IC/93/427
INTERNAL REPORT
(Limited Distribution)

International Atomic Energy Agency
and
United Nations Educational Scientific and Cultural Organization
INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS

CHARACTERIZING RAINFALL PARAMETERS WHICH INFLUENCE EROSIVITY IN SOUTHEASTERN NIGERIA

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MIRAMARE – TRIESTE
December 1993

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ABSTRACT

An investigation was carried out to characterize some selected parameters which influence rainfall erosivity in southeastern Nigeria. Rainfall amount, distribution, duration, intensity, storm types, energy loads and frequency of rain events in the region were studied using data from stations located in three major agroecological zones (i.e., southern Guinea Savanna (GS), Forest (F) and Coastal (C) belts). Raindrop size and detaching capacity were evaluated in one of the stations for two months. The highest rainfall per event ranged from 117 mm in GS belt to 183 mm in the F belt. The highest maximum 6–minute intensity of rainstorm ranged from 191 mm h^{-1} in the C belt to 254 mm h^{-1} in the F belt. More than 60% of rainstorms fell at intensities exceeding 25 mm h^{-1}, a threshold intensity established as erosive in tropical Zimbabwe. Rainfall intensities in the range of 100 to 125 mm h^{-1} would likely occur more than five times in a year in southeastern Nigeria. Intensities above 150 mm h^{-1} were of rare occurrence. Rainfall amount between 50 and 100 mm per rain event would occur about twice a year in the GS and F zones, and about 4 times a year in C belt. Advanced storms were dominant in the region. The energy loads of the rainstorms as calculated using the KOWAL and KASSAM (1976) equation, E_k, were 1.6 times higher than those calculated using the WISCHMEIER and SMITH (1978) empirical equation, E. Median raindrop size (D_{50}) ranged from 1.1 to 2.9 mm in the GS zone. The mean annual rainfall erosivity values in southeastern Nigeria using the $EI_{30}, KE \geq 25$ mm h^{-1} and AI_m ranged from 12814 to 18611 MJ.mm/ha.h, 141 to 249 MJ ha^{-1}, 849 to 1421 cm^2 h^{-1}, respectively. Computed values of several other erosivity indices were also reported. All examined indicators point to the fact that rainfall in southeastern Nigeria tend to be highly erosive.

1 Introduction

Rainfall erosivity, the potential ability of rain to cause erosion, is a function of the physical characteristcs of the rainfall. In the tropics, the rains are comparatively intense and sometimes of long duration. These aspects as well as those relating to amount, drop size distribution, terminal velocity and the extraneous factors like wind velocity and slope have bearing on rainfall erosivity (LAL 1977). The momentum of the rainfall, according to ROSE (1960) and particularly the kinetic energy (WISCHMEIER & SMITH 1978, HUDSON 1981) have been shown to affect erosivity. Compound parameters such as the product of the total storm kinetic energy (E) and maximum 30-minute (I_{30}) intensity or EI_{30} (WISCHMEIER & SMITH 1978), the product of the total storm amount (A) and maximum 7.5-minute intensity (I_m) or AI_m (LAL 1976) are among such indices.

LAL (1976), WILKINSON (1975), OBI & NGWU (1988) and SALAKO et al. (1991) have examined the applicabilty of some of these indices to southern Nigeria. Such information, particularly on rainfall factors affecting soil erosion is of singular importance in this region which has, for long, continued to witness enormous soil degradation and gully erosion. Emerging data point to the fact that the erosion problems stem more from climatic erosivity and soil management rather than from inherent erodibility of the soils.

Various attempts at tackling the erosion problems have tended to rely heavily on the use of indices and parameters developed in other regions. A serious consequence is the failure of workers to properly assess the erosive power of rainfall in the area leading to failure of key erosion projects.

The magnitude of rainfall parameters which influence its erosivity is expected to vary in different agroclimatic zones as shown by WILKINSON (1975), LAL (1976), KOWAL & KASSAM (1976), AINA (1980), ARMON (1984) and SALAKO et al. (1991) for different parts of Nigeria. SALAKO et al. (1991) compared several erosivity indices in southeastern Nigeria and found that empirical relationships developed with tropical rainfall data would be more promising for the assessment of rainfall erosivity than those developed with temperate region rainfall data. There had been very few attempts to map soil erosion in southeastern Nigeria in spite of its spectacular nature because of inadequate data (SALAKO 1988). The purpose of this study was to characterize somc of the

rainfall factors which influence its erosivity in southeastern Nigeria and to help further in the urgent requirement by policy makers and soil conservationists for a data base on the soil erosion problem in Nigeria.

2 Materials and Methods

2.1 Study area

Southeastern Nigeria is located between latitude 4° and 7°, and longitude 6° 30' and 9° 30'. The tropical climate of the region is characterized by uniformly high temperature and a seasonal distribution of bimodal rainfall (MONANU 1975). There is a long wet season from April to July with a short, dry season (August break) followed by a short wet season (September to October) and finally by a long, dry season (November to March). The normal annual rainfall amount ranges from about 1500 mm in the northern boundary to more than 4000 mm in some coastal areas. The soil erosion problem of the area is alarming and can, now, be regarded as an ecological disaster (LAL 1990).

