Rainfall Characteristics and Soil Tillage Timing for Rainfed Crop Production in the Northern Guinea Savanna of Nigeria

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1. Abstract

Soils in the Northern Guinea Savanna Zone of Nigeria are continually being degraded. Soil erosion by water and wind are major factors degrading soils of the zone. Soil erosion in the zone is prominent during the early part of the rainfed cropping season, when the soil surfaces are largely bare. In order to estimate the magnitude of soil losses, rainfall amounts were obtained, and computed for rainstorm kinetic energy, intensity, and erosion index in the Zaria area of the Northern Guinea Savanna Zone of Nigeria.

Results obtained show that the Northern Guinea Savanna Zone of Nigeria has a defined wet season spanning from May to September, and peak rainfall in August. Monthly mean rainfall amounts for the months of June to September range from 20.75 to 29.63 mm, with kinetic energy averaging between 30.52 and 36.73 Jm^{-2} mm^{-1}, and rainstorm intensity ranging from 29.45 to 38.60 mm hr^{-1}

Suitable soil and land use management practices that would control wind and water erosion in cultivated lands are suggested.

Key Words: Rainfall Characteristics, Soil Tillage, Sustainable Crop Production.

2. Introduction

Crop production in the Nigerian Guinea Savanna is increasing in scope and intensity. Crops commonly grown under rainfed conditions include maize, sorghum, rice cowpea, groundnut, cotton, and soybeans. However, the soils are increasing being degraded by soil erosion (wind and water), overgrazing, and poor management practices. The soils consequently do not contain sufficient plant nutrients to support vigorous crop growth and high production. Also, the soils have a dominance of low activity clays, and low water holding capacity (Jones and Wild, 1975; Kowal 1972; Bala Subramanian and Nnadi, 1980; Ike, 1986; and Adeoye, 1984).

Rainfall in the Nigerian Guinea Savanna is erosive and can cause appreciable soil loss (Kowal, 1970; Kowal and Kassam, 1976; Kowal and Knabe, 1972; Lal, 1976, and Odunze 1997). Rainfall in the zone establishes between June and August during which period rainfed crop production is at its peak (Kowal and Knabe, 1972). In order to control soil loss in cultivated fields in the zone, management practices requiring knowledge of rainfall characteristics in the area should be articulated for practical use by farmers. Therefore, this study is aimed at characterizing rainfall in the zone with a view to recommending appropriate timing of soil tillage for rainfed crop production. Also, the need for appropriate land use

management practices to check soil erosion in the zone has become crucial for sustainable crop production. Hence, management practices that would curb soil loss from cultivated fields would be suggested.

3. Materials and Methods

The study area is located in Zaria, within the Northern Guinea Savanna Zone of Nigeria. It lies between longitudes 7^{o} $30^{'}$ and 7^{o} $50^{'}$ North, and latitudes 11^{o} $00^{'}$ and 11^{o} $10^{'}$ East. Long term mean annual rainfall in the area is 1150 mm (Kowal and Knabe, 1972), with a peak between June and August. The dry season in the zone lasts from October to April (Kowal and Knabe, 1972), but adequate rainfall amounts are received in the Zaria area during rainfed cropping periods of June to September (Kowal, 1972; Odunze, 1997).

4. Field and Laboratory Work

Two rain gauges were installed in opposite directions in the field at the Ahmadu Bello University farm in 1993 and 1994; Rainfall amounts were collected from the rain gauges for the estimation of rainfall characteristics in Zaria area. Monthly mean rainstorm kinetic energy (JM^{-2} mm^{-1}), intensity ($mmhr^{-1}$) and erosive index (cm^{-2} hr^{-1}) were estimated using the following models:

$KE = (41.4\ Ra - 20)\ 10^{3}\ ergs/cm^{2}$

$KEa = \frac{KE}{DV}$ JM^{-2} (Kowal and Kassam, 1997)

$I = 3.49e^{0.065xKEa}\ mm\ hr^{-1}$ (Adewumi, 1997)

