A Comparative Analysis Of Relevant Erosion Variables In Two Sixth Order River Basins In Tropical Humid South Eastern Nigeria

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Abstract

This study uses the area–order law in the search for equivalence in the magnitudes of the erosion variables in two sixth order basins, the Ude and Mamu river basins in South Eastern Nigeria. The area-order law of drainage basins postulates that basins of similar orders created under similar environmental conditions would have equal or comparable areas. Erosion variables namely: the moisture factor, soil erodibility (geology), vegetation cover, infrastructural development and mean basin slope on the one hand as independent variables and basin area on the other hand, as the dependent variable in each basin were measured. The relationship (relative contribution) of each variable to the basin area was verified using the Multiple Linear Regression Analysis. The results revealed that deforestation and geologic factors are important erosion variables and that the magnitudes of the erosion variables varied in the two basins. The observed variations in the basins were explained by the black box concept and the doctrine of equifinality.

Key Words: Ude, Mamu, Erosion, Variables, Equivalence

1.0 Introduction

Rivers are common features of the world. River systems consist of related channels contained in their basins. They vary in their flow and erosional character (Birnir 2008). Water is the most important agent of earth surface erosion. Rivers create their valleys by erosion (Ofomata 2001,2008). Various theories and models have been proposed to explain earth surface erosion in different settings (Ofomata 2008). These models and theories were inchoate until Gilbert 1877 cited in Young (1972) and his associates presented the first general principles of earth surface sculpture known as the "Laws of the Terrain." The laws of the terrain stated inter alia:

(a) that under similar climatic conditions, variations of the topography could be explained by variations in the geology and (b) that under conditions of similar geology, variations in the topography could be explained by variations in the climatic conditions. These principles largely explain the basis of landscape evolution. The later development of dynamism, quantification and systems approach (Strahler,1964) provided a strong scientific character to geomorphology that offered it great opportunities for predicting the character of terrains with a high degree of certainty, such that the utility of geomorphological surfaces could be ascertained when the variables can be measured. Thus, where the values, magnitudes and tendencies of operating variables can be ascertained, the processes, possible features, developmental potentials and management problems of any terrain or other terrains in similar settings can be predicted (Aitchinson and Grant (1968).

Rivers had from the time of Herodotus been recognized as agents of erosion (Ofomata 2001). Gravellius' 1914 quoted in Haggett and Chorley (1969) stream ordering scheme reflected a sequence of stream development by backward erosion. The next model of basin erosion cum enlargement and stream network composition was propounded by Horton (1945). The laws said that streams enlarge their basins by backward erosion of their main and tributary streams. The third law of stream networks was developed by Schumm (1956) which said that basin areas increase in proportion to the rate of headstream erosion and elongation within the basin. These laws portray erosive powers of streams by way of basin enlargement via head stream elongation along the main and tributary streams. Basin enlargement is explained by the infiltration model of overland flow (Horton 1945; Dunne and Black (1970; Summerfield, 2000). The processes comprise water infiltraton into the soil-rock structures, saturation, ponding, commencement of overland flow, channel initiation and establishment, headward erosion, elongation of stream segments and ultimately, stream basin enlargement (Summerfield, 2000). Schumm (1956) said that channel extension occurs in depressions within the basin, receiving maximum water supply or in places of the weakest earth materials offering minimum resistance to erosion in the basin. We additionally hold and add the view that the greatest rate of channel extensions within the river basin will occur in the areas comprising the weakest rocks which receive the greatest amount of water flow. Haggett and Chorley (1969) used Lachenbruch's (1962) fracture theory to suggest that lines of geological weaknesses where the rocks have been shattered offer the most feasible sites for headward erosion, while the other areas within the river basin, the interfluves, remained intact and were eroded at slower rates than the zones of shattered rocks. The basins enlarged through the increases in the lengths of the river segments particularly through the elongation of the first order stream segments usually along the shatter lines and soft rocks (Oyegoke and Ifeadi 2008). Because of importance of the erosion factors, it is important that the climatic, geologic and other factors in the basins to be compared must be similar or as similar as possible to allow their comparison. It has been established that under a wide range of physiographic conditions, river basins of the same order located in similar physiographic settings would have catchment areas of similar dimensions (Knighton, 1984). The influences of climate and geology in defining the character of drainage basins had been established by a long string of geomorphologists (Reddy, Maji and Gajbhiye 2004; Hardy 2005; Niemann and Huang 2007; Eze 2009; Larsen, Germanowski and Wilson 2009; Babyaraj and Gurugnanam 2011). The equal areas of two basins suggest the possibility that the variables creating basins of similar dimensions on similar geologic substrates could also be of similar or comparable magnitudes. Put in another way, where two basins lie within the same or similar environmental settings, the verification of the magnitudes of the processes creating them provide some attraction for their being verified on the presumption of their being equal. Whether either of these propositions is true is the subject-matter and the rationale for this paper which compares the magnitudes of erosion variables in the Ude and Mamu river basins (Bowale 2008). Such studies as this provide platforms for the understanding of the operation and relationships of erosion variables and the management of the problems in river basins such as: flood prediction and control, soil erosion, sediment generation, landslides, deforestation, urbanization, and water quality control (Jeje, 2007; Newson 2007). Thus, where two or more basins have similar settings, one basin could serve as an analogue for understanding another basin with which it shares similar environmental characteristics. The analogue paradigm which runs on the presumption of similarities has been shown to reduce the steps and costs in terrain (land) analysis for development purposes cheaper and less costly in terms of finances, time and human investments (Ongley 2004).

