JOURNAL OF METEOROLOGY AND CLIMATE SCIENCE
J. Met & Clim. Sci. 21(1): 114-122 (June, 2022)

Analysis of Rainfall Variability for Crop Planning in Abeokuta, Nigeria.

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ABSTRACT

The study analyzed temporal variability in annual, seasonal, monthly and weekly rainfall in Abeokuta. Daily rainfall data for Abeokuta was obtained from the Nigerian Meteorological Agency Abuja for a period of 21 years. Coefficient of variation was used to analyze the temporal rainfall variability. Markov Chain Model was adopted for drought analysis using the Standard Meteorological week (SMW). The Coefficient of variation of 18.3 per cent indicated that the annual rainfall of Abeokuta has a low variability over the years. The seasonal contribution to annual rainfall was 43.8% and 50.9% for early and late planting (rainy season) and 5.3% for dry season respectively. Within the rainy season, September was the highest rainfall contributing month (16.3%) followed by July (14.3%) and June (14.0%). Mean weekly precipitation amount and its assurance reaches the peak (>50 mm/week) during 18th SMW, 28th SMW, 29th SMW and 39th SMW but lower in other SMW weeks. Onset of rainy season occurred at 14th SMW and runs till the 44th SMW before decline in rainfall for the dry season to set in. There is water availability for rain water harvesting from the month of April to October which can be utilized as crop saving irrigation during the short dry spell period of the rainy season and for irrigation farming during the dry season.

Key words: ***Rainfall variability, Marcov chain model, Crop planning, Standard Meteorological Week***

INTRODUCTION

Unpredictable distribution and variability of seasonal rainfall has generally characterized the tropical climate. Therefore, moisture remains the most critical agrometeorological factor for crop production in the region (Bello, 1996). Reduction in yield and change in the pattern of crop growth are often results of water (Bello, 1986). The majority of farmers in West Africa and Nigeria in particular depend on rain-fed crop production systems (Boko *et al*., 2007).

Abeokuta is characterized by a tropical climate with distinct wet and dry seasons (Eruola, 2011). The wet season is associated relatively with the prevalence of the moist Maritime Southerly Monsoon from Atlantic Ocean and dry season by the Continental North Easterly harmattan winds from Sahara desert. The area is located within a region characterized by bimodal rainfall pattern (commences in March and reaches the peak in July and September, with a short dry spell in August). The long dry period extends from November to February (Eruola, 2011). The annual rainfall ranges between 1400 and 1500mm in Abeokuta and environs. The region is characterized by relatively high temperature with mean annual air temperature of about 30^{o}C. The greatest variation in temperature is experienced in July (25.7^{o}C) and in February (30.2^{o}C). The humidity is lowest (37-54 %) at the peak of dry season in February and highest at the peak of the rainy season between June and September (78-85 %).

According to Tiwari *et al*, (1992), the general picture of a particular region can be understood through the knowledge of average monthly, seasonal and annual rainfall but the weekly rainfall data analysis gives more useful and precise information for the rainfall based crop planning. Selection of different cropping systems will be made possible by making use of Wet and Dry spells rainfall probabilities (Jadhav *et al*., 1999). The coincidence of wet spells with the sensitive phenophases sometimes may be more detrimental to the crop development (Bello, 1987). On the other hand, the occurrence of dry spell at the time of ripening would become beneficial. Therefore, for establishing precise crop-weather relationships to take some useful decisions for crop management practices, contingent crop planning and related farm operations for sustaining crop production the probabilities of wet and dry spells can serve as a basic input (Sheoran *et al*, 2008).

Analysis of annual, seasonal and monthly rainfall of a region is useful to design water harvesting structure. Similarly weekly rainfall analysis gives more useful information in crop planning (Sharma et al., 1979).

Marcov chain probability model has been used by researchers to determine the long term frequency of wet and dry spells (Panda 2002). Using the Markov Chain approach, Kingra, Gill and Singh (2013) computed weekly rainfall probabilities for crop planning for the Sub-Mountainous Punjab area of India. The week-wise analysis was done for initial and conditional probability at different rainfall limits (10, 20, 30, 40 and 50mm).

In Nigeria Bernard T and Michael T.I (2019) used the marcov chain model for dry and wet spell for agricultural planning in the middle belt region of Nigeria and found that the earliest onset of rainy season in the region occurred on week 9th (26th February) at Ilorin and the latest cessation was on week 46th (12th-18th November) at Lokoja with a mean cessation on week 42nd (15th-21st October) over the whole region.

