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ANALYSIS OF DRY SPELLS AND ITS APPLICATION TO CROP PLANNING IN THE SUDANO-SAHELIAN REGION OF NIGERIA

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Abstract

This study analyzed the sequences of dry and wet spells occurrence using the 1918-2004 rainfall data from the Sudano-Sahelian region in Nigeria (SSRN). It evaluates and uses the distribution and probabilities of the intra-season dry spell to describe how effective crop planning can be achieved in the midst of prevailing dry spells in SSRN. The approach adopted also involves the use of some other empirical computations to determine the risk level and percentage frequencies of dry spells for successive days after sowing (DAS) a crop. The results of the probabilities of maximum dry-spell length exceeding 7 to 15 days over the next 30-days helped to assess if the break of a dry spell due to rain has a significant impact on the subsequent spell length. The maximum dry spell length at five probability levels (risk levels) for different DAS and rainfall thresholds as well as the computation of the probable length of growing season provides estimates of appropriate time of sowing, type of crop to grow, and the cropping pattern to be adapted in the midst of the prevailing dry spell conditions in SSRN.

1. Introduction

A dry day and its sequence called dry spell is a useful proxy definition of drought condition or occurrence at a place. It simply connotes the absence of rain for a period in a locality. The characteristics of dry spell observed in an arid or semi-arid region, determines to a great extent what becomes of the few, scanty and poorly distributed rains usually observed in such areas (Wilhite, 2000; Adefolalu, 1986). Its impact on an environment cannot be over emphasized. Its occurrence and distribution over an area impinges and heavily undermines the effect of the previous rainfall occurrences (Otun, 2005). Furthermore, it also accounts for the usual and subsequent heat interactions and exchanges within such environment. Dry spells are usually associated with high rate of evaporation and transpiration, high demand for water among human beings and animals (Sawa, 2002). The knowledge of the hazards associated with such prevailing drought conditions or spells makes it imperatively necessary to carefully study its characteristics so as to provide useful information for its management (Panu and Sharma, 2002; Wilhite, 2000; and Oladipo, 1993).

The empirical analysis of dry spell (EADS) is one of such approaches aimed at studying the characteristics, occurrences and the distributions of these dry spells, especially within the growing season, in order to provide useful information required for effective crop planning and subsequent drought management (Sivakumar, 1992).

The Sudano-sahelian region in Nigeria (SSRN) is a semi-arid region and lies between latitudes 10^{o} N and 14^{o} N and longitudes 3^{o} E and 14^{o} E as shown in Figure 1 below. It has a distinct and well-defined long dry season of continuous dry spells, starting from the month of October to March of the following year. The occurrence of the inter-year dry spell has been of great concerns over the years (Sawa 2002). It is therefore necessary to study the

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distribution and the probability of occurrence of these dry spells in the years with available records.

