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Geomorphological Analysis and Terrain Characterization of the Du and Anambra Rivers System of Southeastern Nigeria

Romanus Udegbunam Ayadiuno[1], Dominic Chukwuka Ndulue[2], Arinze Tagbo Mozie[3], Phil O. Phil-Eze[4]

[1,2,3,4] Department of Geography, University of Nigeria, Nsukka Enugu State Nigeria
Email: [1]romanus.ayadiuno@unn.edu.ng

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ABSTRACT

The study, Geomorphological Analysis and Terrain Characterization Between the Du and Anambra River Systems was carried out in Uzo Uwani and Ayamdum Local Government Areas in Enugu and Anambra states, Southeastern Nigeria for agricultural and engineering purposes. Topographic and soil data were obtained by abstraction from the Nigeria 1: 50,000 topographic map sheets (Ilushi South East; Onitsha North East, Udi North West and Nsukka South West). Further topographic data were obtained from satellite photograph of the study area which was used for preliminary mapping of the topography of the study area. The result of the topographic analysis showed that the study area was an inverted undulating tectonic plain with a mean slope angle of 1.750. The Principal Component Analysis model was applied to the results of the soil analysis. The analysis showed a strong influence of topography on soil distribution in the study area. The Principal Components Analysis identified three soil types and explained 73.336% of the variations in the soil attributes in the study area. This paper was concluded on the note that the area has great promises for future economic development and constitutes a support for the execution of pre-development surveys for regional development on a geomorphological basis.

1. Introduction

Background to the Study

Almost every activity of man is based on land. It could be farming, industrial development, all forms of constructions, mining and all manner of excavations, rearing of animals, etc, are all land based activities of mankind. The land surface is varied in nature because it has undulations and features such as mountains, hills, valleys, rivers, vegetation, and many other features. Geomorphology is that branch of the environmental sciences whose province is the study of the earth's surface (Ofomata, 2001, 2008). Geomorphology is defined by Pitty (1969); as the scientific study of the landscape. Other scholars such as Summerfield, (2000) and Umeuduji (2000) defined geomorphology as landscape science. The term science implies the ability to study the landscape through empirical methods and offer rational explanations to the observed state of the land. Science by its nature connotes statements or findings made on any subject-matter on the basis of verified and verifiable evidence. In this project, geomorphology is the scientific study of the landscape and its constituent landforms, their characteristics and their implications for human society in its pursuit of livelihood.

Land is the principal factor of production by man. Its rational use is central to the social, economic and environmental advancement of the advanced economies of the world (Evans, 2003). Geomorphology has different areas of specialization including fluvial geomorphology which is interested in streams, rivers and flowing bodies and features formed by such agents (Wechsler & Kroll, 2006). There is also general and specific geomorphometry which deals with the quantitative analysis of the land surface (Pike and Dikau, 1995; Evans, 2003). It is in this aspect of geomorphology that this research work is located. There are other areas of geomorphology which include Paleogeomorphology, Applied Geomorphology, Geomorphological and or Morphological Mapping, Engineering Geomorphology among others.

Man is naturally a dweller of land and his life on earth is determined by the combination of the climate, vegetation, water, and the land resources available to him (Mozie, 2010). Because of the special, sensitive and scarce nature of land, it must be very well studied. It is necessary to understand and document in the most careful manner, the processes operating on and within it, the quantity, variety and interaction of the processes which gives land its quality. This understanding which is vital can only be achieved through detailed scientific study of the land. This understanding must be based on observations of the land indices which indicate the tendencies of landscape processes and range of possible uses to which any tract of land can be put without risk or hazards (Townshend, 1981; Wilson, 2000).

Most disaster and environmental management agencies in the world rely on geomorphological information in predicting occurrence of disasters like soil erosion, flooding, landslides etc. (Evans, 1998). Morphometric studies are not only important to earth scientists but also to engineers, biologist and medical experts because their objects of study are also environmentally based. Each field of application has things to teach the other (Pike, 2000). In our study area, a morphometric study is important especially at this time when climate change is becoming a threat to human existence. Madu (2011) showcased the areas where most households in Nigeria are vulnerable to climate change. It is not different in our study area as it consists predominantly of plains. During high water regimes in the Du and Anambra plains, the arable lands lying close to the river channels are inundated destroying crops, thus, worsening the food security of the people and the region as seen in (plate 1).