Ezeh *et al*, 2016 used the Marcov chain model for simulation of probability of dry and wet spells at a given annual intervals for a semi-arid (Bsh) and the equatorial (Af) climatic zones in the Northern and Southern Nigeria using Katsina and Borno States (in the Bsh climatic zones) and Lagos and Rivers States (in the Af zones).

Oduwole et al (2011) also investigated probability of dry and wet spells at Yola, Nigeria.

WMO (1982) described a spell as being wet if 30 mm or more rainfall is received in 10 days period and based on that, this study assumed that the week is wet if it receives 21 mm or more rainfall.

Therefore, an attempt has been made to analyze the daily rainfall data of Abeokuta to determine the annual, seasonal, monthly and weekly rainfall frequency and their implication for crop planning.

MATERIALS AND METHODS

The daily rainfall data of Abeokuta spanning 21 years (figure 1) which was the volume available at the period of collection was obtained from the Nigerian Meteorological Agency Abuja and analyzed for rainfall distribution pattern of the area to determine the probability of wet and dry spells and its implications for crop planning. From the daily rainfall data, annual, seasonal, monthly and weekly total rainfall was determined for each year. The Standard Meteorological week (SMW) was determined in drought analysis using Markov Chain Model and planning crops accordingly. A week receiving less than 21 mm rainfall is taken as dry spell week and a week receiving 21 mm or more rainfall as a wet week (Subramaniam and Raju, 1988).

According to Subramaniam and Raju, (1988) the initial probability of a week being dry is defined by,

$P(d) = F(d) / N$ ……………………………………(1)

Where

P(d) = probability of the week being dry

F(d) = frequency of dry weeks,

N= total number of years of data being used

Thus the probability of week being wet is given as

$P(w) = F(w) / N$ ………………………………………….(2)

Where

P(w) = probability of the week being wet

F(w) = frequency of wet weeks,

The conditional probabilities of a week being dry preceded by another dry week is

$P(d/d) = F(dd) / F(d)$ ……………………………………(3)

Where

P(d/d) = probability of the week being dry preceded by another dry week

F(d/d) = frequency of dry week preceded by another dry week

The consecutive dry and wet probabilities are computed as under

$P(2D) = P(dw1) \times P(ddw2)$…………………………….(4)

$P(3D) = P(dw1) \times P(ddw2) \times P(ddw3)$…………………(5)

Where

P(d/d) = probability of 2 consecutive dry weeks

P(dw1) = probability of the first week being dry

P(ddw2) = probability of 2^{nd} consecutive dry week given the preceding week being dry

P(ddw3) = probability of 3^{rd} consecutive dry weeks

P(ddw3) = probability of 3rd week being dry given the preceding week dry.

Similarly, probability of occurrence of three consecutive wet weeks were also determined using the Markov Chain process (Robertson, 1976).

