QUANTITATIVE ANALYSIS OF GULLY MORPHOMETRY IN OBOTME AREA OF SOUTH EASTERN NIGERIA

BY

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ABSTRACT
A detailed statistical analysis of eight morphometric properties of a medium sized gully in the unconsolidated Coastal Plains Sands of Obotme (Eastern Nigeria) reveals strong interdependence of gully morphometric elements. Of all the eight parameters considered, only shoulder width correlated weakly with other parameters. This indicates that the process of gully widening is independent of the other variables. Its low correlations with both bed width and distance from the gully head has been attributed to differences in the processes operating on gully floor, head and sides.

INTRODUCTION
A gully is any eroded channel so wide that it cannot be crossed by a wheeled vehicle or eliminated by ploughing (Udosen, 2000). Gully development is often associated with disruptions in the ecosystem balances in an environment as a result of climatic change towards higher humidity; crustal movements or human activities involving large-scale removal of vegetation cover.

The literature on gully erosion in Nigeria is replete with studies on the causes, development, growth mechanisms and rates of gully erosion (Ologe, 1972, 1974, 1988; Olofin, 1987 and Jeje, 1991). However, we do know that the morphology of fluvial systems (for example gully channels) reflect very closely the mechanics and dynamics of the processes and the properties of the surficial materials influencing the operations of these processes. Heede (1970), therefore, saw the understanding of the gully morphology as "a first step in evaluating gully processes"… and a connecting link between past,

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natural environment and the area is everywhere riddled with gullies.

METHODOLOGY

Gully parameters were measured and derived from the survey of the longitudinal and cross-sectional profiles of the 106m long gully channel using a 30m linen tape, ranging poles and pegs. Abney level was used in measuring slope angles.

Data identifying and characterizing the cross-sectional variables includes gully depth, shoulder width (or top width) bed width and cross-sectional area, while the shoulder width/depth width ratio and shoulder width/bed width ratio were derived from cross files drawn to scale.

Data on the longitudinal variable involved measuring the distance from the gully head scarp to the gully mouth, noting the length of the gully at intervals of 10m. Slope angles at interval of 10m were also measured. The pair-wise correlation coefficients were computed. A correlation matrix was computed and tested for significance at both at 0.05 and 0.01 level.

GULLY MORPHOLOGY IN OBOTME AREA

Unfavourable lithological condition predisposes Obotme area, located at the highest elevation in Akwa Ibom State (south eastern Nigeria) to severe gully erosion. The 106m long roadside gully system has a fairly direct course i.e. a sinuosity index of 1.19 with mean top width of 2.2m, mean depth of 1.8m, mean bed width of 0.5m and with steep sloping banks of more than 60 degrees (Fig. 2)*. The steep gully sides originate as vertical walls exposed by overfall erosion. They are then eroded by the four gully wall erosion processes identified by Ologe (1972). These are mud tricklings, washing, mass spalling and sloughing. The rapidity with which the gully head scarps recede is a function of the rate at which undermining occurs. Gully floor erosion on the other hand was maintained by the migration of small within - gully head. These initiated were side collapse temporarily dammed the floor creating an overfall.

*The mean value of shoulder width/depth ratio was 1.36 while that of shoulder width/bed width ratio was 5.26. It has a broadly-lobed head rim, with the semi-circularity ratio being 0.4.

DATA ANALYSIS AND DISCUSSION

The result of the simple Pearson's product moment correlation analysis presented in table 1 indicates that most of the gully morphometric properties are strongly interrelated. Of the 28 correlation coefficients, only 7 (25%) are not significant at the 0.05 level and 17 (60.7%) are significant at the 0.01 level. This result is almost similar to the one obtained by Ebisemiju (1989, pp. 318). This finding is very important as it indicates the existence of steady state adjustment between the form elements of the gully systems.

Table 1 illustrates that the slope angle i.e. gully relief has its strongest correlation with the cross sectional area (0.98). Other variables that correlate strongly with gully relief include gully depth (0.92) and shoulder with/bed width ratio (0.87). This is expected because higher hills tend to have steeper and deeper valleys. It explains why gully relief has a negative correlation with the shoulder width/depth ratio (-0.87). It is also illustrates that the process of channel erosion leading to gully deepening takes place at faster rates than that of landslides and slumping (which account for valley widening).

The strong negative relationship between the gully relief and distance from the gully head (0.85) is expected, as runoff water tends to flow from higher grounds to lower elevation. Unlike in Ebisemiju's work on Guyana (1989), (0.13). This suggests that the gully is young, fresh and actively involved in gully deepening. In older gullies, the rate of gully sides retreat is proportional to the rate of gully depending. In an earlier study (Ebisemiju, op. cit. pp. 318) the shoulder width and gully depth were strongly correlated (0.84).

Shoulder width has very low correlations with most of the variables, wit bed width (0.2), gully depth (-0.1), shoulder width/bed ratio (0.01) and distance from gully head (-0.05). This can be attributed to the fairly low variability in the value of the shoulder width along the gully channel. This implies that the anticipated steady state adjustment between the shoulder width and other variables is in progress as the gully system is still in its youthful stage of development.

However, besides the shoulder width, no other variable has low correlations with most of the morphometric properties. As expected, bed width increases marginally with gully size i.e. distance from gully head and therefore it correlates strongly with gully length (0.81). Its correlations with gully depth and shoulder width/bed width ratio are – 0.88 and –0.81 respectively i.e. negatively correlated. Its highest correlation is with the adjustment that is taking place between the shoulder width and the gully depth i.e. shoulder width/depth ratio (0.95). This value is significant at the 0.01 level.