2.2 Rainfall data analyses

Rainfall data were collected from four meteorological stations in southeastern Nigeria, located in three agroecological zones, namely, the Guinea Savanna (GS), Forest (F) and Coastal (C) belts. The specific stations were Nsukka (6° 52' N; 7° 24' E) in the GS belt, Umudike (5° 13' N; 7° 26' E) and Owerri (5° 29'N; 7° 10' E) in the F belt and Port-Harcourt (4° 40' N; 7° 10' E) in the C belt. These represent the major climatic subregions in southeastern Nigeria (INYANG 1975).

Auto-recording raingauge charts for the periods 1976 to 1983, 1974 to 1985, 1973 to 1982, and 1973 to 1981 were collected from the respective stations for analysis. Only storms of at least 13 mm in total amount were included in the study. However, few cases where as much as 6 mm rain fell within 15 minutes were also included (FOSTER et al. 1981).

The 6-minute intensity data were used to characterize the storms in terms of intensity class distribution, storm type (SCHWAB et al. 1981) and recurrence intervals. The recurrence interval was calculated using a procedure outlined by HJELMFELT Jr. & CASSIDY (1975):

$$P_e = M/N \quad \text{--} \quad (Eq.1)$$

where P_e is the number of times in a year a hydrological event would occur, M is the order number of rainfall amount or intensity, with the largest amount or intensity having an order number equal to the total number of years (N) of observations. The reciprocal of P_e, i.e., $1/P_e$ is the recurrence interval.

The distribution of monthly and annual rainfall amounts in all the stations was studied. The monthly rainfall data for the period 1973 to 1984 were compared with the long-term (1931 to 1960) average monthly data. Raindrop sizes and detaching capacities were evaluated for two months (August and September) at Nsukka using the flour pellet method (CARTER et al. 1974). Twenty eight rainfall events were sampled for analyses. The detaching capacities of the drops were determined with fine sand (0.1 - 0.25 mm) placed in Ellison-type splash cups (BISAL 1950, ELLISON 1947, HUDSON 1981) having diameter and depth of 76 and 50 mm.

2.3 Rainfall Erosivity Indices Evaluation

The kinetic energy of rainfall was computed for all the stations using WISCHMEIER & SMITH (1978) and KOWAL & KASSAM (1976) equations. The kinetic energy of the respective equations were designated E and E_k following the procedure of SALAKO et al. (1991). The EI_{30} (WISCHMEIER & SMITH 1978), KE≥25 mm h^{-1} (HUDSON 1981) and AI_m (LAL 1976) erosivity indices were computed. Furthermore, the E_kI_{30} and E_kI_m indices proposed by SALAKO et al. (1991) were used for evaluating rainfall erosivity. The EI_{30} and AI_m were defined earlier but I_m in this study is maximum 6-minute intensity. The KE≥25 mm h^{-1} is the kinetic energy (E in this study) of rainfall at intensities equal to or exceeding 25 mm h^{-1}; E_kI_{30} and E_kI_m are products of E_k and I_{30}, E_k and I_m, respectively.

The erosivity indices of ROOSE (1977) and ARNOLDUS (1977) were also used for evaluation using rainfall amount data from the various stations.

3 Results and Discussion

3.1 Rainfall amount and distribution

Typical annual distribution of rainfall at two of the stations are presented in Fig. 1. The annual rainfall averages were 1569 mm and 2005 mm for Nsukka and Umudike, respectively, between 1973 and 1984. The normal rainfall amounts based on long term data for the locations in the GS, F and C belts were 1500, 2130 and 2400 mm, respectively. The coefficients of variation of the annual rainfall for the respective belts are 18, 12 and 11 %.

The months of July and September were usually very wet (Fig. 2) and erratic rainfall distribution pattern could be observed in months which would normally be regarded as dry. The monthly coefficients of variation for rainfall amounts at all the stations were 40 and 280 % for the months of April and January, respectively; 60 and 187 % in November and December, respectively. In contrast, within the wet season (May to October), the coefficients ranged from 30 to 80 %. There were greater variation of monthly than annual rainfall amounts. MONANU (1975) made a similar observation.

The highest rainfall amounts per event were 117, 183, 134 and 163 mm at Nsukka (GS), Umudike (F), Owerri (F) and Port-Harcourt (C), respectively. The mean monthly rainfall amount in the whole region generally exceeded 150 mm during the rainy season. The large sizes of the storms would be expected to bolster their erosiveness and, therefore, must be taken into consideration in soil conservation planning.

3.2 Storm type

The percentage distribution of storm types in southeastern Nigeria is given in tab. 1. The advanced, composite/intermediate and delayed storms (LAL 1976, SCHWAB et al. 1981) ranged from 46 to 57, 31 to 42, and 7 to 18 %, respectively. Thus, advanced storms with high initial peak intensities were dominant whereas delayed storms featured least. Figs. 3 and 4 show an advanced (single peak intensity) and an intermediate (multiple peak intensities) storm types, respectively. The single rain event in Fig. 4 was exceptionally high in amount and intensities to cause severe erosion damage. AINA et al (1977) stated that 55 % of storms attained their peak intensities in less than 5 minutes at Ibadan, western Nigeria.

