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Full Length Research Paper

Rainfall characteristics, runoff rate and traffic flow on gully morphometric parameter growth and soil loss in sand-mined peri-urban, Uyo, Nigeria

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The number of rain days, rainfall amount, intensity and erosivity, runoff rates and traffic count influenced soil losses or degradation of gully morphometric parameters of length, width and depth, and semi-circular ratio (SCR) and contributed significantly (p<0.01) to gully initiation and growth in sand-mined peri-urban. 42 gullies in 42.80 m^2 were studied, indicating that gully initiation and development on sand-mined land use in peri- urban was very intense. Rill/gully erosion initiation was more severe from the onset of rains in March to June than from July to August. June experienced high rainfall intensity, the most erosive rain and the highest gully frequency (21%) in the study area. June to August accounted for 57% of all gully frequencies, which correlated significantly (p <0.01) with runoff discharge (r = 0.811) and traffic count (r = 0.811) and their combined increase led to increased frequency or number of gullies developed. Highest monthly gully frequency (52%) occurred at the middle of the slope with 10, 21 and 17% frequencies at upper, lower slopes and valley sections respectively gully erosion grew by the degradation of the individual morphometric parameters of length, width and depth severally. The only 2nd order gully widened to increase gully growth and soil loss while the 1st order gullies lengthened to achieve gully growth and soil loss. For the 2nd order gully with final stage depth/width (D/W) ratio of 2.20, total soil loss was 155.00T per year.

Key words: Uyo, sand-mined, soil loss, semi-circular ratio, gullies.

INTRODUCTION

A major soil conservation problem is soil degradation due to actual soil erosion which is the removal of soil material from the soil surface, in this case, by anthropogenic factor-human excavation of red earth, thus making the agent of water (rain drop and runoff) more erosive and soil surface highly erodible. In the course of rainfall occurrence over the land surface, a part of it is intercepted by vegetation cover (above ground and at ground surface), buildings, and other objects lying over the land surface which prevent its drops from impacting directly on the soil surface (Valentin et al., 2005; Suresh, 2004). Erosion is influenced by rainfall through rain drop impact (splash erosion) and runoff. The splash detaches soil particles by the kinetic energy of impact and encases them in a film of water which are then lifted into air and re-deposited at another spot, while the runoff carries the detached soil particles away as sediments to deposit on a flat portion or into flow concentrating channels (Poesen, 1985; Bagarello and Fero, 1999; Suresh, 2004; Shinde et

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al., 2010; Bagarello et al., 2011) The distance traversed by the splash may be small especially if it is on a flat surface but may increase as slope steepness and transportation aided by gravity increases. Heavy tipper compacts and creates localized depressions on roads which enhance concentrated runoff leading to gully initiation. Sand- mining disturbs, removes and roughens top soil in the mined area and borrow pits as lateritic soil is dug deeper into the subsoil and carted away for various land grading purposes. The process also removes protective vegetative cover, opening the surface to impacting raindrops and erosive runoff during rains and, in some cases, soil encrustation in the dry period following the cessation of rains.

Naturally these activities reduce the infiltration capacity of the sand-mind area thereby increasing surface storage or runoff stream and mud-splashes under rain drop impact; thereby increasing runoff and splash erosion. These processes render the disturbed soil surface less resistant and more vulnerable to the brunt of the impacting raindrops and runoff. They also produce puddles of washed soils in surface ditches which may coalesce into erosive advance on the least slopes formed by the rough of soil surface and undulations from soil excavation and borrow pits during sand-mining. These interactions are to be evaluated and quantified under active sand-mining and sand-loaded truck traffic land uses in the suburban micro-catchment (Knapen and Poesen, 2010; Nunes et al., 2011). Therefore the objectives of this study were: (1) to quantify and correlate the effect of rainfall parameters and traffic flow on/with disturbed soils gully initiation and morphometric parameter degradation and (2) to decipher parameters causing intensive gully erosion and the magnitude of such degradation on soil losses so as to inform a decision for erosion control.

