Determination Of Erosivity Indices For Uyo Municipal And Its Environs Using The Fournier's Method

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ABSTRACT

This paper is designed to determine erosivity indices for Uyo Municipal area and its environs in Akwa Ibom State, using Fournier's method and to create a database of rainfall amount in all existing rainfall gauging stations in Uyo Municipal and its environs. Climatic data were collected from the Federal Ministry of Aviation, Uyo Meterological Department. The data collected were the monthly rainfall data, monthly relative humidity data and monthly temperature data for twenty years from 2000-2019. The monthly rainfall data were added up to get the annual rainfall amount for these years, also it was done for relative humidity and temperature. The results gotten were presented in form of tables and figures and inference were drawn based on the results. The rainfall erosivity indices were determined using the Fournier's method for the period of twenty years and it was noted that the rainfall erosivity indices vary from year to another year depending on the intensity and the amount of rainfall received in that year. The average rainfall erosivity indices were determined after adding all the yearly erosivity indices and divided by the total number of years worked, which gave 329.16mm.
Keywords: indices, experimental**,** erosivity, research, uyo, nigeria

INTRODUCTION

The problems of soil erosion in the humid tropical region of Nigeria leave much to think about. It has been observed by [6] that erosion has devastated a large extent of Nigerian soils mostly in Akwa Ibom State. Obviously the action of raindrops and runoff on the soil constitute two major aspects of water erosion. Raindrops which possess potential energy are converted to kinetic energy (shear force) as the drops reach the ground. In dealing with erosion, therefore, the ease with which soil is eroded is an important factor; hence the study of the determination of erosivity using Fournier's method is very important.

[8] defined soil erosion as the gradual removal of top soil by water or wind. The particles dislodged by water(rainfall) has been noted to depend on the size of the raindrops (R), the intensity (I) and the duration of the rainfall (T) hence, the following equation put forward by [9];

$$F_p = RIT \tag{1}$$

Where: F_p = force of particles dislodged by rainfall

R = Size of raindrop

I = Intensity of rainfall

T =Time of rainfall

He further remarked in his proposal that this force was needed to overcome the resistance (r) of the soil.

$$r = (c- \tan\theta) \quad (2)$$

Where: r = resistance of the soil

C = cohesion of the soil or normal reaction

θ = angle of shear detachment

According to [1], soil is naturally removed by the action of water or wind. Soil erosion has been occurring for some 450 million years. Since the first land plants formed the first soil, natural processes moved loosed rock or regolith off the earth's surface just as has happened on the planet mars.

In general, background erosion removes soil at roughly the same rate as soil is formed, unlike accelerated soil erosion there is loss of soil at a much faster rate than it is formed. It is always as a result of man's unwise actions, such as overgrazing or unsuitable cultivation practices. These leave the land unprotected and vulnerable. Then, during times of erosive rainfall or windstorms such soil may be detached, transported and deposited.

Accelerated soil erosion by water or wind may affect both agricultural areas and the natural environment and is one of the most widespread of today's environmental problems. It has impacts which are both on-site (at the place where the soil is detached) and off-site (wherever the eroded soil ends up).

More recently, the use of powerful agricultural tillage implements has in some parts of the world led to tillage erosion of soil. This involves the movement downslope merely under the action of gravity. According to [16], soil erosion is just one form of soil degradation. Other kinds of soil degradation include salinization, nutrient loss, acidification, desertification, crusting and compaction.

Soil erodibility was defined by [4] as the ease with which soil materials can be removed by water or wind. According to [9], soil with high erodibility suffers more serious damages than one with low erodibility under constant erosivity. Also noted that several physical and chemical properties have been reported to be key factors influencing porosity, permeability, soil structure, clay mineral, organic matter content, interparticle cohesion and dispersion. Hence, these factors include; rock type, nature of fluid, soil grain size, the nature and characteristics of sand and other sediments that accumulate, the uniformity of the sand grains and the amount of cementation.

According to [6], erosion detaches individual soil grains from the soil mass and carries it along on raindrop splash and moving water. And this erosion affects the fertility and productivity level of the soil and as a matter of fact, no nation can successfully improve on its agricultural productivity when the soil resources are continually being lost by erosion. Excessive erosion causes problems such as desertification, decrease in agricultural productivity due to land degradation, sedimentation of water ways and ecological collapse due to loss of the nutrient rich upper soil layer, [7].