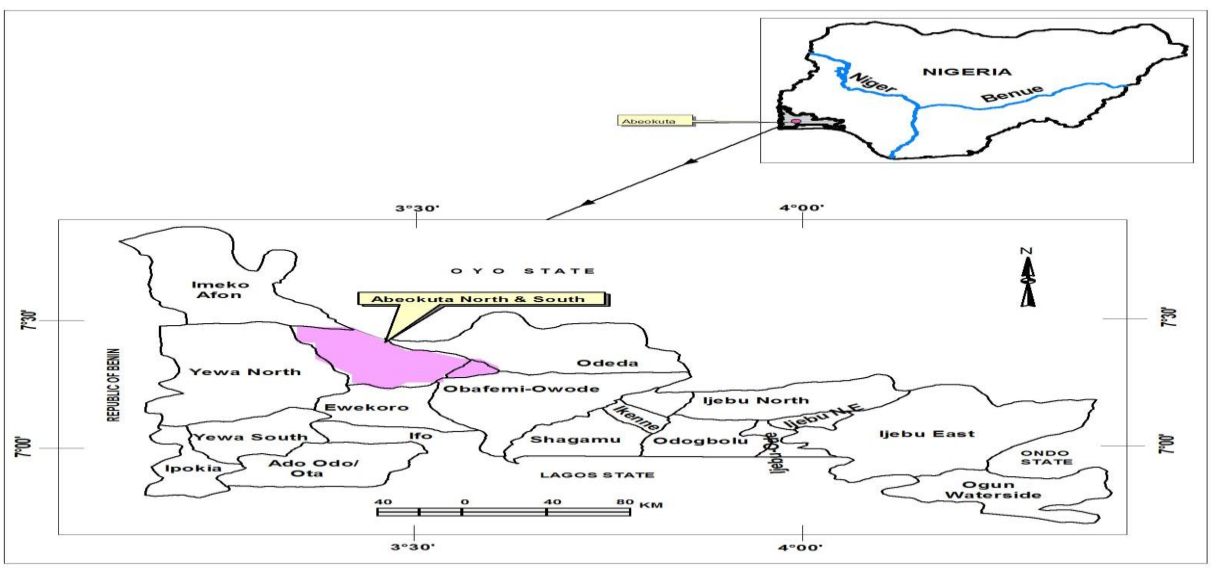

Figure 1: Location of the study Area

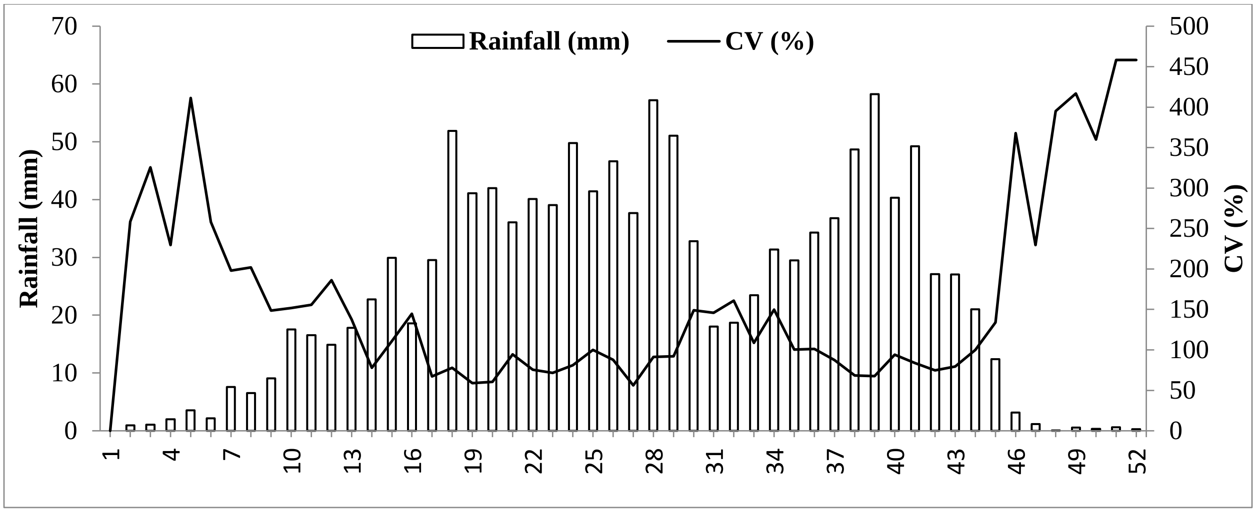

Figure 2: Mean weekly rainfall distribution at Abeokuta (1997-2017)