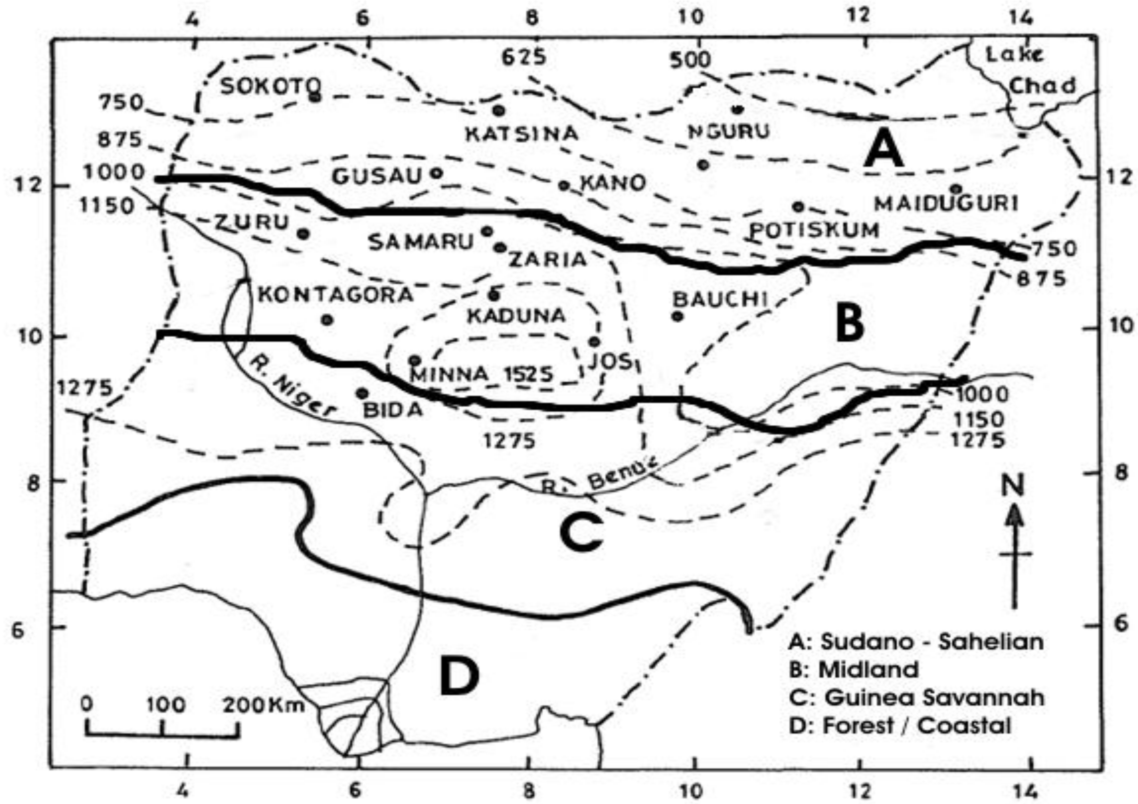

Figure 1: Map of Nigeria Showing the Sahelian Region and the Synoptic Stations Used in the Study.

2. Dry spell analysis (DSA) and its applications

The empirical DSA approach proposed by Sivakumar (1992) for agricultural applications is being adopted in this study. It was however, slightly modified to include the following analytical steps and computations.

- Analysis of the distribution of dry days within the month of each year for each station under study; and the subsequent average number of dry spells within each station under study.
- Analysis of the maximum dry spells within 30 day period starting from the first day of each decade of each growing month.
    - Calculate the probabilities of dry spells computed on calendar day basis. i.e. Obtain the respective probabilities of dry spells exceeding 7, 10 and 15 days within the 30 days after the first day of each decade of the year at each station.(Note that the probability of event A is estimated as nA / n; if a sample of n observations has nA values in the range of event A,).

Estimating the length and frequencies of dry spells computed with respect to sowing-day basis. It involves using seven (7) different rainfall threshold values (i.e 1, 5, 7, 10, 15, 20, 25mm) to define dry spell or moisture inadequacy, Obtain the length of dry spell (in days) at three probability levels for different days after sowing (DAS). The onset of rains will be assumed as the sowing date. Empirical derivation of the onset of rains as presented in the literature by Stern *et al*. (1981) and Olaniran and Summer (1989) will be followed, since their estimation is based on a simple and practical definition of soil moisture adequacies as a condition for sowing or planting date.

- Calculating the percentage frequency of dry spells for different rainfall threshold at each station.

The application of this modified empirical DSA approach is expected to characterize the drought occurrences, as well as provide useful information on the inherent dry spell conditions that can be easily interpreted by crop planners and managers for effective coping and management of such dry spell anomaly. Such information is also useful for plant breeders in developing breeds or varieties of crops which can adequately cope with the various inherent dry spell conditions being evaluated.

3. Results and Discussion

The available rainfall records between 1918 and 2004, for seven stations in the Sudano-Sahelian Region of Nigeria (SSRN), namely Gusau, Kano, Katsina, Maiduguri, Nguru, Potiskum and Sokoto were checked for consistency and used for the dry spell analysis (DSA) mentioned above.

Table 1 shows the probability of occurrence of dry days and wet periods. It is clear from this table that, the occurrence of the 1-day dry spell is up-to four times the wet spells for the 1-day rainfall totals for each of the stations under study. This makes it crucial to look closer into the pattern of the dry days and make a clearer picture of the dry spells within the wet season and within the year for all the stations under study.