Plate 1*: Submerged Arable Lands Lying Close to a River Channel in Anaku*

2. Study Area

The study area is located between Latitudes 6^0 35'00" – 7^o10'00"N and Longitudes 6^o30'00" – 7^o00'00"E. The study area includes part of the flood plains of the Anambra River, the Ezu River, the Du-River and the Obina River and covers communities in the present Ayamelum Local Government Area of Anambra State. The communities are Omor, Anaku, Umerum, Umumbo, Igbakwu, Omasi, Ifite-Ogwari and Umueje. The study area also covers communities in parts of Uzo-Uwani Local Government Area of Enugu State and they are Umulokpa, Adaba, Ogurugu, Ojjor, Adani, and Ukpata communities. The study area has an approximate area of 880.533km^2. It is bounded in the South by Anambra East and Awka North Local Government Areas and Nsukka Local Government Areas in the North, in the West is Anambra West – Local Government Area. The study area is the home of Lower Anambra Irrigation Project located at Omor.

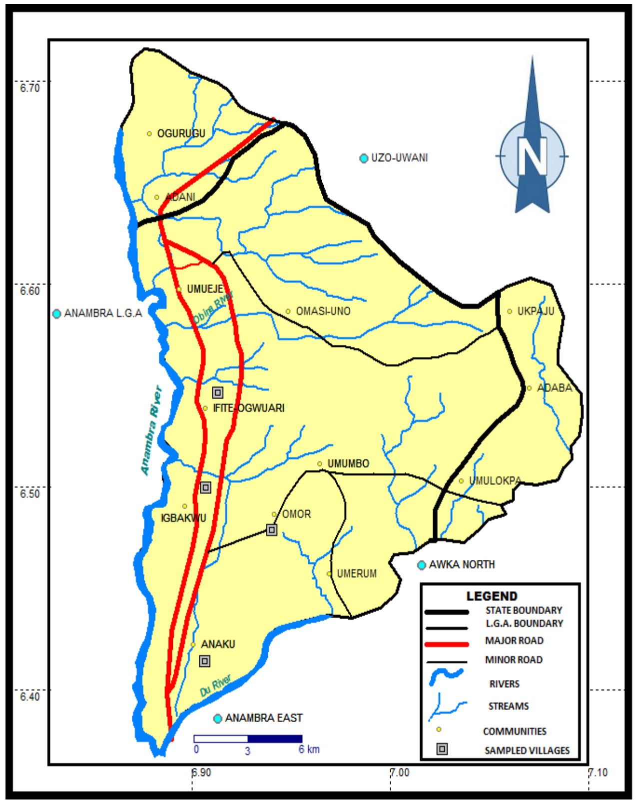

Figure 1: *Study Area*

Source: *Author's Fieldwork and Geography Department Map Archive.*

Geology, Climate, Relief and Drainage

The geology of the study area consists of the Lower Coal Measure, the False – Bedded Sandstone and Imo clay Shales (Nwachukwu, 1976; Iwaloye, 1986). These geologic formations are depicted in figure 2.

The study area has a tropical wet-and-dry climate of Koppen's Aw-type (Koppen, 1936). The mean temperature of the study area is 29^{o}C (Inyang, 1975). The mean annual rainfall is between 1600m and 1800m (Inyang ,1975; Anyadike, 2002). The rainy season starts in March and last till late October. The study area also experiences the little dry season in late July to early August depending on the annual trend as its occurrence varies in between these two months.

The study area is an undulating plain made up of the western reaches of the dip slope of the Nsukka Plateau. It has been described by Ofomata as part of the Anambra River plains lying above 125metres above mean sea level. Two major residuals made of reddish brown lateritic materials are found in Ifite Ogwari and Igbakwu. A smaller one is found at Omor. The landscape is generally higher in the western side (Ofomata, 1978) as seen in (Figure 3).

The study area is drained by the following rivers which have their sources outside it – Omambala, Ezu, Du and Obinna rivers. Some parts of the study area liable to flooding are usually inundated during high water regime known locally in the Igbo Language as “Iji” (flood) and lasts from August to October. The Anambra river plain is marked on the eastern side by a bluff which is about 15 metres to 20 metres in height, thus giving the impression that the surface of the study area must have been created before the river commenced carving its flood plains. The bluff lies between 200 metres to 500 metres away from the river channel in some places (Ofomata, 1978).

Population and Economic Activities

As at 1991 and 2006 censuses, Ayamelum Local Government Area had 76,038 and 137,192 inhabitants respectively, while part of Uzo-Uwani Local Government has 42,236 and 56,995 in 1991 and 2006 census respectively (NPC, 2006). The much noted increase is as a result of people migrating from different areas in search of fertile land for farming. Some are civil servants working in the two Local Government Areas, while others are civil servants working with Lower Anambra Irrigation Project and various primary and secondary school teachers and their families.