It is therefore important and necessary for land use and conservation planners to give urgent attention to erosion menace hence meaningful suggestions and methods aimed at minimizing the effects of the phenomenon and carrying out proper assessment of the phenomenon that caused it.

[12] defined rainfall erosivity as the potential ability of rain to cause erosion or the aggressiveness of rainfall to induce erosion. [13], further defined erosivity index as a rainfall pattern which describes its capacity to erode soil from an unprotected field.

According to [2], rainfall erosivity is the action of raindrops, intensity and duration of rainfall to cause soil erosion. He added that, thus raindrop possessed a kinetic energy which was converted to shear force as the drops reached the ground, which dislodge the particles from the soil mass. [4] defined erosivity index as the method formulated to estimate or calculate rainfall erosivity. Food and Agricultural Organisation [5] also stated that rainfall erosivity index was a formulated method adopted for estimating or determining rainfall erosivity with reference to the difference in rainfall regions as influenced by the intensity and duration. According to [11], rainfall erosivity indices were formulated and developed to determine the rainfall erosivity.

Method of rainfall erosivity (RE) has been suggested mathematically [11]

$$FI = \Sigma \, pi^2/p \quad (3)$$

Where; FI = the Fournier's index

Pi^2 = annual rainfall intensity squared

P =annual rainfall

OR

$$C = \Sigma \, pi^2/p \quad (4)$$

Where; C = the climatic index in unit of length

Pi^2 = annual rainfall intensity squared

P = annual rainfall

Σ = summation

]13] expressed that the inherent susceptibility of a given soil type to water erosion is its erodibility factor. It is used to indicate the different ways in which different soil are eroded when the other erosion producing factors i.e. Slope, rainfall, vegetation cover, length factor, crop management factor and conservation practice factor remain constant. It is the measure of susceptibility of the soil to erosion. Some soils erode more easily than others, which is to say that soils vary in their inherent susceptibility to erosion and this intrinsic property is referred to as soil erodibility.

The erodibility factor (k) represents the ground tonnage carried away from an area. Primarily, erodibility is a function of soil properties. Soil properties that influence erodibility may be grouped into two types; firstly, those that affect infiltration, cohesion and structural stability and resistance to dispersion and strength. Secondly, those influenced indirectly by land use, crop cover and management practices.

[16] established the dependence of soil susceptibility to erosion by water, textural, structural and hydrological properties. They developed equations and monograms which were recommended for estimating erodibility factor (k) values whenever experimental values are not available.
[14], further explained soil erodibility as a function of soil interaction among its physical and chemical properties. [15], developed a method of predicting soil erodibility using the soil properties such as texture, organic matter content, soil structure and soil permeability.
He developed the following relationship;

$$K = 2.1 \times 10^{-6} (12- 0M) M^{1.4} + 0.0325(S-2) + 0.025(P-3) \quad (5)$$

OR

$$100k = 2.1 \times 10^{-4} (12 - 0M) M^{1.4} + 3.25(S-2) + 2.5(P-3) \quad (6)$$

Where;
0M = percentage of organic matter content
M = percentage of silt and very fine sand (i.e. 100% - % age of clay)
P = permeability class
S = structural index (i.e. Soil structure code or class)

UNIVERSAL SOIL LOSS EQUATIONS (USLE)

The average annual soil loss as determined by wischmeier and smith (2012), can be estimated from the equation;

$$A = RKLSCP \quad (7)$$

Where;

A = average annual soil loss in mg/ha
R = rainfall and runoff erosivity index for geographic location
K = soil erodibility factor. It varies to account for seasonal variation in soil erodibility. It can be calculated from the regression equation;

$$K = 2.8 \times 10^{-7} m^{1.14} (12 - a) + 4.3\times 10^{-3}(b -2) + 3.3 \times 10^{-3}(c-3) \quad (8)$$

Where;
m = particle size parameter (%silt +%very fine sand) × (100 - %clay)
a = percent organic matter
b = soil structure code (very fine granular 1, fine granular 2, medium or coarse granular 3, blocky, platy or massive 4)
c = profile permeability class(rapid 1, moderate to rapid 2, moderate 3, slow to moderate 4, slow 5, very slow 6)
L = slope length factor

$$L = (l/22)^{m} \quad (9)$$

L = slope length in meter
m = dimensionless exponent

$$m = \sin\theta/\sin\theta + 0.269(\sin\theta)^{0.8} + 0.05 \quad (10)$$

Where;