Table 1: Probability of occurrence of dry and wet spells for various seasonal rainfall totals

	Percentage Occurrence of Dry and Wet Periods for each Seasonal Rainfall Totals (%)											
	1-Day		5-Days		7-Days		10-Days		15-Days		30-Days	
Station	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Gusau	80.9	19.1	57.1	42.9	53.0	47.0	49.3	50.7	46.4	53.6	40.5	59.6
Kano	84.0	16.0	62.1	38.0	58.9	41.1	55.1	44.9	51.9	48.2	45.7	54.3
Katsina	85.9	14.1	63.8	36.2	60.6	39.4	56.7	43.3	53.6	46.4	48.7	51.3
Maiduguri	86.1	13.9	64.3	35.7	60.4	39.6	56.7	43.3	52.1	48.0	46.8	53.2
Nguru	89.2	10.9	69.6	30.4	65.9	34.1	61.7	38.3	58.2	41.8	52.4	47.6
Potiskum	85.5	14.5	62.8	37.2	58.9	41.2	54.4	45.6	50.7	49.3	45.8	54.2
Sokoto	86.4	13.6	64.8	35.2	60.6	39.4	56.1	43.9	52.3	47.7	47.1	52.9

Table 2: Probability of occurrence of dry spell occurrence within SSRN

	Probability of occurrence of Dry Spell (%)					
Months	< 2 days	3-4 days	5-6 days	7 – 8 days	9-10 days	>10 days
Jan	0.01	0.08	0.04	0.11	0.07	99.67
Feb	0.03	0.11	0.00	0.11	0.22	99.53
Mar	0.19	0.07	0.37	0.16	0.34	98.86
Apr	1.39	2.56	2.85	3.01	2.52	87.66
May	8.70	11.38	10.72	10.33	8.78	50.09
Jun	21.78	23.92	17.04	11.50	7.84	17.92
Jul	42.39	30.54	15.44	7.06	2.90	1.67
Aug	54.22	27.77	12.04	2.77	1.11	2.09
Sep	27.41	24.03	15.74	10.30	8.18	14.35
Oct	2.18	3.13	4.06	4.52	3.07	83.04
Nov	0.06	0.11	0.08	0.05	0.00	99.70
Dec	0.01	0.00	0.00	0.00	0.00	99.99

The dry day's series were further processed to obtain the maximum dry spell in a 30-day period starting from the first day of each defined decade. The three decades in each month is defined as starting from the 1st, 11th and 21st day of each month. Obviously, the last decade in each month, which includes all the days to the end of the month, could either be 8, 9, 10 or 11 days, depending on the month.

Probabilities of maximum dry-spell lengths exceeding 7, 10 and 15 days within a month (30-days), from the first day of each decade, were then calculated. According to Sivakumar (1992), the choice of these spell lengths reflect the need to consider shorter spell lengths for drought-sensitive crops such as Maize, as opposed to drought-hardy crops such as millet, which can withstand longer dry spells of even 15 days. Also, for a given crop, certain growth stages are more sensitive to droughts and have a higher water requirement.

Furthermore, a probability of occurrence of conditional dry spell was also calculated and used to assess whether a break of a dry spell due to the occurrence of a prior rain has any significant impact on the subsequent dry spell.

3.1 Dry spell analysis for agricultural applications in SSRN

Table 3 below shows the probabilities of dry spell occurrences exceeding 7, 10 and 15 days within a month after the first day of each decade of the year in SSRN. This provides a quick overview of the drought risks associated with dry spell observed within the rainy season in SSRN. Up-to mid June, the probability of occurrence of maximum dry-spell exceeding 5 and 7 days is above 30%. The conditional dry-spell probabilities also show that even if the dry spell is broken due to rain, the risk of dry-spell not exceeding 10 days exceeds 20% up to 1st decade in June. It is clear that sowing field crops with first rains before June is prone to considerable risks.