A lot of variables are used in drainage basin studies. Drainage basin studies involve the study of single basins, two or multiple basins (Ocheja 2012). There are no rules as to the number of variables that is best for the comparison of basins. The variables used in this study are those supported by existing literature and applicable in the study area (Haggett and Chorley 1969, Acreman 2000), Egboka et. al.2006) and consist of: climate, vegetation cover, geology (history and substrate), topographic slope, relief, and land cover/ land use.

2.0 Descriptions of the Ude and Mamu Basins

The Ude and Mamu basins are depicted in Figure 1.

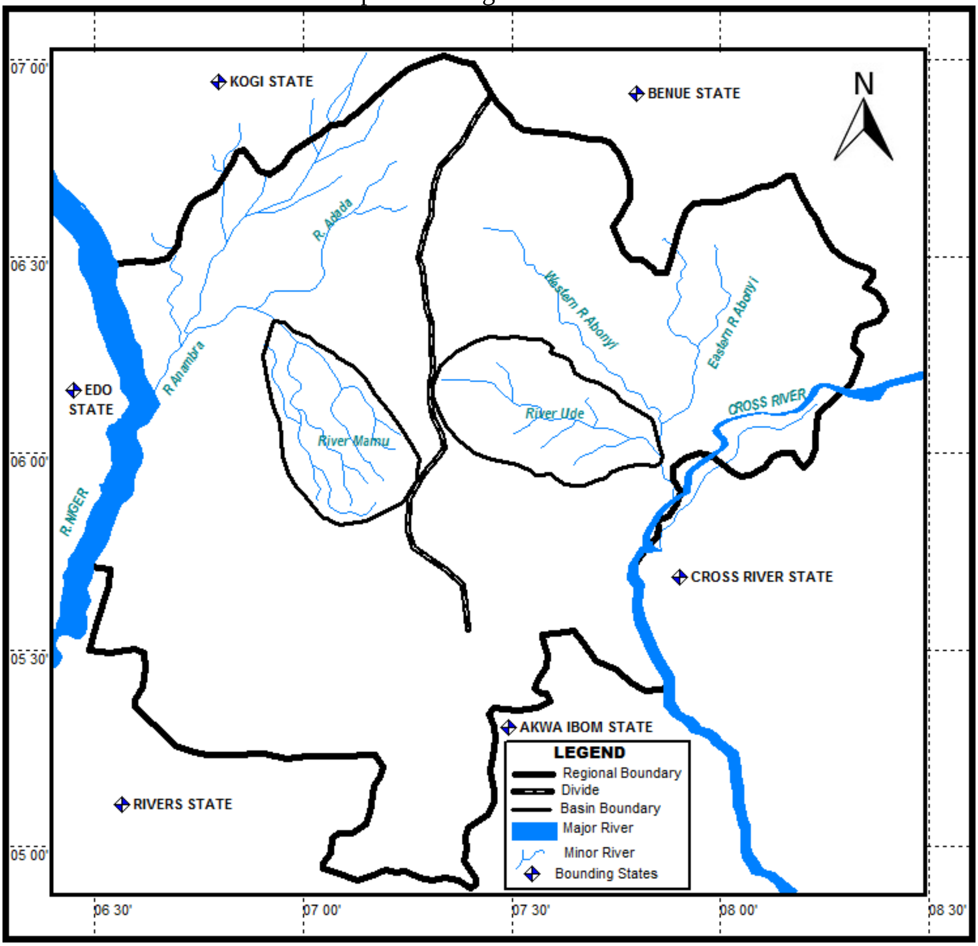

Figure 1: The Ude and Mamu basins.

Source: Digitized from the google earth image (2013).

The Ude and Mamu basins lie within tropical humid Southeastern Nigeria. The Ude basin (Latitudes $6^0 21^I$ North and $6^0 41^I$ North; Longitudes $7^0 25^I$ East and 7^0 50' East) lies in the Cross River basin and the Mamu basin (Latitudes $5^0 49^I$ North and $6^0 20^I$ North and Longitudes $6^0 53^I$East and $7^0 26^{\ I}$ East) lies within the Anambra inland basin (Umeji 2002). The two basins lie within Koppen's (Aw^-) climate region (Anyadike, 2002).The Ude and Mamu basins are developed on flexed and fractured shales of marine origin (Coniachan- Santonian) (Umeji, 2002).The surface of the Ude basin consists of exposed shale. The Mamu basin consists of shales overlaid by the Ogwashi Formation (Holocene), Nanka Sands (Egboka, Nfor and Banlanjo, 2006). Both basins are covered by derived vegetation resulting from human interference. The species consist of tree forms, shrubs, herbs and grasses. Agricultural land use dominates in both basins.

Methods and materials: The images of the river basins obtained via the google map and google earth map libraries were used during the field work as general guide by the author and to assure the accuracy of data collection points and elevation data (www.google.com 2012, 2013).Other pieces of data (rainfall and temperature), were collected from sources that had proper custody of the data in question to assure reliability. Existing literature relevant to the area and subject matter of the research were used to lay the theoretical foundations of the study and decide the most appropriate methods of data collection and tools of data analysis.

