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Haulage Vehicle Traffic and Runoff Effect on Gully Growth on Roadside Slopes of Unpaved Sand-Quarry Road, Uyo.

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***Abstract:* -** Rainfall runoff and sand haulage truck traffic count were quantified and regressed on gully soil loss and gully morphometric volume growth on unpaved haulage roadside erosion. The gully erosion on unpaved roadside was accelerated by the agency of runoff in splash wash from the road, and high axle sand haulage trucks traffic. The effect of the Runoff discharge and traffic count, as independent variables and cumulative quantities, on the cumulative soil loss from jagged side slope gullies, and the gully volume growth were very significant at $P < 0.01$ generally. Predictive coefficient of determination, significant at $P < 0.01$, were very perfect at R^2 = 88.8 to 98.9%. Different regimes of association were obtained such as: high runoff and high traffic count; high flow rate and low traffic count, and low runoff and high traffic count for effect ~~and~~ on gully loss and gully volume growth, and they gave accurate and significant relationship. Regulation of sand-mining over a catchment is recommended as it has otherwise destroyed landform and initiated unrestrained gullying.

***Keywords:* -** *Sand haulage road, sand quarry, unpaved roadside/mechanized soil excavation, runoff, truck traffic count, gully soil loss, gully volume growth.*

I. INTRODUCTION

Destructive land use leads to land degradation and structural inability. One destructive landuse is an unplanned and unregulated sand mining that leads to gully initiation and growth. This is the case at Uyo peri-urban where the whole subcatchment is quarried daily for laterite sand used for the extensive construction and building projects in the urbanization expansion of the Uyo state capital, and some contiguous communities in the rural-urban fringe. The process of sand quarrying in the study area uses different stages of mechanization. Generally the land is cut into clods of sand heaped out before scooping with human labor into haulage trucks.

Soil surface vegetal cover and fallows and farms have been removed, and soil has been cut down to the sublayer for laterite; leaving jagged undulations of localized depressions for sedimentation or ponding of water. The haulage road was built up with the burrowed soil from the sand mine land to a height above the land mined fields, resulting in steep sides slopes of the road, which also is cleared of vegetal cover and top soil, so that no filtering strips was available to wedge runoff from the sides. The roadside slope is steep with no tuft or weed or runoff collecting drains to reduce runoff cascades down the side slope.

Usually there is some kind of erosion taking place along the roadside [1], especially where road was constructed by cut and fill method. Under rainfall characteristic and increase in slope length, soil erosion increases on roadside [2]. The process of gully erosion on the roadside of unpaved haulage road on the sand quarried landform involves the rainfall, the runoff, soil particle distribution and human factor – the high axle haulage truck traffic; however only the effect of runoff and truck traffic count are considered in the study, since rainfall and soil particles were considered in previous study [3].

When trucks of loaded laterite move up and down the haulage road, the loaded trucks tires cause abrasion of the wet or dry soil surface, dislodging particles, digging out ditches across the crown and eventually splash-washing the sediments laden water on traffic tyre impact to the roadsides, so that it flows down the road side slope. It causes levees at first, then the levees are broken by runoff wash off and rainfall impact [4]. Rills are created on the road crown across to the road side. Further runoff downstream finds the micro channels as easy drainage routes for flow rivulet to the sides. Steady rills are formed as weak parts of sediment on side slopes break up, and, eventually, these grow bigger into gully and the growth rate of the gullies need to be determined as the degradation continues especially in the rainy season.

Roadside erosion could have been checked if tufting, sodding, pitching (agronomic method) or erection of retaining wall or bench terracing (permanent structure) of slope of filled road took place [1]. As the weed cover was removed during land mining and the road was unpaved and the side slope untamped and higher above the quarried land surface, a check in erosion, gully initiation and growth was hardly possible as no authority took functional responsibility on haulage road for sand quarrying, which is a private financial responsibility in haulage business.