The Onset of rains is often being used as a guide for selecting sowing dates for a year. The one major criterion for defining the onset of rains is usually when a cumulative of N-days rains is above a threshold (Stern et. al., 1981 and Sivakuma, 1992). The frequency distribution of the first dates of each year with cumulative of N-days rainfall above 10, 20 and 30mm were analyzed and used to obtain the most probable onset dates. Using N = 2 days (Stern *et al.* (1982), and with the assumption that a 80% probability of occurrence of this dates can be a guide to obtaining the most probable sowing dates; which turned out, by using Figures 2 and 3, to be 163rd day of the calendar year..

The length of dry spells occurring after each consecutive 10-days after DAS was also determined for each of the five rainfall thresholds (requirement) and at five probability of occurrence levels (90%, 75%, 50%, 25% and 10%). The five rainfall thresholds, 5, 10, 15, 20 and 25mm depths selected are representative of the demands of water; which stands in agriculture applications as proportion of crop water requirements. These thresholds have some relevance for water required for sowing, fertilizer application and weeding operation under rainfed condition. The choice of the probability of dry spell occurrence or levels also reflects the degree of certainty or risks associated with the dry spell observed. Tables 4 and 5 below show the mean rainfall and the dry-spell length at different probability levels of occurrence for each of the stations under study.

Table 3: Probability (%) of maximum and conditional dry spells exceeding indicated lengths within 30 days after a starting date at SSRN

Decade / Date		Maximum Dry Spell Exceeding 5, 7, 10 and 15 days.							
		Maximum Dry Spell				Conditional Dry Spell			
		>5 Days	>7 Days	>10 Days	>15 Days	>5 Days	>7 Days	>10 Days	>15 Days
1	May	95	86	66	38	72	57	36	16
11	May	90	73	48	21	75	53	28	10
21	May	82	57	32	10	69	43	21	5
1	Jun	70	48	23	6	64	40	16	3
11	Jun	59	32	15	2	50	25	9	1
21	Jun	47	21	5	0	40	16	4	0
1	Jul	36	14	3	0	33	11	2	0
11	Jul	30	7	2	0	28	6	2	0
21	Jul	25	6	1	0	25	6	1	0
1	Aug	21	6	2	0	19	5	1	0
11	Aug	25	9	3	0	25	9	3	0
21	Aug	42	21	7	1	41	21	7	1
1	Sep	66	44	21	6	65	43	21	5
11	Sep	91	75	54	26	89	73	51	24
1	Sep	99	91	80	55	91	84	71	46
1	Oct	100	98	95	79	73	71	66	50