MATERIALS AND METHODS

The study area

The study area was located at Uyo peri-urban within latitude 4°30'and 5°30' N while the actual site was within 5° 02' N and longitude 07° 30' E. This was measured using global positioning system (GPS). The rainfall pattern is bimodal. Rainfall begins about mid March and ends around mid November with a little dry spell, "the August break", occurring in August. The mean annual rainfall in the wet season is usually heavy, ranging from 2000 mm inland to over 3500 mm along the coast. The dry season starts from November and last till February or March with the mean annual temperature between 26 and 28°C. The highest temperatures are experienced between January and February, the period which coincides with overhead of the sun. High relative humidity of 75 to 90% is common. Alluvial deposited sands and clays cover over eighty percent (80%) of Akwa Ibom State and constitute the Benin Formation otherwise known as the "costal plain sands". The land mass rises gently from the southern areas and eastern base levels to a hilly topography in the north of the State; the soils which are derived from the sandy parent materials are highly weathered and dominated by low activity clay (AKADEP, 1995). The soils have a low content of organic matter, cation exchange capacity, plant nutrients reserves and limited water storage capacity and are therefore highly susceptible to accelerated erosion (Ogban and Ekerete, 2001). The predominant land use practice in the study area is sand-mining from borrow pit. The area is the major borrow pit in Uyo metropolis. This may be because of the hilly topography of the land area which does not favor agricultural activities, or due to the influence of Ikpa basin that drains the area.

The major traffic in the area is the tipper truck used for the sand-mining business. This system has led to serious soil erosion, particularly gully development, hence, decline in soil productivity due to degradation of soil physical and chemical nutrient properties. It affects the soil structure and structural indices including bulk density, total porosity and pore size distributions, infiltration rate, aggregate stability among others.

Measurement of rainfall amount

A non-recording rain gauge was used in the determination of rainfall amount on the field at the study site. It was mainly an assembly of a collector with a gun metal ring, a base and a polythene bottle. A collector with open area of 100 to 200 cm^2 was used. Rainfall amount was obtained by emptying the content of the collector after every rain into a graduated cylinder (20 mm). Rainfall amounts, duration of rain were measured between the time of start and end of rainfall of a specific day. Rainfall intensity, kinetic energy, erosivity, discharge rate were determined using mathematical relationship with field data as input. Rainfall amount from the field was calibrated by correlating with the values obtained from the standard non-recording rain-gauge of the Weather Bureau type. Number of rainy days and duration of the rainfall was recorded.

Rainfall analysis

Erosivity indices such as EI_{15}, EI_{30}, KE > 25, AI_{15} and maximum intensity were determined from data from the study site for ten months (January to October). Total daily and monthly rainfall and rain days/month were also extracted from the data. Processing of rainfall charts was based on the principle of dividing such storm into successive increments at fifteen minutes intervals as elucidated by Morgan (1978). The total rainfall for every fifteen minutes divided by the duration gives the rainfall intensity EI_{15}. Processed data was used to extrapolate to 30 minute maximum intensities (EI_{30}). To compute the Kinetic energy of a storm, the equation given Wischmeier and Smith (1958, 1978) was employed as given as follows:

$$Ek = 210.3 + 89 \text{Log } I \quad (1)$$

Where Ek is the kinetic energy in J m^{-2} mm^{-2} and I is the rainfall intensity (mm/h). Only intensities greater than 25.4 mm/h were used in determining the KE > 25.4 (Suresh, 2004). The total/average monthly values were computed for a period of ten months.

Determination of rainfall erosivity

This index is easier to compute than the EI_{15}, EI_{30} and KE > 25 indices and is based on intensity rather than on kinetic energy. The erosivity index EI_{15} is the product of the quantity of rain per storm in

Table 1. Daily rainfall characteristics in the study area.