θ = field slope steepness in degrees

$\theta = \tan^{-1}(s/100)$

s = field slope in percent

$s = 3.0(\sin\theta) + o.56$ (11)

For slope longer than 4m and s<9 percent

$s = 10.8\sin\theta + 0.03$ (12)

For slope longer than 4m and s≥9 percent

$s = 16.8\sin\theta - 0.50$ (13)

P = conservation practice factor

$P = Pc \times Ps \times Pt$ (14)

Where;

Pc = contouring factor based on slope

Ps = strip cropping factor

Pt. = terrace sedimentation

The main purpose of this paper is to determine the erosivity indices using the Fournier's method for Uyo Municipal and its environs. Secondly, to create database of rainfall amount in all existing rainfall gauging stations in Uyo Municipal and its environs. Thirdly, to use the rainfall data and Fournier's equation to compute the rainfall erosivity indices and to relate the rainfall erosivity indices to soil erosion in the study area. And finally, to make suggestions on appropriate measure to mitigate the effects of rainfall on soil erosion

METHODS OF DATA COLLECTION

Some of the information used is primary in nature which includes collection of rainfall data and other climatic data and information for a period of 20 years (2000-2019) from the office of the Nigerian meteorological agency Akwa Ibom State airport.

Secondly, most information was obtained from texts, journals, manuals, workshops, addresses, theses and seminar papers. Some of these information was collected from private and public libraries as well as newsletter and seminar presentations.

METHOD OF DATA PRESENTATION AND ANALYSIS

The data which provided the basis for the determination of erosivity using Fournier's method were obtained and presented in table and histogram form and discussed in the next chapter. The totality and mean of analyzed information were recorded and subjected to descriptive analyses as follows;

Annual rainfall amount

$= \Sigma\, pi^2$ (15)

Where;

Pi^2 = annual rainfall intensity squared

Σ = the sum of monthly rainfall total for the twelve months.

Annual rainfall intensity

This is given as, $\Sigma\, pi^2/12$ (16)

Where;

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Pi^2 = annual rainfall intensity squared

12 = twelve months in a year

Annual total rain days

Total rain days for each year = sum of monthly total rain days for the twelve months (17)

The annual rainfall erosivity;

This was determined using the Fournier's method (1960)

$$FI = \Sigma\, pi^2/p \quad \text{(3 above)}$$

Where;

FI = the Fournier's index

Pi^2 = annual rainfall intensity squared

P = annual rainfall

RESULTS AND DISCUSSION

Table 1: Annual rainfall, annual rain days and mean annual rainfall in Uyo municipal in Akwa Ibom state for twenty years.

Years	Annual rainfall(mm)	Annual rain-days(mm)	Mean annual rainfall
2000	2394.4	124	199.5
2001	2112.4	115	176.0
2002	2345.1	148	195.4
2003	1754.6	88	146.2
2004	2154.3	120	179.7
2005	2103.5	111	175.3
2006	2482.7	123	206.9
2007	2075.5	125	173.0
2008	2563.7	131	213.6
2008	2581.5	119	215.1
2010	2726.9	135	227.2
2011	2564.1	96	213.7
2012	2424.1	113	202.0
2013	2179.1	115	181.6
2014	2368.8	90	197.4
2015	2622.3	128	218.5

2016	2699.6	132	225.0
2017	2899.9	136	241.7
2018	1671.5	90	139.3
2019	2516.4	126	209.7
Total	**47242.4**	**2365**	**3936.8**
Mean	**2362.12**	**118.3**	**196.84**

Source: Federal Ministry of Aviation Nigerian Meteorological Agency, Uyo.

Table 2: Annual temperature and mean annual temperature in Uyo municipal in Akwa Ibom state for twenty (20) years

Years	Annual Temperature	Mean Annual Temperature
2000	373	31.08
2001	372	31.00
2002	372	31.00
2003	381	31.75
2004	380	31.67
2005	380	31.67
2006	373	31.08
2007	355	29.58
2008	377	31.42
2009	376	31.33
2010	374	31.17
2011	374	31.17
2012	373	31.08
2013	377	31.42
2014	378	31.5
2015	377	31.42
2016	386	32.17
2017	383	31.92
2018	392	32.67
2019	375	31.25
Total	**7528**	**627.35**
Mean	**376.4**	**31.37**

Source: Federal Ministry of Aviation (Nigerian Meteorological Agency) Uyo.

