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Assessment of Rainfall Erosivity in Awka, Nigeria using the Modified Fournier index

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ABSTRACT : *Erosion is one of the major environmental problems in the world, especially in the Southeastern part of Nigeria. This has affected agriculture and other activities involving the use of land. Excessive rainfall which results in peak runoff causes detachments which leads to erosion. In soil erosion modeling, especially using the Universal Soil Loss Equation (USLE), rainfall erosivity (R) factor is an important factor, as this defines the aggressivity of rainfall. Rainfall erosivity is the ability of rainfall to detach soil particles. The modified Fournier Index (MFI) is a widely used method to estimate rainfall erosivity, which is a measure of the potential of rainfall to cause erosion. For this study, a rainfall data of 21 years (2003-2023) for Awka, Anambra State was collected from Nigerian Meteorological Agency (NIMET). The Modified Fournier Index (MFI) was used to determine the rainfall erosivity in this study because of the availability of rainfall data. The MFI values were determined from monthly and yearly rainfall data. From the obtained monthly MFI, lower values were obtained in dry season, while higher values were in rainy season, with highest MFI value of 216.87 in September 2018. The yearly MFI ranges from 204.44 to 556.5. From test of significance at $p<0.05$, a significant p value of 0.03 was obtained, which shows that that the grouped data are similar. The result shows that the aggressivity of rainfall is high in the area and this can result in removal and detachment of soil particles and this may lead to erosion. This study helps to understand rainfall patterns and intensity and this can provide insights into the impacts of climate change on soil erosion and water resources for the study area. By estimating rainfall erosivity, researchers can identify areas prone to soil erosion and provide valuable information.*

KEYWORDS: *Modified Fournier index, Universal soil loss equation, rainfall erosivity, aggressivity, detachment*

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I. INTRODUCTION

Erosion, caused by natural or anthropic process is one of the most serious environmental problems in South-East Nigeria. Rainfall and human activity are the sources that increase soil erosion which has impact on agricultural land, construction site and water resources (Al-Sharmati et al 2019). Rainfall erosivity is an important factor in determining soil erosion (Coman et al 2019)The Universal Soil Loss Equation (USLE) improved by Wischemier and Smith 1978 uses equation 1 to determine soil erosion;

A = annual soil loss (t-ha-1year-1)

R = rainfall erosivity factor (MJ-mm-ha-1h-1year-1)

K = soil erodibility

LS = topographical factor (L-slope length, S- slope steepness)

C = crop management factor

P = conservation practices

According to Wischmier and Smith 1978, the factors responsible for erosion are; rainfall, soil, vegetation, topography and anthropogenic factors. Rainfall erosivity, (R), is an input for USLE equation, not only is it used for modeling soil erosion, it is also used for sediment yield, water quality modeling and other purposes, accurate determination of (R) is important for good modelling (Wischmier 1959). The rainfall factor (R) is an important indices of the erosivity of raindrop (Lobo et al 2015). Daily and monthly rainfall data have been used to determine erosivity (Leo and Heo, 2011; Bonilla and Vidal, 2011; Hernando and Romana, 2015; Reinard and Freimund, 1994). One of the methods of deriving R is by the Modified Fournier Index (MFI) (Arnoldus 1980) and it uses the average monthly precipitation for a number of years. MFI originated from Fournier index (Fournier 1960)

II.. MATERIALS AND METHODS

A. Study Area

The study area is Awka Anambra state (Fig. 1), southeast of Nigeria, with coordinate's latitude $6^0\ 10^1$N and $6^o\ 17^1$N and longitudes $7^o\ 2.4^1$E and $7^o\ 7.2^1$E.The dry season occurs normally from November to March, while the rainy season is mainly from April to October.

