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ASSESSMENT OF RAINFALL EROSIVITY FACTOR (R) FOR SELECTED LOCATIONS IN IMO STATE, SOUTHEASTERN NIGERIA

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Abstract*-Soil erosion in southeastern Nigeria is a major environmental issue of which rainfall is a major contributor to its elevated level(s). This study gives a critical assessment on the rainfall erosivity factor (R) for selected sites in Imo State representing different soil groups geologically by making use of mean monthly rainfall data and GIS techniques. By applying empirical methods the rainfall intensity for all the locations were obtained and was further determined at three different intervals of 30-minutes, 45-minutes and 60-minutes respectively. Through the use of the revised universal soil loss equation (RUSLE) the rainfall erosivity factor (R) was obtained for each of the locations and they are as follows; 6054.93 MJmm/ha/hr, 5211.48 MJmm/ha/hr, 5977.29 MJmm/ha/hr, 6171.57 MJmm/ha/hr, 6478.06 MJmm/ha/hr, 5567.54 MJmm/ha/hr, 5350.84 MJmm/ha/hr and 5470.29 MJmm/ha/hr for *Ehime Mbano*, *Ideato North*, *Ikeduru*, *Oguta*, *Ohajiegbema*, *Orlu* and *Owerri West* respectively. Likewise the rainfall erosivity factor (R) was determined at different rainfall intensities and it was observed that the factor (R) reduced with increase in rainfall intensity, thus conforming to the fact that as rainfall duration increases the soil approaches saturation and erosive force reduces as well. Also, the rainfall erosivity factor (R) for all the locations were subjected to a correlation analysis and they all yielded a strong/perfect correlation with a correlation coefficient of about 0.95 which shows or implies 95% strength. On further subjection to ANOVA the rainfall erosivity factor (R) for all the locations showed statistical significance at 5% value thus showing uniformity of region and non-variation in rainfall characteristics. The values obtained for each of the locations were mapped also to show the varying degree in the factor. Though rainfall is a natural climatic factor which is not amenable to human interference, it is therefore important to enact and adopt proper cover/management practices/measures so as to sustain the environment against further effects.

Keywords: Soil, Erosion, Erosivity, RUSLE, Rainfall Erosivity Factor

I. INTRODUCTION

Agricultural soils are the richest supplies of minerals, nutrients, moisture, air, organic materials and microbial activities that support plant growth and production. They provide the pathways through which water and nutrients move to the roots of plants, and they are the matrix of nutrient transformation with the resultant environment for micro-organisms and fauna (Powlson *et al*., 2011). The availability of soils for agricultural production and food security is limited by the irreparable/destructive effects of erosion. Soil erosion is a serious environmental, economic and social problem, which causes severe land degradation, reduced productivity levels and threatens the stability and health of society in general alongside sustainable development of rural areas (Wang *et al*., 2013).Soil erosion is the gradual or rapid weathering/disintegration, removal and transportation of soil aggregates through the action of erosive agents such as wind, water, gravity and human disturbance (Gunawan *et al*., 2013). Soil loss by runoff (overland flow caused by rainfall) is a severe ecological problem occupying 56% of the world wide area and is accelerated by human induced soil degradation (Gelagay and Minale, 2016; Bai *et al*., 2008). Also the extent of deterioration of soils and water resources due to erosion and pollution has assumed a frightening dimension with its attendant effects on global food security, water quality and hygiene for sustainable livelihoods (Akinbile *et al*., 2016). The impact of soil erosion is felt in the inability of the soil to meet up with the moisture and nutrient requirements of the plants thereby resulting into soil

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degradation and low agricultural productivity. According to Michael and Ojha (2003), the potential for erosion is dependent on certain factors which include soil nature/characteristics, slope/topography, presence of vegetative cover and general climatic conditions. The major contributing factor to soil loss and movement is rainfall and its characteristics (intensity, duration, frequency, energy, distribution e.t.c) (Okorafor *et al*., 2017). The erosive ability of rainfall to initiate soil detachment, movement/transportation and eventual deposition in different locations is regarded as the erosivity of rainfall. Rainfall erosivity factor (R) is one of the six factors of the Universal Soil Loss Equation (Wischmeier and Smith, 1978) and Revised Universal Soil Loss Equation (Renard *et al*., 1997) which is stated thus;

$A = RKSCP$…………………………………….. (1)

Where A= Annual soil Loss
R= Rainfall Erosivity Factor
K= Soil Erodibility Factor
S= Slope Length and Steepness Factor
C= Cover Crop Management Factor
P= Conservation/Management Practice Factor

Rainfall erosivity factor is dependent on the amount, duration, intensity, raindrop size, distribution, frequency and kinetic energy of a rainfall/storm event (Okorafor *et al*., 2017). This is a natural factor since it is not amenable to human modification and cannot be adjusted or regulated to prevent the resultant damage it may cause. The main objective of this study is to make use of mean monthly rainfall data to determine rainfall erosivity factor (R) for Imo State (different soil groups/locations) and to make use of geographical information system (GIS) to map the study area according to the magnitude of the rainfall erosivity factor (R).

