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Rainfall - Sediment Loss On Land use Types in Calabar River Catchment, Cross River State, Nigeria

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ABSTRACT

Natural rainfall-induced sediment loss was investigated in this study. It entailed the use of contiguous experimental plots for five landuse types: urban, farmland, grassland, bare and forest surfaces, generated by installing a 2 inch pipe in the midway of the lower boundary of each plot/landuse type ($5.4m^2$) to a metal sedimentation box (31 by 23cm); arranged in a convex slope series on a foothill of 20% gradient slope oriented at the strike of the slope. In each of the experimental plots/landuse types; rainfall, morphological and hydraulic factors were determined. The fieldwork was conducted between October, 2014 and December, 2015 to cover the two seasons and all rainfall events. Equations of sediment loss for the individual stations were derived to develop a stochastic empirical model. Rainfall amount had the greatest relationship in the study. Forest surfaces and grasslands lose significantly less sediment than farmlands, bare and urban surfaces. The study recommends among others reforestation to ameliorate hazards associated with sediment loss. This would foster sustainable watershed management in the region.

Keywords: Soil erosion, river catchment, urbanization, morphology, experimental plot, rainfall

INTRODUCTION

Soil erosion is undoubtedly one of the many environmental phenomena that have spurred quite a number of studies over the years. The importance of soil erosion is not limited to its place in landform processes, but also a threat to the environment (Abua & Digha, 2015).

Soil loss is a direct consequence of soil erosion which is a function of several environmental factors. These include rainfall amount, intensity and duration, surface configuration (relief/slope); nature of surface materials and vegetation. The nature and magnitude of soil erosion and invariably rate and amount of soil loss (sediment yield) depends on erosivity capacity of rainfall and the nature of surface materials (Oyegun, 1982; Oyegun, 1984; 1994; Oyegun & Ede, 2003; Oche & Iorkua, 2012; Abua & Digha, 2015).

Studies has shown that the effect of surface cover on runoff generation is not unconnected to the observed enormous effects of the nature and magnitude of surface cover in determining the amount of wash and its consequent effect on soil loss. It has also been observed by scholars that there is a strong connection between the nature of surface cover (either natural or artificial) and soil loss and runoff generation (Gurnel, 1995; Descroix, 2001; Abua & Ajake, 2013).

Vegetation cover has influence on hydrological processes directly intercepting precipitation to the ground surface and hence partitioning water between infiltration and over land flow and by affecting the rate and routing of water transmitted through the rock, soil or overland or overland to the river network. Gurnell and Midgley (1994) illustrated the direct effect of vegetation on hydrological processes on catchment, small plots and river channels and observed that hydrogeomorphological processes and vegetation are so intimately related, as any management of vegetation will have hydrogeomorphological consequences.
Research works on artificial surface cover in relation to runoff and soil; given an amount of rainfall have been carried out. The effect of vegetation on soil detachment, runoff production and soil loss has been an area of interest (Eze, 1993; McFero et al., 2002; Abua et al., 2016; Adekalu, 2006). Field evaluation has however shows researches that involve rainfall worked well under natural condition as there is the need for an increased knowledge on the relationship among rainfall, runoff and sediment yield (Abua & Digha, 2015). It is apparently unrealistic to make a single exhaustive study on erosion. In light of this, this study is being delimited to a workable size since it is inpracticable to make a global study on erosion that is giving considerations of all factors that will determine the rate of erosion everywhere.
This study therefore, posits that the intensity of soil loss (erosion) in the study area is dependent on the rainfall amount and intensity and the landuse that has changed overtime due to increasing human activities. Studies of soil loss have identified the causes to include excessive rainfall, landuse changes, nature of slope, soil texture and vegetation cover (Ward, 1973; Obi &Asiegbu, 1980; Nduji, Nnam & Ekpete, 2012) hence, the thrust of the study. The study is aimed at examining sediment loss from land use types in Calabar river catchment of Cross River State, Nigeria.
To achieve the aim above, the specific objectives were to:

i. Determine the intensity of sediment loss on the different land use types in the study area
ii. Develop a statistical model of sediment loss based on its explanatory variables.