Thus, ~~is~~ the causative factors are anthropogenic degradation of landform through erosion agencies of rainfall-runoff, splash wash and traffic abrasion. The objectives of these research aims to quantify these factors and correlate them with gully growth and soil loss for erosion control check in such vulnerable land use areas.

II. MATERIALS AND METHODS

2.1 Measurement of runoff discharge

A five-liter collector was used to fill a 20L container. A mouthpiece of metal plate was constructed and inserted on the scarp head of the gully and water flowed on it to the collector. The time taken to fill each 5L container was recorded using snap stop-watch. The total volume of container filled was divided by the total time taken, to give the discharge rate of runoff at respective gully line. Filling was so managed that no spillage was allowed. A fresh 5L – collector was waiting so as to change over and withdraw the filled sample collector without allowing it to brim nor overflow.

2.2 Determination of gully parameters

2.2.1 *Slope Length***.** The length of the main gully slope from the crest to the slope base on the road side slope was measured with a 30m linen tape and expressed in metres. Five measurements were made in each sampling location. The average value for each sampling area was computed.

2.2.2 *Truck Traffic Count.*

A check point was mounted at the road entrance. The number of trucks entering and leaving the unpaved haulage routes were recorded, loaded or empty. A sentry was posted each day from 6am till 6pm.

2.3 Statistical Analysis

All data were organized into groups (see Results) and their description statistics, ANOVA, paired statistics, correlations and regression were carried out using SPSS software version 17.

III. RESULTS

The results are tabulated in tables below. Runoff discharge (RO) and Traffic count (TR) are independent variables.

Data collected were organized into three groups; namely:

(i) High traffic count (TR) and low runoff discharge (RO) and their combined effect on soil loss (SL) and on gully growth volume (both as dependent variables (Table 1).

(ii) High runoff discharge (RO) and low traffic count (TR) as independent variables and the recorded gully soil loss (SL) and on gully growth volume (GR) (Table 2);

(iii) High runoff discharge (RO) and high traffic count (TR) on gully soil loss (SL) and gully volume growth rate (GR) (Table 3).

The fourth and fifth groups are the mixed magnitudes of independent variables and the point values of each variable. These are too many to be presented here. Since the gully growth is additive geometric dimension or cumulative morphometric degradation over time, it is essential to relate the variables in cumulative values. Hence, the values in Tables 1 – 3 are presented as cumulative magnitudes of the variables.

Table 1. High traffic count and low runoff discharge effect on soil loss and gully volume growth rate.

S/N	High traffic count (TR)	Low runoff discharge (cumulative) (RO)	Soil loss (SL)
1.	18	1.1	4.25
2.	38	2.0	8.75
3.	90	2.7	12.13
4.	113	3.8	16.76
5.	135	4.4	19.21
6.	159	5.1	23.71
7.	189	5.9	27.21
8.	210	6.8	29.69
9.	245	7.4	32.69
10.	281	7.8	36.59
11.	304	8.6	40.07
12.	328	9.0	44.35
13.	348	9.8	47.70
14.	378	10.7	51.30
15	398	11.6	54.43
16.	435	12.3	58.23
17.	487	13.3	61.81
18.	532	14.1	64.69
19.	563	15.0	67.89
20.	617	16.0	71.44
21.	663	16.5	74.12
22.	699	17.8	76.70
23.	731	18.8	79.13
24.	781	19.6	81.88
25.	832	20.2	83.63
26.	872	20.9	88.26
27.	909	21.6	101.64
28.	937	22.2	106.39
29.	981	23.0	109.69
30.	1033	23.7	112.52
31.	1093	24.7	114.20
32.	1157	24.4	116.83

IV. DISCUSSION

4.1 Effect of gully growth

Gully growth is the cumulative dislodgement and transportation of soil particles from a location to a deposition at a distance. It is also erosive water effect which erosive water may not be constant in magnitude and force but vary in time and place. As such the infinitesimal or discrete change in morphometric dimension by successive current of erosive water (and or erosive rainfall) and abrasive tractive truck wheels (which grind the soil) enlarge or widen the gully geometry. By the cessation of the rains (i.e. erosive water current productive season), the resultant gully dimensional morphology is a cumulative geometric addition of the infinitesimal time dimensional increments.