Advanced storms dominated between January and April, and between September and December (tab. 2). These were periods of isolated rainstorms at the beginning and end of the wet season. Very severe erosion-causing storms (the delayed, composite and intermediate storms) concentrated between the months of May and August, the first rainy period.

3.3. Frequency of rainfall amount and intensity

Rainfall amounts between 50 and 100 mm per rainevent would occur about twice a year at GS and F belts, and about four times a year at the C belt. Rainfall amounts exceeding 100 mm per rain event were of rare occurence in all the locations.

Rainfall intensities within the range of 100 to 125 mm h^{-1} would likely occur more than five times a year in southeastern Nigeria. Also, intensities between 125 and 150 mm h^{-1} were not uncommon whereas those above 150 mm h^{-1} were rare. Although the deductions are based on limited data, there is, a great need to provide tentative information on frequencies of extreme rainfall events in the region.

Fig. 5 shows that 64, 68, 73 and 64 % of storms exceeded 25 mm h^{-1} at Nsukka (GS), Umudike (F), Owerri (F) and Port-Harcourt (C), respectively. Furthermore, 27, 25, 27 and 16 % of storms exceeded 75 mm h^{-1} at the respective agroecological belts. The intensity distribution suggests that rain events falling at erosive intensities (HUDSON 1981) were very frequent. Examination of detailed data showed that the highest maximum 6-minute intensities were 250, 254, 250 and 191 mm h^{-1} at Nsukka (GS), Umudike (F), Owerri (F) and Port-Harcourt (C), respectively. Instantaneous intensity such as the 6-minute intensity reflects the erosivity of tropical rain better than long-period intensity (KOWAL & KASSAM 1976).

3.4 Raindrop sizes and detaching capacity

The raindrop sizes obtained at the GS belt ranged from 0.6 to 3.4 mm (Fig. 6). The median drop sizes (D_{50}) of the 28 rainfall events ranged from 1.1 to 2.9

mm. The dominant drop size exceeded 2 mm. LAL (1982) reported that the predominant D_{50}'s of erosive rains were between 1.7 and 2.5 mm. D_{50}'s of approximately 2.5 mm were reported to be frequent in northern and western Nigeria (AINA et al. 1977, AINA 1980, KOWAL & KASSAM 1976).

The fine sand splashed by raindrops ranged from 24 to 1641 g m^{-2} per rainday. The daily rainfall amount during the period ranged from 0.5 mm (drizzle) to 62 mm. Only two rain events, of amounts 14 and 62 mm, caused sand to be splahed beyond a depth of 2 mm from the rim of the cups. The amount of splashed sand was significantly correlated with the rainfall amount (r = 0.8**) and this suggests that rainfall amount would be an important characteristic influencing the erosivity of rains in the GS belt.

3.5 Rainfall erosivity indices

The monthly variation of kinetic energy of rainstorms at the GS, F and C belts are given in tab. 3. The E_k equation (KOWAL & KASSAM 1976), generally, evaluated kinetic energy of rainfall 1.6 times higher than the E equation (WISCHMEIER & SMITH 1978) and this would seem to suggest that the latter equation was underestimating the energy of tropical rainfall (HUDSON 1981, LAL 1976, AINA 1980) since E_k was empirically derived from tropical rainfall data. The mean annual kinetic energy using E_k are 321.6, 433, 515 and 544.6 MJ ha^{-1} for Nsukka (GS), Umudike (F), Owerri (F) and Port-Harcourt (C), respectively. On the other hand, the mean annual values using E are 204.5, 288, 319.4 and 324.6 MJ ha^{-1} for the respective location.

The monthly variation of the EI_{30}, KE≥25 mm h^{-1}, AI_m, E_kI_{30} and E_kI_m are shown in tabs. 4 to 7 for Nsukka (GS), Umudike (F), Owerri (F) and Port-Harcourt (C), respectively. The variations suggest that soil conservation needs should vary from month to month. This fact is often obscured when data are presented on annual basis. It is shown that the mean annual erosivity in southeastern Nigeria using the EI_{30}, KE≥25 mm h^{-1}, AI_m, E_kI_{30} and E_kI_m ranged from 12814 to 18611 MJ.mm/ha.h, 141 to 249 MJ ha^{-1}, 849 to 1421 cm^2 h^{-1}, 16697 to 29610 MJ.mm/ha.h, and 32752 to 62238 MJ.mm/ha.h, respectively. There is an indication from the various erosivity indices used that rainfall erosivity would vary from one agroecological zone to the other. This variation will be pronounced between distinct agroecological zones like savanna and forest or coastal area. It appeared the annual erosivity values in the F and C belts were not subtantially different. ARMON (1984) also used the EI_{30}, $KE\geq25$ mm h^{-1} and AI_m indices to evaluate rainfall erosivity for some locations in southeastern Nigeria.