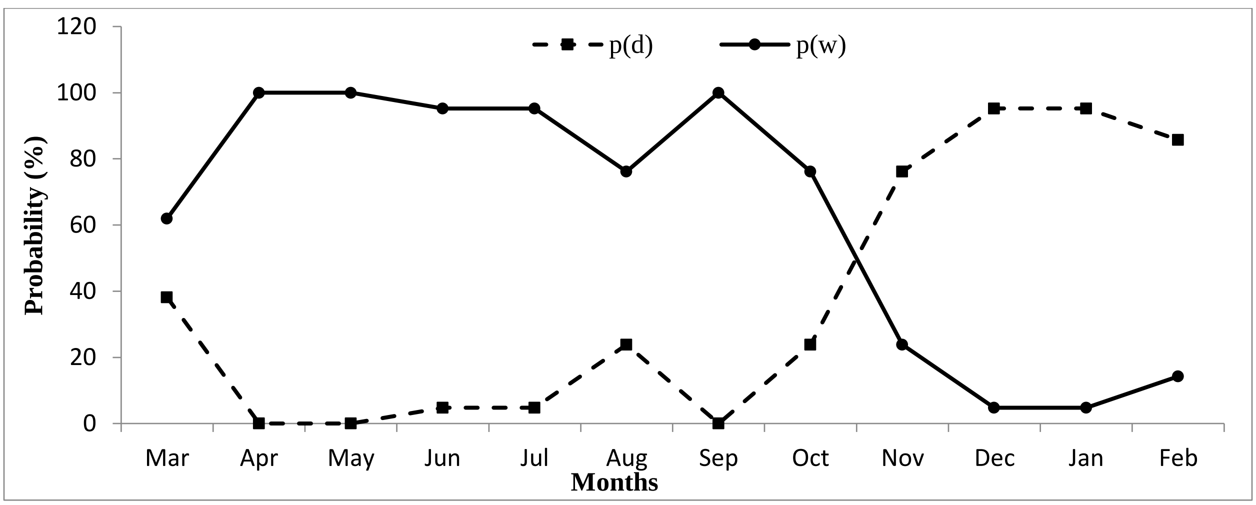

Figure 3: Mean monthly probabilities of dry and wet spells sequences

RESULTS AND DISCUSSION

Annual rainfall

The compilation of 21 years daily rainfall data of Abeokuta revealed that the average annual rainfall of the station was 1208.2 mm with 18.3 per cent coefficient of variation (CV) indicating low variability over the years (Table 1). The rainfall was above normal in 8 years and below normal in 13 years. The maximum and minimum rainfall of 1615.7 mm and 849.2 mm was recorded in the years 2007 and 2001 respectively.

Seasonal rainfall

The seasonal rainfall distribution (Table 1) in terms of early planting (March to June), late planting (July to October) and Dry season (November to February) revealed that Abeokuta enjoys a well-defined pattern of seasonal rainfall. The rainfall received was highest in late planting rainy season (615.4 mm) followed by early planting rainy season (529.1 mm). The seasonal percentage contribution to total annual average rainfall was 43.8%, 50.9% and 5.3% for early planting, late planting and dry seasons, respectively. The lowest CV recorded in early planting rainy season (22.9%) indicates more reliable receipt of rainfall.

Monthly rainfall

The data on monthly rainfall (Table 1) revealed that September had the highest (196.8 mm) rainfall value followed by July (172.6 mm) and then June (168.6 mm). The least rainfall receiving months were January (6.9 mm) and December (6.9 mm), contributing 0.7% each to the total percentage. The period from April to June was the most dependable for receipt of rainfall (CV 48.5%, 32.8% and 46.5%), while there will be a need for supplemental irrigation in the month of April (CV 81.2%). Despite the late planting period having the highest rainfall value (615.4 mm), only the month of September with 27.5% CV has a reliable receipt of rainfall. Hence supplemental irrigation will be required in the months of July, August, and October. The months of November to February represent the dry season with very low to no rainfall at all with CV of 102.5%, 248.7%, 211.3% and 112.2% respectively. Water harvested during the rainy season can be applied for irrigation farming during the dry season months in order to have an all-year-round cropping.

Table 1: Mean monthly and seasonal rainfall (mm) at Abeokuta (1997-2017)

Months	Rainfall (mm)	Contribution to total (%)	STD	SE±	CV (%)
March	70.1	5.8	56.9	12.4	81.2
April	129.2	10.7	62.6	13.7	48.5
May	161.3	13.3	53.0	11.6	32.8
June	168.6	14.0	78.4	17.1	46.5
Early rainy season	529.1	43.8	121.3	26.5	22.9
July	172.6	14.3	101.7	22.2	58.9
August	102.8	8.5	65.6	14.3	63.9
September	196.8	16.3	54.1	11.8	27.5
October	143.2	11.9	74.2	16.6	51.8
Late rainy season	615.4	50.9	197.8	43.2	32.1
November	29.3	2.4	30.0	6.7	102.5
December	6.9	0.6	17.2	3.9	248.7
January	6.9	0.6	14.5	3.2	211.3
February	20.7	1.7	23.2	5.1	112.2
Dry season	63.7	5.3	40.6	8.9	63.8
Grand total	1208.2	100.0	221.0	48.2	18.3