Variable	Unit	Range	Mean/Sd	CV
Rainfall amount	Cm	0.0 to 930	1.30±1.70	131.20
Duration	H	0.30 to 8.80	2.60±2.00	76.10
Intensity	Cm/h	0.1 to 3.20	0.60±0.70	116.70
Kinetic energy	Jm^{-2} m^{-2}	208.60 to 210.80	209.80±0.50	0.20
Erosivity	Cm/h	4.50 to 675.80	1.10±135.70	116.90

cm and the peak 15 min intensity of the storm in cm/h (Lal, 1977). The annual erosivity index AI_{15} was computed from Lal's equation where AI_{15} = erosivity in cm/h, A is the amount of rain/individual storm, I is the maximum 15 min intensity of the individual storm.

Measurement of runoff

The rational method of runoff computation was used to predict the peak runoff rate. Rational method used the following formula for computing the design runoff:

$$Q_{peak} = CIA/360 \quad (2)$$

Where, Q_{peak} is peak runoff rate (m^3/s), C is runoff coefficient, I is rainfall intensity (mm/h) for a duration equal to the time of concentrations and for given recurrence interval. A is watershed area (hectare). Runoff coefficient (C) was computed from the formula:

$$C = X_d/\Sigma R_m \quad (3)$$

Where, X_d is the direct runoff depth (cm), ΣR_m is total annual rainfall amount (mm). This gave the annual runoff rate; hence formula was modified to give daily and monthly values to suit the major objective of the study.

Measurement of discharge rate

A 5 L collector was used to fill a 20 L container. The time used in filling each of the 5 L containers was noted and recorded. The total volume of container filled divided by the total time taken, gave the discharge rate of runoff.

Measurement of gully morphometric parameters

Gully morphometric properties include the measure of three dimensions of the gully- length, width and depth - at distances from head cut to deposition. Using steel and straight edge ruler the length was measured in the direction of the gully progression or runoff flow. The width was gauged at perpendicular direction to the length at selected intervals along the length, noting points with changes in dimension. The width was gauged at the surface was 0.2, 0.6 and 0.8 levels of the depth at the local point of measurement. So also was the depth measured at the point that the width was measured Measurement of the dimensions was repeated soon after new rainfall took place in other to capture the progress in morphometry. Spirit level was also placed on platform across the incision to record the local surface slope along the length of the gully.

Statistical analysis

Descriptive statistics namely mean, range, coefficient of variability (CV) and standard deviation as well as inferential statistics like analysis of variance, correlation coefficient and regression coefficient were computed.

RESULTS AND DISCUSSION

Rainfall pattern

Table 1 shows the rainfall pattern in the study area. The rainfall properties considered were: number of rainy days per month, total rainfall amount, duration, intensity, kinetic energy of rain drop and erosivity (Er). Great variability in daily rainfall properties were observed except for Kinetic energy (Ek). For instance, daily rainfall amount range was 0.0 to 9.30 cm with mean of 1.30±1.70 cm and CV of 131.20%. Rainfall lasted between 0.30 and 8.80 h per day with mean of 2.60±2.00 h and CV of 76.10%. The amount and duration of daily rainfall yielded rainfall intensity of between 0.1 and 3.20 cm/h with mean of 0.60±0.70 cm/h and CV of 116.70%. kinetic energy (Ek) ranged from 208.60 to 210.80 J m^{-2} mm $^{-2}$ with mean of 209.80±0.50 J m^{-2} mm^{-2} and CV of 0.20%. Rainfall erosivity ranged from 4.5 to 675.80 cm/h with mean of 116.10±135.70 cm/h and CV of 116.90% (Table 1). The high values of CV obtained in rainfall properties other than kinetic energy is a confirmation that rainfall distribution in the study area varied greatly with days. This may be attributed to seasonal effect and climate variability. However, the low variability in daily kinetic energy is an indication that the rain storm obtained at the study site throughout the period had almost similar drop size and also felt from the same altitude. An examination of the results also revealed that the minimum number of rainy days per month was four (4) occurring in February while the maximum number of rainy days was 25 occurring in July and August respectively with the mean of 13.6 days. The accumulated rainfall amount ranged from 46.90 mm in January to 368.50mm in June with mean of 167.92 mm.