Data Collection

(a) The rainfall data in the two basins were obtained from the Nigerian Meteorological Services, Lagos. Six readings of the total annual rainfalls in the basins were selected between 1997 and 2004 at two yearly intervals for the two basins for reasons of data availability. The rainfall factor for the selected six years was generated by dividing the rainfall days in each year with 240 days, that is, the number of rainfall days in the year in the basins and multiplying the outcome with the total annual rainfall for the year in question. This variable was designated X_1 (rainfall) .

(b) Two soil samples were collected at randomly selected points within each of the sixth basin order areas in both basins. Twelve samples were collected in each basin. The samples were tested in the laboratories of Department of Civil Engineering of the University of Nigeria, Nsukka in respect of their particle size distributions and erodibilities. Erodibilty was determined by dispersal method. The mean values of the soil variables were computed and used to characterize the soils in the basins. The erodibility of the geologic substrates is X_2 (geology).

(c) Percentage vegetation cover was obtained in the sixth basin order units in the basins via the LANDSAT image obtained from National Space Research Development Agency Abuja, Nigeria (NASRDA 2013).This variable is $X_{3.}$

(d) Percentage area of infrastructural development which indicates rainfall interception and runoff generation was obtained from satellite altimetry (NASRDA 2013).This variable is X_4 (infrastructural development).

(e) The relative reliefs in the basins were read off from the Google earth imageries of the basins. The mean basin slope angle was computed (Nwokocha 2009). The mean basin slope was designated X_5 for each basin.

(f) The proportions of the basin area covered by each order of stream segments in the basins were obtained from the Google earth image and designated Y the sixth variable and the dependent variable.