Rainfall erosivity was further evaluated by approximate methods of ROOSE (1977) and FOURNIER (ARNOLDUS 1977) as shown in tab. 8. These values are not approximate values of the EI_{30} values in tabs. 4 to 7 because the relationships between EI_{30} and rainfall amount were developed in the customary units used by WISCHMEIER & SMITH (1978). FOSTER et al. (1981) had since converted the factors of the Universal Soil Loss Equation to SI units and it might be necessary to obtain the approximate SI values of the EI_{30} (MJ.mm/ha.h) as shown in tabs. 4 to 7 by converting the values in tab. 8, using a multiplication factor of 17. Approximation of rainfall erosivity from rainfall amount is often necessitated by lack of equipment and personnel (MBAGWU & SALAKO 1985, SALAKO 1988). Attention is drawn to the appropriate units of measurement in view of less emphasis placed on them in literature by researchers.

4 Conclusion

Rainfall erosivity was characterized for the Guinea Savanna (GS), Forest (F) and Coastal (C) belts of southeastern Nigeria (4° and 7° N; 6° 30' and 9° 30'E). The highest maximum rainfall amounts ranged from 117 to 183 mm per rain event whereas the maximum 6-minute intensities ranged from 191 mm h^{-1} to 254 mm h^{-1}. The values of the KOWAL & KASSAM (1976) kinetic energy equation, E_k, were 1.6 times higher than the values obtained using WISCHMEIER & SMITH (1978) equation, E. The mean annual erosivity values in southeastern Nigeria using the EI_{30}, $KE\geq25$ mm h^{-1}, AI_m, E_kI_{30} and E_kI_m indices ranged from 12814 to 18611 MJ.mm/ha.h, 141 to 248 MJ ha^{-1}, 849 to 1421 cm^2 h^{-1}, 16697 to 29610 MJ.mm/ha.h and 32752 to 62238 MJ.mm/ha.h. Rainfall erosivity approximations from rainfall amount using ROOSE (1977) and modified FOURNIER (ARNOLDUS 1977) indices may be converted to SI units (FOSTER et al. 1981) by multiplying by a factor of 17.

The monthly rainfall erosivity data would help in precise soil conservation planning. Also, since the effectiveness of the indices has not been widely tested, there is a likelihood of any of them being found suitable within or outside the locations studied. The provision of a database as in this study would augment such study. Rainfall erosivity differences were more pronounced between the GS belt and F or C belt than between F and C. Erosivity was higher in the F or C belt than the GS belt.

Acknowledgments

One of the authors (M.E.O.) would like to thank Professor Abdus Salam, the International Atomic Energy Agency and UNESCO for hospitality at the International Centre for Theoretical Physics, Trieste, and the Swedish Agency for Research Cooperation with Developing Countries, SAREC, for financial support during his visit at the ICTP under the Associateship scheme.

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TABLE CAPTIONS

Table 1. Percentage distribution of storm types in southeastern Nigera.

Table 2. Seasonal distribution of storm type in southeastern Nigeria.

Table 3. Monthly variation of kinetic energy (MJ ha^{-1}) at the different locations in southeastern Nigeria using KOWAL & KASSAM, E_k, and WISCHMEIER & SMITH, E, equations for evaluation

Table 4. Monthly variation of erosivity indices at Nsukka (Guinea savanna belt), southeastern Nigeria.

Table 5. Monthly variation of erosivity indices at Umudike (Forest belt), southeastern Nigeria.

Table 6. Monthly variation of erosivity indices at Owerri (Forest belt), southeastern Nigeria.

Table 7. Monthly variation of erosivity indices at Port-Harcourt (Coastal belt), southeastern Nigeria.

Table 8. Rainfall erosivity approximations* for southeastern Nigeria.

Table 1.

Location	Study period	Storm type (%)		
		Advanced	Composite+Intermediate	Delayed
Nsukka (GS)	1976-1983	56.8	36.2	7.0
Umudike (F)	1974-1985	50.9	31.1	18.0
Owerri (F)	1973-1982	51.5	38.6	9.9
Port-Harcourt (C)	1973-1981	46.1	42.0	11.9

Table 2.

Period	Location	Storm type (%) Advanced	Storm type (%) Composite+Intermediate+Delayed
January to April	Nsukka (GS)	8.1	3.2
	Umudike (F)	16.8	6.3
	Owerri (F)	10.9	6.4
	Port-Harcourt (C)	11.6	8.1
May to August	Nsukka (GS)	25.4	25.4
	Umudike (F)	22.5	29.5
	Owerri (F)	23.5	25.2
	Port-Harcourt (C)	19.0	27.8
September to December	Nsukka (GS)	23.3	14.6
	Umudike (F)	11.3	13.6
	Owerri (F)	17.2	16.8
	Port-Harcourt (C)	15.8	18.3

Table 3.