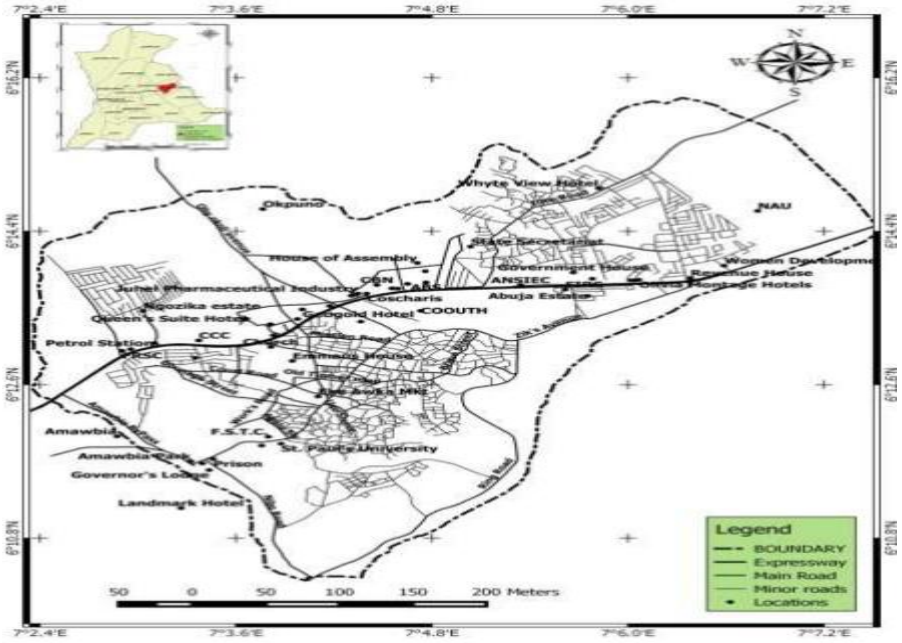

Fig. 1: Map of Awka
Source: Nzoiwu et al 2017

B. Data Collection

Rainfall data of the study area was collected from Nigerian Meterological agency (NIMET). The data collected was rainfall of 2003-2023.

C. Methodology

Modified Fournier index (Arnoldus 1980) was used for this study to determine rainfall erosivity (R) as shown in equation 2

$$MFI = \sum_{i=1}^{12} \frac{p_i^2}{p} \qquad 2$$

Where:
MFI = Modified Fournier Index
P^i = Average rainfall for the i^{th} month (mm)
P = Annual average rainfall (mm)

Table 1 Rainfall Aggressivity Index (RAI)

Rainfall Erosivity (MJ mmha^{-1}hr^{-1})	Interpretation
0-60	Very Low
61-90	Low
91-120	Moderate
121-160	High
Above 160	Very High

Source: Arnoldus 1980

D. Statistical analysis

This was done using ANOVA, the yearly MFI was analyzed and the test of significance was done at $p \leq 0.05$ significant level.

III. RESULTS AND DISCUSSION

A. RESULTS

a. Monthly Rainfall Aggressivity

The results of the monthly rainfall aggressivity are presented in tables…..

Table 2 Modified Fournier index for monthly rainfall in Anambra (2003-2012)

Month	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
January	0.74	0.00	0.43	0.06	0.00	0.00	5.83	0.00	0.00	0.41
February	0.02	0.27	0.33	0.00	0.01	0.00	0.00	2.81	0.19	2.25
March	0.85	0.01	1.59	5.89	0.59	2.60	1.19	0.12	1.97	0.13
April	9.83	24.34	4.49	5.69	2.54	49.94	6.80	26.11	5.57	21.7
May	13.79	82.75	50.46	60.58	44.83	35.39	25.04	16.41	43.51	28.56
June	21.45	31.93	82.40	41.14	62.26	16.96	28.56	23.22	20.02	54.78
July	96.16	70.82	61.19	5.08	47.85	21.13	69.30	11.02	25.33	27.44
August	23.95	24.00	28.15	5.55	48.25	199.41	37.19	56.71	19.19	67.18
September	78.07	55.33	19.75	63.14	51.39	42.4	28.84	59.20	144.08	14.29
October	33.08	14.00	16.03	94.18	30.89	7.39	65.55	17.56	25.68	36.26
November	0.42	0.69	4.99	0.15	1.72	0.01	4.30	1.18	0.10	1.26
December	0.01	0.00	0.08	0.00	0.00	0.36	0.00	0.00	0.35	0.00

Table 2 shows the MFI of 2003-2012 for the study area. From the result, lower MFI values were obtained in dry season, while higher values were obtained in rainy season. From the table, the lowest MFI values of 0.01 were obtained in December 2003, March 2004, February 2007, November 2008, and November 2011; also, the higher MFI value of 199.41 was obtained in August 2008.