The result in Table 2 shows that the distribution of total rainfall amount increased from January to June and

Table 2. Monthly rainfall characteristics at the study site.

Months	No. of rainy days	Rainfall (cm)	Duration (h)	Intensity (cm/h)	Ek ($Jm^{-2}m^{-2}$)	Er (cm/h)
January	5	4.69	7.25	0.65	210.11	3.05
February	4	5.80	6.40	0.61	209.90	3.54
March	7	6.35	9.17	0.69	210.14	4.38
April	9	16.54	23.33	0.71	210.15	11.74
May	16	16.69	40.52	0.41	209.91	6.84
June	20	36.85	52.30	0.70	210.15	25.80
July	25	23.83	77.88	0.31	209.79	7.39
August	25	27.67	120.06	0.23	209.66	6.36
September	12	21.40	63.15	0.34	209.83	7.28
October	13	8.10	51.03	0.16	209.50	1.30
Min	4.00	4.69	6.40	0.16	209.50	1.30
Max	25.00	36.85	120.06	0.71	210.15	25.80
Mean	13.60	16.79	45.11	0.51	209.95	7.77

Er: erosivity; k: Kinetic energy.

decreased from July to October.

Rainfall duration increased from February to June, slightly increased from July to August and then a decreased from August to October. Thus total rainfall amount increased with number of rainy days per month, although mean rainfall amount did not show any definite pattern with the months instead a sharp fluctuation was observed. The duration was computed by adding aggregate time for ach daily rain in a particular month and that varied in the study area from 6.40 h in February to 120.60 h in August with mean of 45.116 h. Hence, January to March were not months with heavy down pour compared with April to October. Rainfall duration is directly related to the volume of runoff due to the fact that infiltration rate of the soil goes on decreasing with the duration of rainfall till it attains a constant rate. As a result of this, a very mild intensity of rainfall lasting for longer duration may yield a considerable amount of runoff. Hence there may be more runoff effect between May and October than from January to April. This also suggests that more gullies may develop between the months of May and October than January to April. Rainfall intensity ranged from 0.16 cm/h in October to 0.71 cm/h with April having the highest rainfall intensity while October had the least. Rainfall intensity decreased as the chance of rain increased Rainfall in January and June except May was very erosive while that of July to October were very weak in relation to their intensities. This may be due to the onset of rain which is always very heavy as rainy season sets in but decreases in intensity as the season lasts till the onset of dry season. The result may suggest from the distribution of rainfall intensity in the study site that rill erosion/gully initiation was more severe from the onset of rain precisely from March to June than from July to August. This is similar to the results by Suresh (2004). Hence, rainfall intensity plays significant role in gully development.

The kinetic energy (Ek) of rainstorm of the study area was high from 209.50 to 210.15 J. The high kinetic energy of rainstorm in March, April and June may be attributed to their high rainfall intensity (Table 2). Only slight variability was observed in kinetic energy in ten months data. This may be attributed to drop size and altitude of the site which were similar throughout the months. Kinetic energy is a measure of the force of raindrop on land surface, and has much effect on splash erosion as it relates to detachment of soil particles which marks the onset of soil erosion. Rainfall erosivity ranged from 1.30 cm/h in October to 25.80 cm/h in June with mean of 7.77 cm/h, and implies that June rainfall had the most erosive rain in the study area while that of October was the least. However, trend in monthly rainfall erosivity is similar to that of rainfall intensity and amount. Hence, it may be inferred that rainfall erosivity depends partly on rainfall amount and intensity and vice versa. Rainfall erosivity has a major role in gully development.