$AIM \sum_{1}^{12} \sum_{1}^{n} (aim)$ (Lal, 1994) in Materials & Method

Where KE = kinetic energy if rainstorm in $ergs/cm^{2}$, KEa = Kinetic energy of rainstorm in JM^{-2} $mm^{-1,}$ DV = Drop volume of rains (mm^{3}), I = Rainstorm intensity ($mmhr^{-1}$), AIM = Annual erosivity index (Lal, 1994) cm^{2}/hr, a = total rainfall in any one storm in cm and 'im' is the maximum storm intensity in cms/hr 'n' is the number of rainy days in the month [Lal and Elliot, 1994]. Also, records of rainfall amounts for 1980 to 1994 were obtained from the meteorological office of the Institute for Agricultural Research, Ahmadu Bello University, Zaria, and processed for mean annual and monthly rainfall amounts.

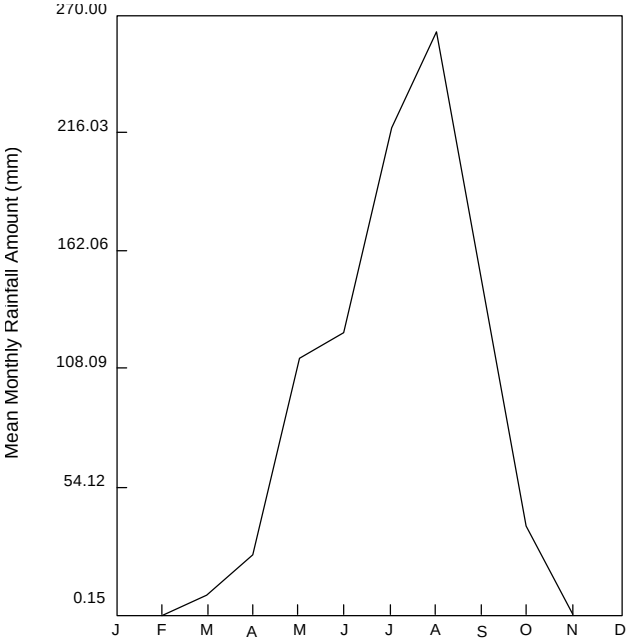
5. Results and Discussion

Rainfall Characteristics

Table 1 presents data on rainfall amounts for 1980 to 1994.

Periodic Rainfall Amounts

Table 1 shows that trace amounts of rainfall may be received in February [0.23mm], and March [5.52mm], November [0.17mm], and December [0.36mm]. These amounts are however not enough to sustain crop life in the area. The months with the least probability for a rainfall event include November, December, January and February. These months correspond with the dry season months in the Northern Guinea Savanna Zone of Nigeria. However, in the months of March, April and May, monthly rainfall amounts averaging 5.52, 23.89 and 113.69mm were received. These rainfall amounts are very low and are poorly distributed over time [Kowal and Knabe, 1972]. Also, mean air temperature in the months of March, April, and May is commonly in the range of 35^{oC} and above [Kowal and Knabe, 1972; Awujoola,1979].Therefore, most of the rainfall amounts in the period would be lost to evapotranspiration. During the period March to May, most cultivable lands would not be



moist enough to allow for proper tillage without accelerating wind erosion. Soils in farm lands harrowed and/or ridged during the periods of March to May are often lost to wind erosion. This is due to the high wind speed of May to June [Kowal and Knabe, 1972] that precedes rainfall establishment in the Nigerian Northern Guinea Savanna region. Table 1 therefore suggests that the periods March to May are not ideal for land tillage for the purpose of rainfed crop production.

