STATISTICAL PREDICTION OF GULLY EROSION DEVELOPMENT ON THE COASTAL PLAIN SANDS OF THE SOUTH EASTERN NIGERIA

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ABSTRACT
A statistical model for predicting gully initiation was developed using variables from 20 randomly selected sites. The random samples gave 10 gully sites and 10 non-gully sites. In all, 12 *variables were identified but using students t-tests approach, only four variables contributed to gully development. These four variables include Maximum slope, Maximum slope length, Microrelief amplitude and percentage coarse sand. The four variables were combined through factor analysis and statistical manipulations to form Linear Discriminant Function (LDF). Three functions were obtained by combining the variables in three different ways. An application of the three functions to the field situation identified function 1,γ1 as a very comfortable prediction. When Y*l *was used to classify the various sites using the variables obtained from the field, a* 25% *wrong classification was obtained. This value was quite low when compared with the other two functions whose wrong classification ranged from* 35% *and above.* It *was observed from the study that when* Yl is *less than 30,* it *indicated little or no gully erosion threat.*

INTRODUCTION

Today, in our country Nigeria, erosion menace has become all object of discussion and a major ecological problem facing the nation. In Imo State alone, over 350 gully erosion sites have been identified [4]. Every local government area has its own share of escalating gully and sheet erosion. For the purpose of this study, the erosion sites identified in Imo and Abia states were as follows: Okwudor Secondary Technical School in Nkwere, Amanator, Amanator and Isiekenesi, in Ideato LGA, Uratta Road gullies in Owerri, Abia State University, Uturu, Army Barracks Ohafia, General Hospital, Oguta; Okwoyi gully in Ibeku. Onukwu gully near Emekuku and Ulasi Road in Aba. In spite of peoples' awareness of the problems, only few people know what to do are either prevent the formation of gullies or control existing ones. The erosion problems of South Eastern Nigeria has been discussed by many scholars [1-8]. Attempts were made by most of the scholars to study the factors and processes of erosion, as well as describing the morphology of erosion features. Others aim at identify the spatial distribution of rainfall as induced gully formation in most of our towns and express the need to adopt good planning and policy objectives.

The introduction of live materials specifically vegetation, offer a promising solution to gully erosion control in the South Eastern Nigeria [8]. The bio-chemical stabilization measures utilize mechanical elements (or structure in combination with biological elements or parts to control slope failures and soil erosion. The efforts of the previous authors were mainly on control of existing gully sites, rather than preventive or prediction of erosion prone areas. In this paper, the author tries to dwell more on the preventive aspect of gully erosion development. Therefore, the paper is aimed at ascertaining the gully erosion variables that contribute to erosion problem in the South Easter Nigeria, using Imo and Abia States as a study area. Another objective of the paper is to establish a guide or empirical formula, after a series of statistical testing that will enable one to predict erosion prone areas. Finally, is to determine the effect of each variable on gully and non-gully erosion sites.

In order to investigate if gully initiation could be predicted by means of variables which are relatively easy to determine in the field, a number of such variables were sampled in the randomly selected gully and non-gully sites.

MATERIALS AND DISCUSSION

A site with signs of active vertical incision deeper than an arbitrary one-meter was identified as a gully site. In this research work, ten gully and ten non-gully sites were selected for analysis. Each individual variable was statistically tested for its separation power between gully and non- gully sites. The maximum slope of the site, the restricted length of the slope, micro-relief and the gravel content of the surface layer are useful variables to separate gully from non- gully sites in the study area.

Linear discriminant analysis was used to combine these three variables into one function for optimum separation between gully and non-gully sites. It is suggested that in the study area the resulting discriminant function can be used as an indicator of areas with potential gully erosion. In this way, erosion protection measures can be concentrated on the high risk areas as indicated by high scores of discriminant function. This function is restricted to the study area and its direct environment with the same lithology. The method of work may, however, be applied to other areas.

SELECTION OF SITES

Ten (10) gully and ten (10) non-gully sites were selected for analysis. These were randomly selected from various local government areas in the states; the list below shows the gully and non-gully sites.

Gully Sites Selected

1. Uratta Road/MCC (Methodist Church), Owerrri.
2. Cathedral of Transfiguration Erosion Site,Owerri.
3. Onukwu, Emekuku Gully site (near Azaragbelu).
4. Amanator Gully Site (Ideato LGA).
5. Abia State University Erosion Site (Uturu).
6. Inyishi Alluminium Extrusion Gully Site (Ikeduru LGA).
7. Army Barrack Gully site (Ohafia).
8. General Hospital Gully Site (Oguta).
9. Okwoyi Gully in Ibeku (Umuahia).
10. Okwudor Gully Site (Nkwerre Isu LGA).
11.

