RELATING URBAN PARAMETERS TO GULLY DEVELOPMENT IN SOUTHWESTERN NIGERIA

BY

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INTRODUCTION

- Gullies have been recognized as an important environmental threat
- It is a major factor particularly in humid tropics:
  - in soil degradation,
  - water quality deterioration; and
  - changes in channel morphology
- It is very severe in areas of high population growth and rainfall intensity
- it possesses destructive dimensions; especially in urban environment, causing
  - destruction of valuable urban land and buildings,
  - destruction of communication lines
  - loss of lives and properties (Ledger, 1968).

PHOTO SPEAKS




RESEARCH PROBLEM

- Several studies exist on the effects of urbanization on soil and sediment loss in both temperate and tropical regions (e.g. Harvey, 1974; Gregory, 1977; Hollis, 1975; Walling, 1979; Hooke, 1980; Sawatsky and Tuttle, 1996; Lei, 2008, Jeje, 2005; Odemerho and Sada,1984, Aziegbe 2006, Ionita, 2006, Jimoh 2008 etc.).

- Several conferences, (i.e. AIG, 1986, SCOPE – IUG, 1999) on urban erosion have also been held in various parts of the world. All these are evidence of growing concern among geomorphologists of the phemomenon.

- In many of the studies, attention was on the contributions of climate, soil characteristics and anthropogenic factors to gully development with less attention paid to contributions of catchment parameters i.e. impervious surface, drainage and building density. Hence, this study.

Research Questions

- How does terrain configuration of gully catchments affect gully development and growth?
- What are the relationships among the gully morphometric attributes as well as between them and soil loss?
- What are the factors promoting gully development in the urban area of Southwestern Nigeria?
- What are the dimensions of gully and volume of eroded soil material in the study area?

AIM AND OBJECTIVES

The aim of this study is to evaluate the effects of urban surface characteristics on gully development.

The specific objectives are to;

i. determine the various parameters that cause gully development in the urban area and identify the most important factor.

ii. determine the relationship among some climatic parameters (rainfall, runoff), soil properties (bulk density, sand clay, and catchment attributes (catchment area, surface area, slope gradient, housing density etc)

- iii. generate Digital Terrain Models (DTM) to show terrain configuration of all the gully catchments, and

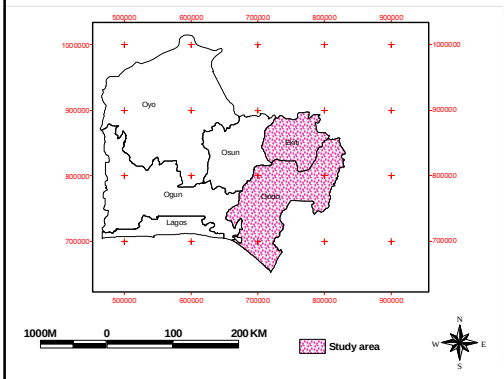
JUSTIFICATION

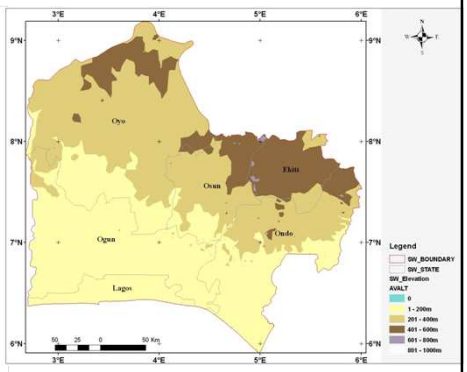
- Urban centres in Nigeria like most developing countries are vulnerable to the disastrous effects of erosion, especially due to the poor urban land use management .
- In Nigeria, urbanization and population increase have been noted, and these factors are known to increase vulnerability to erosion, with the attendant negative impacts.
- To prevent spread effect of this problem (erosion), this study has exemplify the concern, and involved detailed inventory and cause-effect analysis of surface of some urbanized settlements in the southwest Nigeria, using some geo spatial approaches.
- This study is therefore providing a template for erosion problems not only in the study area but in other regions with similar physiographical characteristics.