3.2 Data Analysis

The data were subjected to descriptive statistics. The drainage basins were described using their parameters. The areas of the basins were compared using the t-test statistic. Multiple linear regression analysis was applied to the erosion variables. The proportions of the basin order areas in each basin were the dependent variables and the other variables X_1, X_2, $X_{3,}$ X_4 and X_5 were the independent variables to determine their relative contributions to the expansion of the river basins.

The Multiple Linear Regression analysis is a mathematical summary of the relationship between a dependent variable(Y) on the one hand and a set of independent variables $X_{1,}$ $X_{2,}X_3$..................... X_n. It is a model which shows or reveals the degree of association between the dependent variable and the independent variables. The model states that an observation Y is equal to a constant term known as the *base constant* plus a series of powers of independent variables called the *coefficients* of the independent variables plus a random error. The coefficients of the independent variables give the rate of change or slope in the dependent variable for a unit of change in the associated independent variable when all other independent variables are held constant. The model is written as $Y= b_o + b_1 X_1 +b_2 X_2 + b_3 X_3+ b_4 X_4$......................$b_5 X_5 +e$…………….Equation (1) (Akpogomeh, 2003; Amegiebor, 2007; Anyadike 2009, Ogbu 2013).

The coefficients 'b' are called *raw coefficients* and provide estimates for the *standardized (beta) coefficients* which indicate the true rate of change of each dependent variable in relation to the independent variable. Other features of the model are the R^2 which is the proportion of the variation in the dependent variable (Y) explained by the independent variable (X). It assumes values ranging from +1.0 to 0.0 to – 1.0; the Regression Sum of Squares which indicates the level of explanation achieved by the model and the Residual Sum of Squares indicates the fit of the model to the phenomena being analyzed, that is to say, the variation in the data not explained by the model. A model with a large regression sum of squares in comparison to the residual sum of squares indicates that the model accounts for a large proportion of the variation in the dependent variable. The higher the residual sum of squares in relation to the regression sum of squares the lower the explanation offered by the model (Ogbu, 2013). The computations were carried out using the Statistical Package for the Social Scientist (SPSS) Version 16.0 software.

4.0 Presentation And Discussion Of The Results

4.1 T-test of the basin areas for statistically significant difference

There is a difference of 35km^2 in areas of the two basins. This difference is negligible, 8.8% of the Ude basin and was found not to be statistically significant. The mean order-area ratio for the Mamu basin was determined to be 94.00km^2/order with a standard deviation of 126.16. The mean order-area ratio for the Ude basin was determined to be 99.83km^2/order with a standard deviation of 99.02. The pooled variance for the data sets was determined to be 15433.58. t was calculated to be 0.000065 vis-à-vis the critical value of 3.169 at 95% confidence level at 10 degrees of freedom. This result meant that the areas of the Ude and Mamu basins were not statistically significantly different and so could be compared ex-facie.

4.2 Results of the analysis of the soils in the Ude and Mamu basins.

The soil test results in the Ude and Mamu basins are contained in Table 1.

		MAMU BASIN		
Variables	**UDE BASIN**	**Ogwashi Formation**	**Nanka Sands Formation**	**Imo Clay- Shale Formation**
Clay %	36.00	18.20	9.00	42.37
Silt	17.00	12.45	12.35	12.20
Coarse Sand %	13.00	20.44	40.65	18.12
Medium Coarse Sand %	10.00	26.40	24.00	10.29
Fine Sand %	14.00	12.51	18.00	12.02
Permeability	0.15×10^{-3}	0.93×10^{-3}	1.64×10^{3}	0.17×10^{-3}
Mean Basin Slope	3^0	3.5^0		

Table 1: The physical properties of the soil samples in the Ude and Mamu basins. Source: Authors' field work and laboratory tests, 2012

Field observations and laboratory analyses of the soil samples collected in the Ude and Mamu basins indicated as follows:

The Mamu basin consists of: lateritic top soil (Ogwashi formation) which is cohesive with a clay content about 12% ; followed by the Nanka sands which are non-cohesive and friable with clay content of 9% and the soils of the Mamu formation consisting of 42.37% of clay developed from shale which underlie the entire basin. A minimum of 10% clay content is the critical amount of clay that qualifies any soil to be classified as cohesive (Eze 2008). The shale has very low permeability, allows relatively long periods of soil wetting, prolonged period of chemical reaction and high runoff at the sand-shale interface. While the shale in the Mamu basin is masked by the Ogwashi and Nanka formations, the shale in the Ude basin has no cover, is directly exposed, weathered and eroded by water and has a slightly larger area than the Mamu basin. The soils in the Ude basin are dominantly clayey and also have low permeability like in the Mamu basin. Low permeability is a characteristic of shale and clays where they are intact and not fractured (Manohar, 1999). Shale is more erodible than sands and sandstones (Manohar, 1999; Summerfield, 2000). The prolonged wetness and chemical weathering in the sand-clay interface in the Mamu basin, result in the relatively more intense and continuous erosion of the shale and sands causing the overlying sands and laterites to fail via slides and topplings, resulting in headstream elongation and basin enlargement. The erosional processes in the Ude basin occur directly on the shale and appear to be more efficacious.

4.2.1 The relative contributions of the erosion variables in the Ude and Mamu basins.

The erosion variables used in this work were measured. The values of the variables were analyzed using the multiple linear regression analysis.

4.2.1.1 The Ude Basin.

The data on the erosion variables in the Ude basin are contained in Table 2

S/N	Y	X1	X2	X3	X4	X5
1	0.17	1873.08	44	44	58	238
2	1.02	1973.76	36	45	10	205
3	6.5	1058.79	40	37	15	195
4	19	1943.33	46	32	23	177
5	75	1138.67	52	48	29	169
6	100	827.22	35	53	22	140

Table 2: The Variable Values Obtained and Used in Computing the Regression Equation for the Ude basin.

Source: Field work and laboratory analysis by the author (2012-2013).

The relationship between the basin area and the erosion variables is described in Tables 3,4and 5.

Model Summary

Model	R	R Square
1	1.000[a]	1.000

Table 3: The summary of the model equation of the analysis of the variables In the Ude Basin.

a. Predictors: (Constant), mean elevatio (slope angle), rainfall, geology, % of vegetation cc

ANOVA[b]

Model		Sum of Squares	Df	Mean Square
1	Regression	106227.573	5	21245.515
	Residual	.000	0	
	Total	106227.573	5	.

Table 4: The ANOVA test result of the regression equation in the Ude basin

a. Predictors: (Constant), mean elevation (slope angle), rainfall, geology, % of vegetat infrastructural development

b. Dependent Variable: area of the Ude basin.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	43.991	.000	

	Rainfall	1.211	.000	.533
	Geology	-13.890	.000	-.987
	% of vegetation cover	-22.940	.000	-2.821
	% of infrastructural development	40.977	.000	2.314
	mean elevatio (slope angle)	2.062	.000	.611

a. Dependent Variable: area of the Ude basin

Table 5: Result of the Multiple Linear Regression Analysis of the Variables in the Ude Basin.

Table 5 is the following equation: $Y=43.911+0.533X_1-0.987X_2-2.821X_3+2.314X_4+0.611X_5$. 43.911 is the base constant which indicates the fixed amount of basin area increase that will occur before the influence of any of the independent variables begins to be felt. +0.533 is the coefficient of the rainfall factor showing that each unit increase in the area of the Ude basin is associated with an increase in rainfall supply. This finding raises concern for soil resources conservation in the Ude basin in this period of climate change. -0.987 is the coefficient of erodibility of the shale substrates in the basin. This coefficient indicates that each unit increase in the area of the Ude basin, is associated with the decrease in the erodibility of the geologic substrates (X_2) (shale). This result suggests that other variables are more important in explaining the basin area of the Ude river. We lean on the intensive fracture of the fracture of the shales as an important variable of in the loosening and scouring of the shale substrate- a soft rock. -2.821 is the coefficient of the vegetation cover variable(X_3). It signifies that each unit increase in the Ude basin is associated with a decrease of -2.821 of vegetation in the Ude basin. This finding is important in view of the phenomena of de-vegetation in the less-developed countries of the world. Poverty has been identified as the main cause of the people in these countries relying on their primary resources for survival (Ajake 2008). This result suggests the need for aggressive re-establishment of vegetation to be taken up in the basin. +2.314 is the coefficient of the infrastructural development variable (X_4). It signifies that a unit increase in the area of the Ude basin is associated with increase in infrastructural development, the associated interception surfaces created by the roofs of houses and cement and mortar surfaces which lead to the generation of greater runoff and the increased scouring off of soils. This result complements the result obtained in variable X_1 and suggests the need for strong control of land use in the basin especially by way of control and management of runoff. + 0.615 is the coefficient of basin slope(X_5). Basin slope is an indication of the erosion risk in the basin (Klingebiel and Montgomery 1961). In the equation, a unit increase of the basin area is associated with an increase of 0.615 in the basin slope. This result reflects the effect if the Udi – Awgu escarpment on the western flank of the Ude basin from where the rivers take their sources.

