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Determination of Rainfall Erosivity Index (R) For Imo State, Nigeria

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ABSTRACT: *In order to proffer solutions to erosion within the southeastern part of the country predominantly by the erosive nature of rainfall, the study aims at determining the rainfall erosivity index (R) of Imo State by the use of historical data of over thirty years (1980-2010). The data for rainfall records were grouped in mean groups for each month (January - December), the mean, standard deviation and coefficient of variation were 199.15, 144.76 and 0.727 respectively. From empirical equations rainfall intensities and erosivity index were obtained at 30, 45 and 60 minutes duration of rainfall respectively, and based on 30minute maximum erosive rainfall Rainfall erosivity index R was obtained as 6033.40 MJmmha^{-1} h^{-1}. A close observation of the data obtained revealed that as rainfall intensity increased with duration the rainfall erosivity index reduced or decreased. The study area was grouped as a medium – strong erosivity zone based on R index obtained. Nevertheless it is expected that if proper cover crop and management practices are applied despite the region (rain forest) the study area falls within, the effect of rainfall erosivity can be cushioned thus reducing further tendencies of erosion and enhance chances of food production from productive lands within the area.*

Keywords: *Rainfall erosivity, RUSLE, Soil erosion, USLE*

I. INTRODUCTION

Soil erosion which is a global threat responsible for soil nutrient depletion, degradation of soil quality, destruction of soil structure and disruption of ecosystem; have reduced the availability of productive lands for cultivation which in turn has greatly reduced chances of food sufficiency and security in the country. Though the potential for erosion is dependent on certain factors which include soil nature/characteristics, nature of slope/topography, presence of vegetation and climatic conditions, (Michael and Ojha, 2002). The major contributing factor to soil loss and movement is rainfall and its characteristics (intensity, distribution, duration, frequency, kinetic energy). Soil erosion by rainfall causes many problems, such as decreased agricultural productivity due to the loss of arable land, increased landslide activity, ecosystem disturbance, and contaminant diffusion by the inflow of sediment to rivers, (Joon-Hak and Jun-Haeng, 2011). According to Lal, (2002); Ezemonye and Emeribe, (2012),under particular environmental conditions rainfall is the main factor driving degradation because it can erode soils and nutrients by force of raindrops, surface and sub-surface runoff. Idah *et al.*, (2008) stated that when there is too much water on the soil surface, it fills surface depressions and begins to flow, then with enough speed, surface runoff carries away the loose soil. Suresh (2012), stated equally that soil erosion occurs in three phenomena detachment, transportation and deposition; and rainfall creates the medium through which they all take place. The ability of rainfall to cause soil disturbance, detachment, transport and eventual deposition which results in soil erosion is referred to as rainfall erosivity. Rainfall erosivity is the main parameter to relate soil losses to erosion, which is the ability of rainfall to detach soil particles, (Sanchez-Moreno *et al.*, 2013). Erosivity is the power of a storm to erode soil, it is usually determined from the characteristics of the storm, (Wang *et al.*, 2013). Rainfall erosivity is one of the factors of the USLE (Universal Soil Loss Equation by Wischmeier and Smith, 1978) and RUSLE (Revised Universal Soil Loss Equation by Renard *et al*., 1997), It states as follows;

A = R x K x S x C x P ………………… (1)

Where R = Rainfall Erosivity factor
K = Soil Erodibility Factor
S = Slope length and Steepness factor
C = Cover Crop Management Factor
P = Conservative/Management practice Factor

Rainfall erosivity factor is designated by R, this factor according to (Ezemonye and Emeribe, 2012; Igwe, 2012; Angelo-Martinez and Beguaria, 2009; Bhaware, 2006) rainfall erosoivity depends on amount, duration, intensity, rain drop size and shape, distribution, frequency and kinetic energy. Rainfall erosivity is of paramount importance among natural factors affecting soil erosion, and unlike some other natural factors, such as relief or soil characteristics, is not amenable to human modification (Angelo-Martinez and Beguaria, 2009). The objective of this study is to make use of mean monthly rainfall data to determine the rainfall erosivity index/factor of Imo State, Nigeria.