Month	Nsukka (GS) E_k	Nsukka (GS) E	Umudike (F) E_k	Umudike (F) E	Owerri (F) E_k	Owerri (F) E	Port-Harcourt (C) E_k	Port-Harcourt (C) E
January	0	0	3.0	2.1	5.3	3.3	4.5	2.7
February	0	0	6.6	3.9	10.4	6.9	29.8	20.0
March	13.4	13.7	30.1	20.9	24.1	16.9	50.3	31.1
April	21.0	16.2	43.2	28.3	34.2	20.8	32.0	19.5
May	28.7	19.9	59.1	43.8	55.0	33.6	62.4	39.5
June	37.6	23.8	62.3	39.6	90.1	58.9	68.4	40.7
July	40.8	24.8	67.9	42.3	61.5	34.8	62.6	37.2
August	54.4	32.2	50.3	35.5	71.9	42.1	52.1	29.0
September	53.4	32.1	63.5	41.7	73.8	46.2	82.1	43.5
October	50.8	33.0	[illegible]7.2	23.9	63.7	39.3	70.5	42.7
November	9.4	6.7	7.3	5.0	21.5	13.1	26.4	16.5
December	3.1	2.1	2.5	1.0	3.8	3.5	3.5	2.2

Table 4

Month	EI_{30} MJ.mm/ha.h	KE≥25 MJ/ha	AI_m $cm^2\ h^{-1}$	E_tI_{30} MJ.mm/ha.h	E_tI_m MJ.mm/ha.h
January	0	0	0	0	0
February	0	0	0	0	0
March	289	7	24	434	1009
April	508	9	48	824	1753
May	988	16	99	1597	3812
June	3150	16	127	1896	4915
July	1344	16	90	2025	3653
August	1834	20	119	2867	4574
September	2262	24	156	3466	5999
October	1779	26	147	2626	5596
November	305	5	27	428	977
December	367	2	12	536	465

Table 5

Month	EI_{30} MJ.mm/ha.h	KE≥25 MJ/ha	AI_m $cm^2\ h^{-1}$	E_tI_{30} MJ.mm/ha.h	E_tI_m MJ.mm/ha.h
January	97	2	14	143	527
February	145	3	18	238	674
March	1209	17	95	1794	3270
April	1502	22	115	2285	4292
May	2398	33	192	3196	10341
June	2557	31	181	3942	7140
July	2466	30	243	4088	9553
August	1562	19	102	2599	4497
September	2185	29	168	3380	17339
October	1362	20	112	2158	3104
November	343	4	31	493	1210
December	94	0	4	262	151

Table 6

Month	EI_{30} MJ.mm/ha.h	KE≥25 MJ/ha	AI_m cm^2 h^{-1}	E_1I_{30} MJ.mm/ha.h	E_1I_m MJ.mm/ha.h
January	16	3	0	25	61
February	63	6	29	401	1090
March	866	15	6	1231	2453
April	1610	19	92	2184	3546
May	2046	30	143	3194	5473
June	4140	49	199	6022	12008
July	2170	30	163	3435	6241
August	1872	19	105	2532	12703
September	2677	34	199	4252	7902
October	2015	30	242	3214	7009
November	897	12	83	1324	3158
December	185	3	16	265	596

Table 7.

Month	EI_{30} MJ.mm/ha.h	KE≥25 MJ/ha	AI_m cm^2 h^{-1}	E_tI_{30} MJ.mm/ha.h	E_tI_m MJ.mm/ha.h
January	175	2	11	303	408
February	1745	16	105	2534	4039
March	2329	26	170	3814	6675
April	805	14	61	1289	2285
May	2478	31	169	3453	6471
June	2345	31	179	3888	6909
July	1764	25	127	2932	4841
August	1343	18	95	2364	4165
September	2399	29	225	3983	6649
October	2363	28	210	3721	8202
November	804	13	64	1230	2395
December	62	2	5	90	183

Table 8

Location	Approximate* Erosivity Indices F.A.O Modified FOURNIER Index	ROOSE Index
Nsukka (GS)	856.1	784.4
Umudike (F)	1280.2	1002.4
Owerri (F)	1260.6	1147.7
Port-Harcourt (C)	1107.1	1116.8

* The values can be converted to MJ.mm/ha.h by multiplying by 17 (FOSTER et al. 1981)

FIGURE CAPTIONS

Figure 1 Annual rainfall amount from 1973 to 1984 at Nsukka (Guinea Savanna belt) and Umudike (Forest belt), southeastern Nigeria*.

Figure 2 Monthly rainfall distribution in the past (1931-1960) and during the period of study (1973-1984) in southeastern Nigeria.

Figure 3 An advanced storm (high initial peak intensity) on 14th November, 1980 at Owerri (Forest belt), southeastern Nigeria.

Figure 4 An intermediate storm (183 mm, 5 h duration) with multiple peak intensities on 15th July, 1978 at Umudike (Forest belt), southeastern Nigeria.

Figure 5 Frequency distribution of rainfall intensity classes for southeastern Nigeria.

Figure 6 Cumulative volume versus raindrop diameter for selected rain events at Nsukka (Guinea Savanna belt), southeastern Nigeria.

