

Contents list available at [Journal of e-Science Letters](http://scienceletters.researchfloor.org/)

Journal of e-Science Letters

journal homepage: <http://scienceletters.researchfloor.org/>

Analysis of Rainfall Erosivity Potential in Parts of Southeastern Nigeria

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ARTICLE INFO

Article History:

Received 8 June 2022

Revised 22 June 2022

Accepted 29 June 2022

Available Online 30 June 2022

Keywords:

erosivity,
rainfall, s
urface runoff,
soil loss,
revised universal soil loss equation,
spatial extent

ABSTRACT

This study aims at rainfall analysis for erosivity potential in parts of Southeastern Nigeria. The information on the mean annual rainfall (mm) was used to determine the spatial extent (km²) and percentage volume of rainfall. The distribution revealed that the intensity of rainfall (mm) varied over space in Imo State. The lowest volume of rainfall between 162mm and 171mm recorded a spatial extent of 663.85 km² in the northern parts of the state. The highest volume of rainfall between (184.01mm and 190mm) and between (190.01mm and 198mm) occupied spatial extents of 1197.54 km² and 1165.85 km² in the south-south and south-western respective parts of the state. The central region of the state also showed a relatively high rainfall volume of between 178.01 mm and 1854mm. The lowest mean annual rainfall has the least spatial coverage of 663.85 km². The rainfall erosivity analyzed for Anambra state revealed that the highest erosivity factor was between 177.77 and 202.83 but with low spatial variability of 469.67 km² (9.9%). This highest erosivity factor (R) spreads within the southern (south-west) part of the state. This was followed by an erosive factor that ranged between 162.33 and 177.76 covering 1008.83 km² (21.2%) within the southern part of the state tending towards the central part. However, the lowest erosivity factor computed from the mean annual rainfall values was between 107.51 and 126.86 with a relatively high spatial coverage of 1289.81km² (27.1%) and this covers the northern (north-western and north-eastern) parts of the state. This means that the erosive capacity of the rainfall received by volume in Anambra State within the southern parts (including south-west and south-east) has influenced more surface run-off through erosion process in time leading to soil loss in the study area. The spatial differences in erosivity provide an important source of information for predicting erosion in Anambra and the Imo States, respectively. It would be interesting to also compare these results with those obtained in neighboring states, as this may be carried out through a framework of regional rain erosivity mapping exercise.

1. INTRODUCTION

Erosivity is a function of rainfall, a natural phenomenon that is outside human control and manipulation. Rainfall intensities can be usually high in Southeast Nigeria (Nwankwo&Nwankwoala, 2018a). Obi and Salako (1995) reported that rainfalls with intensities

between the ranges of 100 to 125mmh⁻¹ are likely to occur more than five times a year. Storms with 25mm/h intensity have been reported by Hudson (1981) to be erosive. The nature of the rainfall regime contributes significantly to the erosivity of rainfall Nicholson (2000). Rainfall erosivity is the potential ability of rain to cause erosion. It is also a function of the physical characteristics of rainfall. Obi and Salako (1995) reported that the raindrop sizes obtained generally in the Guinea savannah ecological zone of West Africa ranged from 0.6 to 3.4 mm. The mean drop sizes (D_{50}) of 28 rainfall events ranging from 1-1 to 2.9 mm. There is experimental evidence to suggest that intensity and energy are likely to be closely linked

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with erosivity. Several statistical relations have been established in the past between the erosive power and the amount of rainfall in other parts of the tropical region (Morgan, 2005).

The best estimator of soil loss was found to be a compound parameter, the product of the kinetic energy of the storm and intensity. In Nigeria, the total kinetic energy load of 1091 mm rainfall at Samaru in Northern Nigeria was about 3600 Jm^{-2} . This was twice the amount recorded in southern Africa (Isikwue et al., 2015). However, the product of the kinetic energy of the storm and the maximum intensity of the rainfall during the first 30 minutes of a storm (EI_{30}) was most significantly correlated with soil loss determined on standard field plots (Lal, 1998). Erosivity values, therefore, have been used successfully to produce an iso-erodent map of West Africa.

Rainfall, therefore, plays very significant role in the erosion hazard of southeastern Nigeria (Nwankwo & Nwankwoala, 2018b; Abdullahiet al., 2020). The rainfall distribution, amount, and intensity in a combination of other environmental factors contribute to accelerating the rate of interrill and gully erosion in southeastern Nigeria (Igbokwe et al., 2022). This is evidenced in the sense that as rainfall amounts

decrease northwards, the rate of all types of soil erosion by water decreases (Abdullahiet al., 2019).