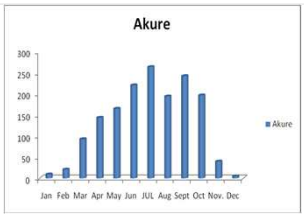
STUDY AREA

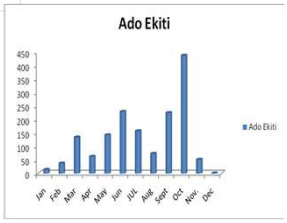
- **Location**:- Between latitude 5^{o} 57` N and $9^{o}$ 12` N and longitude 2^{o} 40` E and $6^{o}$ 03` E.
- **Population**:- Approx. 5.8m people (Ondo 3.4m, Ekiti 2.4m)
- **Geology**:- Post-jurassic sedimentary in the south and Basement complex rock in the north.
- **Soil**:- Underlain by ferruginous tropical soil in the north part, ferralitic soils in the central part and fluvial and lacustrine Alluvium in the south part.
- **Climate:-** Humid tropical climate, mean temp = 27^{o} c, rainfall range between 1250mm in the north and 2500mm in the south and distributed between March and October with a break in August.

STUDY AREA CONT.









RESEARCH METHODOLOGY

Site selection

- Selection of urban towns was based on UN criterion of 20,000 and above inhabitants.
- Some towns that served as administrative headquarters or university towns were considered for the study.
- The towns were further classified on the basis of those with gullies and without gullies. In all, 25 towns (13 in Ekiti and 12 in Ondo States) were identified to have serious gully occurrence. From the list, 10 towns were randomly selected from each State using table of random numbers making a total of 20 towns.

METHODOLOGY CONTD.

Sources of data and data collection

Primary Data

- A single frequency geodetic Global Positioning System (GPS, South H66 and H68) was used to provide more control points.
- Where distances to the gully channels are not too far from the existing GCPs, the Total Station (South 525 model) was used to transfer the coordinates to the gully sites.

Secondary Data

- Imageries from Google Earth with resolution of 2.5m were used for spatial locations of gullies and delineation of gully catchments.
- Population data of selected settlements in the study area, from the Federal Office of Statistics.
- In addition, rainfall data for Akure, Owo, Ikare, Oka, Okitipupa, Irele, Ado Ekiti, Aramoko, Ilawe, Ikole, Igede and Ijero were collected from Agro-climatological and Ecological Project Office, Ministry of Agriculture and Forest Resources, Akure and Ado Ekiti, respectively.

METHODOLOGY CONTD.

Field Data Collection

- Each of the selected gully was measured on the field for dimensions (i.e. length, width, depth and gully surface areas) using Total Station and terrain configuration of catchment using GPS receivers ('track and go' method)
- Determination of gully lengths, widths, surface area
- Determination of gully catchment area, drainage lengths, number of houses and impervious surface
- Determination of gully depth
- Determination of cross sectional areas
- Determination of volume of soil removed by gully
- Determination of DTM and other terrain derivatives

PHOTO SPEAKS






METHODOLOGY CONTD.

Soil Sampling and Laboratory Analysis

Soil samples were collected from the gully shoulders, walls and floors. Soil samples for analysis of bulk density were also collected in their natural state.

The soil samples collected were brought to the laboratory (Soil Science Laboratory, Federal University of Technology, Akure) and analyzed for:

- Bulk density (Db)
- Moisture content
- Porosity and
- Soil texture

METHODOLOGY CONTD

Statistical Analysis

Various statistical methods were used to analyze the data obtained for gullies in this study.

- **Summary statistics:** Descriptive analysis (mean, standard deviation, range)
- **Pearson correlation**: Used to determine the relationships among variables; especially soil parameters and catchment attributes
- **Factor Analysis:** Used to group factors influencing gully development in the study area
- **Multiple (stepwise) regression analysis:** Used to identify most predictor variable that contributed to soil loss in the study area and develop a model for predicting erosion, and reduce model redundancies.

RESULTS

Mean values of soil physical characteristics

- Bulk Density was 1.53g/cm^3 at gully top and 1.72g/cm^3 at gully floor
- Moisture (%) was 14.56% at gully top and 16.32% at gully floor
- Porosity (%) was 26.13% at gully top and 33.06% at gully floor
- Sand (%) was 53.43% at gully top and 44.88% at gully floor
- Clay (%) was 32.45% at gully top and 42.64% at gully floor
- Silt (%) was 14.12% at gully top and 12.48% at gully floor
- Clay Ratio was 2.30 at gully top and 1.48 as at gully floor

RESULTS CONTD.