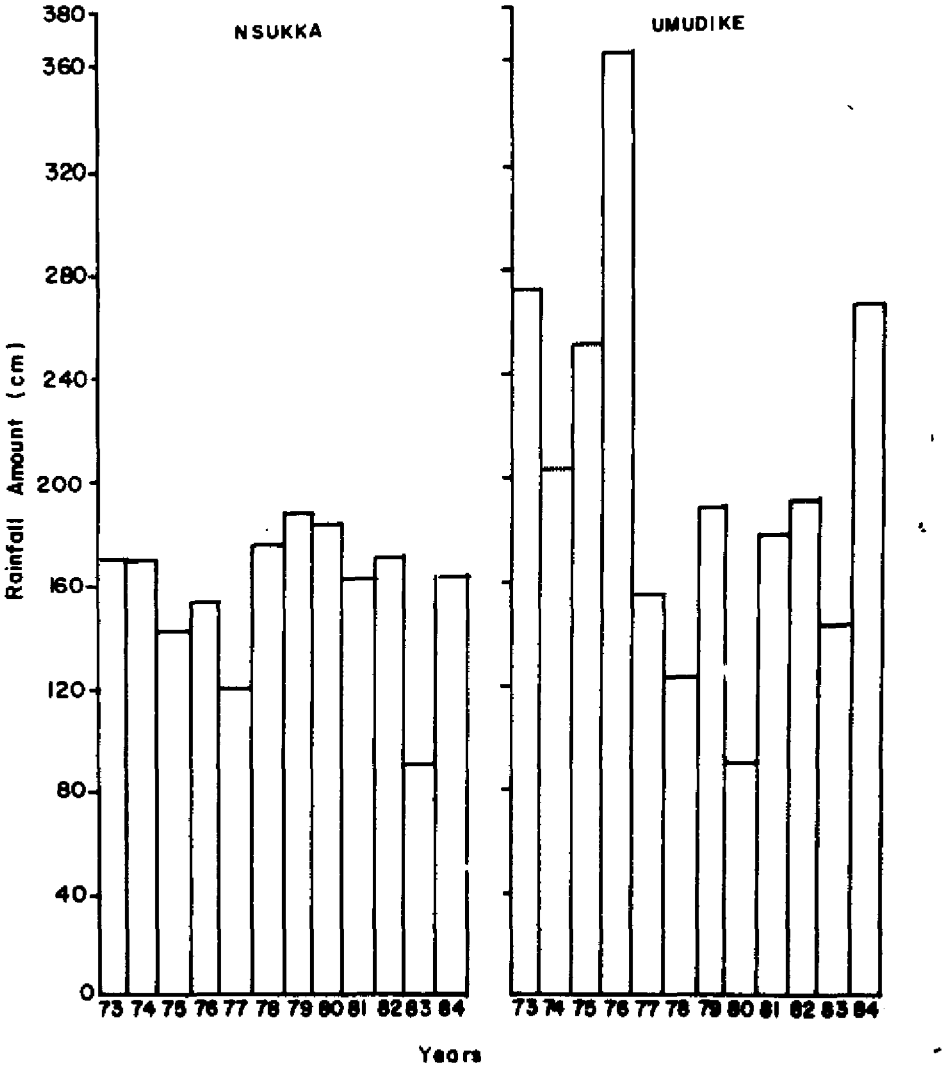

NSUKKA
UMUDIKE
Rainfall Amount (cm)
380
360
320
280
240
200
160
120
80
40
0
73 74 75 76 77 78 79 80 81 82 83 84
73 74 75 76 77 78 79 80 81 82 83 84
Years