Gully system in the study area

Monthly gully frequency

Gully erosion is due to the action of running water or concentration of runoff. Gully begins with rill. Hence, the frequency of gullies determined here includes that of rill and well developed gullies within the study period. The frequency was obtained by counting the number of gullies (including rills) developed after the first rain that produced

Table 3. Gully frequency in the study area.

Month	Frequency	Cumulative	(%)
January	0	0	0.0
February	1	1	2.38
March	2	3	4.76
April	3	6	7.14
May	5	11	11.90
June	9	20	21.43
July	8	28	19.05
August	7	35	16.67
September	4	39	9.53
October	3	42	7.14
Total	42	182	100.00

Table 4. Distribution of gullies along slope section.

Slope section	Frequency	(%)
Upper	4	9.52
Middle	22	52.35
Lower	9	21.43
Valley	7	16.67
Total	42	100.00

the first runoff water. There were variations in date of development of gullies but peculiar observation was that gully frequency increased with rainfall amount and runoff volume. Table 3 shows gully frequencies obtained within the study period. A total of 42 gullies were obtained from an area of 42.80 m^2 cutting across the upper, middle, lower slopes and valley bottom. An examination of the results revealed that the highest number of gullies was obtained in June (21.43%) followed by July (19.05%) then by August (16.67%) while little or none was found in February and January. The results revealed that more gullies were developed as the amount of rain increased. The highest rainfall was obtained in June hence the highest number of development of gullies obtained in June (Table 3). Hence, it can be inferred that rainfall was the major cause of gully development in the study area.

Spatial distribution of gullies along slope sections

Table 4 shows the spatial distribution of gully frequency along slope sections of the study area. About 10% of the total gully frequency was found in upper slope, about 52% in the middle slope, 21.43% in the lower slope while 17% was found in the valley bottom. The classification of slope position was based on the slope angle and there were slight variations in area occupied as corroborated by Udosen (2008) in Ikpa Basin, Uyo and Akwa Ibom State who found about 80% of the total gullies in the middle section of the basin. But in the upper section of the slope, the slope was not very steep; hence, runoff velocity was less while it slowed down at the lower slope and valley bottom. Therefore, more emphasis should be placed on the middle section of the slope when taking management decision.

Relationship between gully frequency, rainfall characteristics and traffic flow of the area

Table 5 shows correlation coefficients between gully frequency (GF) and rainfall characteristics of the study area. Gully frequency (GF) correlated significantly ($p<0.01$) and at equal level with runoff discharge rate (DR) ($r = 0.811$) and traffic count (TR) with $r = 0.811$ (Table 5). The correlation was not significant among other parameters of the model. The positive coefficient of r implies a direct relationship. That is, increase in discharge rate and traffic count leads to increase in number of gully developed. This result was expected. The rate at which run-off is discharged on soil surface determines the detachment potential of the rain water. Similarly, traffic posted problems especially as the amount of rainfall increased and the soil surface became very wet. Heavy tipper loads compacted soils and created localized depressions on roads which enhance concentrated runoff leading to gully initiation. Also, discharge rate had significant relationship with traffic count ($r = 0.926$). Rainfall intensity correlated significantly and positively with rainfall amount ($r = 0.834$), while kinetic energy of storm had significant interaction with rainfall erosivity (Er) only with $r = 0.996$.

Runoff distribution in the study area

Table 6 shows monthly distribution of rate of runoff in the area, and ranged from 5.59 to 30.20 m/s with mean of 17.63±13.49 cm/s with very high coefficient of variability (CV) in March, with variability attributable to rainfall frequency (Table 5) Altogether June had the highest mean rate of runoff (39.12±31.81 cm/s) followed by September with mean of 20.62±37.16 cm/s, August with 25.46±31.99 cm/s while January had the least (6.29 cm/s). Rate of runoff was very high within the peak rainfall months than in the months with low rainfall activities and the highest rate of run-off obtained in June was due to its rainfall distribution. Though the relationship between rate of runoff and rainfall amount was not significant ($p<0.05$) (see Table 5), the positive sign implies that rate of runoff increased as rainfall amount

Table 5. Correlation of coefficient for runoff, rainfall characteristics and traffic flow of the study area.