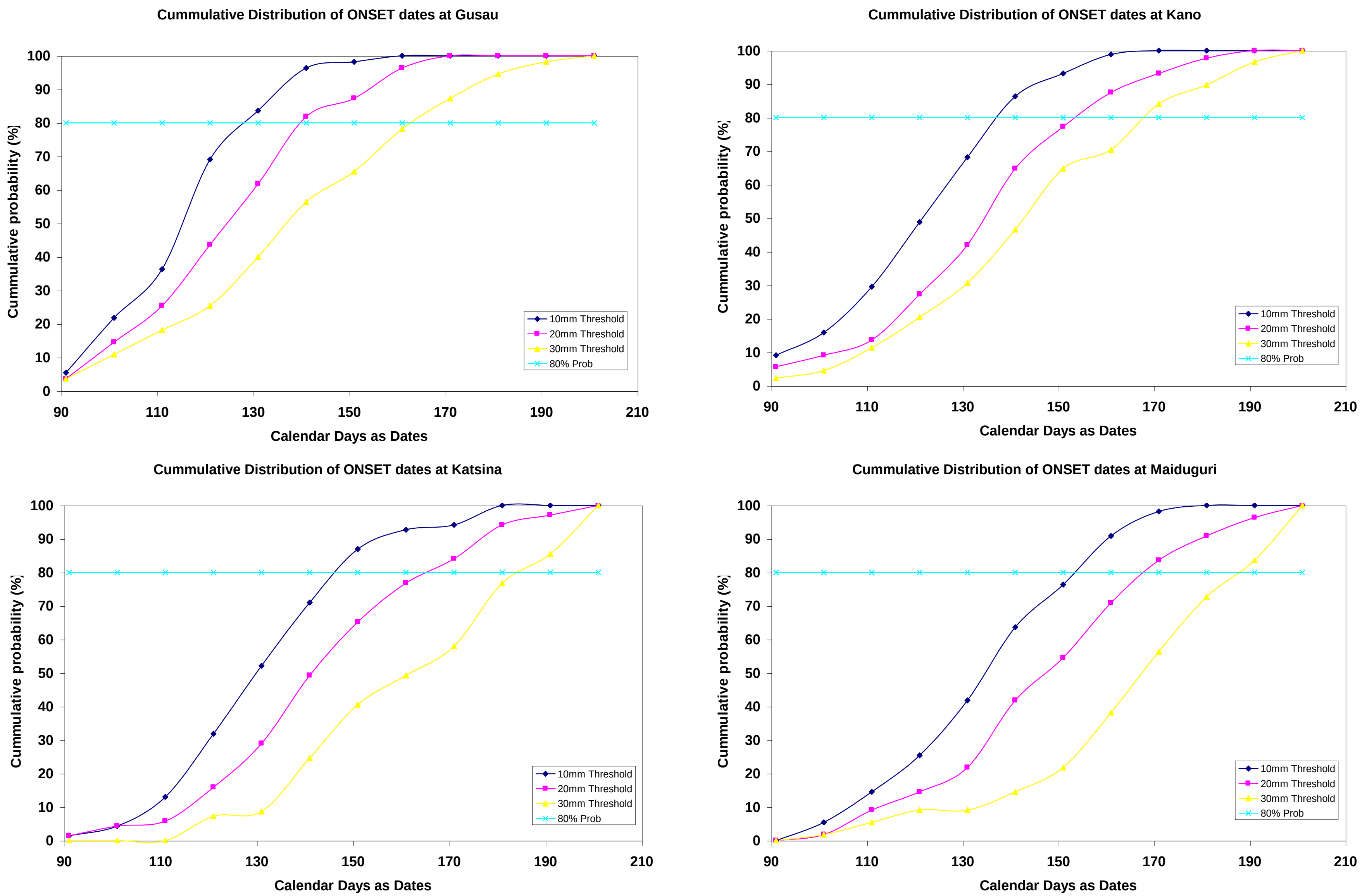

Figure 4: Onset dates at Gusau, Kano, Katsina and Maiduguri Stations for different rainfall thresholds