Table 3: Annual relative humidity and mean annual relative humidity in Uyo municipal in Akwa Ibom State for twenty (20) years.

Years	Annual relative humidity (%)	Mean annual relative humidity (%)
2000	786	65.5
2001	751	62.5
2002	654	54.5
2003	671	56.1
2004	688	57.3
2005	771	64.3
2006	767	63.9
2007	747	62.2
2008	716	59.7
2009	689	58.2
2010	711	59.7
2011	766	63.8
2012	670	55.8
2013	662	55.2
2014	689	57.4
2015	704	58.6
2016	872	72.6
2017	652	54.3
2018	697	58.1
2019	752	62.7
Total	**14415**	**1193**
Mean	**720.8**	**59.7**

Source: Federal Ministry of Aviation (Nigerian Meteorological Agency) Uyo.

Table 4: **Rainfall Erosivity Indices for twenty years (1999 – 2018)**

Year	Erosivity indices (mm)
2000	323.21
2001	324.17
2002	276.60
2003	335.66
2004	283.56
2005	265.16
2006	333.96
2007	323.54
2008	327.36
2009	333.52
2010	436.10
2011	369.05

2012	313.66
2013	280.37
2014	390.14
2015	361.65
2016	388.42
2017	357.01
2018	229.06
2019	331.09

The average rainfall erosivity indices for these twenty years (2000 – 2019) are given below:

$$= \frac{323.21+324.17+276.60+335.66+283.56+265.16+333.96+323.54+327.36+333.52+436.10+369.05+313.66+280.37+390.14+361.65+388.42+357.01+229.06+331.09}{20}$$

$$= \frac{6583.29mm}{20}$$

$$= 329.16mm$$

DISCUSSION

The data collected show that Uyo municipal experienced the highest rainfall in 2017, highest temperature in 2018 and highest relative humidity in 2016, with annual rainfall of 2899.9mm and mean annual rainfall of 241.7mm, annual temperature of 392 and mean annual temperature of 32.67 and annual relative humidity of 72.6% respectively

It also experienced the lowest rainfall in 2018, lowest relative humidity in 2017 and lowest temperature in 2007 with lowest annual rainfall of 1671.5mm and lowest mean annual rainfall of 139.3, lowest annual temperature of 355 and lowest mean annual temperature of 29.58 and lowest annual relative humidity of 654% and lowest mean annual relative humidity of 54.3% respectively.

The rainfall erosivity for these twenty years (2000-2019) are; 323.21 for 1999, 324.17 for 2000, 276.60 for 2001, 335.66 for 2002, 283.56 for 2003, 265.16 for 2004, 333.96 for 2005, 323.54 for 2006, 327.36 for 2007, 333.52 for 2008, 436.10 for 2009, 369.05 for 2010, 313.66 for 2011, 280.37 for 2012, 390.14 for 2013, 361.65 for 2014, 388.42 for 2015, 357.01 for 2016, 229.06 for 2017 and 331.09 for 2018. (All in millimeters).The above rainfall erosivity data show that Uyo Municipal experienced the highest rainfall erosivity in 2010 with rainfall erosivity indices of 436.10mm and also experienced the lowest rainfall erosivity in 2018 with rainfall erosivity indices of 229.06mm.

According to Venacious (2008), the average rainfall erosivity for Owerri West for the period of twenty years (1993-2012) he recorded as 229.16mm.

When compared to that of Uyo municipal for the same period of twenty years (2000-2019) recorded as 329.16mm, based on this research work, the rainfall erosivity in Uyo Municipal is higher than that of Owerri West, hence this constitute the major reason for gully problems in Uyo Municipal today.

CONCLUSION

Water erosion occurs when conditions are favorable for the detachment and transportation of soil material. Climates, soil erodibility, slope gradient and length, the surface and vegetative conditions influence how erosion will take place.

In order to solve water erosion problems the following steps should be taken;

1. Synoptic stations should be established with regular readings and the ones that have gone bad should be repaired.
2. Soil excavation for sand and stones should be controlled and soil erosion when it has not developed into gully erosion.
3. Construction or reconstruction of roads should be done with drainage or road side drains to channel out flood and should be made a condition for award of contract.

From the data collected, it will be noticed that the number of minutes and hours of rainfall were not kept adequately due to one reason or the other and these are important for optimum and better result, so more people should be assigned such work. Environmental protection awareness campaign should be mounted, so that people will know the implications of water erosion.

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