Fig.1 Mean Monthly Rainfall Amount (1980 - 1994)

Table 1. Sumaru rainfall data 1980 – 1994 (mm)

Month	1980	1981	1982	1983	1984	1985	1986	1987	1988
Jan	-	-	-	-	-	-	-	-	-
Feb	-	-	-	-	-	-	-	-	3.50
March	-	-	-	-	5.20	32.90	-	-	-
April	3.70	100.70	59.70	-	30.10	-	5.80	-	34.60
May	154.40	90.70	72.10	73.30	98.90	140.70	59.10	135.70	94.40
June	116.40	159.00	113.90	74.30	55.40	142.20	82.00	146.80	133.20
July	268.90	254.80	168.70	107.50	173.80	313.10	293.60	276.70	181.50
Aug.	215.80	280.60	190.70	259.70	158.10	256.30	322.10	268.30	402.50
Sept.	71.90	133.30	117.60	93.40	189.00	163.30	205.70	102.10	192.30
Oct.	16.30	-	45.80	-	177.50	3.30	-	42.60	114.70
Nov.	-	-	-	-	-	-	-	-	-
Dec.	-	-	-	-	-	-	-	-	-
Total	847.4	1019.10	768.50	608.20	888.0	1051.80	968.30	972.20	1156.70

Month	1988	1989	1990	1991	1992	1993	1994	Mean	SD
Jan	-	-	-	-	-	-	-	-	-
Feb	3.50	-	-	-	-	-	-	0.23	0.90
March	-	-	-	44.70	-	-	-	5.52	13.76
April	34.60	15.00	-	47.80	32.30	8.30	20.40	23.89	28.45
May	94.40	113.00	123.30	243.00	73.10	113.6	120.10	113.69	45.38
June	133.20	124.40	155.70	87.00	112.4	155.80	231.90	126.03	43.39
July	181.50	154.60	221.90	189.60	243.60	269.00	169.20	219.10	60.08
Aug.	402.50	170.40	255.30	390.00	287.30	300.80	218.60	265.10	70.96
Sept.	192.30	118.30	131.50	51.20	229.70	181.80	99.60	138.71	52.52
Oct.	114.70	52.90	-	28.70	39.9	10.10	-	37.99	51.12
Nov.	-	-	-	-	2.60	-	-	0.17	0.67
Dec.	-	-	5.00	-	-	-	-	0.36	1.34
Total	1156.70	748.60	892.70	1082.0	1020.90	1039.40	859.8		

In the month of June, mean monthly rainfall amount was 126.03 mm for the period from 1980 to 1994. This rainfall amount, coupled with the residual moisture of the months of March to May, would moisten the soils for proper tillage in the month of June. Also, the moist soils at this period would resist the wind's erosive force and thus check soil loss to wind erosion. The period June to September therefore represents a period of availability of

adequate soil moisture for sustainable crop production in the Nigerian Northern Guinea Savanna ecozone.

5.2 Rainstorm Kinetic Energy

The estimated kinetic energy of rainstorms in Samaru-Zaria in June, range from 32.58 to 40.32J/M^2/mm with mean values of 30.52 and 32.06J/m^2/mm in 1993 and 1994 respectively. In August, the kinetic energy of rainstorms ranges from 258.44 to 39.97J/$M^{2/}$mm, with mean values of 35.11 and 34.61J/$M^{2/}$mm in 1993 and 1994 respectively. In September, the kinetic energy of rainstorms ranges from 31.68 to 39.0J/$M^{2/}$mm, with a mean to 36.84J/M^2/mm. The range of kinetic energy values obtained by Kowal and Kassam[1976] for 18 rainstorms in the Samaru-Zaria ranges from 21.81 to 38.40J/M^2/mm,and is thus confirmed by the rainstorm kinetic energy values estimated from this study.

The monthly mean kinetic energy of the rainstorms shows that the highest value of 36.73J/M^2/mm was obtained in June. In July, the kinetic energy values averaged 30.52 and 32.06J/M^2/mm in 1993 and 1994 respectively. These values are very high, and under the bare to very low vegetation cover significant amounts of soil loss would occur in cultivated lands in June and July. The Kinetic energy average in August ranges from 34.61 to 35.11J/M^2/mm; in September, the monthly kinetic energy average was 35.92J/M^2/mm. However, in these months, most cultivated lands are optimally vegetated and significantly intercept raindrops preventing splash erosion. Therefore, the high kinetic energy of rainstorms in August and September may not result in significant soil loss in the Northern Guinea Savanna zone of Nigeria.