The Study Area

The study area is located geographically within latitudes $4^{\circ} 47' 35''\text{N}$ and $7^{\circ} 7' 44''\text{N}$, and longitudes $7^{\circ} 54' 26''\text{E}$ and $8^{\circ} 27' 10''\text{E}$ (Figure 1) in the tropical rain forest zone of Nigeria, and is made up of Anambra and the Imo States. The area covers about 29095 km^2 which is about 3.19 % of the total area of Nigeria (Anejionuet al., 2013).

Geology of the Study Area

The area lies in the Anambra and Niger River basins. The Anambra River Basin is a NE-SW trending syncline that is part of the Central African Rift System which developed in response to the stretching and subsidence of major crustal blocks during a lower Cretaceous break-up phase of the Gondwana super-continent (Ogalaet al., 2009). The tectonic movements for the formation of the Anambra Basin and the other areas were reactivated by further plate activity in the lower Tertiary soon after the intermittent Upper Cretaceous rifting (Ogalaet al., 2009). The separation of the African and South American

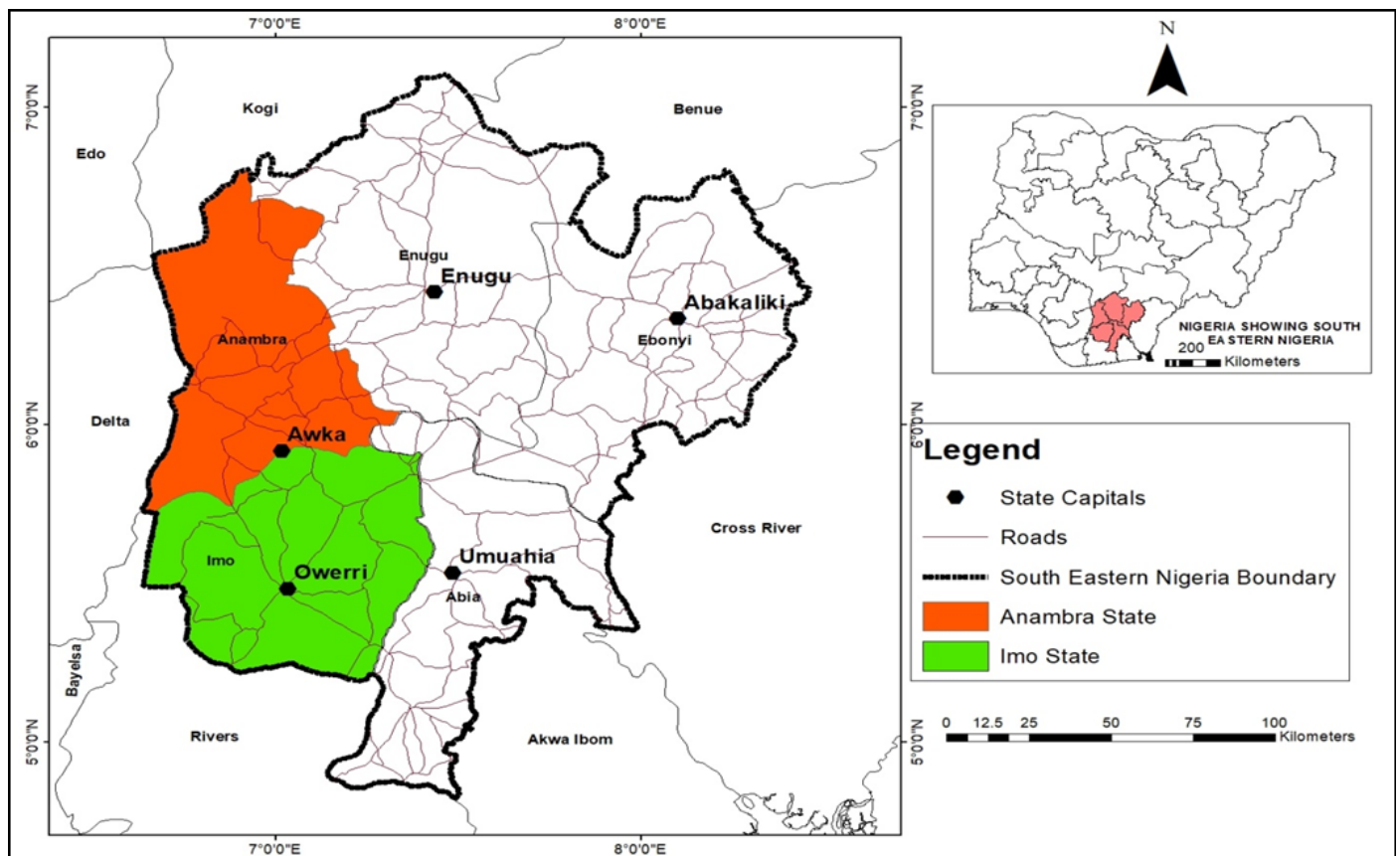


Figure 1: Map of Anambra and Imo States

plates left the Benue Trough as an Aulacogen. Geologic formations such as hills that elongate in the north east to south westerly directions include Missions hill and Abakaliki hill. The hills are generally of volcanic rocks and sandstones. It is found that from these hills that several streams that recharge the rivers that drain the area originated. In Ebonyi State, the outcrops of folded Cretaceous limestone and shale are found in so many places (Nwankwoet *al.*, 2015).

The geology of the area is a major factor in gully erosion causation and massive landslides that occur in several communities. The sandy members of the Ajalli Sandstone, Ameki Formation, and Nanka Sands are very prevalent to denudation where they become exposed as sandy outcrops. Sometimes these sandy formations have overlying and underlying shaley members that may bind the sandy units together (Egbokaet *al.*, 2019)[]. These Geologic Formations contain saturated groundwater members or aquifers whose pore water pressures enhance groundwater flows and movement of sedimentary materials. Sedimentary units of these Formations sometimes form escarpments or cuestas that may be folded and faulted with fractures of joints and faults all of with planes of weaknesses that facilitate the incidences of gully erosion and landslides. Blocks of sedimentary units of rocky sands and shales may break out and slide downslope into the gully valleys (Egbokaet *al.*, 2019).

Drainage and Vegetation