	DR	RI	RA	DU	EK	Er	TR	RO	
GF	**1**								
DR	0.81**	1							
F1	0.404	0.216	1						
RA	0.408	0.355	0.834	1					
DU	-0.429	-0.445	-0.319	-0.355	1				
Ek	0.153	0.308	-0.153	-0.124	-0.167	1			
Er	0.192	0.337	-0.122	-0.108	-0.183	0.996**	1		
TR	0.811**	0.926**	0.355	0.349	-0.442	0.201	0.253	1	
RO	0.510	0.306	0.401	0.415	-0.501	0.026	0.099	0.505	1

GF: gully frequency, Dr: discharge rate, RI: rainfall intensity, RA: rainfall amount and RO: runoff rate.

Table 6. Monthly rate of runoff in the study area.

Month	Range (cm/s)	Mean (cm/s)	Sd	Cv (%)
January	6.29	6.29	0.00	0.00
February	17.77 - 26.10	21.93	5.89	26.85
March	5.59 - 30.20	17.63	13.49	76.53
April	2.82 - 29.74	13.18	10.41	78.99
May	4.37 - 56.77	17.13	19.44	112.28
June	0.88 - 73.32	39.12	31.84	81.40
July	2.40 - 51.44	17.59	17.59	99.99
August	3.16 - 111.74	25.46	31.99	125.65
September	3.06 - 125.68	30.62	37.16	121.39
October	2.14 - 50.78	11.40	13.65	119.77

increased. Another peculiar feature of rate of runoff is its high variability within the months (Table 6). The highest CV was 125.65% obtained in August while the least was in January. Therefore, not all rainfall events generated runoff.

Gully morphometry of the study area

The morphological properties of gullies depends largely on the topography, state of development of the gullies, the characteristics of the soil profile, slope position on which they developed and widening (Udosen, 2008). Out of forty two (42) gullies developed in 42.80 m^2 of land studied, only four gullies (Gully 01, 02, 03 and 04) were randomly selected from the four slope sections for the determination of morphometric properties. Their choice was informed by their level of development as at the time of commencement of measurement. Gully 01 developed immediately after the first rain in January while 02 to 04 developed in March. These four gullies were taken as representative gullies whose morphometric properties were measured. An examination of the results also revealed that only gully 01 was second order gully while others were simple first order gullies. The gully systems have fairly straight courses and most of the gullies developed on very steep slopes which were subjected to mass wasting processes. They were characterized by well defined head scarps. The semi-circular ratio (SCR) was used as index to determine shape of the gully head scarps. SCR of 0.5 is for a perfectly semi-circular gully head (Udosen, 208). Broadly lobed heads have lower values while pointed gully heads have SCR of 1.0. Thus gully 01 had a broad –loped shape while gullies 02, 03 and 04 had sharply pointed head.

The sharply pointed head scarp indicates an active erosion at the head scarp of order 1 gully.

Initial, final state and total loss in basic morphometric properties of the representative gullies

Table 7 shows the initial and final states and total loss in basic morphometric properties of the representative

Table 7. Initial, final stage and total loss for the basic morphometric properties of the representative gullies.

Gully ID	Stage	D(m)	W(m)	L(m)	D/W-ratio	Volume loss
01	Final	1.00	2.20	27.1	2.20	59.62
	Initial	0.5	2.10	26.98	1.83	28.329
	Loss	0.5	0.10	0.72	0.37	0.036
02	Final	0.15	0.40	10.4	2.62	0.624
	Initial	0.01	0.37	9.19	2.09	0.034
	Loss	0.14	0.13	1.21	0.53	0.022
03	Final	0.7	0.50	27.9	0.72	9.765
	Initial	0.19	0.39	1.25	1.02	0.093
	Loss	0.17	0.17	1.29	0.30	0.037
04	Final	0.7	0.50	27.90	0.72	9.765
	Initial	0.19	39.0	1.25	1.02	9.263
	Loss	0.51	0.11	20.65	0.30	1.158

D = depth, W = width and L = length.