4.2.1.2 Mamu Basin.

The values of the erosion variables used in the regression analysis in the Mamu basin are contained in Table 6

S/N	Y	X1	X2	X3	X4	X5
1	0.23	844.85	48	72	24	130
2	2.05	960.8	40	65	16	90
3	8.75	972.15	36	57	11	70
4	23	857.24	28	48	8	50
5	65.49	923.78	47	31	5	30
6	372	1002.72	22	28	1	10

Table 6: The variable values obtained and used in computing the regression equation in the Mamu basin.

Source: Field work and laboratory analysis by the author (2012-2013).

The relationship between the basin area and the erosion variables in the Mamu basin is described in Tables 7, 8 and 9.

Model Summary

Model	R	R Square
1	1.000[a]	1.000

Table 7: The summary of the model equation of the analysis of the variables in the Mamu basin.

a. Predictors: (Constant), mean elevation (slope angle), geology, % of vegetation cover, rainfall, % of infrastructural development

Model		Sum of Squares	Df	Mean Square
1	Regression	9249.510	5	1849.902
	Residual	.000	0	.
	Total	9249.510	5	

Table 7: The ANOVA test result of the regression equation in the Mamu basin.

a. Predictors: (Constant), mean elevation (slope angle), geology, % of vegetation cover, rainfall, % of infrastructural development

Model	R	R Square
1	1.000[a]	1.000

b. Dependent Variable: area of the Mamu basin.

coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients
		B	Std. Error	Beta
1	(Constant)	97.877	.000	
	Rainfall	-.006	.000	-.075
	Geology	.818	.000	.123
	% of vegetation cover	2.128	.000	.375
	% of infrastructural development	.601	.000	.237
	mean elevation (slope angle)	-1.052	.000	-.820

a. Dependent Variable: area of the Mamu basin

Table 8: The Result of the Multiple Linear Regression Analysis of the Variables in the Mamu Basin.