Table 2. High runoff discharge and low traffic

High runoff discharge	Low truck traffic count	Soil loss	GV (Gully growth Volume)
40.7	1839	143.37	1,295,123
41.8	1867	148.14	1,375,917
42.5	1900	150.59	1,430,777
43.8	1944	158.59	1,584,954
48.3	2128	171.67	1,921,439
48.7	2154	175.95	2,031,056
47.5	2173	179.3	2,121,979
48.4	2201	182.9	2,259,261
49.4	2233	186.03	2,316,669
53.4	2432	203.04	3,003,833

Table 3. High amplitude regime

High runoff discharge (Cum RO)	**High traffic count (CUM TR)**	**Soil loss CUM SL**	**Gully growth Volume (CU GV)**
40.7	1839	143.37	1,295,123
41.8	1867	148.14	1,375,917
42.5	1900	150.59	1,430,777
43.8	1944	158.59	1,584,954
48.3	2128	171.67	1,921,439
48.7	2154	175.95	2,031,056
47.5	2173	179.3	2,121,979
48.4	2201	182.9	2,259,261
49.4	2233	186.03	2,316,669
53.4	2432	203.04	3,003,833
56.1	2567	211.7	3,236,993
55.3	2529	209.3	3,130,949
54.3	2475	206.7	3,003,833

N/B. Cum RO = Cumulative runoff discharge, cum TR – Cumulative vehicular traffic count, cum SL = Cumulative soil loss, Cum GR = Cumulative gully growth volume (cm^3)

$$\therefore Gully\ volume = \int_t (L + dt)(w + dw)(D + dd)dt$$

Where n is number of infinitesimal dimensional changes in the period (t) of the season. Thus, the ultimate gully geometry $[L.W.D]$.
= cumulative sum of changes in gully dimension in time interval dt under cumulative runoff, etc.

Tables 1-3 indicate the cumulative changes (continuous) of the four parameters (RO, TR, SL, GR) occurring within the rainy season. The values reflect the background of prior sand-mining of the road banks and filling of road with subsoils from the sand-quarried subcatchment.

The main difference in the groups is combining soil erosion factors.

4.1.1 Regression Relationship (soil loss).

1. High traffic count is a scene occurring under dry earth routes. Runoff is a scene under the threshold period of rainfall and dry season.

The effect of both Cum, RO and Cum.TR on soil loss was tested with a regression relationship, which gave:

$$Cum\ SL = 1.328 - 0.059cum\ RO + 4.606cum\ TR + 3.537\ @\ R^2 = 99.0\%, adj\ R^2 = 98.9\%.$$

Where estimated standard error of estimate is the constant 3.5375. (1)

The ANOVA indicated significant change at $P < 0.01$. The R^2 showed significant association of predictors to dependent variable (cum SL) @ $P < 0.01$. The coefficient of TR was also significant in predicting at $P < 0.01$ using t-statistics. The coefficient of the constant and RO were not significant, hence the error in estimation.

2.Case of high runoff and low traffic count (Table 2). This scene is usually observed under high rainfall amount in the months of July to October, which condition also reduces the traffic flow of haulage truck, even as constructive and building activities tend to subside.

The regression function relating their regime effect and gully soil loss was obtained as:

Cum SL = 2.479 cumRO – 0.060cumTR – 94.096 + 4.030 (2)
@ R^2 = 88.8%, adj R^2 = 85.6%.

Regression coefficient showed significant association @ $P < 0.01$ and significant difference of variance $(P < 0.01)$ also.