The shoulder width and depth of gullies were correlated with the distance from gully head by Seginer (1966) in Israel. It turned out that both had significant correlations with the distance from gully head. Finally the product of gully width and gully depth were related to the distance from the gully head. It was discovered that the cross sectional area tends to increase in size with increasing distance from the gully head. But in this study, the cross sectional area has a negative correlation with distance from gully head (-0.86), indicating that more soil materials i.e. sediments are removed from the upstream sections than from the downstream (especially near the gully head). However, field measurements showed the actual cross sectional area eroded to be about 50% of the products (Seginer, op Cit p. 245).

The study by Leuder (1959), postulated that an inverse relationship exist between the size of gully bed materials and width when he suggested that the extent and shape of the bottoms of gullies are related to the nature of materials forming gully sides and bottoms, and to the nature of water flow. Upon further analysis, he stated that "coarse, cohesionless soils allow only narrow channels of flow along the bottom". This is observable in the Obotme gully channel (see fig. 2). This narrow channel, according to him, is attributed to "the constant side slippage as angles of repose or critical heights are exceeded…" among other factors. As a result of those factors, gully bottom in granular materials tend to be narrow. "The characteristic V-shape and narrow bottoms of the gullies in this unconsolidated Coastal Plain Sands, therefore, are in agreement with Leuder's postulate for coarse and cohesionless soils.

It should be noted that some of the high values of correlation coefficients between the eight variables may, however, be misleading. This is because the correlation coefficients do not indicate the explanatory power of the bivariate regression model. To be able to determine this, the coefficient of determination R^2 was computed and is shown in table 2.

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Table 1: Intercorrelations among the eight gully morphometric properties***

	L	D	SW	BW	SA	SW/D	SW/BW	S
L	1.00	* -0.95	-0.05	* 0.81	** -0.85	+ -0.77	+ -0.77	* -0.86
D		1.00	0.13	* -0.88	* 0.92	* 0.80	* 0.83	* 0.93
SW			1.00	0.22	-.01	0.36	0.01	0.32
BW				1.00	* -0.88	* 0.95	* -0.81	0.98
SA					1.00	-0.87	0.87	0.98
SW/D						1.00	+ -0.69	+ -0.75
SW/BW							1.00	* 0.86
S								1.00

+ Significant at 0.05 level
** Significant at 0.01 level
Source: Computed by Udosen, 2002

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Tale 2: Correlation Coefficients of Morphometric properties

	L	D	SW	BW	SA	SW/D	SW/BW	S
L	1.00			** 57.34		* 64.27		
D		1.00	1.81		* 0.92		** 62.69	** 90.14
SW			1.00			12.54		11.22
BW				1.00		** 89.14		
SA					1.00		** 30.5	** 90.21
SW/D						1.00		
SW/BW							1.00	* 72.66
S								1.00

+ Significant at 0.05 level
*** Significant at 0.01 level**
Source: Computed by Udosen, 2002

There is a remarkable difference between the correlation coefficient in table 2 and the corresponding coefficient of determination R^2 values calculated for some of the coefficients. For instance, the relationship between the gully size (i.e. distance from the gully head) and the bed width is very strong (0.81). But it should be noted that gully size actually accounts for 57.34% of variation in the bed width. As earlier mentioned, the erodibility status of the soils, among other factors account for the remaining 42.66%, which is not accounted for by the gully size.

Similarly, gully relief, which has high correlations with the shoulder width/bed width ratio (0.87), accounts for just 30.5% of the variations in the adjustment-taking place between the shoulder width and bed width. Theoretically, a short gully developed on a very steep slope should, on account of the greater potential energy induced by steep gradient, have greater depth, shoulder width and cross-sectional areas. This explains why gully relief accounts for 90.21% of the variation in cróss sectional area. This may not hold in all cases. For instance, in the laterite terrain of Guyana, Ebisemiju (op cit) noted that short gullies were found on gentle slopes while long gullies developed on steep valley sides. However, he established a moderately strong positive relationship between hill slope length and gradient (0.63).

Therefore, in a given region, the effects of either gully relief or gully length or both on gully cross sectional variables like the shoulder width, cross sectional area, shoulder width/bed width ratio, etc. are likely to be masked by other stronger factors which control gully size. Such factors include the soil erodibility status and the nature and relative efficiency of the processes operating on gully sides, bottoms and heads. The stage of gully development is also an important factor that affects the nature of interrelations among the variables.

CONCLUSION

Eight gully morphometric properties were identified and analysed statistically. Most of the variables were strongly interrelated, indicating that there is a steady state adjustment between the variables.

An important objective of the research on the morphology of gullies is to see whether what operates in Obotme area conforms to some principles and hypothesis of gully incision and growth as espoused by Leuder (1959); Heede (1974); Imeson and Kwaad (1980) and Ebisemiju (1989).

In conformity with Leuder's (1959) view, quoted by Ebisemiju (1989), the coarse unconsolidated Coastal Plains Sands allow only narrow channels of flow along the bottom. On account of this, bed width did not change remarkably as the gully grew in size, although, it tended to increase marginally as the distance from the gully head increases. Thus, the gully was characterized by a gorge-like V-shape and narrow bottom in agreement with Leuder's postulate for cohesionless, coarse and granular materials.

However, the major contradiction to the existing theories found in this study is that shoulder width and gully depth are weakly correlated (0.13). This contradicts the theory that the rate of gully side retreat is proportional to the rate of gully deepening (Ebisemiju op. cit).

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