II. MATERIALS AND METHODS

2.1 Description of Study Area

Imo State is located within latitude 4°45′N and 7°15′N and longitude 6°50′E and 7°25′E and covers an area of about 5100 km^2 and falls within the rain forest belt of Nigeria with two distinct seasons (*i.e*. wet and dry) which exists within the region (Okoro *et al*., 2014; Okorie, 2015). The study area experiences high rainfall amounts of about 1600-2900 mm (Selemo *et al*., 2012; Okorafor *et al*., 2018). The relative humidity ranges from 75-90% (Udokporo *et al*., 2015) with mean minimum temperature of 23.5°C and mean maximum temperature of 32.9°C (Okorie, 2015). According to Nkheloane *et al*., 2012; Ernest and Onweremadu, 2016), the soils of Imo State have a characterized brown colour ranging from strong dark brown to yellowish red thus indicating the strong presence of iron oxide; also soils of Imo State are characterized by high sand percentage, low organic matter content and low water storage capacity thus placing the zone as an area of high susceptibility to accelerated erosion and land degradation (Ufot *et al*., 2016: Ibeje, 2016). The soils are predominantly ultisols derived from coastal plain sand (benin formation) and have low pH with exchangeable bases (Onwudike, 2010). The high temperature and humidity experienced within the region favors luxuriant plant growths which produce the climax vegetation of the tropical rainforest zone (Udokporo *et al*., 2015). Furthermore the watershed is covered by depleted rainforest shrubs having thick under brushes, creeping vines and deep green vegetation which is as a result of heavy decay of plant droppings, foliage and litter. The map of Imo State is as shown in Figure 1.

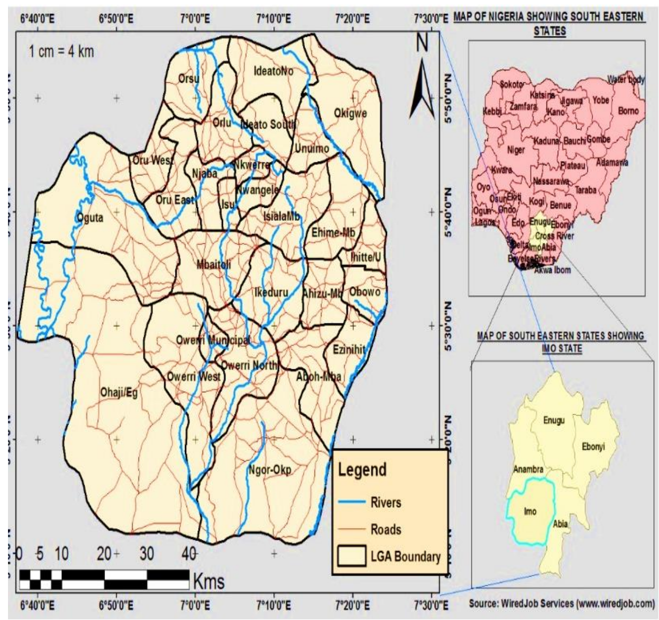

Figure 1: Map of Study Area (Okorafor *et al*., 2018)

2.2 Selection of Locations

The study area was subdivided into eight soil groups based on geological classification of base materials found within each zone. The various soil groups with their major towns and percentage area of coverage are as summarized in Table 1. The soil map also indicating the various soil groups are as shown in Figure 2.

Table 2.1: Soil Groups, Percentage Coverage and Site Locations

Soil Type/Group	Percentage Coverage	Site Location
Sands, gravel and clay (Meander belts).	5.9	*OhajiEgbema*
Sands and clay (Coastal plains sands).	48.6	*Owerri West*
Sands, clays and swamps (Sombreiro Deltaic plane)	1.8	*Oguta*
Clays, sandstones, lignite and shales (Lignite formation)	12.2	*Ikeduru*
Clayey sands and shales (Bende-Ameke and Nnanka stones).	20.3	*Orlu*
Clay and shales (Ebenebe and Umuna sandstones).	6.3	*Ehime Mbano*

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Sandstones (Imo formation).	1.2	*Ideato North*
Sandstones, Limestones and Coal(Upper coal).	3.6	*Okigwe*

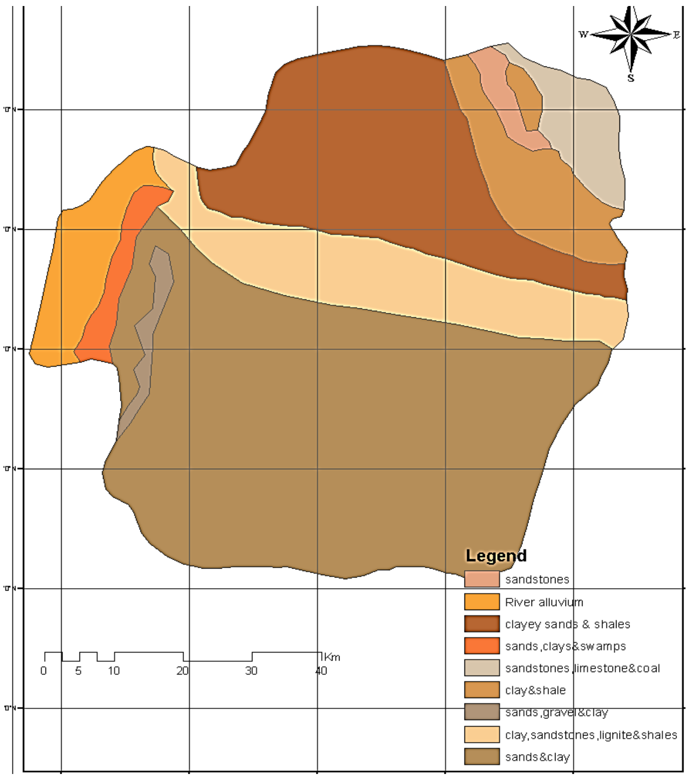

Figure 2: Soil Map of the Study Area (Okorafor *et al.*, 2018)