Table 8. Soil losses from gully degradation at final stage development

Gully ID	Dev. Stage	Area m^2	D/W ratio	Volume loss m^3	Tones
01	Final	59.62	2.20	59.62	155.012
02	Final	4.16	2.62		1.622
03	Final	13.95	0.72	9.765	25.389
04	Final	13.95	0.72	9.765	25.389

gullies. The highest loss in depth was obtained in gully 04 (0.51 m), gully 01 (0.5 m) and in gully 03 (0.17 m) while gully 02 had the least (0.14). The highest width loss was in gully 03 (0.17), gully 02 (0.13) and gully 04 (0.11 m) while 01 had the least (0.10 m). The highest loss in length was obtained in gully 03 (1.29 m), gully 04 (1.25) and gully 02 (1.21 m) and gully 01 had the least (0.72 m). Gully 01 was wide and broad while gullies 02 to 04 were narrow and long. Also, gullies 01 and 02 were deeper than gullies 02 and 03. Filling gullies 02 and 03 is very easy than filling gullies 01 and 04. However, gullies 02 and 03 including 04 may quickly cross the road and cause more damage than gully 01 due to their rapid increase in length. Comparing the loss (growth rate of gully dimension) among the three basic morphometric parameters, width had the greatest soil loss (that is, the fastest growth) in gully 01 (1.11 m) followed by length (0.72) while depth had the least growth (0.5 m). In gully 02, length had the highest loss (1.21 m) followed by depth (0.44 m) which was almost similar to width (0.13). Gully 03 followed the pattern of gully 02. This may be due to position effect. Gully 02 and 03 were incipient gullies with almost similar morphometric dimensions. Similarly, the highest loss was observed in length (20.65 m) followed by depth (0.51 m) while width had the least (0.11 m). Altogether, gully 01 decayed fastest in width while 02 to 04 decayed fastest in length. Therefore in managing these gullies much emphasis should be paid to width in gully 01 and length in 02 to 04. In all the gullies, total monthly loss in the three parameters increased from March to June and decreased to October. The highest loss was obtained in June and decreased to October.

The highest loss was obtained in June followed by September which was almost similar to August while the least was in March, the initial stage. Definitely the pattern of loss in the three parameters follows similar pattern in monthly rainfall of the study area. This is a confirmation that gully development becomes more severe as rainfall of the area increases. Hence, rainfall played a major role in gully development in Akwa Ibom State (Table 8).

Conclusion

Effects of rainfall characteristics, runoff rate and traffic flow on gully morphometric parameter growth and soil loss in sand-mined peri-urban, Uyo, Nigeria were investigated. Sand-mining produced very high gully erosion frequency (42 gullies in 42. 80 m^2). Four representative gullies were fully evaluated and showed that the number of rainy days, rainfall amount, intensity, erosivity and runoff rate were the rainfall parameters that influenced soil losses by degradation of the gully parameters, hence, they were factors that contributed significantly to gully initiation and development in the sand-mined area. Gully frequency correlated significantly with runoff discharge rate (r = 0.811) and traffic flow (r = 0.81). Morphometric properties of the representative gullies revealed that only gully 01 was a second order gully while gulies 02 to 04 were 1st order gullies. Examination of the effect of rainfall on gully development shows that change in gully width, length, depth and W/D ratio had significant relationship with rainfall amount and erosivity while length of gully only had significant relationship with rate of runoff in gully 01. Similar results were obtained in gullies 02, 03 and 04 which were representative gullies. It was therefore concluded that rainfall amount and intensity, erosivity and rate of runoff have significant effect on gully initiation and development.

The month June had the highest rainfall amount, runoff discharge, and the highest gully erosion frequency (21%). Soil losses from parametric degradation were high at final stage development under sand-mining land use.

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