Fig.1

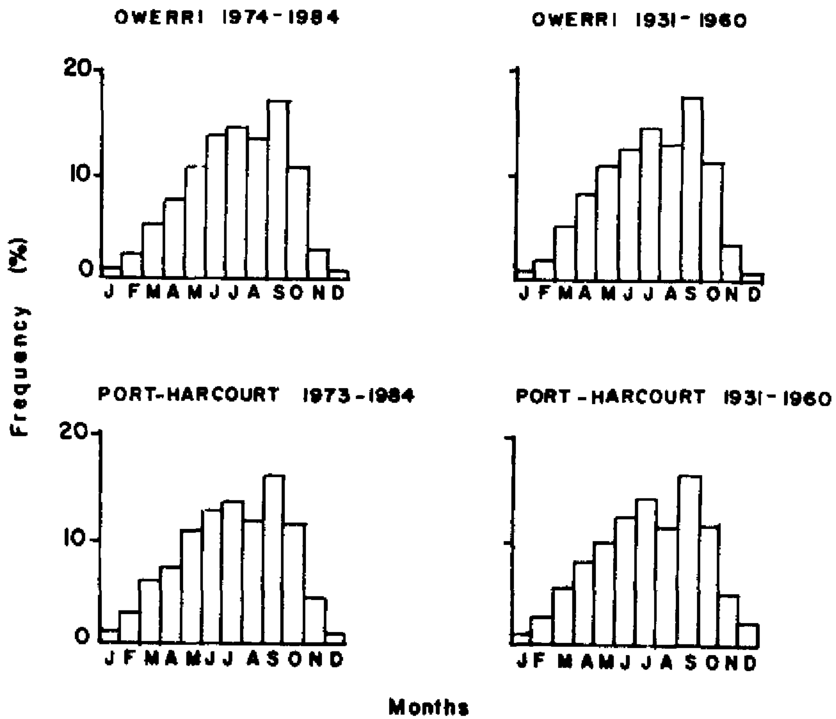
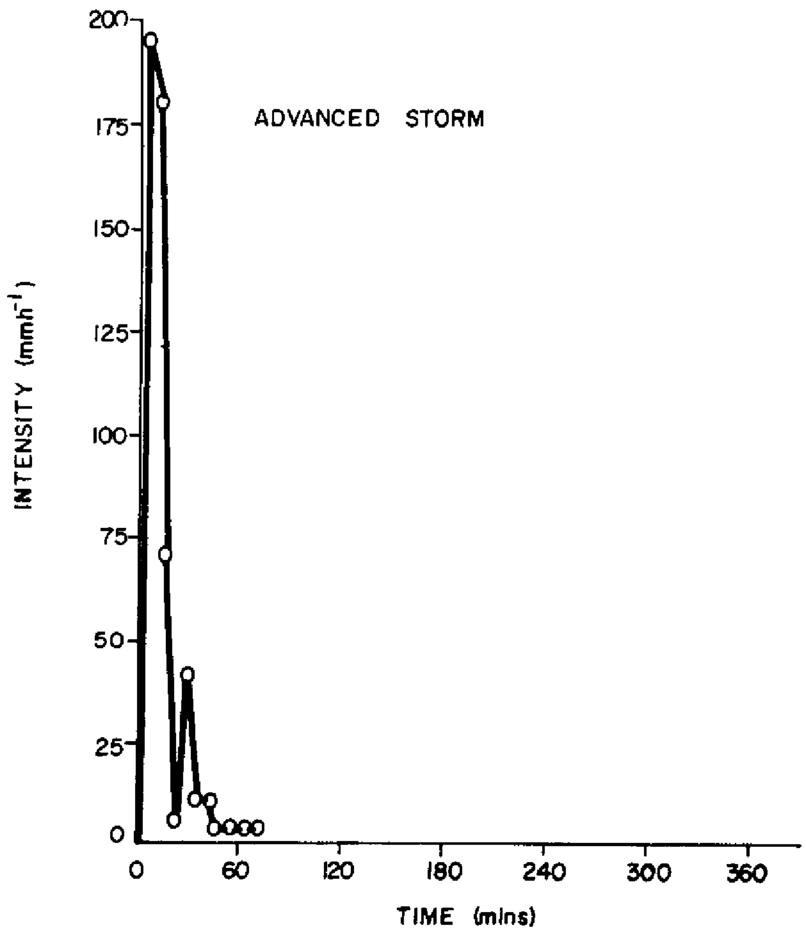
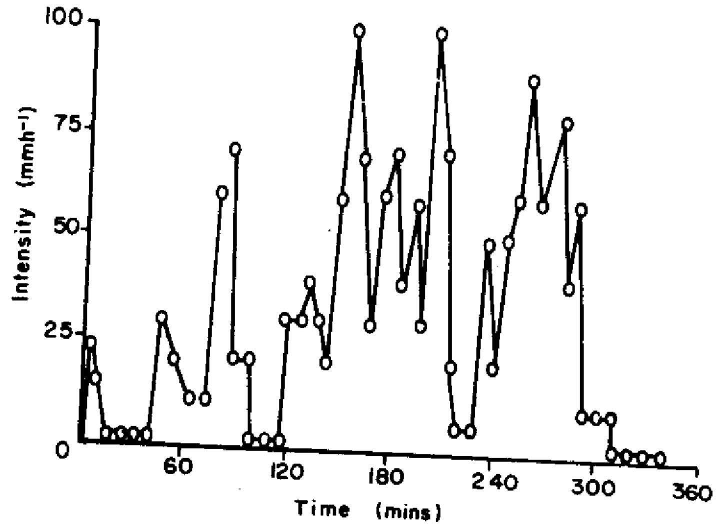

OWERRI 1974-1984
OWERRI 1931-1960
PORT-HARCOURT 1973-1984
PORT-HARCOURT 1931-1960
Frequency (%)
20
10
0
J F M A M J J A S O N D
Months