II. MATERIALS AND METHODS

2.1 Study Area Description

The study area falls within Latitudes 4°45"N and 7°15"N and Longitudes 6°50"E and 7°25"E, with an area of 5100 km^2. It lies within the humid tropics and is generally characterized by a high surface air temperature regime all year round, with mean minimum temperature of 23.5° C and mean maximum temperature of 32.1° (Okorie *et al.*, 2012). The rainfall pattern in the area is oscillatory, bimodal and usually has tow peaks within the year. The peaks vary between June, July and September with a short recess in August usually referred to as August break. The study area is within the rainforest region, so it experiences annual rainfall ranges from 1600-2900mm (Selemo *et al*., 2012). The soil predominant in the area is sandy soil with little percentages of clay, loam and silt (Njoku *et al*., 2011). The soil profile is remarkably uniform throughout the area, deeply weathered and intensely leached.

III. DATA COLLECTION

In obtaining the rainfall erosivity factor/ index of the study area (Imo), mean monthly rainfall data (rainfall amount and days) for 31 years (1980-2010) was obtained from Nigerian Metrological Agency (NIMET), Oshodi, Lagos. The rainfall data was grouped and according to Sanchez-Moreno *et al.*, 2013; Suresh, 2012; Oliviera *et al.*, 2012 and Wischmeier and Smith 1965, the Rainfall erosivity factor/index is given by;

$R = \Sigma(EI_{30})$ ……………………… (2)

Where E = Kinetic Energy of storm or rainfall events
I_{30} = 30 minute rainfall intensity

From the above equation to obtain the kinetic energy of the storm or rainfall events the relationship is given by Soo Huey Teh, (2011) as;

$E = 210.3 + 87\log_{10} I$ ………………. (3)

Where I = Rainfall intensity (cm/hr)

Rainfall intensity which is the rate of rainfall expressed as depth per time (Michael and Ojha, 2003) is given by;

$I = P/T$ ………………………………………...4.0

Where P = Precipitation in cm or mm
T = Duration of rainfall in hours

IV. RESULTS AND DISCUSSION

Table 1.0: Values of rainfall amount and days

MONTH	M.R.A (cm)	M.R.D (days)	$(X_1\text{-}X)$	$(X_1\text{-}X)^2$
JANUARY	24.97	1.03	-174.18	30338.67
FEBRUARY	32.94	1.48	-166.21	27625.76
MARCH	105.56	4.10	-93.59	8759.09
APRIL	174.91	6.90	-24.24	587.58
MAY	259.68	10.07	60.53	3663.88
JUNE	319.90	10.97	120.75	14580.56
JULY	378.42	13.94	179.27	32137.73
AUGUST	348.79	14.58	149.64	22392.13
SEPTEMBER	387.79	14.07	188.64	35359.04
OCTOBER	269.11	11.45	69.96	4894.40
NOVEMBER	74.87	3.10	-124.28	15445.52
DECEMBER	12.83	0.52	-186.32	34715.14
	Σ= 2389.77			Σ=230499.50

Where;
M.R.A = Mean Rainfall Amount (cm)

M.R.D = Mean Rainfall Days (days)

$X = \Sigma MRA / N$ = 2389.77/12 = 199.15

$SD = \frac{\sqrt{\Sigma(x_1 - X)}}{N-1} = \frac{\sqrt{230499.50}}{11} = 144.76$

$CV = \frac{X}{SD} = \frac{144.76}{199.15} = 0.727$

From TABLE 1.0 the rainfall data obtained for the specified period of 31 years (1980-2010), were grouped according to mean rainfall amount and mean rainfall days. The data was then subjected to statistical analysis and the mean (X), standard deviation (SD) and coefficient of variation were 199.15, 144.76 and 0.727 respectively. With reference to the coefficient of variation (CV) it signifies that the level variation in rainfall amount over the last thirty one (31) years have been high, this basically is observed in response to climate change.

