).

The probability of dry spell duration for March-October is presented in **Table 4**.

Dry spells of approximately four to seven days are expected in each month of the growing season, except for September, at about 80% probability; four years out of five are likely to have dry spells of this duration. There is also almost a 50% possibility that dry spells of approximately eight days will occur in June, July, and August, whereas dry spells of 9-13 days have a probability of 30-40% (one in three years) in the same months. In October, the chances of longer dry spells of 12 to 17 days are relatively high, at 56-28%.

These results are comparable with earlier studies [16], in the Nyankpala study area near Tamale. Even though the earlier researchers did not conduct analysis on a monthly basis, their analysis of dry spells based on 30 years of daily records (1969-1999) showed that dry spells of up to five days in duration have an almost 100% probability of occurring in the rainy season, with 88-96% for seven to eight days and 65-56% of 10-11 days. The limitation of their study was that the months in which these spells occurred were not indicated. Timing and duration of the spells within the growing season are, however, of crucial importance to farmers, in addition to duration, as clearly shown in the present study.

5. Conclusions

Analysis conducted in the present study indicates clear evidence of numerous dry spells occurring in Tamale throughout the rainy season. These results are of utmost importance, with implications for the food security of small-scale farmers, because major food crops in northern Ghana are still cultivated solely under rainfed conditions and dry spells affect their yield. Dry spells in the study area are longer in duration at the start of and toward the end of the rainy season than during the month of peak rainfall (September), which agrees with the evidence provided by different authors working in the sub-region and in the country. The minimum dry spell duration is two to four days at the period of highest rainfall (at approx-

Table 3. Dry spell analysis for Tamale during 1960-2011 (in days).

Year	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
1960	10	17	7	4	4	5	4	26
1961	1	10	8	5	5	6	4	16
1962	18	22	7	6	5	5	2	8
1963	23	25	8	7	6	5	5	7
1964	3	19	9	5	10	5	3	8
1965		20	7	3	11	4	5	12
1966		10	14	5	9	6	6	6
1967		7	7	7	11	6	3	12
1968	26	9	10	6	5	6	3	9
1969		7	5	12	7	8	4	8
1970		26	27	10	6	4	4	16
1971	25	7	6	8	7	3	3	13
1972		20	10	11	4	8	3	9
1973		10	9	6	12	2	2	17
1974		17	9	4	3	7	4	7
1975		5	10	9	11	19	5	10
1976			7	7	5	9	6	5
1977		29	7	7	13	13	5	9
1978	20	21	7	5	8	5	4	10
1979		22	13	5	4	10	3	12
1980			9	5	9	3	3	10
1981		12	8	7	9	5	7	11
1982		18	11	6	9	15	4	12
1983		21	7	5	15	16	3	27
1984	10	16	13	5	4	7	4	14
1985	4	6	9	8	3	3	4	23
1986	13	9	11	6	4	8	6	17
1987	11	23	34	10	4	4	8	15
1988	10	15	7	6	5	8	5	21
1989	11	15	7	5	5	4	4	14
1990		43	11	10	6	4	4	17
1991	11	13	6	5	5	5	6	7
1992	29		8	5	4	13	6	21
1993	21		14	5	6	6	4	8
1994	10	14	14	7	7	7	8	5
1995	21	13	9	6	8	7	5	10
1996	22	27	12	7	8	10	6	10
1997	1	9	5	4	6	6	4	7
1998			10	5	7	7	5	8
1999	26	7	6	6	5	5	4	13
2000		14	7	5	12	10	5	9
2001		6	7	8	4	4	3	14
2002	24	28	11	6	5	4	6	12
2003		14	9	3	9	8	4	9
2004	28	9	8	5	5	6	3	17
2005	12	12	11	6	5	14	5	16
2006	20	25	10	6	6	9	3	13
2007	8	10	6	14	17	3	4	10
2008	10	13	8	14	11	3	3	10
2009	28	9	8	6	6	2	3	6
2010	14	18	21	6	7	9	3	5
2011	17	8	17	5	8	6	4	11
Ave.	17	13	10	7	8	6	4	11

(Source: G-Met, 2013)

Table 4. Probability of exceeding dry spell duration (1960-2011).

Dry spell duration (days)	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
43	4.55						
42							
41							
40							
39							
38							
37							
36							
35							
34		6.67					
33							
32							
31							
30							
29	9.09						
28							
27		13.33					5.56
26	18.18						11.11
25	22.73						
24							
23	27.27						16.67
22	31.82						
21	36.36	20					22.22
20	40.91						
19	45.45				6.67		
18	50						
17	54.55	26.67		7.14			27.78
16	59.09				13.33		33.33
15	63.64			14.29	20		38.89
14		33.33	8.33		26.67		44.44
13	68.18	40		21.43	33.33		50
12	72.72	46.67	16.67	28.57			55.56
11		53.33	25	35.71			61.11
10	77.27	60	33.3	42.86	40		66.67
9	81.82	66.67	41.67	50	46.67		72.22
8		73.33	50	57.14	53.33	12.5	77.78
7	86.36	80	58.33	64.29	60	25	83.33
6	90.91	86.67	66.67	71.43	66.67	37.5	88.89
5	95.45	93.33	75	78.57	73.33	50	94.44
4			83.33	85.71	80	62.5	
3			91.67	92.86	86.67	75	
2					93.33	87.5	

(Source: G-Met, 2013)

imately 80% probability), whereas in the other months, dry spells of 7-13 days are not exceptional. At the start and the end of the rainy season, dry spells of two to three weeks in duration can also be expected.

Additionally, even though the current work could not detect evidence of changes in rainfall patterns, based on the available data, many earlier studies have indicated that the rainy season may become shorter and the climate of West Africa may become drier. This is especially important in light of the increasing population, accelerated land degradation through unsustainable cultivation practices, and other socio-economic factors contributing to uncertainty of the farmers' livelihoods.

The Government of Ghana, through relevant agencies such as the Ministry of Food and Agriculture (MoFA), Ministry of Local Government and Rural Development (MLGRD), Environmental Protection Agency (EPA), and others should make use of these results as well as those of similar studies to develop appropriate action-oriented policies and fact sheets for farmers and extension service providers, which would greatly assist their efforts in coping with adverse climatic conditions.

Acknowledgements

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