The area is well-drained. The notable lakes, rivers, and streams that are found draining the area in this zone include Rivers Niger, Imo, Nike Lake, Anambra, Idemili, Njaba, Oguta Lake, Nkisi, Ezu, Oji, etc. (Egbokaet *al.*, 2019. The River Niger Basin forms part of the almost north-south trending River Niger that catches up with the tributary dissections of the Anambra, Idemili, and Njaba Rivers as well as their distributaries that flow from east to the west as they forcefully- empty into the River Niger that flows southwards into the Atlantic Ocean. Similarly, in the eastern area, the Imo and Cross Rivers together with their tributaries flow southwards and discharge their waters into the Atlantic Ocean (Igbokweet *al.*, 2008).

The natural flow patterns of the rivers and their tributaries form a dendritic kind of drainage

pattern in the area (Igbokweet *al.*, 2008). The waters of these rivers, lakes, tributaries, and distributaries together with their groundwater components, their flows and fluxes contribute immensely to the origins, growth, and dynamics of gullies and landslides all over southeastern Nigeria (Egbokaet *al.*, 2019).

The vegetation in the southeastern part of Nigeria is the richest and very diverse, with many families in it being represented by small numbers of species. In the grassland flora, the majority of species belong to a few well-represented families. The transition zone vegetation is the poorest in species but in other respects intermediate between the forest and the grassland (Hall and Medler, 1975). However, by way of classification, the vegetation iin the southeastern states consist mainly of rain forest and woodland and tall. Thus, geographically, Imo state as one of the states is located within the rainforest zone while the remaining states fall under the woodland and tall grass zone (CANUK, 2011).

Population and Urbanization

The population figures for Anambraand IMO according to the 2006 population census were 4,182,032 and 3,934,899 respectively. Anambra State with a landmass of 4,844km² has the highest population density (863 people per km²). As more rural areas in Southeastern Nigeria acquire urban status, there is generally improved standard of living, job opportunities and increased literacy level, exposure to people from different parts of the world and improved medical facilities which orchestrate rural-urban migration. However, urbanization results in high cost of living, environmental pollution, deforestation, high population density, high crime rate, impersonality, high rate of accidents, and a host of other socio-economic problems. The increase in demographic growth in population and urbanization put a lot of stress on the system that may result in some the environmental disasters of floods, soil and gully erosion, landslides, environmental pollution, and contamination all compounded by the incidence of global climate change (Egbokaet *al.*, 2019).