2.3. Data Collection and Computation

In order to determine the rainfall erosivity factor (R) of the selected locations rainfall data (Mean monthly rainfall amount and rainfall days) were obtained from NIMET (Nigerian Meteorological Agency) for a period of 31 years (1986-2016). According to Sanchez-Moreno *et al*, (2013); Oliviera *et al*, (2012) rainfall erosivity factor (R) is computed thus;

$R = \Sigma(EI_{30})$…………………………………. (2)

Where R= Rainfall Erosivity Factor

I_{30} = 30 minutes rainfall intensity

E = Total Storm Kinetic Energy

The kinetic energy of the storm or rainfall event is obtained from the following relationship according to Teh (2011) as;

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

Where E = Unitary kinetic energy

I = Rainfall Intensity

The rainfall intensity (I) which is the rate of rainfall express as depth per time (Michael and Ojha, 2003) is given by Yin *et al*, (2007) as;

$I = {}^{P}/_{T}$ …………………………………………... (4)

Where P = Precipitation

T = Duration of Rainfall

The resultant 30 minute interval rainfall (I_{30}) is also obtained according to Yin *et al*, (2007) as;

$I_{30} = {}^{P_{30}}/_{0.5h}$ ………………………………….. (5)

Where P_{30} = Maximum 30 minute rainfall

0.5h = 30 minutes duration

The results obtained for the rainfall erosivity factor (R) for all the locations representing different soil groups was interfaced with ArcGis 10.1 and under raster distribution the study area was mapped to reveal the variation of rainfall erosivity factor (R) within the various soil groups.

III. RESULTS

Based on the 31year rainfall data used rainfall intensity for different time intervals (30minutes, 45minutes and 60minutes) was obtained and based on the varying time intervals the kinetic energy and rainfall erosivity factor (R) were also obtained for all the various locations representing different soil groups as well. The results for rainfall intensity, kinetic energy and rainfall erosivity factor (R) for each location are as shown in Tables 3.1-3.9. The summary of the mean rainfall erosivity factor (R) i.e EI_{30} for all the locations (different soil groups) are also as shown in Table 3.10.

Table 3.1: Mean Rainfall Amount and Rainfall Days for all the Locations (1986- 2016)

Month	Ehime Mbano (mm)	Ideato North (mm)	Ikeduru (mm)	Oguta (mm)	Ohaji (mm)	Okigwe (mm)	Orlu (mm)	Owerri West (mm)	Rainfall Days (hrs)
January	110	90	90	130	110	100	110	8	24.72
February	520	370	390	410	450	430	360	300	35.52
March	1100	980	1120	1000	1220	1030	950	1090	98.40
April	1460	1470	1490	1580	1680	1420	1510	1560	165.6
May	2830	2800	2700	2850	2930	2790	2700	2670	241.68
June	3200	2920	3610	3520	3880	2980	2860	4070	263.28
July	3550	3120	3470	4090	3500	3310	3370	3030	334.56
August	3320	3030	3600	3150	3410	3400	3070	3990	349.92
September	3210	3080	3110	3640	3500	3100	3280	2760	337.68
October	2610	2490	2680	2900	2830	2570	2550	2790	274.8
November	740	620	750	790	840	710	650	680	74.4
December	110	70	120	90	120	80	80	14	12.48

Table 3.2: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ehime Mbano* (Clay and Shales)

Month	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30} (R) (MJmm/hahr^{-1})	EI_{45} (R) (MJmm/hahr^{-1})	EI_{60} (R) (MJmm/hahr^{-1})
January	8.899	5.933	4.449	267.995	2381.95	1590.01	1192.31
February	29.279	19.519	14.639	314.030	9202.39	6129.55	4597.09
March	22.358	14.905	11.179	303.507	6788.05	4525.26	3394.02
April	17.633	11.755	8.816	294.429	5191.67	3461.01	2595.69
May	23.427	15.612	11.709	305.398	7154.56	4767.09	3575.32
June	24.309	16.456	12.154	306.840	7458.97	5049.34	3729.33
July	21.222	14.147	10.611	301.592	6400.39	4266.62	3200.19
August	18.976	12.651	9.488	297.268	5640.96	3760.74	2820.48
September	19.012	12.675	9.506	297.341	5653.05	3768.79	2826.52
October	18.996	12.664	9.498	297.309	5647.68	3765.12	2823.84
November	19.892	13.262	9.946	299.091	5949.52	3966.55	2974.76
December	17.628	11.752	8.814	294.420	5190.04	3460.02	2595.02