RESEARCH METHODOLOGY

This study was conducted in Akim-Akim in Odukpani Local Government Area, Southern Cross River State of Nigeria on Latitude $5^0 06^1$ -31.72"N and Longitude $8^0 17^1$ - 08.08"E at an altitude of 42m. Five land use types were examined viz: forest, grassland, farmland, urban and bare surfaces using contiguous experimental plots of size (3 x 1.8m) each and installing a 2 inch pipe in the midway of the lower boundary of each plot/land use to a metal sedimentation box (31 by 23cm) (Sensoy and Kara, 2014). Both fine (≤ 2 mm) and coarse (>2 mm) soil particles were filled in each plot and then grasses, trees, cassava were planted for grassland, forest and farm plots respectively and allowed for one month to sprout. For urban plot, the surface was concretized before filling. Neither planting nor concretization was carried out on bare plot. Two days were used to prepare the plots and test run after a month (Plates 1 and 2). In each of the plots/landuse types; rainfall, morphological and hydraulic factors were determined. The fieldwork was conducted between October, 2014 and December, 2015 to cover the two seasons and all rainfall events were determined using a standard rainguage. A total of 65 rainfall events capable of dislodging sediment were registered. Measurements of the dependent (Y) and independent (X) variables were simultaneous for all rainfall events from beginning to end of experimentation.

Plate 1: Researcher's Experimental Plot with Ranging Poles and Rain guage

Plate 2: Researcher's Experimental Plot with Sedimentation Boxes

METHODS OF DATA ANALYSIS

The data derived in this study were presented in standard management tools such as tabulations, means, standard deviations and percentages for the purpose of statistical analysis. To this end, it was relevant to establish both individual and joint contributions of the independent variables of rainfall amount, rainfall intensity, slope length, slope gradient, particle - size characteristics, infiltration capacity and vegetation cover on the dependent variable of sediment loss from the Calabar river basin. Thus, there arose the need to employ the student 't' test within the context of the study's explanatory framework to determine their contributions from the results of multiple regression summary tables and correlation matrix. The acquired data were then processed and subjected to inferential analysis. Equations of sediment loss for the individual stations in the study area were developed while the data for all stations were collapsed to develop a sediment loss model for the Calabar river catchment. The resultant was the multiple linear regression models for estimating sediment loss in the study area. The equation for this study was of the form:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + e \text{ ....(equ. 1).}$$

Where:

Y = sediment (soil) loss in kg/m^2
$a, b_1, b_2 \ldots\ldots\ldots b_m$ are regression coefficients
e = error term
X_1 = rainfall amount in mm
X_2 = rainfall intensity in mm/min
X_3 = slope gradient in %
X_4 = slope length in m
X_5 = particle-size characteristics in kg
X_6 = vegetation cover in dummy variable
X_7 = infiltration capacity in cm/h

RESULTS AND DISCUSSION

The variables found to be significant in the various sediment loss models of the landuse types were developed. The seven variables are rainfall amount, rainfall intensity, infiltration capacity, slope length, slope gradient, particle size and vegetation cover. Of all the variables, rainfall amount had the greatest significant in all the landuse types. In all the sediment loss equations developed in this study, at least one of the variables was linearly related to sediment loss either directly or indirectly **(**Table 1).

Table 1: Models Developed in the Study

Land use	Coefficient of Determination %	F – ratio (Regression Equation)
Urban Surface	17.6	$Y = 11.580 + 0.434x_1 + e$
Bare Surface	41.0	$Y = 5557.614 + 0.965x_1 – 0.445x_2 + 26.606x_3 – 26.356x_4 + 0.231x_7 + e$
Farmland	32.1	$Y = 20.307 + 0.576x_1 + e$
Grassland	14.7	$Y = 27.213 + 0.400x_1 + e$
Forest Ground	8.4	$Y = 2.683 – 0.356x_3 + e$
Model	42.4	$Y = 62.521 + 0.268x_1 + 0.229x_3 – 0.532 x_4 – 0.160x_6 + e$

Source: Computer Analysis Output of SPSS (*significant at the 0.001)