Non-Gully Sites Selected

1. Bishop Lasbrey TTC, Irete (Owerri).
2. FUTO Temporary Site (Owerri).
3. Police Barrack (Ohaji-Egbema).

4.. Secondary School Inyishi (lkeduru).

5. Umudiagba Abajah (kwerre LGA).
6. Dikenafia (Ideato LGA).
7. Mercy High School (Okigwe).
8. Isiarna Ohafia.

9 AlCE Campus (Umuahia) Abia.

10. Ibeme Ugiri (Mbano LGA).

SOIL SAMPLE COLLECTION

Soil samples were collected from the ten (10) gully and non-gully sites at a depth of 15cm at various sites for laboratory analysis. This is to identify variables such as particle size distribution, moisture content, shear strength of failure, co-efficient of cohesion and angle of internal friction.

The result of soil analysis conducted on the ten gully and non-gully sites are shown in Tables 1 and 2.

MORPHOLOGICAL VARIABLES

Longitudinal profile survey of some of the erosion sites were obtained from the Ministry of Agriculture and Natural Resources, Owerri (Erosion Control Unit) and others obtained by direct measurement. With the help of the drawings, we were able to measure out variables such as Total Slope length, maximum slope, restricted slope length and weighted mean of slope steepness.

Micro-relief and micro-relief aptitude were measured on each site both for gully and non-gully sites.

Vegetation cover for gully and non- gully sites were measured by inspection.

Table 1: shear strength parameters gully erosion sites.

Soil Code	Sample Load kg	Normal Stress KPA (X)	Shear Stress at Failure KPA (Y)	C KPA	ϕ (Degree)	M.C. %
G1	2	5.45	19.02			
	4	10.90	19.98			
	8	21.8	30.93	13.42	34.76	12.00
	2	5.45	12.64			
G2	4	10.90	27.54			
	8	21.8	22.45	22.5	38.6	12.2
	2	5.45	15.55			
G3	4	10.90	30.46			
	8	21.1	22.45	15.10	23.32	13.1
	2	5.45	20.88			
G4	4	10.90	30.46			
	8	21.8	41.52	30.5	31.65	14.2
	2	5.45	18.5			
G5	4	10.90	24.36			
	8	21.90	27.4	16.75	26.5	12.6
	2	5.45	16.75			
G6	4	10.90	22.6			
	8	21.8	27.4	9.98	42.2	12.45
	2	5.45	21.6			
G7	4	10.90	23.45			
	8	21.8	26.66	19.6	16.2	15.0
	2	5.45	21.6			
G8	4	10.90	23.45			
	8	21.8	23.3	12.75	21.5	14.6
	2	5.45	17.42			
G9	4	10.90	25.65			
	8	21.8	37.0	12.5	49.1	13.75
	2	5.45	22.2			
G10	4	10.90	26.75			
	8	21.8	34.3	18.7	35.2	11.88

Table 2: shear strength parameters a some non-gully erosion sites

Soil Code	Sample Load kg	Normal Stress KPA (X)	Shear Stress at Failure KPA (Y)	C KPA	ϕ (Degree)	M.C. %
	2	5.45	17.16			
GI	4	10.90	18.10			
	8	21.8	27.61	13.5	31.0	12.04
	2	5.45	17.76			
NG2	4	10.90	19.54			
	8	21.8	30.47	15.5	24.5	13.65
	2	5.45	18,45			
NG3	4	10.90	21.00			
	8	21.8	30.47	14.5	37.0	16.75
	2	5.45	18.86			
NG4	4	10.90	21.32			
	8	21.8	29.60	15.56	32.0	15.07
	2	5.45	20.42			
NG5	4	10.90	23.46			
	8	21.8	3?68	15.5	35.2	14.57
	2	5,45	19.81			
NG6	4	10.90	22.40			
	8	21.8	30.56	15.96	33.0	12.05
	2	5.45	17.6			
NG7	4	10.90	18.76			
	8	21.8	28.23	13.98	32.0	13.4
	2	5.45	16.78			
NG8	4	10.90	19.60			
	8	21.8	34.50	12.32	32.5	11.78
	2	5.45	19.32			
NG9	4	10.90	21.42			
	8	21.8	22.86	18.2	15.2	14.24
	2	5.45	17.6			
G 10	4	10.90	22.26	13.2	39.0	13.33
	8	21.8	32.36			

STATISTICAL ANALYSIS OF VARIABLES

Factor Analysis

A factor analysis [2] was indiscriminately performed on the gathered data. Three factors were identified by their role and they represent 75% of the total variance. Ten samples from each site and on each variable were analyzed the results are summarized below:

Factor 1: made up of soil characteristic, is linear combination of percent gravels, percent silt and clay and percent medium to fine sand. It accounted for 35 percent of the total variance. Coefficient of cohesion, angle of internal friction, plastic limit and liquid limits, all showed no significance and were dropped. Slope showed some relationship with particle size distribution.