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Table 3.3: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ideato North* (Sandstones)

Month	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30} (R) (MJmm/hahr^{-1})	EI_{45} (R) (MJmm/hahr^{-1})	EI_{60} (R) (MJmm/hahr^{-1})
Jan.	7.282	4.854	3.641	260.25	1895.14	1263.25	947.57
Feb.	20.833	13.889	10.417	300.88	6288.23	4178.92	3134.27
Mar.	19.919	13.279	9.959	299.14	5958.57	3972.28	2979.14
Apr.	17.754	11.836	8.877	294.69	5231.93	3487.95	2615.96
May	23.179	15.447	11.586	304.99	7069.37	4711.18	3533.61
Jun.	22.182	15.016	11.091	303.30	6727.80	4554.35	3363.90
Jul.	18.651	12.434	9.326	296.60	5531.89	3687.92	2766.09
Aug.	17.318	11.546	8.659	293.74	5086.99	3391.52	2543.49
Sept	18.242	12.161	9.121	295.74	5394.89	3596.49	2697.45
Oct.	18.122	12.081	9.061	295.49	5354.87	2569.82	2677.43
Nov.	16.667	11.111	8.333	292.25	4870.93	3247.19	2435.32
Dec.	11.218	7.48	5.609	276.95	3106.83	2071.59	1553.41

Table 3.4: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ikeduru* (Clays, Sandstones, Lignite and Shales)

Month	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R) (MJmm/hahr^{-1})	EI_{45}(R) (MJmm/hahr^{-1})	EI_{60}(R) (MJmm/hahr^{-1})
January	7.282	4.854	3.641	260.25	1895.14	1263.25	947.57
February	21.959	14.639	10.979	302.91	6651.60	4434.30	3325.65
March	22.764	15.176	11.382	304.30	6927.09	4618.06	3463.54
April	17.995	11.997	8.998	295.22	5312.48	3541.75	2656.39
May	22.351	14.896	11.172	303.58	6839.96	4522.13	3391.60
June	27.423	18.564	13.712	311.50	8542.27	5782.69	4271.29
July	20.744	13.829	10.372	300.71	6337.95	4158.52	3118.97
August	20.576	13.717	10.288	300.39	6180.83	4120.45	3090.41
September	18.419	12.279	9.209	296.12	5454.23	3636.06	2726.97
October	19.505	13.003	9.753	298.33	5818.93	3879.19	2909.61
November	20.161	13.441	10.081	299.61	6040.44	4027.06	3020.37
December	19.231	12.821	9.615	297.78	5726.61	3817.84	2863.16

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Table 3.5: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Oguta* (Sands, Clays and Swamps)

Months	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R) ($MJmm/hahr^{-1}$)	EI_{45} ($MJmm/hahr^{-1}$)	EI_{60} ($MJmm/hahr^{-1}$)
January	10.518	7.012	5.259	274.46	2886.77	1924.51	1517.49
February	23.086	15.390	11.543	304.85	7037.77	4691.64	3518.88
March	20.325	13.550	10.162	299.92	6095.87	4063.92	3047.79
April	19.082	12.721	9.541	297.48	5676.51	3784.24	2830.22
May	23.593	15.723	11.793	305.68	7211.91	4806.21	3604.88
June	26.739	18.101	13.369	310.52	8302.99	5620.72	4151.34
July	24.450	16.300	12.225	307.07	7507.86	5005.24	3753.93
August	20.062	12.003	9.002	295.24	5923.10	3543.77	2657.75
September	21.559	14.373	10.779	302.20	6515.13	4343.52	3257.41
October	21.106	14.071	10.553	301.38	6360.93	3035.20	3180.46
November	21.237	14.158	10.618	301.62	6405.50	4270.34	3202.60
December	14.423	9.615	7.211	286.66	4134.49	2756.24	2067.11

Table 3.6: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ohaji* (Sands, Gravel and Clay)

Months	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R) ($MJmm/hahr^{-1}$)	EI_{45} ($MJmm/hahr^{-1}$)	EI_{60} ($MJmm/hahr^{-1}$)
January	8.899	5.933	4.449	267.99	2381.95	1590.01	1192.31
February	25.338	16.892	12.669	308.44	7815.25	5210.17	3907.63
March	24.797	16.531	12.398	307.61	7627.81	5085.10	3813.75
April	20.289	13.527	10.145	299.86	6083.86	4056.21	3042.08
May	24.255	16.165	12.124	366.74	7439.98	4958.45	3718.92
June	29.474	19.953	14.737	314.29	9263.38	6271.03	4631.69
July	20.923	13.949	10.462	301.05	6298.87	4199.35	3149.59
August	19.490	12.993	9.745	298.30	5813.87	3875.81	2906.93
September	20.729	13.819	10.365	300.69	6233.00	4155.24	3116.65
October	22.597	13.731	10.298	300.44	6188.16	4125.34	3093.93
November	22.581	15.054	11.290	303.99	6864.40	4576.27	3432.05
December	19.231	12.821	9.615	297.78	5726.61	3817.84	2863.16