Table 3 Modified Fournier index for monthly rainfall in Anambra (2013-2023)

Month	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
January	0.26	2.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
February	0.00	0.00	10.37	0.33	0.00	0.08	2.43	0.00	0.00	0.00	0
March	5.45	6.93	4.60	7.39	0.31	0.43	3.67	15.88	2.41	3.63	10.53
April	16.84	10.19	11.97	17.19	74.50	28.68	6.75	9.88	36.67	98.21	4.50
May	34.90	21.24	33.18	25.82	24.81	15.84	64.33	72.71	19.94	108.92	80.7
June	77.00	11.82	27.79	39.11	128.18	52.93	132.13	40.47	75.92	52.95	20.62
July	11.88	50.84	117.48	28.21	117.5	130.56	76.51	164.73	30.04	15.16	22.86
August	10.29	18.09	23.44	86.29	45.82	54.95	62.88	3.90	162.96	23.98	44.20
September	42.84	65.53	136.65	24.14	98.97	216.87	188.58	30.60	39.76	22.16	79.98
October	24.30	12.26	16.21	34.46	30.41	46.68	16.68	75.27	21.55	62.25	20.52
November	0.00	5.27	1.65	0.90	2.25	5.48	2.54	0.00	19.89	0.00	11.59
December	0.02	0.00	0.00	0.00	0.00	0.00	0.00	1.77	0.00	0.00	0

Table 3 represents the MFI for 2013-2023. In these years, the lowest MFI values were also recorded in dry season while highest values were obtained in rainy season. The lowest MFI value of 0.04 was obtained in January 2023, while highest MFI value of 216.87 was obtained in September 2018.

b. Yearly Modified Fournier index for Anambra State (2003-2022)

Table 4 Yearly modified Fournier index of Anambra (2003-2022)

Year	MFI	Year	MFI	Year	MFI
2003	278.37	2013	223.78	2023	295.54
2004	304.14	2014	204.44		
2005	269.84	2015	383.34		
2006	281.46	2016	263.84		
2007	290.33	2017	522.75		
2008	375.59	2018	552.5		
2009	272.6	2019	556.5		
2010	214.34	2020	415.21		
2011	285.99	2021	410.14		
2012	254.26	2022	386.96		

c. Statistical Analysis

Table 5 ANOVA for the MFI

Groups	*Count*	*Sum*	*Average*	*Variance*
2003-2007	5	1424.14	284.828	170.2287
2008-2012	5	1402.78	280.556	3550.081
2013-2017	5	1598.15	319.63	17721.3
2018-2023	6	2616.85	436.1417	10265.46

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	89963.62	3	29987.87	3.71858	0.031885	3.196777
Within Groups	137093.7	17	8064.335			
Total	227057.3	20				

The yearly MFI of the study area was analyzed statistically using ANOVA as shown in table 5. The result shows that the grouped MFI for the grouped years are 1424.14. 1402.78, 1598.15 and 2616.85 for 2003-2007, 2008-2012, 2013-2017 and 2018-2023 respectively. The highest mean MFI of 436.14 was recorded in grouped years of 2018-2023, while the lowest mean MFI of 280.56 was recorded in grouped years of 2008-2012. The test of significance of the groups at $p \leq 0.05$ is statistically significant with a value of 0.03.

B. DISCUSSION

From the results of the modified Fournier index calculation of Awka, Nigeria, the monthly MFI values ranged from 0.01-216.87, this shows that rainfall aggressivity of the study area ranges from very low (0-60) to very high (above 160) according to Arnoldus 1980; this is also in agreement with Ezemonye and Emeribe, 2012 which stated that rainfall erosivity over Southeastern Nigeria range from very low to very high erosivity. The yearly MFI values of the study area ranged from 204.44 to 556.5. The MFI result shows that rainfall amount affects its aggressivity Ekpo *et al.,* (2021), with highest MFI recorded in rainy season and lowest recorded in dry season. The modified Fournier index values obtained in this study are consistent with previous studies on rainfall erosivity in Nigeria. The results suggest that Awka experiences very low to high rainfall erosivity, which can lead to significant soil erosion and sediment transport.