5.3 Monthly Rainfall Events

Monthly rainfall amounts range from 16.0 to 49.00 mm, with a mean of 29.63 mm in June 1994. In July however, rainfall amounts range from 7.5 to 48.50 mm, with a mean of 22.85 and 20.75 mm respectively in 1993 and 1994. In August, rainfall amounts range from 9.30 to 40.00 mm, with a mean of 25.73 and 25.53 mm respectively in 1993 and 1994. In September 1994, rainfall amounts range from 14.75 to 36.50 mm, with a mean of 26.65 mm. Table 2 shows that the monthly mean rainfall amounts in June to September in Zaria exceed the 20-25 mm threshold value for erosive rains [Hudson, 1976;Lal, 1976]. This suggests that the rains could cause significant soil loss in Zaria, and the Northern Guinea Savanna areas, especially when the soils are bare. Surface soils in Samaru and the Northern Guinea Savanna zones are largely bare in the months of June and July. This is a result of the tillage practices undertaken in the months of May and June for rainfed cropping in June to September. Soil erosion would occur intensively in Zaria area in the months of June and July. This confirms the views of FAO [1978], that soil erosion is accelerated when preparing the land for production of food and fibre, and of Aina [1979] that soil erosion decreases exponentially with increasing ground cover.

5.4 Monthly Rainstorm Intensity

The estimated intensity of rainstorms in the Samaru-Zaria area observed in 1993 and 1994, ranges from 29.01 to 47.98mm/hr with a mean of 38.60mm/hr in June. In July, rainstorm intensity ranges from 14.38 to 46.26mm/hr with means of 29.45 and 30.18mm/hr respectively in 1993 and 1994. In August, rainstorm intensity ranges from 18.24 to 45.25mm/hr, with mean values of 35.49 and 31.68mm/hr respectively for 1993 and 1994. Rainstorm intensity obtained by estimation falls within the 36 to 111.1mm/hr reported by Kowal and Kassam [1976] for 18 rainstorms.

5.5 Rainstorm Erosivity Index[AIm]

In June, the estimated rainstorm erosivity index range from 4.64 to 23.51cm^2/hr, with a mean of 12.35cm^2/hr. In July, the rainstorm erosivity index range from 0.42 to 23.23cm^2/hr, with mean values of 9.04 and 7.86cm^2/hr in 1993 and 1994 respectively. In August, the rainstorm intensity in the Samaru area range from 1.70 to 16.38cm^2/hr, with mean values of 10.34 and 7.97cm^2/hr in 1993 and 1994 respectively. In September 1994, the erosivity index of the rainstorms ranges from 4.04 to 16.31cm^2/hr, with an average of 10.54cm^2/hr. The range of mean erosivity of rainstorms from June to September estimated under this study confirms findings of Lal [1979], that AIm is usually in the range of 1 to 10 cm^2/hr areas with annual rainfall up to 1000mm, and between 1 and 20 cm^2/hr for areas receiving 1000 to 2000mm of annual rainfall. The Samaru-Zaria area [Northern Guinea Savanna zone] receives annual rainfall amounts ranging from 608 to 1150 mm [Table 1].

Table 2. Selected Rainfall amount, Intensity, Kinetic Energy and Erosivity of the Rains in Samaru-Zaria, 1993 and 1994