ANOVA showed that the null hypothesis of variance homogeneity (of cum RO and cum TR) can be rejected at P<0.01 [5].
The coefficients for cumRO and cumTR showed significance at P<0.01

3. Case of high runoff discharge and high traffic count. This scene is usually in the post August break period with high intensity rainfall lasting for long hours (2 ½ -6 hours, [6]). The cumulative variable in regression relationship gave a predictive function as:

Cum SL = 2.348cum RO +0.143cum TR – 89.422 + 2.581. (3)
@ R^2 = 98.8%, adjusted R^2 = 97.3%, which were significant at P<0.01. ANOVA showed insignificance at P<0.01 indicating no homogeneity of variance; hence the variable variance were significantly different at P<0.01.
The accuracy of the relationship was significantly high @ P<0.01.

In general, using the cumulative criterion, the accuracy of the predictive association between the predictors (cumRO and cumTR) and the criterion (dependent) variable (cumSL) was very high and significant at P< 0.01.

4.1.2 Regression Relationship (Gully volume growth)

The gully volume growth (cum GR) is another criterion variable that depends on the predictor variables (cum RO, cum TR). Specific regimes were observed.

1. Case of high traffic count and low runoff.
   The effect of cumulative high traffic count (cum TR) and cumulative low runoff (cum RO) was established as:
   cum GR = 2140cumTR – 44940.50cumRO – 397276.450 – 3.2097E5 (4)
   @ R^2 = 89.9%, adj R^2 = 89.5% at P<0.01. ANOVA shows criterion variable and predictors have accurate association significant at P<0.01. The coefficient of the constant and cum TR were significant at P<0.01 and 0.1 respectively.
2. Case of high runoff and high traffic counts.
   The predictive association was obtained as:
   cumGR = 2636997.624cumRO – 56477.606cumTR – 450688.340 + 2.10891E6 (5)
   @ R^2 = 92.2%

The dependence of criteria variable (GR) on the predictors were 92.2% accurate. Only 7.8% of estimate could be said to depend on any other factor. There was a significant difference in the variable variances. The coefficients of the constant and predictors were, however, not significant at P<0.05.
The coefficients of the constant and predictors were, however, not significant at P<0.05.

3. The case of high runoff discharged and low traffic count.
   The predictive association was obtained as:
   cumGR = 4432.175cumTR – 79546.954cumRO – 3629338.062 + 61695.863 (6)
   @ R^2 = 99.0%; Adj R^2 = 98.7%

ANOVA: The F-ratio shows that we can reject the null hypothesis of the homogeneity of variances of cumRO and cumTR at P<0.01.

Also, the contribution of the constant, and the coefficients of cumRO and cumTR were significant at P<0.01, P = 0.05 and P<0.01 respectively.

V. CONCLUSION

Sand mining land use caused the onsite removal of soil vegetative cover and topsoil to the sublayer depths at a peri-urban sub catchment in Uyo for construction and building projects in adjoining areas. The unplanned and unregulated activity exposed the area and the unpaved haulage road to water and truck traffic erosion.
The gully erosion on unpaved roadside was accelerated by the agency of runoff in splash wash from the road, and high axle sand haulage trucks traffic.

The effect of the Runoff discharge and traffic count, as independent variables and in cumulative quantities, on the cumulative soil loss from jagged side slope gullies, and the gully volume growth were very significant at P<0.01 generally. Predicative coefficient of determination significant at P<0.01, were very perfect at R^2 = 88.8 to 98.9%. Different regimes of association were obtained such as: high runoff and high traffic count; high flow rate and low traffic count, and low runoff and high traffic count for effect and on gully loss and gully volume growth, and they gave accurate and significant relationship.

The case of using mixed magnitudes and point values of variables however, did not show accuracy and significance at R^2 = 12.4%. The growth of gully and its soil loss is really a cumulative addition of geometric changes over time in a given rainy season.

Regulation of sand-mining over a catchment is recommended as it has otherwise destroyed landform and initiated unrestrained gullying.

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