IV. CONCLUSION

The study demonstrates the application of the modified Fournier index in assessing the erosivity index of Awka, Nigeria. Rainfall aggressivity estimation helps in soil erosion management in studying soil loss. The MFI for Awka in Anambra state has been determined and the outcome shows that the rainfall is erosive.
The following findings were observed from this research:

1) The rainfall aggressivity of the study area ranged from very low to very high.
2) The monthly MFI values show that high MFIs were obtained in rainy season while low MFI values were obtained in dry season.
3) From rainfall aggressivity table in table 1, some of the MFI values in the study area exceeded the very high range of aggressivity and this implies that the rainfall for the period was erosive, and could cause detachment of the soil which could lead to erosion.
4) The highest MFI value was obtained in September in the study area and this shows that the amount of rainfall affects its aggressivity.

Findings in this study highlight the need for effective soil conservation measures in Awka, particularly during the rainy season. The results suggest that soil erosion control measures, such as terracing, mulching and afforestation, should be implemented to reduce soil erosion and protect the region. Overall, this study contributes to the understanding of rainfall erosivity in Awka and provides valuable insights for soil conservation and sustainable land management.

REFERENCES

Al-Shamarti HAS, Manji OB, Albw Jbianah MIK (2019). Using monthly rainfall data to estimate rainfall erosivity factor of Iraq. Science Review-Engineering and Environmental Sciences. 28(3), 444-454.

Arnoldus HMJ (1980). An approximation of the rainfall factor in the Universal Soil Loss Equation. In the Boodt M. and Gabriels D, editors, Assessment of Erosion, John Wiley and Sons, Chichister. P. 127-132

Bonilla CA and Vidal KL (2011). Rainfall erosivity in Central Chile. J. Hydrol., 410:1-2, 126-133

Coman AM, Lacatnan G, ,Acism AM and Lazar G (2019). Assessment of soil erosion using Fournier indexes to estimate rainfall erosivity. Environmental Engineering Management Journal. 18:(8), 1739-1745.

Ekpo AE, Orakwe LC, and Nwachuwu CP (2021). Determination of rainfall erosivity in Akwaibom state using modified Fournier index. Journal of Engineering and Applied Sciences, 19:1, 427-435

Ezemonye MN, Emeribe CN (2012). Rainfall erosivity in Southesatern Nigeria. Ethiopian Journal of environmental studies and management (EJESM), 5:2, 112-122.

Fournier F (1960). The relationship between water erosion of soils and atmospheric precipitation. Paris: Presses Universitaries de France

Hernando D and Romana MG (2015). Estimating the rainfall erosivity factor from monthly precipitation data in Madrid region (Spain). J. Hydrol. Hydromech., 63:1, 55-62

Leo and Heo (2011). Evaluation of Estimation methods for rainfall erosivity based on annual precipitation in Korea. J. Hydrol., 409: 1-2, 30-48

Lobo GP, Frankenberger JR, Flanagan DC, and Bonilla CA (2015) No-till surface runoff and soil losses in southern Brazil. Soil Tillage Res 152: 85-93

Nzoiwu CP, Ezenwaji EE, Enete IC, and Igu NI (2017). Analysis of trends in rainfall and water balance characteristics of Awka, Nigeria. Journal of Geography and Regional Planning. 10(7), 186-196.

Renard KG and Freimund JR (1994). Using monthly precipitation data to estimate the R-factor in the revised USLE. J. Hydrol., 157:287-306

Wischmeier WH (1959). A rainfall erosion index for a universal soil-loss equation. Soil science society of America journal. 23(3), 246-249

Wschmeier WH and Smith DD (1978). Predicting rainfall erosion losses- a guide to conservation planning, Hyatsville, Maryland: United States Department of Agriculture.