Methods of Study

The study involved obtaining secondary data on land use erodibility factors which were related

to the information determined from the land use analysis. The information on the mean annual rainfall (mm) was used to determine the spatial extent (km²) and percentage volume of rainfall. This information was used to determine the Rainfall erosivity factors (R); ($R=0.04830 \times P^{1.61}$). The topographical images of the study area (Anambra and Imo states) were determined using the Shuttle Radar Topographic Mission (SRTM) for image and other analysis. Data were also obtained from journals and articles especially as it relates to the subject matter of study. Rainfall erosivity (R factor) is the most important factor in the Revised Universal Soil Loss Equation (RUSLE) and responsible for soil erosion in an area. It is a long-term average of rainfall erosivity. Thus, the R-factor describes the intensity of precipitation in a given location, based on the extent of soil erosion (Biswas and Pani 2015), which is essential for assessing soil erosion risk under future land use and climate change (Thapa, 2020). The R factor quantifies the influence of precipitation on the amount and rate of runoff factor (Tzioutzois&Kastridis, 2020; Pangali-Sharma *et al*, 2021). In the present analysis, the rainfall erosivity was calculated using the mean annual rainfall data collected from the WorldClim website. Table 1 shows the study areas in the two southeastern states. Furthermore, the R Factor was calculated from the formula shown in Equ 1.

$$R = 0.0483 \times P^{1.61} \dots\dots\dots (1)$$

Where; R is the measure of rainfall erosivity expressed in (MJ·mm ha⁻¹ h⁻¹ year⁻¹) in the RUSLE equation and P is the average annual precipitation (mm).

Table 1: Study Areas in Anambra and Imo States

Anambra	LGA	Town/Community
	Anaocha	Agulu
		*Akwaeze
	Aguata	*Naka
		Igbo Ukwu
		Nkpologwu
	Isu (Orumba South)	*Eziagu
	Idemili North	*Umuoji
		Abatete
	Njikoka	*Abagana

Imo State	LGA	Town
	IsialaMbano	*UmuOkpukapra
		Umueke
	Ideato South	*Isiekenesi
		DikenafaiUmudi
	Orlu	*Obibi
		Ogbelulu
	Ideato North	*Akukwa
		Ndizilogu

*Selected Communities

RESULTS AND DISCUSSION

(a) Rainfall erosivity (R factor) for Anambra State

The rainfall erosivity (R factor) was computed for the study area. The spatial distribution of mean annual rainfall (mm) for Anambra State is shown in Table 2 while Figure 2 shows the rainfall erosivity factor for Anambra State. The rainfall erosivity shows the capability of rainfall to influence soil loss concerning slope gradient characteristics in the study area. For instance, soil texture determines the rate of run-off (K factor) (which will be discussed later). Thus, the intensity of rainfall coupled with slope (elevation), and soil characteristics will determine the rate at which soil detaches and is being washed down the slope before final deposition. Rainfall erosivity is linked to soil loss. That is, the capacity of the rain to produce erosion. Thus, increased rainfall erosivity means the greater erosive capacity of the surface water flow. In other words, soil erosion through the action of running water (velocity) is being influenced by increasing rainfall effects and intensity especially when the rainfall intensity is more than the soil infiltration capacity thereby leading to more overland flow which results to soil erosion leading to soil loss. Therefore, rainfall erosivity is the capability of rainfall to cause soil loss from hill slopes by water.

The rainfall erosivity analyzed for Anambra state, therefore, revealed that the highest erosivity factor was between 177.77 and 202.83 but with low spatial variability of 469.67 km² (9.9%). This highest erosivity factor (R) spreads within the southern (south-west) part of the state. This was followed by an erosive factor that ranged between 162.33 and 177.76 covering 1008.83 km² (21.2%) within the southern part of the state