Fig.2



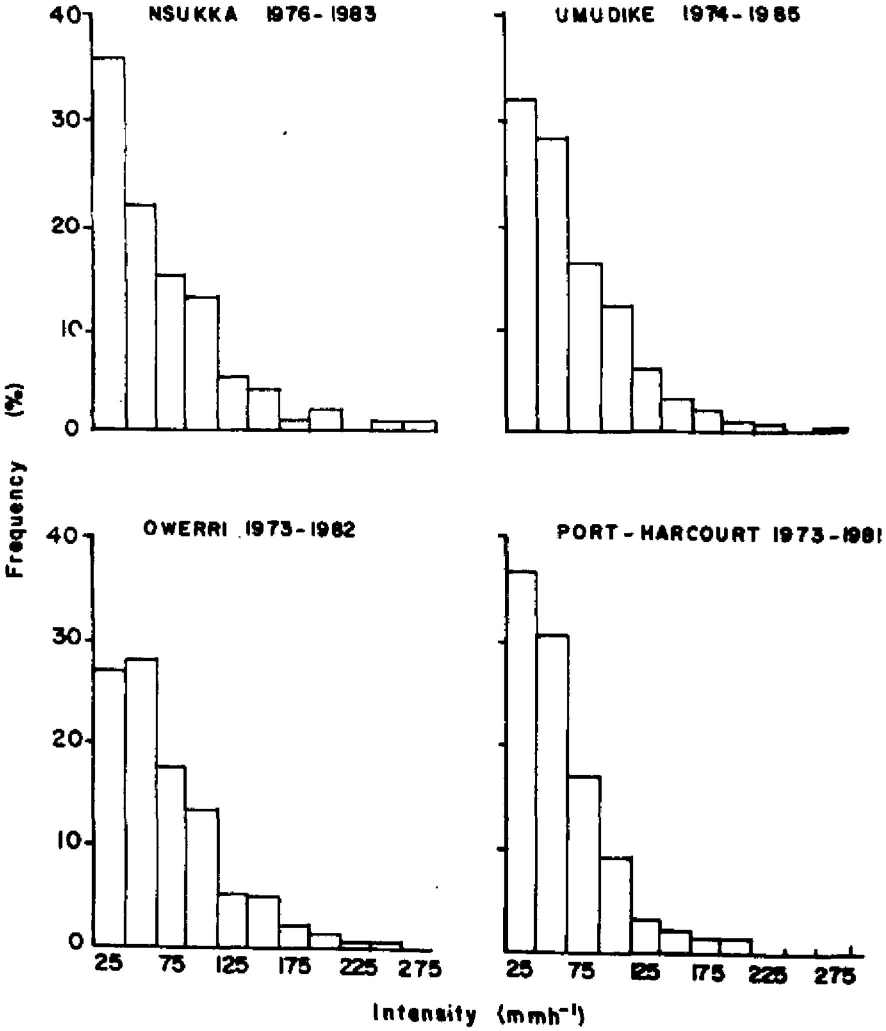
ADVANCED STORM
INTENSITY (mmh^{-1})
200
175
150
125
100
75
50
25
0
0
60
120
180
240
300
360
TIME (mins)

Fig.3



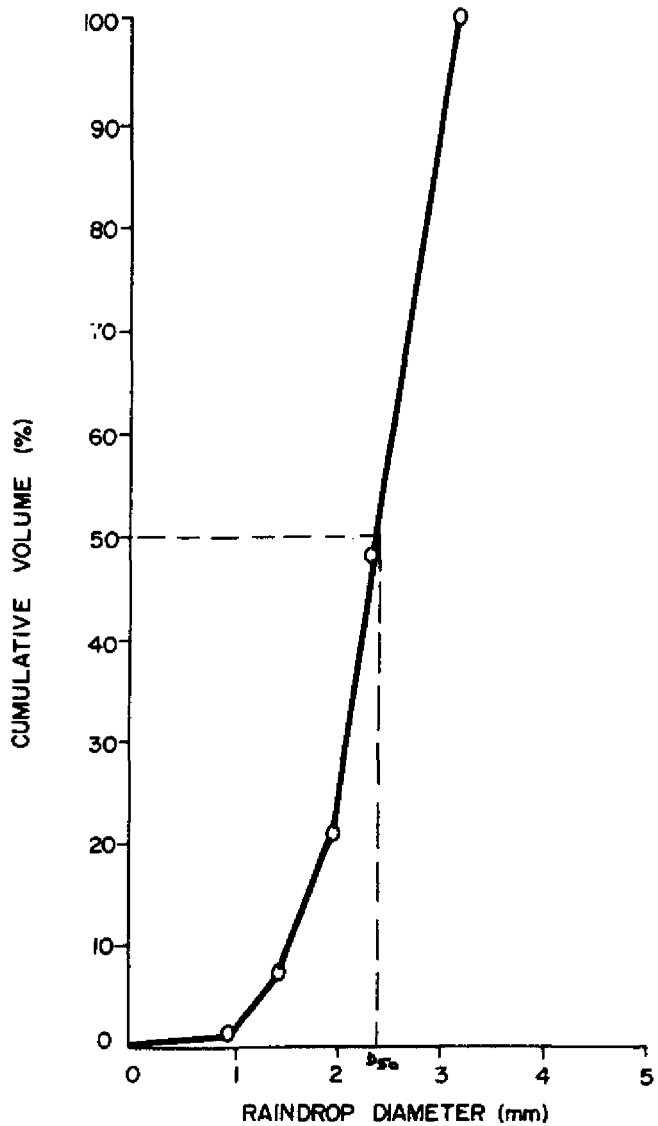
Intensity (mmh^{-1})
100
75
50
25
0
60
120
180
240
300
360
Time (mins)

Fig.4



NSUKKA 1976-1983
UMUDIKE 1974-1985
OWERRI 1973-1982
PORT-HARCOURT 1973-1981
Frequency (%)
0
10
20
30
40
25
75
125
175
225
275
Intensity (mmh⁻¹)

Fig.5



CUMULATIVE VOLUME (%)
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
RAINDROP DIAMETER (mm)

Fig.6