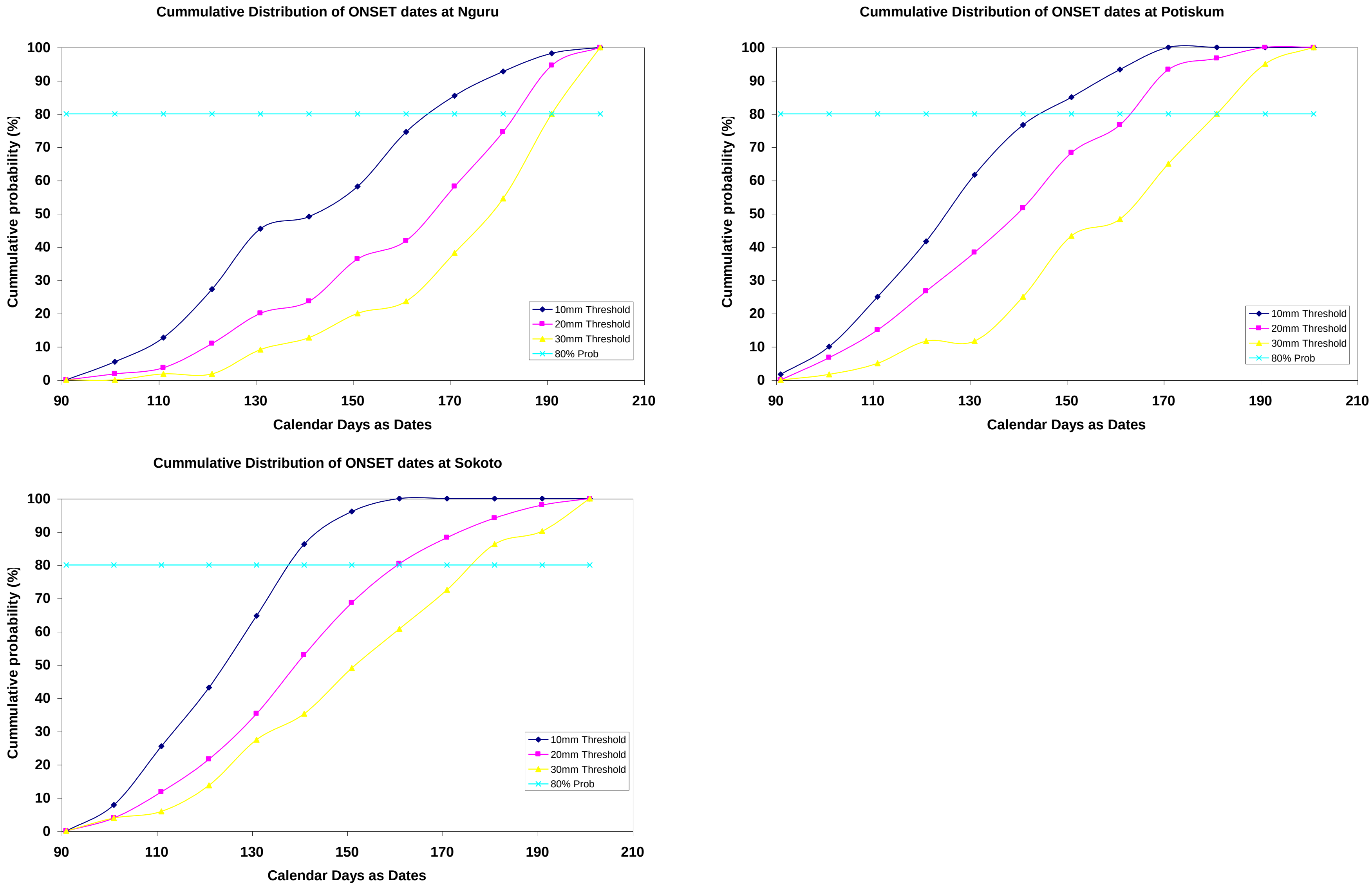

Figure 5: Onset dates at Nguru, Potiskum and Sokoto Stations for different rainfall thresholds

Table 4: Maximum length of dry spell (days) at five probability levels for different DAS at SSRN.Data are presented under each of the five rainfall thresholds (5, 10, 15, 20 & 25mm) used for dry-spell computations. (Optimum Sowing Day: 163rd day)

DAS	Rainfall Depth (mm)	Rainfall Totals Thresholds (Representative of Water Demand Conditions)																								
		5mm					10mm					15mm					20mm					25mm				
		90%	75%	50%	25%	10%	90%	75%	50%	25%	10%	90%	75%	50%	25%	10%	90%	75%	50%	25%	10%	90%	75%	50%	25%	10%
10	48.4	6	4	1	1	0	9	6	3	1	0	14	8	4	1	0	18	11	6	2	1	27	16	9	3	1
20	59.9	5	3	2	1	0	8	5	2	1	0	12	7	4	1	0	17	10	4	2	1	23	14	7	3	1
30	63.7	6	3	1	0	0	8	4	2	1	0	11	6	3	1	0	15	9	4	2	0	22	13	6	3	0
40	74.2	5	3	1	0	0	7	4	2	1	0	10	6	3	1	0	16	8	4	1	0	26	14	6	2	1
50	80.1	5	3	1	0	0	8	5	2	1	0	15	8	3	1	0	25	12	5	2	0	30	23	9	3	1
60	73	11	4	2	0	0	13	6	3	1	0	19	12	4	2	0	26	18	5	3	0	30	25	14	4	1
70	67.3	14	9	3	0	0	21	12	4	1	0	23	18	10	2	0	29	23	15	3	1	33	28	21	5	2
80	60.9	22	17	8	2	0	24	22	12	3	1	29	26	20	8	2	33	29	22	10	4	36	32	26	19	6
90	41.2	26	21	19	8	1	32	26	20	14	7	33	31	26	19	8	41	32	27	20	9	41	41	32	25	15
100	19.8	31	30	23	18	9	41	31	26	19	14	41	34	31	24	18	41	41	31	25	19	41	41	32	30	24
110	8.1	41	41	31	25	19	41	41	35	30	24	41	41	41	30	25	41	41	41	31	30	41	41	41	33	30
120	4.4	41	41	41	31	30	41	41	41	33	30	41	41	41	41	30	41	41	41	41	31	41	41	41	41	33
130	1.1	41	41	41	40	30	41	41	41	41	32	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
140	0.2	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
150	0	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35