The contents of Table 8 are described in the equation: $Y=97.877 - 0.75X_1 + 0.123X_2+0.375X_3+0.237X_4-0.82X_5$. In the Mamu basin, the base constant is 97.877.This is the amount of area expansion that will occur before the effects of the dependent variables begin to be felt. The coefficients of the variables are as follows: - 0.75 for the moisture factor (X_1), a negative trend to the rate of areal expansion of the basin. This suggests that each unit increase in the basin expansion results in the decrease in the moisture factor. This result is typical of valley incision stages of basin evolution at the early and middle stages of basin evolution. This stage is followed by later expansion via slope failures as the valley walls acquire heights and angles beyond their natural angles of repose otherwise called their angles of internal friction and critical heights. The slope failures may however be accelerated by later wet phases as is happening presently (Egboka et. al. 2006). The control of the rainfall factor can be done via the amelioration of its effects by vegetation establishment, runoff control and the redesigning of the topography using terraces and similar structures. + 0.123 is the coefficient of erodibility of the geologic substrate in the basin(X_2). This result means that each unit increase in the basin is associated with the increase in the erodibility of the geologic substrates. For the purposes of comparison, the value of the erodibility factor in the Ude basin is higher than that in the Mamu basin because of the absence of over- burden in the Ude basin. Shale is also more erodible than sands (Manohar 1999) . +0.375 is the coefficient of vegetation cover (X_3). A unit increase in the basin area is associated with the increase in vegetation cover in the Mamu basin. This relationship manifests the role of vegetation in basin expansion especially via slides and slumps because vegetation translates short term water flow through the soil into long- term flow. The long –term stay of water in the soil encourages chemical weathering, rock decay and ultimately ground loss. It is factual that while vegetation reduces wash, it aids gravity processes on steep slopes, basal sapping and basin expansion via wash and gravity- induced processes. +0.237 is the coefficient of the level of infrastructural development (X_4).A unit increase in the expansion of the area of the Mamu basin is associated with 0.237 increase in the level of infrastructural development in the Mamu basin. This result points generally to the role of man in the erosion process and the efficacious role of water as a universal agent of erosion especially where water does not enter the soil in diffuse manner but is concentrated in channels of diverse characteristics as in the Mamu basin (Egboka et. al. 2006). - 0.82 is the coefficient of the mean basin slope(X_5) It has a negative trend to areal expansion in the basin in the sense that a unit increase in the basin area is associated with a decrease in the basin slope. The result reflects the predominance of gentle slopes in the Mamu basin. The mean basin slope was determined to be 2.5^0 and suggests that the basin slope is not a dominant factor in the erosion and expansion of the basin. Further, a hypsometric analysis of the basin showed 73% of the basin to be below five degrees of slope. In the current pluvial phase of climatic conditions, the predicted increase in rainfall will most likely suffuse and erode the basin more intensively. The greater demand for land by a growing population would lead to a greater degree of deforestation and erosion. The increase in infrastructural development will occasion greater runoff generation and greater erosion (IPCC 2007). These findings therefore suggest greater care for the land resources in the Mamu basin and other areas in the tropical humid environments of the world especially in areas of weak geologic substrates, dense human population with sensitive ecosystems.

The result of the multiple linear regression analysis shows that the magnitudes of the variables vary in the two basins irrespective of their similar areas. In the present phase of climate change, the results give good reason for the expectation of greater ground loss and basin area enlargement in tropical humid environments. In the Mamu basin, landslides are rampant and constitute danger for the inhabitants of the basin (Ofomata 2002). The results show that no two river systems or geomorphic surfaces are similar or exactly alike in their evolutions and details even though their areas may be similar or comparable. This result finds explanation in the dual doctrines of the *Black Box* and *Equifinality* in geomorphology (Ofomata 2001). With respect to the black box concept, the details of the operations of erosion variables on geomorphic surfaces are rarely known in detail and take long periods of time before the end products of erosion are seen. This factor limits observations of geomorphic surfaces to the instantaneous state of the surfaces. For this reason, geomorphological systems are called *black-box systems*. Furthermore, different geomorphological processes have in some cases resulted in the creation of similar end features- the doctrine of *equifinality*. *Equifinality* bequeaths scientific status, objectivity and flexibility to geomorphology. In both basins, the values of R^2 which is the level of explanation of the variation in the data set achieved by the model in the two basins were 1.0 and the residuals were 0,000 which imply that both equations fully explained the relationships between the basin areas and the dependent variables in both basins. This result could be suggesting the appropriateness of the variables used in this work. It also suggests the need for other combinations of variables to be tested in subsequent works of this type. The result in this work show how the Multiple Linear Regression Model can be used as a tool for comparing two entities.

Conclusion

This paper sought to discover equivalence in the magnitudes of erosion variables in the Ude and Mamu basin in tropical humid Southeastern Nigeria. The results showed that the magnitudes of the erosion variables varied in the two basins even though they were of comparable areas and similar settings. The results implicate deforestation and geology as being largely responsible in the erosion in the basins. This finding accords with the doctrine of equifinality (Summerfield 2000) and confirms geomorphic systems as black box systems in which the internal mechanism are not fully understood, but the end – products are visible and observable (Ofomata 2001;2008) . The results obtained in this study cause us to make a proposition that the magnitude of similar erosion variables in two basins of similar of comparable areas will vary, irrespective of the similarity of their orders and environmental settings.

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