Weekly rainfall

The weekly average rainfall ranges from 0.00 mm (1st SMW) to 58.24 mm (39st SMW). Mean weekly precipitation amount and its assurance was low from 1st SMWs to 9th SMW reaches the peak (>50 mm/week) at 18th, 28th, 29th, and 39th SMWs to 36th SMW. The weekly average rainfall during the late planting rainy season (July to October) varying from 18.04 mm to 57.18 mm is relatively higher than that of early planting rainy season (March to June) ranging from 14.89 mm to 57.17 mm and that of dry season (November to February) ranging from 0.00 mm to 12.39 mm. (Figure 1). The CV values during the late planting rainy season were relatively less (75%-178%) due to stable rainfall occurrence as compared with early planting rainy season (78.2%-250%) and Dry season (180% to 470%). (Table 2). The low value of rainfall amount (< 21 mm) indicating dry spell weeks in all dry season weeks is a call for irrigation farming in Abeokuta during this period. Likewise during the 10th, 11th, 12th, 13th and 16th SMW of early planting rainy season as well as the 31st and 32nd SMW of late planting rainy season the low value of rainfall amount (< 21 mm indicated that the rainfall was much erratic in distribution and there is need for supplemental irrigation.

Probability of dry and wet spells

The probability of occurrence of dry spells (Table 2) is as high as 80-100 per cent in the first 9 SMWs and also as high as 71.4-100% from 45-52 SMW indicating the dry season months of the year. From the 10th SMW to 16th SMW which represent the beginning of rainy season, the probability of occurrence of dry spells is as high as 57.7-81.1%. From 30th SMW to 34th SMW the probability of occurrence of dry spells is between 52.4-76.2%. The probability of getting double dry spell weeks (P2d) is as low as 0.00 mm-46.7 during the 10th-45th SMWs and also as low as between 47.1-47.6 from 1st to 9th SMWs as well as from 47.6-50% during 46-52 SMWs.

On the other hand, the probability of getting rainfall (wet spell) remains very high (57.1-81.0%) during 17th to 29th SMWs and was also high (52.4-85.7%) during 35-43 SMWs but was low in other SMWs and as low as 0.0% from 1st SMW to 4th SMW and also from 47th SMW to 52nd SMW. The probability of getting double wet spell weeks (P2w) is on the average (50%) at the 39th SMW and was as low as 0.00-47.1% in all other SMWs of the year.

The probability of having two consecutive dry days within a dry week (P2d) is low throughout the 52 SMWs and lowest (0.00%) during 18th, 19th, 23rd, 25th, 38th, 39th and 52nd SMWs. The probability of getting three consecutive dry days within a dry week (P3d) was also found to be low throughout the 52 SMWs and lowest (0.00%) during 17th, 18th, 19th, 22nd, 23rd, 25th, 37th, 38th, 39th 51st and 52nd SMWs.

The probability of having two consecutive wet days within a wet week (P2w) is low throughout the 52 SMWs and lowest (0.00%) during the 1st 7 SMWs, from 45th to 52nd SMWs and at the 15th and 30th SMWs. The probability of getting three consecutive wet days within a wet week (P3w) was also found to be low throughout the 52 SMWs and lowest (0.0-0.09%) during the 1st 12 SMWs, 14th, 15th, 29th, 30th, 30th, 31st, 32nd, 38th, 39th SMWs as well as from 44th to 52nd SMWs.

The probability of occurrence of a dry spell week succeeded by a wet spell week was high throughout the entire 52 SMWs but highest (100%) in the first 8 SMWs and from 46th SMW to 52nd SMW.

The probability of occurrence of a wet spell week succeeded by a dry spell week is as high as from 50-100% during the 52 SMWs with 19th, 20th, 24th, 26th, 39th and 40th SMWs having 100% occurrence probability.

The probability of getting a month being dry remains in the range of 80 – 100 per cent for the entire dry season months of November to February (Figure 2).

However, the months of March to October were found to have 60–100 per cent assured rainfall.