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Table 3.7: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Okigwe* (Sandstones, Limestones and Coal)

Months	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R) ($MJmm/hahr^{-1}$)	EI_{45} ($MJmm/hahr^{-1}$)	EI_{60} ($MJmm/hahr^{-1}$)
January	8.091	5.394	4.045	264.32	2138.61	1425.74	1069.17
February	24.211	16.141	12.106	306.69	7425.27	4950.29	3712.79
March	20.935	13.957	10.467	301.06	6302.69	4201.89	3151.20
April	17.149	11.433	8.575	293.36	5030.83	3353.98	2515.56
May	23.096	15.322	11.544	304.85	7040.82	4670.91	3519.19
June	22.638	15.324	11.319	304.09	6883.99	4659.88	3441.99
July	19.787	13.191	9.894	298.89	5914.14	3942.86	2957.22
August	19.433	12.955	9.717	298.19	5794.73	3863.05	2897.51
September	18.361	12.240	9.180	295.99	5434.67	3622.92	2717.19
October	18.705	12.489	9.352	296.71	5549.96	3705.61	2774.83
November	19.086	12.724	9.543	297.49	5677.89	3785.26	2838.95
December	12.821	8.547	6.410	282.11	3616.93	2411.19	1808.33

Table 3.8: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Orlu* (Clayey Sands and Shales)

Months	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R) ($MJmm/hahr^{-1}$)	EI_{45} ($MJmm/hahr^{-1}$)	EI_{60} ($MJmm/hahr^{-1}$)
January	8.899	5.933	4.449	267.99	2381.95	1590.01	1192.31
February	20.270	13.514	10.135	299.82	6077.35	4051.77	3038.68
March	19.309	12.873	6.654	297.94	5752.92	3835.38	2876.31
April	18.237	12.157	9.118	295.73	5393.23	3595.19	2696.47
May	22.351	14.896	11.170	303.58	6785.32	4522.13	3391.29
June	21.726	14.707	10.863	302.49	6571.89	448.72	3285.95
July	20.146	13.431	10.073	299.58	6035.34	4023.66	3017.67
August	17.547	11.698	8.773	294.24	5163.03	3442.02	2581.37
September	19.427	12.951	9.713	298.17	5792.63	3861.65	2896.16
October	18.559	12.373	9.279	296.41	5501.07	3667.48	2750.39
November	17.473	11.649	8.737	294.08	5138.46	3425.74	2569.38
December	12.821	8.547	6.410	282.11	3616.93	2411.19	1808.33

Table 3.9: Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Owerri West* (Sands and Clay)

Months	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R) (MJmm/hahr^{-1})	EI_{45} (MJmm/hahr^{-1})	EI_{60} (MJmm/hahr^{-1})
January	6.525	4.315	3.236	255.69	1668.38	1103.30	829.41
February	16.891	11.261	8.446	292.77	4945.18	3296.88	2472.74
March	22.154	14.769	11.077	303.25	6718.20	4478.69	3359.10
April	18.841	12.560	9.420	296.99	5595.59	3730.19	2797.65
May	22.103	14.730	11.048	303.15	6700.52	4465.40	3349.20
June	30.918	20.929	15.489	316.21	9776.58	6617.96	4897.78
July	18.113	12.076	9.057	295.47	5351.85	3568.09	2404.36
August	22.805	15.204	11.403	304.37	6941.16	4627.64	3470.73
September	16.347	10.898	8.173	291.50	4765.15	3176.77	2382.43
October	20.306	13.537	10.153	299.89	6089.57	4059.61	3044.78
November	18.279	12.186	9.139	295.82	5407.29	3604.86	2703.49
December	6.571	4.380	3.285	256.27	1683.95	1122.46	841.85

Table 3.10: Mean Rainfall Erosivity Factor (R) for all the Locations

Soil Texture/Location	Mean Rainfall Erosivity Factor (R) (MJmm/hahr^{-1})
Clay and Shales (*Ehime Mbano*)	6054.93
Sandstones (*Ideato North*)	5211.48
Clay, sandstones, lignite and Shale(*Ikeduru*)	5977.29
Sands, Clay and Swamps (*Oguta*)	6171.57
Sand, Gravel and Clay (*OhajiEgbema*)	6478.06
Sandstones, Limestones and Coal (*Okigwe*)	5567.54
Clayey sands and Shale (*Orlu*)	5350.84
Sands and Clay (*Owerri West*)	5470.29

The mean annual rainfall erosivity factors (R) as shown in Table 3.10 for all the locations was transposed into an ArcGIS 10.1 interface and the map of rainfall erosivity was obtained using raster distribution and high aspect supervision. The rainfall erosivity map is as shown in Figure 2.