Factor 2: a linear combination of slope and slope length accounted for 24 percent of the total variance.

Factor 3: micro-relief and vegetation cover contributed to 16 percent. There percentages are taken from the total sample taken,

Student T-Test

In order to distinguish between gully and non-gully sites, the significance of the difference between the means of their population was tested using the t-test And a-level of 0.05 (95% confidence internal) was used to test the hypothesis that there is no difference between the means of the two populations against the alternative that the difference is not equal ato zero. Mathematically,

Ho: there is no significant difference in the means of the population

UG = UG

Hi: UG = UG

However, because of the inherent ambiguity involved in rejecting a hypothetis at a given a-level, the probability approach in nullifying a hypothesis was adopted.

The t-value approach reveals how unusual the sample result is as compared with the sampling distribution under the assumption that Ho is true. It provides more information than simply reporting acceptance or rejection at some level of significance.

Hence, if computed to > tabulated T (2.10), Ho is rejected or otherwise accepted.

An analysis of the 12 variables revealed athat four (4) of tahem showed statistically significant differences between the means of the gully and non-gully populations reflected in Table 3. The four variables include maximum slope, restricted slope length, micro-relief amptitude and percent gravel. Although, gravel content of the soil in the study area is small, it was noticed that gully sites had less gravel than non-gully sites and non-gully sites had more slit and clay than gully sites.

Since the sieve analysis was summed up to 100% and because the percentage silt and clay was small compared with percent sand, the two variables were suspected to be mutually d pendent.

Table 3: Final Statistical Prediction

	VARIABLES		GULLY SITE N = 10		NON-GULLY SITE N = 10		Result of students Test, (t-statistics) Computed t tabulated T Rejected Ho, otherwise Accept Ho X = 0.05	
S/N		UNIT	XG	SG	XNG	SNC	t-Value	T = 2.100 2.10
1	Weighted mean of slope steeepness	%	13.35	6.78	5.93	2.03	3.315	Reject
2	Maximum Slpe length	%	16.42	10.32	9.88	2.36	1.95	Reject
3	Total slope length	m	540.22	470.01	190.83	127.66	2.26	Reject
4			500.01	465.12	183.15	125.51	2.08	Accept
5	Micro-relief	om	54.57	37.84	50.12	19.75	0.3296	Accept
6	Micro-relief Amptitude	cm	40.74	24.52	41.85	15.59	-0.12	Accept
7	Vegetation Cover	%	57.80	18.48	72.79	13.98	-2.89	Accept
8	Gravel	%	11.65	12.44	13.18	4.08	-1.02	Accept
9	Sand	%	48.48	4.32	53.67	3.24	-3.04	Accept
10	Silt and dlay	%	39.86	5.94	33.01	4.70	2.85	Accept
11	Coeff. of Cohesion (C)	KN/m	17.18	6.02	31.54	6.65	1.14	Accept
12	Angle of Internal Friction (0)	0	31.90	10.13	14.92	1.67	0.094	Accept

Smax = Maximum slope steepness
Ma = Microrelief amptitude
Lr = Restricted slope length
G = percent gravel

Linear Discriminant Function

Y1 = 6.314 Smax - 0.1475Lr
Y2 = 0.525 Smax - 0.713Ma - 0.595G
Y3 = 1.302Smax - 0.13421 Lr + 0.407MA + 1.513G
Y1 = >30 (Possibility of non-gully occurrence).
Y1 = >30 (possibility of gully occurrence) .
Y2 - 30 (Gully ocurence).
Y2 - 30 (Non-occurence)
Y3 = <18.65 (gully occurence).
Y3 >18.65 (non-occurence).

LINEAR DISCRIMINANT FUNCTION

The linear discriminant function (LDF) used in this analysis requires independent and random variables only. The percent silt and clay was therefore fropped in preference to percent gravel. In forecasting the gully development, only four variables were used in the discriminant analysis. These are, maximum slope, steepness, restricted slope length, percent gravel and micro-relief amplitude. These have to be combined into one or more equations with view of obtaining a better separation than using one variable. This function (LDP) is an indiex for summarizing observations from given grounds on a one-dimensional scale, which discriminates between the populations by some measure of maximum separation.

Mathematically, (LDF) can be stated as: [2] Y = (XG - XNG) T S - 1 X

Where,

XG and XNG are means of the variables from gully and non-gully populations

X = the pooled estimate of the co- variance matrix of the observed data.

X = any variable.

The expression (XG - XNG)T-I X is regarded as the discriminanat coefficient for the variables, [2]

S is given by:

$$S = \frac{1}{NG + NnG - 2}(AG + AnG)$$

where,

NG and NnG are the number of observation from the gully and non- gully population. AG and ANG are the matrix of the sum and products of the population of gully and non-gully measurements.