Date	Rainfall amount Mm^1	Kinetic Energy J/M^{2}mm^{-1}	Rainfall Intensity Mm/hr	Erosivity Index (alm) cm^2/hr		Date	Rainfall amount Mm	Kinetic Energy J/M^{2}mm^{-1}	Rainfall Intensity Mm/hr	Erosivity Index (alm) cm^2/hr
1993						**1994**				
July						June				
2nd	7.50	21.78	14.38	1.08		17th	24.50	36.42	37.23	9.12
5th	39.00	39.29	44.87	17.50		18th	16.00	32.58	29.01	4.64
11th	10.00	26.56	19.62	1.96		21st	29.00	37.59	40.18	12.12
15th	7.50	21.78	14.30	1.08		27th	49.00	40.32	47.98	23.51
21st	36.00	38.88	43.69	15.73		Mean	29.63	36.73	38.60	12.35
22nd	48.50	40.28	47.85	23.23		SD	12.12	2.78	6.79	8.05
23rd	16.50	32.90	29.62	4.88		July				
24th	5.00	13.55	8.42	0.42		1st	8.00	22.93	15.49	1.24
25th	45.51	40.00	46.99	21.39		8th	10.50	27.28	20.56	3.84
27th	13.00	30.17	24.80	3.22		9th	22.50	35.76	35.67	8.03
Mean	22.851	30.52	29.45	9.04		15th	12.00	29.14	23.20	2.78
SD	16.42	8.91	14.51	8.79		20th	28.50	37.49	39.92	11.38
August						29th	43.00	39.76	46.26	19.89
2nd	17.50	33.50	30.80	5.39		Mean	20.75	32.06	30.18	7.86
4th	13.50	30.64	25.57	3.45		SD	12.26	6.02	11.11	6.97
8th	37.10	39.04	44.15	16.38		August				
16th	10.50	27.28	20.45	3.68		4th	25.50	36.72	37.97	9.68
18th	40.00	39.42	45.25	18.10		6th	32.50	39.24	44.72	14.53
19th	33.00	38.39	42.32	13.97		7th	9.30	25.44	18.24	1.70
21st	28.50	37.49	39.92	11.38		17th	17.50	33.50	30.80	6.65
Mean	25.73	35.11	35.49	10.34		20th	20.40	34.93	38.80	7.92
SD	10.92	4.38	9.13	6.16		23rd	30.00	37.82	24.53	7.36
						Mean	22.53	34.61	31.68	7.97
						SD	7.84	4.50	8.63	4.18
						September				
						4th	37.00	39.02	44.09	16.31
						9th	15.50	32.23	28.36	4.40
						13th	14.75	31.68	27.36	4.04
						15th	29.50	37.71	40.49	11.95
						21st	36.50	38.95	43.89	16.02
						Mean	26.65	35.92	36.84	10.54
						SD	9.78	3.27	7.45	6.03

6. Summary and Conclusion

Rainfall in the Northern Guinea Savanna zone of Nigeria can start from the month of March, but the amounts are very low and unable to sufficiently moisten the soil for proper tillage and prediction against wind erosion. It is suggested that soil tillage for rainfed crop production should take place in the month of June, when the soils are moist, and would resist wind erosion.

Monthly rainfall amounts in June to September in the Northern Guinea Savanna area of Nigeria attain the erosive limit of 20-25mm, and are therefore erosive in nature. High erosion rates[by water] would be expected in the Northern Guinea Savanna areas in the months of June and July, when the soils are largely bare. To check water erosion in cultivated lands therefore, it is suggested that fast growing and establishing forage legumes like Centrosema pascuorum and Macrotyloma uniflorum could be broadcast in the interrows after harrowing and planting of cereal [Maize,sorghum,or millet] crops. The legumes would rapidly provide ground cover against water erosion, and benefit the cereal crops. At the second weeding operation [6-8 weeks after planting maize], the legumes could be ploughed into the soils to enhance organic matter content and nutrient status of the soils.

In 1993 and 1994, monthly mean rainfall kinetic energy in the Samaru area ranged from 30.52 to 36.73J/M^2/mm, between June and September. Also, monthly mean rainstorm intensity in the area ranged from 31.68 to 38.60mm/hr over the period June to September. Rainstorms in the Northern Guinea Savanna would therefore cause significant soil loss, especially when the soils are largely bare.Soil surfaces in the Northern Guinea Savanna ecozones of Nigeria are largely bare in the months of June and July, due to tillage practices which precede rainfed crop production that is the dominant farming activity in the months of May to June in the area.

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