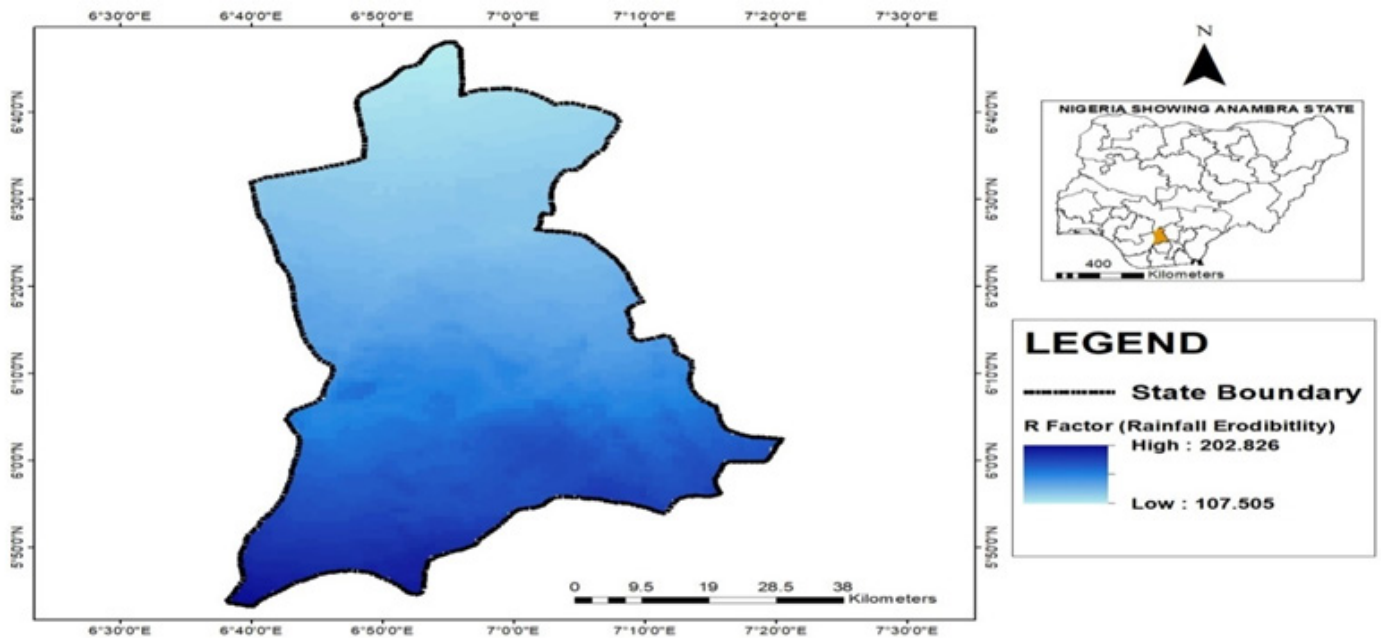


Figure 2: Rainfall Erosivity (R factor) for Anambra State

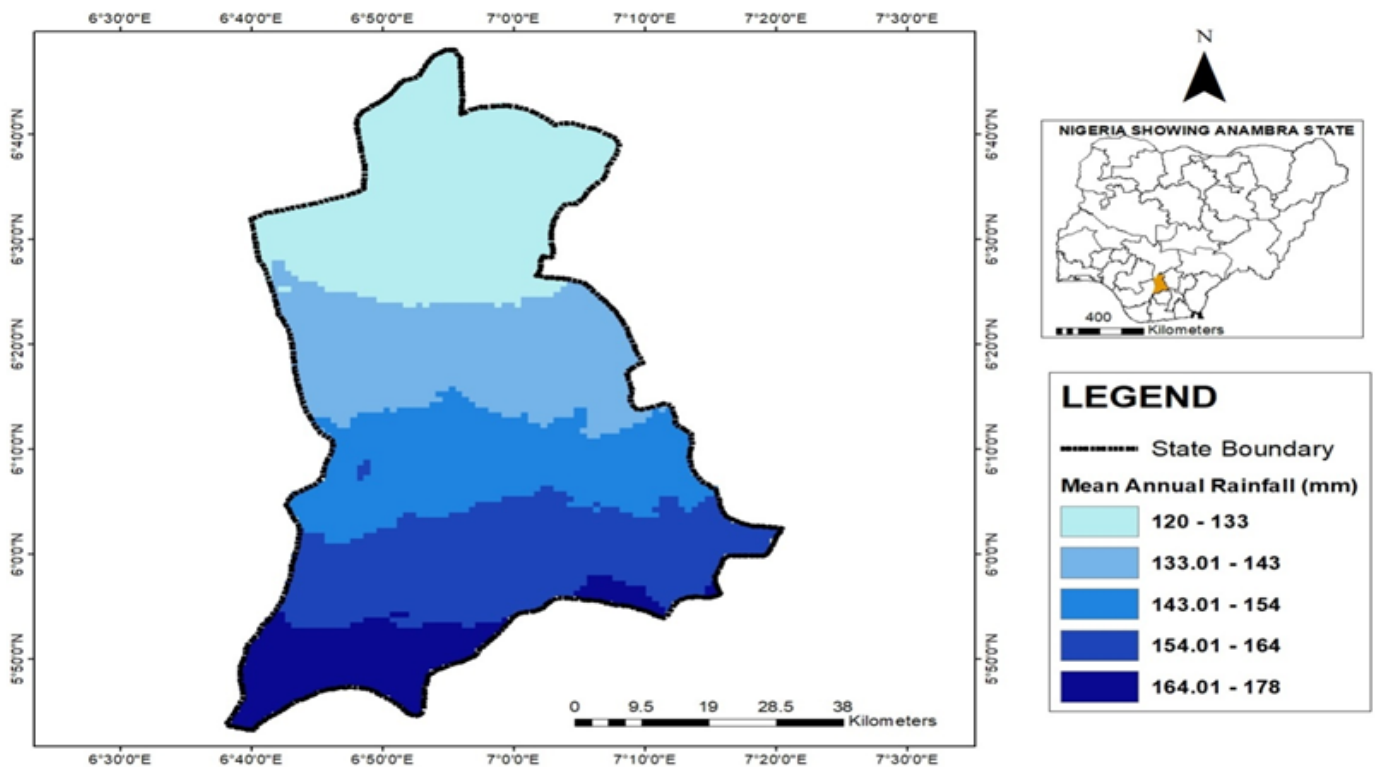


Figure 3: Spatial Distribution of Mean Annual Rainfall (mm) in Anambra State

tending towards the central part. However, the lowest erosivity factor computed from the mean annual rainfall values was between 107.51 and 126.86 with a relatively high spatial coverage of 1289.81km² (27.1%) and this covers the northern (north-western and north-eastern) parts of the state. This means that the erosive capacity of the rainfall received by volume in Anambra state within the southern parts (including south-west and south-east) has influenced more surface run-off through erosion process in the time leading to

soil loss in the study area.

Mean Annual Rainfall (mm) for Anambra State

The information on the spatial distribution of mean annual rainfall (mm) for Anambra state is displayed in Table 2 and Figure 3. The distribution revealed that the intensity of rainfall (mm) varied over space in Anambra State. The lowest volume of rainfall between 120mm and 133mm recorded a spatial extent of 1289.82 km² in the northern

parts of the state. The highest volume of rainfall between (154.01mm and 164mm) and between (164.01mm and 179mm) occupied spatial extents of 1079.01 km² and 469.68 km² in the south-south and south-western respective parts of the state. However, the central region of the state showed a rainfall volume of between 133.01mm and 154mm. However, the least amount of rainfall (133mm) is received over a larger area of land coverage (1289.81 km²) in Anambra State. Table 3 shows rainfall erosivity using mean annual rainfall for Anambra State.

Table 2: Spatial Distribution of Mean Annual Rainfall (mm) for Anambra State

Rainfall (mm)	Spatial Extent (sq km)
120-133	1289.807599
133.01-143	1009.17264
143.01-154	911.798905
154.01-164	1079.014784
164.01-179	469.667369

Table 3: Rainfall Erosivity using mean Annual Rainfall for Anambra State

Rainfall Erosivity (R Factor)	Spatial Extent (sq km)	Percentage (%)
107.51-126.86	1289.81	27.1
126.87-144.18	1081.31	22.7
144.19-162.32	909.88	19.1
162.33-177.76	1008.83	21.2
177.77-202.83	469.67	9.9
Total	4759.5	100.00

(a) Rainfall erosivity (R factor) for Imo State