Gully Morphometry

	Range	Mean/Std. dev.
Length	15m-485.38m	131.44 ± 90.70 m.
Depth	0.6m-7.0m	1.66 ± 1.20 m
Gully head depth	0.13m-6.70m	1.76 ± 1.33m
Gully width	1.25m-17.09m	5.12 ± 3.76m
Width/Depth Ratio	0.82-7.79	3.37 ± 1.61
Surface Area	23.23m^2 – 3544.61m^2	761.37 ±832.63 m^2

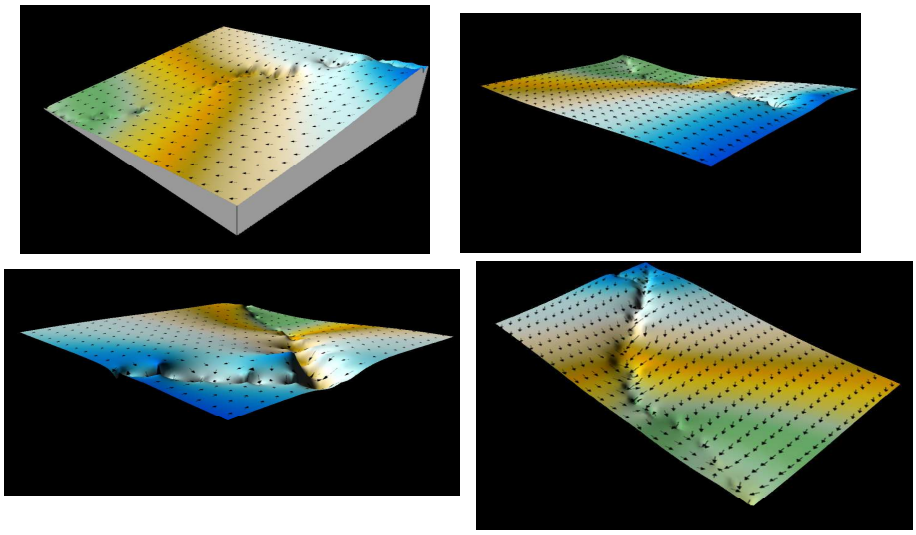
RESULTS CONTD.

CATCHMENT ATTRIBUTES

- Total Catchment Area: 501.248ha
- Catchment Area ranged from 1.18ha-77.26ha
- Impervious Surface: 420.992ha (84% of total catchment area)
- Drainage Length = 1,075,878.15m
- Drainage Density ranged from 0.1- 0.38 mi/mi^2
- Number of houses = 6094
- Housing Density ranged from 4.11 to 34.23
- Gradient ranged from 1^0 4' 21'' to 8^0 24' 40''

Catchment Shape and Drainage Network

- Slope shapes ranged from convex to linear



Results of the Pearson correlation of some soil properties and catchments attributes of gullies in the study area

	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8	Y_9
X_1	1												
X_2	0.038	1											
X_3	0.135	**-0.900***	1										
X_4	-0.318	**-0.668***	0.277	1									
Y_1	-0.225	0.024	-0.146	0.198	1								
Y_2	-0.217	-0.001	-0.138	0.238	**0.994***	1							
Y_3	-0.167	-0.135	0.004	0.292	**0.880***	**0.869***	1						
Y_4	0.192	-0.351	0.295	0.271	-0.364	-0.356	-0.007	1					
Y_5	**-0.632***	0.036	-0.214	0.280	0.061	0.047	-0.056	-0.144	1				
Y_6	0.221	0.086	0.075	-0.321	0.259	0.229	**0.404***	-0.090	-0.253	1			
Y_7	-0.102	-0.145	0.152	0.062	**0.954***	**0.947***	**0.951***	-0.070	0.082.	**0.452***	1		
Y_8	-0.158	-0.271	0.092	**0.411***	**0.841***	**0.857***	**0.740***	-0.127	0.088	0.122	**0.769***	1	
Y_9	0.206	-0.224	0.278	0.018	**-0.462***	**-0.443***	-0.328	**0.533***	-0.183	0.028	0.022	-0.012	1

•Correlation is significant at the 0.05 level

•X1 = Bulk density Y1 = Catchment area Y5 = Slope gradient Y9 = Housing density

•X2 = Sand Y2 = Impervious surface Y6 = Rainfall

•X3 = Clay Y3 = Total channel length Y7 = Runoff

•X4 = Silt: Y4 = Drainage density Y8 = No of houses per catchment area

Correlation Between Soil Loss and Some Gully Catchment and Morphometric Parameters

Variables	Correlation values (r)
Catchment area	**0.513**
Impervious surface	**0.499**
Channel length	**0.554**
No of houses	0.322
Annual rainfall	0.333
Runoff	0.241
Gully depth	**0.617**
Gully width	**0.728**
Gully length	0.247
Depth of gully head	**0.789**
Gully surface area	**0.532**