The summary of the models developed in the study above at the 99.9% probability level show the explanation provided by the various land use types for sediment loss. For instance 17.6% of variation in sediment loss is explainable by urban surface, 41.0% of variation in sediment loss is explainable by bare surface, 32.1% of variation in sediment loss is explainable by farmland, while 14.7% of variation is explainable by grassland, 8.4% of variation is explainable by forest ground and 42.4% of variation in sediment loss is explainable by the model developed for the study. The regression equations shown above depicts that rainfall amount is the major predictor. However, all the models developed in this study are useful in explaining sediment loss in Calabar River catchment. The statistical summary of measured variables of interest in the study is presented in Table 2.

The results of the analysis further revealed that the amount of sediment loss in the urban, bare, farmland, grass and forested surfaces were 28.78, 33.91, 33.45, 14.95 and 5.66kg respectively while the rainfall that generated sediment loss on the five surfaces mentioned above were all 41.74mm. The results also show that the corresponding rainfall intensity for the urban, bare, farmland, grass and forested surfaces were all 0.57mm/min or 34.09mm/hr. The total percentage of slope gradient for the five surfaces was 255.63% while the total slope length amounted to 33.85m for the five surfaces examined. The results of the particle size were sand = 268kg, silt = 61% and clay = 171%). The results revealed that the infiltration capacity for the urban, bare, farmland, grass and forested surfaces were respectively 4.82, 5.96, 4.78, 4.50 and 5.07cm/hr yielding a total infiltration capacity of 25.13cm/hr (see table 2).

Table 2: Summary of Measured Variables of Interest in the Study

Variables		LAND USES				
	Urban Surface	**Bare Surface**	**Farm Surface**	**Grass Surface**	**Forest Surface**	**Totals**
Sediment Loss (kg) ($\bar{x}$)	28.7754	33.9138	33.4992	14.9477	5.6646	**116.8007**
Rainfall Amount (mm) ($\bar{x}$)	41.7385	41.7385	41.7385	41.7385	41.7385	**208.6925**
Rainfall Intensity (mm/min) ($\bar{x}$)	0.5682	0.5682	0.5682	0.5682	0.5682	**2.841**
Slope Gradient (%) ($\bar{x}$)	52.0000	52.0000	52.0000	52.0000	47.6292	**255.6292**
Slope Length (m) ($\bar{x}$)	5.2020	4.0180	4.6177	4.5746	15.4365	**33.8488**
Particle size (kg) sand (%) silt (%) clay (%)	58.0 11.0 31.0	49.0 13.0 38.0	48.0 18.0 34.0	56.0 12.0 32.0	57.0 7.0 36.0	**268.0** **61.0** **171.0**
Vegetation Cover (dummy variable)	4.2469	1.0263	2.3462	5.0917	7.0705	**19.7816**
Infiltration Capacity (cm/hr) ($\bar{x}$)	4.8200	5.9554	4.7831	4.5015	5.0723	**25.1323**

Source: Researchers' Fieldwork (2015)

SUMMARY AND CONCLUSION

In the five experimental plots representing the various land use types, sediment losses increased with the degree of exposure of the surface to rainfall impact. A relationship between rainfall amount and sediment loss in Calabar River catchment was observed. The relationships are linear and hold for all surfaces and morphological conditions. However, forests and grasslands lose significantly less sediment than farmlands, bare and urban surfaces of Calabar River catchment. The amount of sediment loss depends on the rainfall amount and intensity, infiltration capacity of the soil, nature of vegetation cover, particle size characteristics, length and gradient of slope. Rainfall amount played the dominant role in sediment loss in all land use types. Forests and grasslands lose significantly less sediment than farmlands, bare and urban surfaces.

Human activities that trigger-off sediment loss in a drainage basin can be predicted. This is with a view to enhancing sustainable watershed management in the ever - changing land use of the basin. The study recommends reforestation aimed at increasing the vegetation cover and infiltration capacity of the soil. This will in turn displace the particle size characteristics, giving room for permeability; legislation against indiscriminate felling/burning of trees as well as public enlightenment campaign to educate people on hazards associated with sediment loss.

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