Table 2: Mean weekly rainfall, variability and probability of different dry and wet spells at Abeokuta (1997-2017)

Week	Average Rainfall (mm)	Simple Probabilities (%)		Conditional Probabilities (%)				Consecutive dry day probabilities (%)		Consecutive wet day probabilities (%)	
		P_D	P_W	$P_{D/D}$	$P_{W/D}$	$P_{W/W}$	$P_{D/W}$	P_{2D}	P_{3D}	P_{2W}	P_{3W}
1	0.00	100.0	0.0	47.6	52.4	0.0	100.0	47.6	22.7	0.0	0.0
2	0.96	100.0	0.0	47.6	52.4	0.0	100.0	47.6	22.7	0.0	0.0
3	1.04	100.0	0.0	47.6	52.4	0.0	100.0	47.6	23.8	0.0	0.0
4	2.02	100.0	0.0	47.6	52.4	0.0	100.0	50.0	25.0	0.0	0.0
5	3.56	95.2	4.8	50.0	50.0	0.0	100.0	47.6	23.8	0.0	0.0
6	2.14	95.2	4.8	50.0	50.0	0.0	100.0	47.6	22.6	0.0	0.0
7	7.57	85.7	14.3	50.0	50.0	0.0	100.0	40.6	19.1	0.0	0.0
8	6.55	90.5	9.5	47.4	52.6	0.0	100.0	42.6	14.2	2.4	0.4
9	9.06	81.0	19.0	47.1	52.9	25.0	75.0	27.0	11.1	3.2	0.0
10	17.54	71.4	28.6	33.3	66.7	16.7	83.3	29.4	12.1	0.0	0.0
11	16.55	81.0	19.0	41.2	58.8	0.0	100.0	33.3	15.6	4.8	0.0
12	14.89	81.0	19.0	41.2	58.8	25.0	75.0	37.8	9.4	0.0	0.0
13	17.82	71.4	28.6	46.7	53.3	0.0	100.0	17.9	5.5	3.2	1.2
14	22.73	57.1	42.9	25.0	75.0	11.1	88.9	17.6	7.7	16.1	0.0
15	29.95	61.9	38.1	30.8	69.2	37.5	62.5	27.1	9.0	0.0	0.0
16	18.61	76.2	23.8	43.8	56.3	0.0	100.0	25.4	8.5	9.9	4.0
17	29.55	42.9	57.1	33.3	66.7	41.7	58.3	14.3	0.0	22.9	7.6
18	51.90	28.6	71.4	33.3	66.7	40.0	60.0	0.0	0.0	23.8	11.2
19	41.09	28.6	71.4	0.0	100.0	33.3	66.7	0.0	0.0	33.6	8.4
20	42.01	19.0	81.0	0.0	100.0	47.1	52.9	4.2	1.4	20.2	8.1
21	36.09	42.9	57.1	22.2	77.8	25.0	75.0	14.3	2.9	22.9	10.0
22	40.13	28.6	71.4	33.3	66.7	40.0	60.0	5.7	0.0	31.3	11.2
23	39.03	23.8	76.2	20.0	80.0	43.8	56.3	0.0	0.0	27.2	9.9
24	49.79	33.3	66.7	0.0	100.0	35.7	64.3	13.3	0.0	24.2	9.1
25	41.46	47.6	52.4	40.0	60.0	36.4	63.6	0.0	0.0	19.6	8.6
26	46.60	23.8	76.2	0.0	100.0	37.5	62.5	9.5	2.4	33.3	15.7
27	37.70	23.8	76.2	40.0	60.0	43.8	56.3	6.0	2.2	35.9	13.8
28	57.18	19.0	81.0	25.0	75.0	47.1	52.9	7.1	2.2	31.1	7.8
29	51.05	38.1	61.9	37.5	62.5	38.5	61.5	11.7	4.4	15.5	0.0
30	32.78	61.9	38.1	30.8	69.2	25.0	75.0	23.2	8.7	0.0	0.0
31	18.04	76.2	23.8	37.5	62.5	0.0	100.0	28.6	8.8	4.8	0.6
32	18.71	76.2	23.8	37.5	62.5	20.0	80.0	23.4	8.5	3.0	0.9
33	23.43	61.9	38.1	30.8	69.2	12.5	87.5	22.5	6.8	11.4	4.2
34	31.38	52.4	47.6	36.4	63.6	30.0	70.0	15.7	7.0	17.3	7.2
35	29.51	47.6	52.4	30.0	70.0	36.4	63.6	21.2	7.1	21.8	7.3
36	34.31	42.9	57.1	44.4	55.6	41.7	58.3	14.3	2.4	19.0	7.6
37	36.76	42.9	57.1	33.3	66.7	33.3	66.7	7.1	0.0	22.9	11.4
38	48.69	28.6	71.4	16.7	83.3	40.0	60.0	0.0	0.0	35.7	14.3
39	58.24	14.3	85.7	0.0	100.0	50.0	50.0	0.0	0.0	34.3	15.0
40	40.31	28.6	71.4	0.0	100.0	40.0	60.0	5.7	1.3	31.3	10.4
41	49.26	23.8	76.2	20.0	80.0	43.8	56.3	5.3	0.7	25.4	7.8
42	27.12	42.9	57.1	22.2	77.8	33.3	66.7	5.4	2.2	17.6	7.8
43	27.07	38.1	61.9	12.5	87.5	30.8	69.2	15.9	6.3	27.5	9.2
44	21.01	57.1	42.9	41.7	58.3	44.4	55.6	22.9	11.4	14.3	0.0
45	12.39	71.4	28.6	40.0	60.0	33.3	66.7	35.7	17.0	0.0	0.0
46	3.17	95.2	4.8	50.0	50.0	0.0	100.0	45.4	21.6	0.0	0.0
47	1.19	100.0	0.0	47.6	52.4	0.0	100.0	47.6	22.7	0.0	0.0
48	0.07	100.0	0.0	47.6	52.4	0.0	100.0	47.6	22.7	0.0	0.0
49	0.58	100.0	0.0	47.6	52.4	0.0	100.0	47.6	22.7	0.0	0.0
50	0.34	100.0	0.0	47.6	52.4	0.0	100.0	47.6	22.7	0.0	0.0
51	0.60	100.0	0.0	47.6	52.4	0.0	100.0	47.6	0.0	0.0	0.0
52	0.27	100.0	0.0	47.6	52.4	0.0	100.0	0.0	0.0	0.0	0.0