Table 5: Indications of Probable Length of Growing Season in SSRN (days)

	Dry Spell Threshold (days)	Rainfall Totals Thresholds (Representative of Water Demand Conditions)																								
		5mm					10mm					15mm					20mm					25mm				
		90%	75%	50%	25%	10%	90%	75%	50%	25%	10%	90%	75%	50%	25%	10%	90%	75%	50%	25%	10%	90%	75%	50%	25%	10%
1	5	29	96	104	114	124	20	79	97	113	120	20	21	93	109	117	20	20	77	100	114	20	20	21	94	109
2	10	94	101	111	121	129	81	94	103	114	124	20	89	99	111	121	20	47	96	110	117	20	20	83	100	111
3	15	96	101	111	121	130	91	99	107	119	126	79	90	101	111	121	29	84	97	111	119	20	46	91	103	116
4	20	99	104	111	121	130	91	101	110	119	126	86	94	101	111	121	70	87	99	111	120	20	76	93	106	116
5	25	99	104	111	121	130	91	101	111	119	126	89	94	101	111	121	77	90	100	111	120	60	77	94	106	116

Using a 30 mm rainfall depth threshold as defined by Stern *et al*. (1982), (obtained by simple interpretation of Figures 3 & 4), the results provide a good idea of the average rainfall pattern during the crop cycle at each station under study. For SSRN, assuming that a pearl millet variety of a 90-day maturity duration comes to panicle initiation stage within 20 days after sowing (DAS) and to the flowering stage by 50 - 60 DAS, mean rainfall from sowing to panicle initiation stays around 59 mm per decade and increases to 86 mm per decade by the time of flowering.

The deductions that can be made from the 90% probability column of Table 4 is that, for each consecutive 10-day period after sowing, the dry spell with 90% chances or occurrence, will end within the number of days given in Table 4.. Using the earlier example given above, at 50 DAS, for the 10-mm rainfall threshold, 90% of the dry spells will end in 7 days or less, while 75% of the dry spells will end in about 4 days or less.

The frequencies of dry spells have also been computed at five rainfall threshold of 1, 10 and 20 mm for dry spell of < 5, 5 - 10, 10 - 15, 15 - 20, 20 - 25, 25 - 30 and > 30 days. The percentage frequency of dry spells at Gusau, Kano, Katsina, Maiduguri, Nguru, Potiskum and Sokoto were averaged and the mean for SSRN is as shown in Table 6 below. The table also shows that at the lower rainfall threshold of 1 mm, the frequency of dry spells of less than 5 days is by far much higher in comparison to other dry-spell ranges. As the rainfall threshold or water requirement increases from 1 to 20 mm, the percentage frequency of dry spells of less than 5 days decreases and the frequency of dry spell for the other ranges increases. This is an indication of the likelihood of how longer dry spell due to higher water demands are accommodated before 10 - 90 days after sowing.

4. Conclusion

The EADS approach has been utilized to analyze the dry spell occurrences in the semi-arid region of Nigeria. The derived data obtained in the study on maximum and conditional length of dry spell for various decadal dates and DAS in a year, provides ample information for various agricultural applications.

The data on the most probable growing season obtained in the study for SSRN can also serve as guides for developing various crop breeds or varieties that can adequately cope with the various dry spell conditions in SSRN locality.

This information, obtained from EADS, is useful for determining crops that can withstand prevailing dry spell and water deficit conditions. EADS has therefore created the opportunity of obtaining necessary drought information that can be relayed to the general public and thus improving the present poor level of preparedness and lack of mitigation plans within SSRN.

Specifically, the study has been able to provide empirical basis or tool for effective management of the drought in the Sudano Sahelian areas of Nigeria. This can also act as a drought management support tool for proposed National Drought Monitoring Plan in Nigeria.

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