Results of the Varimax Rotated Factor Loading Matrix for Four Factors

Variables	Components			
	Factor 1 (31.56%)	**Factor 2 (18.75%)**	Factor 3 (14.54%)	Factor 4 (13.6%)
Total catchment area	**0.970**	0.081	0.024	0.090
Impervious surface	**0.977**	-0.011	0.067	0.130
Drainage density	0.242	-0.053	**0.778**	0.434
Channel length	**0.877**	-0.048	0.262	0.297
No of Houses	**0.897**	-0.084	0.398	0.053
Housing density	0.218	-0.276	**0.908**	0.041
Slope gradient	**0.602**	0.456	-0.350	0.390
Bulk density	0.087	-0.129	-0.093	0.266
Sand %	-0.042	**-0.990**	0.078	-0.103
Clay %	-0.037	**0.955**	-0.205	-0.178
Silt %	0.233	0.315	0.348	**0.812**
Rainfall	-0.329	-0.093	0.103	-0.164
Runoff	-0.534	0.484	0.252	0.130
Erosivity	-0.450	0.269	-0.023	**0.885**

Results of the factor analysis showing total variance explained by the variables considered for the gullies studied

Component	Initial Eigenvalues			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	**5.353**	**38.234**	**38.234**	**4.419**	**31.562**	**31.562**
2	**3.002**	**21.446**	**59.680**	**2.626**	**18.758**	**50.320**
3	**2.206**	**15.760**	**75.440**	**2.036**	**14.541**	**64.861**
4	1.824	13.028	88.468	1.908	13.627	78.789
5	1.023	7.304	95.775	1.401	10.006	88.495
6	0.453	3.239	99.011			
7	0.115	0.819	99.830			
8	0.024	0.170	100.00			
9	0.00	0.00	100.00			
10	0.00	0.00	100.00			
11	0.00	0.00	100.00			
12	0.00	0.00	100.00			

Results of the Stepwise Regression of Earth Materials and Catchment Parameters of Gullies in the Study Area

			ANOVA				
Variables	**R^2**	**Adj.R^2**	**F-cal**	**Sig.**	**β**	**t**	**Sig.**
Impervious area (x_1) only	**0.716**	**0.443**	**7.368**	**0.030**	0.585	3.16	0.020
bulk density (x_2)	-	-	-	-	0.557	3.011	0.024
Impervious area (x_1) & bulk density (x_2)	**0.898**	**0.741**	**12.462**	**0.007**	-	-	-
Sand (%) (x_3)	0.178				-0.197	0.981	0.372
Silt (%) (x_4)	-0.149				-0.149	0.698	0.516
Clay (%) (x_5)	-0.158				-0.158	0.834	0.442
Catchment area (x_6)	-1.519				-1.519	-1.045	0.344
Drainage length (x_7)	0.429				0.429	0.795	0.463
Drainage density (x_8)	0.029				0.029	0.137	0.896
Slope gradient (x_9)	-0.067				-0.067	-0.246	0.815
Housing density (x_{10})	-0.132				-0.132	-0.668	0.530
Annual rainfall (x_{11})	-0.116				-0.116	-0.498	0.640
Runoff (x_{12})	-0.016				-0.016	-0.172	0.946
Erosivity (x_{13})	-0.127				-0.127	-0.562	0.598

With the percentage contributions of each variable, a predictive equation was generated for sediment loss in the study area. The equation is expressed as follows;

$Y = -45798.82 + 352.51X_1 + 27694.24X_2$ (Ibitoye, 2012)

(t value for the predictors of the model are significant at $p \leq 0.024$)

X_1= Impervious surface (Ha)

X_2= Bulk density (g/cm^3)

Y= Soil loss (m^3)

Conclusion

- Gully formation and development in the study constituted menace in many of the towns.
- It was also observed that large volume of runoff which flow mainly on steep earth Roads and unpaved drains coupled with poor engineering work and drains maintenance are few of the factors that responsible for gully development in the area.
- Environmental factors (impervious surface and Earth material particularly soil bulk density) were found to be the most significant predictor.
- The study also provides a sort of database for gully morphology and surface parameters in part of the southwest Nigeria.
- It also provided significantly reliable model for predicting soil loss in the study area.

CONTRIBUTIONS TO KNOWLEDGE

- The use of digital surveying and GIS methods in gully studies
- Determination of the contributions of urban parameters to gully development and growth
- Providing a predictive model for soil loss in urban gully study and database for gully morphology in the study area.

THANK YOU FOR LISTENING