For N - observations in population

A = (Xh - X) (Xh -x)^T
= Xh Xh^T - NXX^T

where

Xh = the series of observations from h=1 to h = N

X Matrix means of observation

X^T or X1 = Transpose matrix

Three linearization methods were adopted. The first method involved the combination of two variables. The second method was the combination of three variables, while the third involved the combination of four variables. The three combinations yielded three functions or equations, Y1, Y2, Y3.

VERIFICATION WITH LINEA DISCRIMINANT FUNCTION (LDE)

Another attribute to the discriminant function is its usage to classify observations of unknown population. This is done by computing the mean values of the scores of the two samples.

Ya = (XC - XNC) T S- 1 XC
= YNG = (XG - XNG)T S - 1 Xng

The midpoint of these means on the discriminant function scale is

$$\frac{\text{YG} + \text{YNG}}{2} = (\times \text{G} - \times \text{NGS} - 1(\times \text{G} + \text{SNG})$$

where the variables are as previously defined. The midpoint is called the discriminant index (Yo).

The discriminant index Yo was computed using Y1, Y2, and Y3. After the computation, the various values of Xl, X2 and X3 were substituted in the discriminant function to obtain

Y1, Y2 and Y3, a site was classified as gully if Y1 was found greater than the corresponding Yo or as non-gully if the reverse was the case.

The functions, Y1, Y2 and Y3 were tested for their ability to differentiate between gully and non-gully sites. Variables from the various test sites were analyzed and substituted into the functions to obtain an index in each case. From the result, it was observed that function 1, i.e. Y1, performed best having only 25 percent wrong classification

Y3 also performed better with 25 % wrong classification.

Table 4: Classification of gully and non-gully sites.

Gully Site	Classification			Classification			Classification		
SIN	Yl	Good	Wrong	Y2	Good	Wrong	Y3	Good	Wrong
61	-64.5	-	-	-69.04	-	-	-76.4	-	-
62	47.31	-	-	-24.63	-	-	17.6	-	-
63	101.7	-	-	-15.82	-	-	-37.2	-	-
64	39.4	-	-	-30.00	-	-	62.4	-	-
65	80.9	-	-	-44.12	-	-	16.36	-	-
66	101.4	-	-	-24.11	-	-	21.4	-	-
67	-73.5	-	-	3.99	-	-	11.42	-	-
68	-30.2	-	-	-31.63	-	-	14.3	-	-
69	108.2	-	-	-27.68	-	-	19.6	-	-
610	31.5	-	-	-10.55	-	-	-21.6	-	-
N61	20.715	-	-	-31.3	-	-	27.5	-	-
N62	32.1	-	-	-28.0	-	-	27.5	-	-
N63	-4.7	-	-	-68.39	-	-	34.6	-	-
N64	-5.4	-	-	-20.26	-	-	20.5	-	-
N65	11.14	-	-	-34.13	-	-	-3.6	-	-
N66	27.37	-	-	-40.0	-	-	19.26	-	-
N67	19,57	-	-	-')1.<:)<:)	--	-	'26.45	-	-
N68	31.57	-	-	-19.49	--	-	17.6	-	-
N69	16.6	-	-	29.93	--	--	33.4	-	-
N610	22.72	-	-	-48.14	--	--	16.76	-	-
% Classfication	Y1	75%	25%	Y2	65%	35%	Y3	75%	5%

CONCLUSION AND RECOMMENDATIONS

A statistical model for predicting the development of gully erosion has been developed. Allowing for interferences from single, two factor and three-factor interactions among the variables, maximum slope, restricted slope length and percent coarse sand play significant roles in the predicting or differentiating between sampled gully and non-gully sites.

Using the discriminant function arrived at by factor analysis and statistical manipulations, an index value greater than 30 indicates a high probability of gully erosion while a number less than 30 indicates little or no risk. Model has been tested and found valid for the study area.

Since the relationship between risk and discriminant score is not simply linear as a result of the complex situation encountered during gully development, the condition cannot just be explained away with a simple discriminant function. However, with careful application or very well organized data, at the discriminant scores can be seen as indicators of the magnitude of gully risk.

We do not claim to have found a final solution to the problem of gully erosion. At the same time we cannot sit down to see our homes and our farmlands and what we are saying is that if an area is known to be prone to gully erosion before the process begins, adequate management practices can be dopted or enforced on the or by the people in the area to prevent the situation from coming into limelight. The advantage of identifying the possibility of gully erosion cannot be over-emphasized. The disastrous nature of gully erosion demands that the development of a good predictive tool for an early detection be given a priority. What we have done here is to set up machinery in motion for an early detection of this terrible destroyer. The study and the results may be site specific but the authors are convinced that with careful analysis model can be extended to other erosion hazard areas. The methodology can be generalized.

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