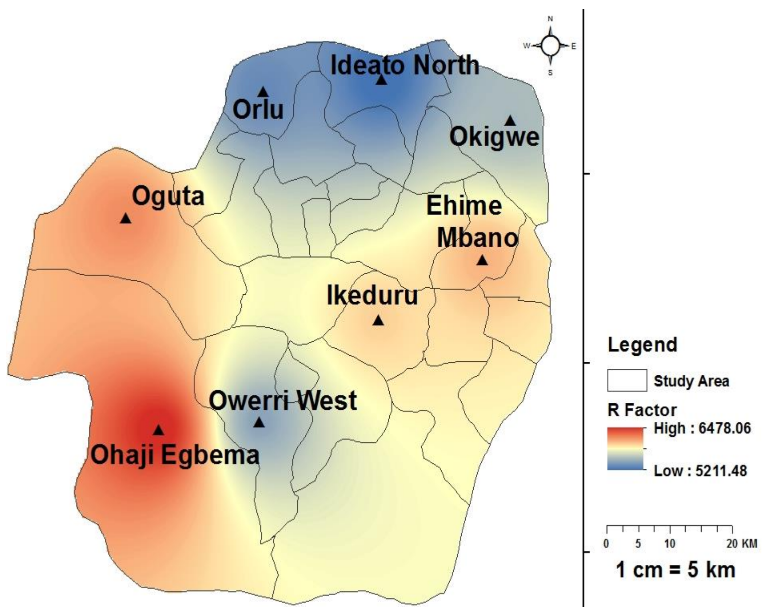

Figure 2: Rainfall Erosivity Map of Imo State.

Table 3.11 contains classification information on the corresponding rainfall erosivity range values for various rainfall erosivity classes and from the range of values obtained for each of the locations it was observed that all the locations within Imo State fall within the erosivity class of medium-strong erosivity on a range of 5211.48 – 6478.06 MJmmha^{-1}hr^{-1}.

Table 3.11: Classification of Rainfall Erosivity Factor (R)

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); Oliviera *et al.*, 2012)

3.1: Correlation Analysis of Data

The rainfall amount, rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for the different rainfall intensities for each of the locations (different soil groups) were subjected to correlation analysis to obtain the coefficient of correlation between the parameters. Tables 3.12-3.20 presents the values of the coefficient of correlation for each parameters and the location

Table 3.12: Correlation of Mean Rainfall Amount and Rainfall Days for all the Locations (1986- 2016)

	Ehime.Mbano	Ideato.North	Ikeduru	Oguta	Ohaji	Okigwe	Orlu	Owerri
Ehime.Mbano	1							
Ideato.North	.997**	1						
Ikeduru	.994**	.989**	1					
Oguta	.992**	.988**	.983**	1				
Ohaji	.992**	.992**	.995**	.987**	1			
Okigwe	.998**	.997**	.993**	.985**	.988**	1		
Orlu	.996**	.997**	.985**	.993**	.987**	.995**	1	
Owerri	.964**	.960**	.986**	.941**	.977**	.967**	.948**	1

**. Correlation is significant at the 0.05 level (2-tailed)

Table 3.12 above shows the correlation of mean rainfall amount for the various locations considered in this study from 1986-2016. From the result it is observed that *Ehime Mbano, Ideato North, Ikeduru, Oguta, Ohajiegbema, Okigwe, Orlu* and *Owerri* all show a strong/perfect correlation with the others location within the regions since all had a correlation coefficient of above 0.9 and the results were all statistically significant at 5%.

Table 3.13: Correlation of Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ehime Mbano* (Clay and Shales)

	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R)	EI_{45}(R)	EI_{60}(R)
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	1.000**	1					
I_{60}(mm/hr)	1.000**	1.000**	1				
E (MJmm/ha)	.976**	.975**	.976**	1			
EI_{30}(R)	1.000**	.999**	1.000**	.970**	1		
EI_{45}(R)	.999**	1.000**	.999**	.969**	1.000**	1	
EI_{60}(R)	1.000**	.999**	1.000**	.970**	1.000**	1.000**	1

Table 3.13 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ehime Mbano* (Clay and Shales). From the result it is observed that rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ehime Mbano* (Clay and Shales) all showed a strong/perfect correlation with the others at *Ehime Mbano* since all had a correlation coefficient of above 0.95 which is about 95% strength and the results were all statistically significant at 5%

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Table 3.14: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ideato North* (Sandstones)

	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30} (R)	EI_{45}(R)	EI_{60}(R)
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	1.000**	1					

I_{60} (mm/hr)	1.000**	1.000**	1				
E (MJmm/ha)	.986**	.984**	.986**	1			
EI_{30} (R)	1.000**	1.000**	1.000**	.982**	1		
EI_{45}(R)	.956**	.957**	.956**	.929**	.957**	1	
EI_{60}(R)	1.000**	1.000**	1.000**	.982**	1.000**	.957**	1

Table 3.14 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ideato North* (Sandstones). From the result it was observed that rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ideato North* (Sandstone) all show a strong/perfect correlation with the others at *Ideato North* since all had a correlation coefficient of above 0.95 which is about 95% strength and the results were all statistically significant at 5%.