Implication of the findings on Crop planning

Based on the above analysis, the following recommendations on Abeokuta could be made to increase an all-year-round crop production. About 95 per cent of the total average annual rainfall occurs during the early planting and the late planting periods of the rainy season which is received from March to October. Rainfall received during April-June can be utilized for supplemental irrigation for the periods when there was short dry spells that could have adversely affected the final yield of crop. The normal onset of rainy season was observed on 14th SMW (April 7th) in Abeokuta and with this, sowing of main seasonal crop like maize should be started between the first and second week of April. In case of early start, short duration and drought tolerant maize varieties and low water requiring crops should be grown accordingly. In the event of mid-season drought, mulching and supplemental irrigation will help in reducing soil evaporation and conserving moisture in top layers of the soil. In the event of terminal drought, receding soil moisture conditions, crop requires supplementary irrigation. Intercropping of maize (50/50cm) with soil covering crops like melon in 1:1 row proportion can be viable option for increasing per unit area crop productivity under rainfed conditions. A major portion of water during the rainy season is generally lost through runoff (40-45%), which can be stored through the construction of suitable water harvesting structures as on-farm reservoirs. The rainfall received during dry season months of November-February is only about 5 per cent of the total average annual rainfall which is very low for the sowing of crops during the dry season. Therefore, soil and moisture conservation measures need due attention to conserve rainwater particularly during the months of July to October when highest amount of rainfall occurred. Sowing of main dry season crops like cassava, groundnut, pepper and vegetables should be started from the first week of November and the rain water harvested during the late planting period of rainy season applied as irrigation water for better crop yields.

Conclusion

Based on this study the onset of wet week is the 14th SMW with 22.73 mm rainfall and 42.9% probability of wet spell and runs till the 44th SM week with 21.01 mm of rainfall and 42.9% probability of wet spell. At this period it is save for farmers to grow their crop in Abeokuta with assurance of abundant rainfall. The onset of dry spell is the 1st SM week with 0.00 mm rainfall, 100% probability of dry spell and runs till 13th SM week with 17.82 mm rainfall. The dry spell continues from 45th SM week with 12.39 mm rainfall and 71.4% probability of dry spell till 52nd SM week with 0.2 mm mm rainfall and 100% probability of dry spell. This will be of immense advantage for farmers in Abeokuta to plan on period of crop planting. It is therefore concluded that rain fed crop planting in Abeokuta should come between the 14th and 44th meteorological weeks, while irrigation farming should come from 1st to 13th meteorological weeks and from 45th to 52nd meteorological weeks for a better crop growth and yield.

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