The rainfall erosivity (R factor) computed for Imo State is displayed on Table 4 and Figure 4. The rainfall erosivity shows the capability of rainfall to influence soil loss in relation to slope gradient characteristics in the study area. Thus, the intensity of rainfall coupled with slope (elevation), soil characteristics will determine the rate at which soil detaches and is being washed down slope before final deposition. The final deposition is used to describe the total soil loss.

The rainfall erosivity analyzed for Imo state, therefore, revealed that the highest erosivity factor was between 225.30 and 240.76 within a spatial variability of 1166.66 km² (22.7%). The spatial variability of the highest erosivity values was within the central, south-western and south-

eastern parts of the state. The erosivity values that ranged between 213.96 and 225.29 which covers an area extent of 1199.07 km² (23.4%) spreading within the central region of the state was recorded as the second highest. However, the lowest erosivity factor recorded values between 174.28 and 190.14 a low spatial coverage of 665.07km² (13.0%) and this covers the northern (north-eastern) parts of the state. This means that the erosive capacity of the rainfall received by volume in Imo state within the central and southern parts of Imo state has contributed to soil erosion/soil loss processes in the study area.

Table 4: Rainfall Erosivity (R factor) Computed for Imo state

Rainfall Erodibility (R Factor)	Spatial Extent (sq km)	Percentage (%)
174.28-190.14	665.07	13.0
190.15-202.83	1064.19	20.7
202.83-213.95	1035.32	20.2
213.96-225.29	1199.07	23.4
225.30-240.76	1166.66	22.7
Total	5130.31	100.0

Mean Annual Rainfall (mm)

The information of the spatial distribution of mean annual rainfall (mm) for the Imo state is displayed in Table 5 and Figure 5. The distribution revealed that the intensity of rainfall (mm) varied over space in Imo State. The lowest volume of rainfall between 162mm and 171mm recorded spatial extent of 663.85 km² in the northern parts of the state. The highest volume of rainfall between (184.01mm and 190mm) and between (190.01mm and 198mm) occupied spatial extents of 1197.54 km² and 1165.85 km² in the south-south and south-western respective parts of the state. The central region of the state also showed a relatively high rainfall volume of between 178.01 mm and 1854mm. The lowest mean annual rainfall has the least spatial coverage of 663.85 km².