Table 2.0: Values of Rainfall Intensity and Kinetic Energy

MONTH	I_{30} (cm/hr)	I_{45} (cm/hr)	I_{60} (cm/hr)	E ($MJmmha^{-1}$)	EI_{30} ($MJmmha^{-1}h^{-1}$)	EI_{45} ($MJmmha^{-1}h^{-1}$)	EI_{60} ($MJmmha^{-1}h^{-1}$)
JAN	2.02	1.35	1.01	236.87	478.48	319.78	239.24
FEB	1.86	1.24	0.93	233.75	434.78	289.85	217.39
MAR	2.15	1.43	1.07	239.22	514.32	342.09	257.16
APR	2.11	1.41	1.06	238.51	503.26	336.30	251.63
MAY	2.15	1.43	1.08	239.22	514.32	342.09	257.16
JUN	2.43	1.62	1.22	243.85	592.56	395.04	296.28
JUL	2.26	1.51	1.13	241.11	544.91	364.08	272.46
AUG	1.99	1.33	0.99	236.30	470.24	314.28	235.12
SEPT	2.29	1.53	1.15	241.61	553.29	369.66	276.65
OCT	1.96	1.31	0.98	235.73	462.03	308.81	231.02
NOV	2.01	1.34	1.01	236.68	475.73	317.15	237.87
DEC	2.06	1.37	1.03	237.61	489.48	325.33	244.74
					Σ = 6033.40	Σ = 4024.66	Σ = 3016.72

The intensity of rainfall was prepared on the basis of three different durations, 30, 34 and 60. From the values displayed it was observed that as rainfall duration increased the ratio of rainfall amount to duration (rainfall intensity) was decreasing. Likewise the erosivity index at different rainfall intensities also decreased with increase in rainfall duration. This relationship is dependent on the fact that as rainfall duration increases the soil undergoes saturation and pore spaces are filled thus exceeding infiltration capacity at this point the soil particles no longer undergoes detachment or splash but movement so therefore as rainfall duration increases rainfall intensity keeps decreasing. According to Wischmeier, (1965) rainfall erosivity is considered a product of kinetic energy and 30-minute maximum rainfall intensity, so the rainfall erosivity index/factor of the study area is 6033.40 $MJmmha^{-1}hr^{-1}$. The rainfall erosivity index (R), determined for Imo state was based on data made available from one station. The data obtained was analyzed using raster distribution from ArcGIS 10.2,to generate the rainfall erosivity map on a 10% variation. The map is presented in Fig.1.0.

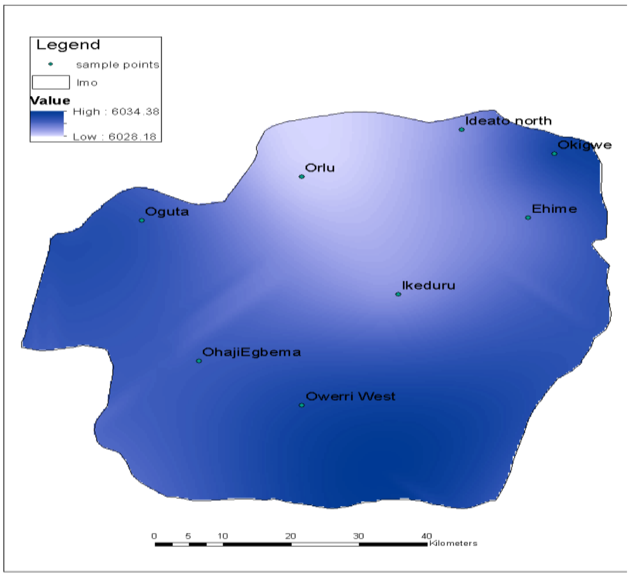

Figure 1.0: Rainfall Erosivity map (R) of Imo State

Table 3.0: Classification Of Rainfall Erosivity

EROSIVITY (MJmmha $^{-1}$hr $^{-1}$)	EROSIVITY CLASS
R≤ 2452	low erosivity
2452<R≤4905	medium erosivity
4905<R≤7357	medium- strong erosivity
7357<R≤9810	strong erosivity
<9810	very strong erosivity

Source: Carvalho (2008)

V. CONCLUSION

Different values of erosivity were obtained for different rainfall intensities of which are EI= 6033.40 MJmmha $^{-1}$h $^{-1}$, EI= 4024.66 MJmmha $^{-1}$h $^{-1}$ and EI = 3016 MJmmha $^{-1}$h $^{-1}$. According to Wischmeier, (1965), the minimum duration for an erosive storm event is 30 minutes, based on which the rainfall erosivity of the study area was taken as 6033.40 MJmmha $^{-1}$h $^{-1}$. Also from Table 3.0 the study area can be classified as an area with medium- strong erosivity, predominantly because of the region in which the study area lies i.e Tropical Rainforest zone.

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