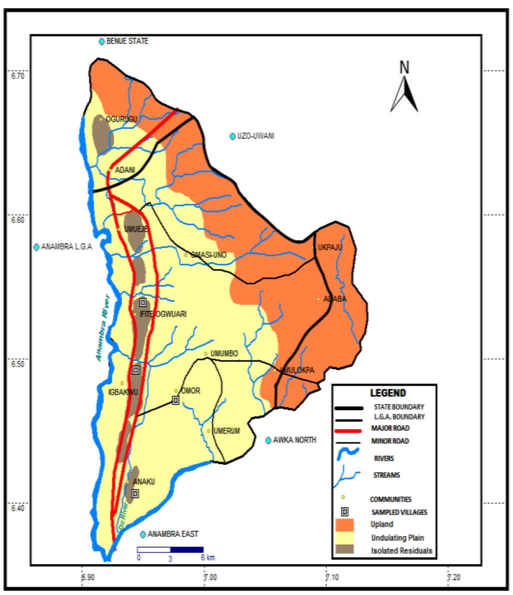

Figure 2: Geology of the Study Area: Part of Anambra Basin
Source: *Author’s Fieldwork and Geography Department Map Archive*

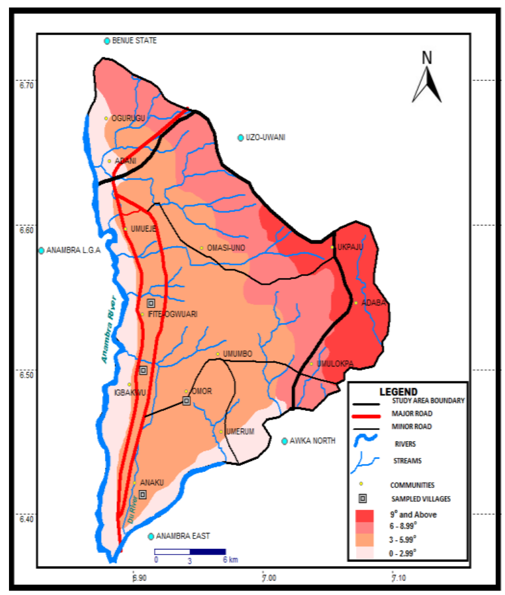

Figure 3: The Relief of the Study Area
Source: *Author’s Fieldwork and Geography Department Map Archive*

3. Materials And Methodology

The data on which this work is based came from primary and secondary sources. Primary data were obtained from direct field activities which include field work such as measurements, collection of soil samples, and confirmatory measurement of certain topographic attributes which includes elevation and slope angles, distances between points, field photography and oral discussions with knowledgeable persons conversant with the area of research. Secondary data consist of the entire body of existing published materials including text books, articles in journals of learned societies, material from the internet, reports in hard and electronic copies obtained from diverse sources including the internet and libraries.

4. Data Analysis And Result

Analysis of Soils

Forty-five soil samples were collected from various sites in the study area were analyzed in the laboratory Department of Soil Science University of Nigeria; Nsukka. The soil samples were analyzed for particle size to obtain textural classes, pH, and nutrient content.

Textural and Nutrient Analysis of Soils

With respect to textural and nutrient analysis contained in Table 5, the soils have a mean clay content of 21.62% with a standard deviation of 9.65; a mean silt content of 29.29% with a standard deviation of 16.53; a mean fine sand content of 20.90% and a standard deviation of 9.33; a mean coarse sand content of 28.19% and a standard deviation of 21.15; water content of 5.33 and a standard deviation of 0.53; a pH of between 3.8 – 4.20 with a standard deviation of 0.65; mean organic carbon (OC) content of 1.57% with a standard deviation 0.83, organic matter (OM) of 2.70% with a standard deviation of 1.43, Total Nitrogen (TN) of 0.10% with a standard deviation of 0.042 and a mean available phosphorus (Av.P) of 4.69 with a standard deviation of 3.71.

The mean clay content of 2.162% is far above the mean clay content of 10% that qualifies soils as cohesive (loams) or granular (Brady and Weil, 2000). The corresponding and relatively high silt and sands contents indicate that the three major fractions contribute 99.91% of the soil mass. Within the 99.91% the fine and coarse fraction account for 49.00% leaving clay and silt with 50.91% of the total soil mass. The essence of looking at the standard deviation of quantities is because it indicates the representatives of the sample over the population from where it was drawn (Eze, 2009). Where the members are more widely distributed around the mean, the standard deviation is nearly equal to or greater than the mean value of the sample population. On the other hand, where the standard deviation is less than the mean of the sample population, it is interpreted that the values of the samples cluster closely around the mean and that the mean is a true reflection of the sample population (Eze, 2009). Applying this principle to the sample population in this study, the standard deviation computed for all the variables in the soil survey are consistently less than the means of the variables and it can be safely said that the samples are good and reliable reflection of the soils of the study area. The soils in the study areas from the textural analyses and matching using the International Soil Science Association Classification Scheme were loams which varied as clay loam, sandy loam, loamy sand, silt loam and silt-clay loam. Loam soils have been acclaimed to be the best agricultural soils (Brady and Weil, 2000).