Table 5: Mean Annual Rainfall (mm) for Imo State

Rainfall (mm)	Spatial Extent (sq km)
162-171	663.85
171.01-178	1065.07
178.01-184	1037.54
184.01-190	1197.54
190.01-198	1165.85
Total	5129.85

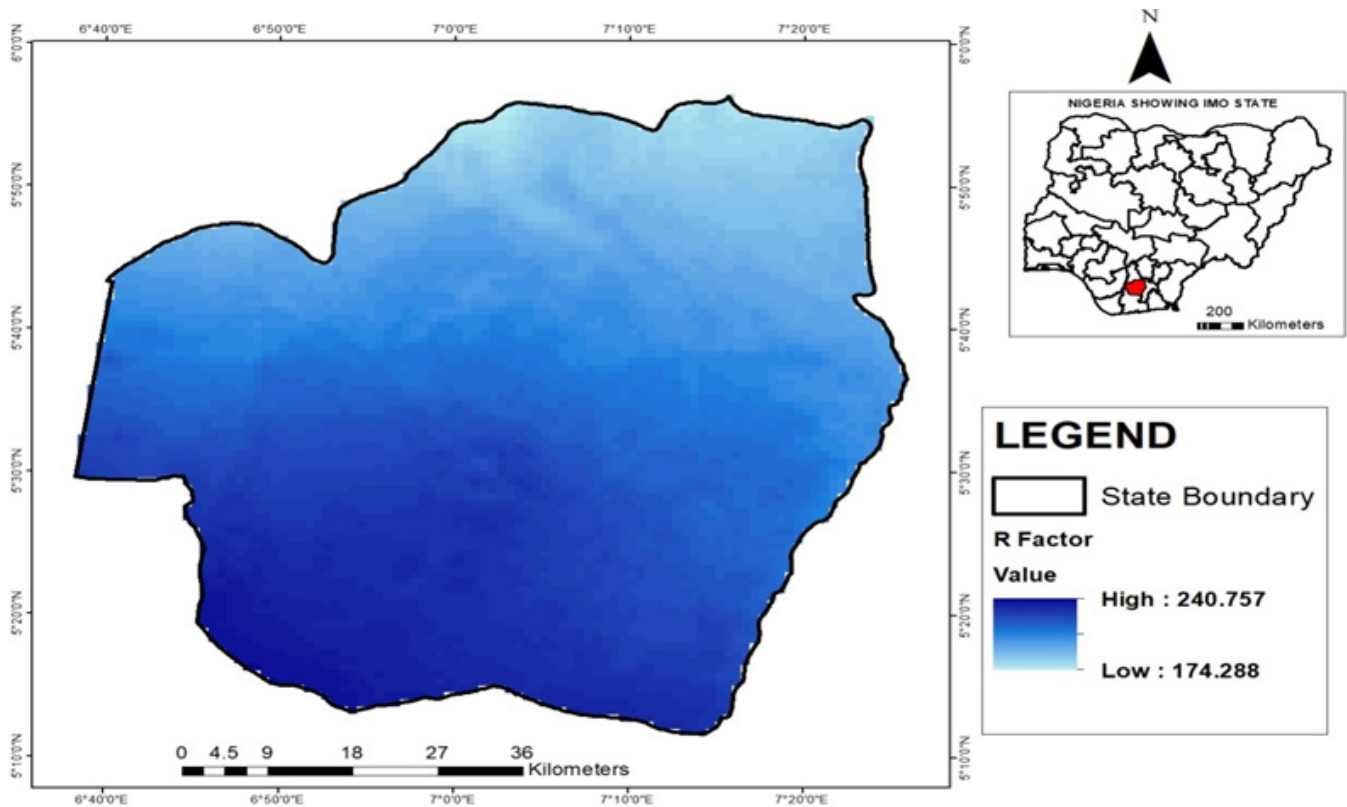


Figure 4: Rainfall Erodibility (R Factor) for Imo State

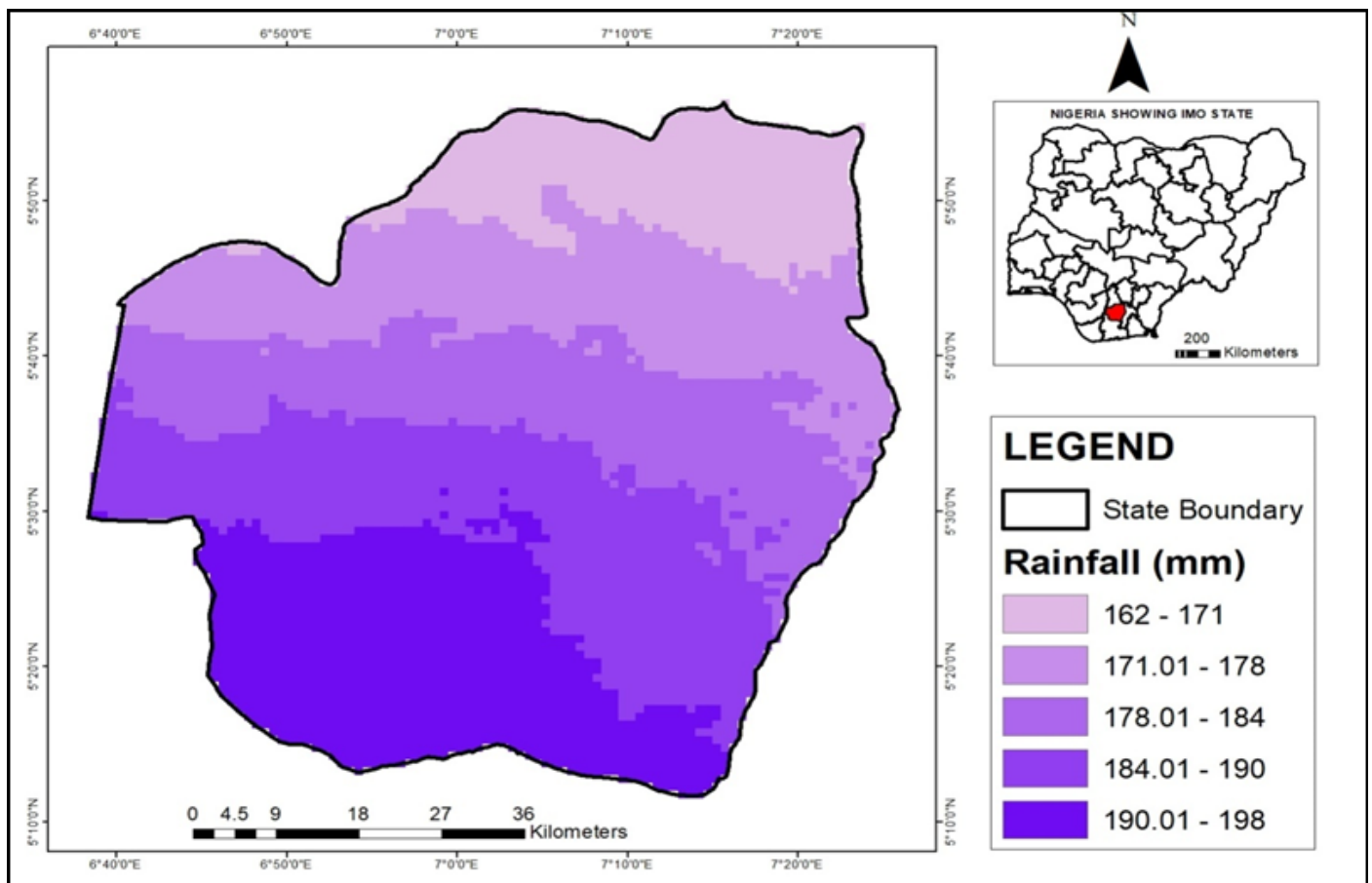


Figure 5: Mean Annual Rainfall (mm) for Imo State

CONCLUSION

This research indicates that the lowest volume of rainfall for Anambra States falls between 120mm

and 133mm with a spatial extent of 1289.82 km² in the northern parts of the state. The highest volume of rainfall between (154.01mm and 164mm) and between (164.01mm and 179mm)

occupied spatial extents of 1079.01 km² and 469.68 km² in the south-south and south-western respective parts of the state.

The distribution revealed that the intensity of rainfall (mm) varied over space in Imo State. The lowest volume of rainfall between 162mm and 171mm recorded a spatial extent of 663.85 km² in the northern parts of the state. The highest volume of rainfall between (184.01mm and 190mm) and between (190.01mm and 198mm) occupied spatial extents of 1197.54 km² and 1165.85 km² in the south-south and south-western respective parts of the state. The central region of the state also showed a relatively high rainfall volume of between 178.01 mm and 1854mm. The lowest mean annual rainfall has the least spatial coverage of 663.85 km². The spatial differences in erosivity provided by this study will an important source of information for predicting erosion in Anambra and the Imo States, respectively. More importantly, it would be interesting to compare these results with those obtained in neighboring southeastern states and this may be carried out through a framework of regional rain erosivity mapping exercise.

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