Table 3.15: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ikeduru* (Clays, Sandstones, Lignite and Shales)

	I_{30} (mm/hr)	**I_{45} (mm/hr)**	**I_{60} (mm/hr)**	**E (MJmm/ha)**	**EI_{30} (R)**	**EI_{45}(R)**	**EI_{60}(R)**
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	1.000**	1					
I_{60} (mm/hr)	1.000**	1.000**	1				
E (MJmm/ha)	.978**	.974**	.978**	1			
EI_{30}(R)	.999**	1.000**	.999**	.972**	1		
EI_{45}(R)	.999**	1.000**	.999**	.968**	.999**	1	
EI_{60}(R)	1.000**	1.000**	1.000**	.972**	1.000**	1.000**	1

Table 3.15 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ikeduru* (Clays, Sandstones, Lignite and shales). From the result it was observed that rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ikeduru* (Clays, Sandstones, Lignite and shales) all show a strong/perfect correlation with the others at *Ikeduru* since all had a correlation coefficient of above 0.95 which is about 95% strength and the results were all statistically significant at 5%.

Table 3.16: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Oguta* (Sands, Clays and Swamps)

	I_{30} (mm/hr)	**I_{45} (mm/hr)**	**I_{60} (mm/hr)**	**E (MJmm/ha)**	**EI_{30}(R)**	**EI_{45}(R)**	**EI_{60}(R)**
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	.991**	1					
I_{60} (mm/hr)	.991**	1.000**	1				
E(MJmm/ha)	.987**	.987**	.990**	1			
EI_{30} (R)	1.000**	.993**	.993**	.986**	1		
EI_{45}(R)	.935**	.942**	.940**	.918**	.939**	1	
EI_{60} (R)	.989**	.999**	.999**	.984**	.992**	.942**	1

Table 3.16 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Oguta* (Sands, Clays and Swamps). From the result it is observed that rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Oguta* (Sands, Clays and Swamps) all show a strong/perfect correlation with the others at *Oguta* since all had a correlation coefficient of above 0.95 which is about 95% strength and the result were all statistically significant at 5%.

Table 3.17: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Ohajiegbema* (Sands, Gravel and Clay)

	I_{30} (mm/hr)	**I_{45} (mm/hr)**	**I_{60} (mm/hr)**	**E (MJmm/ha)**	**EI_{30} (R)**	**EI_{45}(R)**	**EI_{60}(R)**

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I_{30} (mm/hr)	1						
I_{45}(mm/hr)	.993**	1					
I_{60} (mm/hr)	.993**	1.000**	1				
E (MJmm/ha)	.633*	.636*	.642*	1			
EI_{30} (R)	.992**	1.000**	1.000**	.639*	1		
EI_{45} (R)	.992**	1.000**	.999**	.634*	1.000**	1	
EI_{60} (R)	.992**	1.000**	1.000**	.639*	1.000**	1.000**	1
**. Correlation is significant at the 0.01 level (2-tailed).							
*. Correlation is significant at the 0.05 level (2-tailed).							

Table 3.17 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Ohajiegbema* (Sands, Gravel and Clays). It was observed that rainfall intensity (I) and rainfall erosivity factor (R) for *Ohajiegbema* (Sands, Gravel and Clays) all showed a strong/perfect correlation of above 0.95 which is 95% strength while rainfall energy (E) showed a fairly strong correlation of about 0.63 with the others at *Ohajiegbema* , but all the results were statistically significant at 5%.

Table 3.18: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Okigwe* (Sandstones, Limestones and Coal)

	I_{30} (mm/hr)	**I_{45} (mm/hr)**	**I_{60} (mm/hr)**	**E (MJmm/ha)**	**EI_{30} (R)**	**EI_{45}(R)**	**EI_{60}(R)**
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	1.000**	1					
I_{60} (mm/hr)	1.000**	1.000**	1				
E (MJmm/ha)	.986**	.985**	.986**	1			
EI_{30} (R)	1.000**	1.000**	1.000**	.983**	1		
EI_{45}	1.000**	1.000**	1.000**	.982**	1.000**	1	
EI_{60}	1.000**	1.000**	1.000**	.983**	1.000**	1.000**	1
**. Correlation is significant at the 0.01 level (2-tailed).							

Table 3.18 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Okigwe* (Sandstones, Limestones and Coal). From the result it was observed that rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Okigwe* (Sandstones, Limestones and Coal) all showed a strong/perfect correlation with the others at *Okigwe* since all had a correlation coefficient of above 0.95 which is about 95% strength and the results were all statistically significant at 5%.

Table 3.19: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Orlu* (Clayey Sands and Shales)

	I_{30} (mm/hr)	**I_{45} (mm/hr)**	**I_{60} (mm/hr)**	**E (MJmm/ha)**	**EI_{30}(R)**	**EI_{45}(R)**	**EI_{60}(R)**
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	1.000**	1					
I_{60} (mm/hr)	.902**	.903**	1				
E (MJmm/ha)	.991**	.990**	.889**	1			
EI_{30}(R)	1.000**	1.000**	.902**	.989**	1		
EI_{45}(R)	.405	.383	.314	.444	.400	1	
EI_{60}(R)	1.000**	1.000**	.902**	.989**	1.000**	.400	1

Table 3.19 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Orlu* (Clayey, Sands, and Shales). From the result it is observed that rainfall intensity (I), rainfall energy (E), EI_{30} and EI_{60} for *Orlu* (Clayey, Sands, and Shales) all showed a strong/perfect correlation of about 0.90 which is about 90% strength with others while EI_{45} showed a very poor correlation of about 0.40 with the rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) in *Orlu*.

Table 3.20: Correlation on Rainfall Intensity (I), Rainfall Energy (E) and Rainfall Erosivity Factor (R) for *Owerri West* (Sands and Clay)

	I_{30} (mm/hr)	I_{45} (mm/hr)	I_{60} (mm/hr)	E (MJmm/ha)	EI_{30}(R)	EI_{45}(R)	EI_{60}(R)
I_{30} (mm/hr)	1						
I_{45}(mm/hr)	1.000**	1					
I_{60} (mm/hr)	1.000**	1.000**	1				
E (MJmm/ha)	.969**	.966**	.969**	1			
EI_{30} (R)	1.000**	1.000**	1.000**	.961**	1		
EI_{45}	.999**	1.000**	.999**	.958**	1.000**	1	
EI_{60}	.996**	.997**	.996**	.954**	.998**	.998**	1

Table 3.20 above shows the correlation of rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Owerri* (Sands and Clay). It was observed from the result that rainfall intensity (I), rainfall energy (E) and rainfall erosivity factor (R) for *Owerri* (Sands and Clay) all showed a strong/perfect correlation with the others at *Owerri* since all had a correlation coefficient of above 0.95 which is about 95% strength and the results were all statistically significant at 5%. Furthermore an ANOVA was carried out on rainfall erosivity factor for all the locations and it was observed that they did not show any significance since p-value > 0.05, which also signifies no variation in rainfall properties since all the locations considered fall within the same region.

IV. DISCUSSIONS

From the values displayed from Tables 3.1-3.10, it was observed that as rainfall duration increased the ratio of rainfall amount to duration (rainfall intensity) decreased accordingly. Likewise the rainfall erosivity factor (R) 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 undergo detachment or splash but movement so therefore as rainfall duration increases rainfall intensity keeps decreasing on consistent distribution (Ojha and Michael, 2003). According to Salako, (2010) and Salako (2006) rainfall erosivity factor (R) decreased with increase in rainfall duration, and it further stated that rainfall erosivity (R) at 15minutes rainfall intensity gives a better and more precise range of values for erosion prediction and management when compared to higher intensities. For all the locations the rainfall erosivity factor (R) for each of the months varied between 1668.38 – 9776.58 $MJmmha^{-1}hr^{-1}$, the highest rainfall erosivity values were observed in June (rainy season) and the lowest rainfall erosivity values were observed in January (dry season). The mean annual rainfall erosivity (R) for all the soil texture groups/locations was found to be between 5211.48 - 6478.06 $MJmmha^{-1}hr^{-1}$. It was observed that the location having the highest mean rainfall erosivity factor was *Ohajiegbema* and the least mean rainfall erosivity factor was observed in *Ideato* North. Ezemonye and Emeribe (2012) estimated that rainfall erosivity factor for humid regions are between 5000-6700 $MJmmha^{-1}hr^{-1}$. Also according to Salako *et al*., (1995); Obi and Salako (1995) the mean annual rainfall erosivity factors for various locations in southeastern Nigeria ranges as follows; 12814 – 18611 $MJmmha^{-1}hr^{-1}$, 16697 - 29610 $MJmmha^{-1}hr^{-1}$and 32752 to 62238 $MJmmha^{-1}hr^{-1}$.and all the mean rainfall erosivity factors are within this range. The kinetic energy (E) computed for all the soil texture groups/locations were all between 200-350 MJha, and this is in line with the prediction of Balogun *et al*., (2012) which stated that the kinetic energy of rainfall in southeastern Nigeria has a minimum value of 167MJha and can increase further if climate change and rainfall variation increases. According to Carvalho (2008) and Oliviera *et al*., (2012) which states the various degrees or levels of different rainfall erosivity values, the study area fell within the range of medium to high rainfall erosivity with a value range of 5211.48-6478.06 $MJmmha^{-1}hr^{-1}$ while Balogun *et al*., (2012) concurs as the area is considered a high erosivity region as well.

V. CONCLUSIONS

The following conclusions drawn from the study are;

Rainfall erosivity factor (R) for each of the locations are as follows; 6054.93 MJmm/ha/hr, 5211.48 MJmm/ha/hr, 5977.29 MJmm/ha/hr, 6171.57 MJmm/ha/hr, 6478.06 MJmm/ha/hr, 5567.54 MJmm/ha/hr, 5350.84 MJmm/ha/hr and 5470.29 MJmm/ha/hr for *Ehime Mbano*, *Ideato North*, *Ikeduru*, *Oguta*, *Ohajiegbema*, *Orlu* and *Owerri West* respectively.

The mean annual rainfall erosivity (R) for all the soil texture groups/locations was found to be between 5211.48 - 6478.06 $MJmmha^{-1}hr^{-1}$.

The study area falls within the range of medium to high rainfall erosivity with a value range of 5211.48-6478.06 $MJmmha^{-1}hr^{-1}$.

Coefficient of correlation for all the soil group zones/locations considered is 0.95 and above except for *Orlu* and *Ohajiegbema* which showed correlation coefficients of 0.40 and 0.60 at EI_{45} and E respectively.

ANOVA showed that al the locations were statistically significant at 5% thus reflecting uniform/similar rainfall characteristics

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