The results of the textural and chemical analyses were further subjected to correlation analysis. The result of the correlation analyses is presented thus:

Correlation Matrix Results of the Soils

The correlation analysis shows the relationship between the soil properties observed in the study area. The pattern of correlation coefficients gives an immediate insight into the expected pattern of spatial distribution of the soils in the study area and by extension, the general picture of the developmental potentials of the soil units in the study area. The correlation coefficients thus become keys for understanding the nature of the relationships between the properties of the soils. The result of the correlation is shown in Table 7.

Table 1: Correlation Matrix of the Soil Texture and Nutrient Analyses of the Soils

		CLAY	SILT	FINE SAND	COARSE SAND	pH/H_2O	pH/KCl	OC	OM	TN	Av.P
Correlation	CLAY	1.000									
	SILT	.605	1.000								
	FINESAND	-.219	-.464	1.000							
	COARSESAND	-.835	-.828	.102	1.000						
	pH/H_2O	-.384	-.283	-.059	.416	1.000					
	pH/KCl	-.387	-.291	-.049	.423	.946	1.000				
	OC	.491	.329	.136	-.560	-.550	-.483	1.000			
	OM	.490	.325	.134	-.557	-.547	-.482	1.000	1.000		
	TN	.044	.126	.044	-.143	-.147	-.086	.298	.298	1.000	
	Av.P	-.294	-.239	.105	.307	-.106	.061	.137	.134	-.074	1.000

Source: Researcher's computation 2012

A positive correlation is an association in which an increase in one variable is matched by an increase in the other correlate variable and not an explanation of the increase observed (Anyadike, 2009). Table 4 reveals that clay is positively and moderately correlated to silt (r = 0.605); very weakly and negatively correlated to fine sand (r = -0.219); negatively and strongly correlated to coarse sand (r = -0.835); weakly and negatively correlated to soil acidity pH/H_2O r = -0.384 and pH/KCl r = -0.387; positively correlated to organic carbon (OC) (r = 0.491); same as for soil organic matter (OM) (r = 0.490), very weakly positively correlated to total nitrogen r = 0.044 and negatively correlated to Available Phosphorus (Av.P) (r = -0.239).

The results of the correlation of silt to other sand fractions and minerals indicate that silt is very weakly and negatively correlated to fine sand; very strongly negatively correlated to coarse sand, very weakly negatively correlated to pH (pH/H_2O r = -0.283; pH/KCl r = -0.291); weakly positively correlated to organic carbon (C; r = 0.329; organic matter (OM) (r = 0.325) very weakly positively correlated to total nitrogen (TN) (r = 0.126) and very weak and positive correlation with available Phosphorus (Av.P) (r = 0.239).

The results of the correlation of fine sand to other sand fractions and minerals indicate that fine sand is weakly positively correlated to coarse sand (r = 0.102); very weakly negatively correlated to soil acidity (pH/H_2O;r = -0.059; pH/KCL; R = 0.049); weakly positively correlated to organic carbon (OC) (r = 0.136) organic matter content (OM) (r = 0.134); Total Nitrogen (TN) (r = 0.044) and very weakly correlated to Available Phosphorus (Av.P) (r = 0.105).

The results of the correlation of coarse to other sand fractions and minerals indicate that coarse sand is, weakly positively correlated to soil acidity (pH/H_2O) (r = -0.550; r = -0.483); weakly positively correlated to total nitrogen (TN) (r = 0.298) and very weakly positively correlated to available phosphorus (Av.P) (r = 0.137) organic matter is weakly positively correlated to total nitrogen (r = 0.298) and very weakly positively correlated to available Phosphorus (Av.P) (r =0.134). Total nitrogen is very weakly negatively correlated to available phosphorus (Av.P) (r = -0.074).

The results of the laboratory analysis reveal that there is a strong geologic and topographic control over the soil type distribution in the study area. The high positive correlation of clay to silt indicates the continuous breakdown of the sandstone materials by high temperature and moisture and the transportation of the weathered materials by slope wash to various positions on the slopes especially in the middle and lower slope segments in the study area. Russell (1950); Ezeaku (2012) and Telfer (2013) have shown that soil acidity is a very critical factor that determines the availability of certain nutrients in soils while the pH itself is dependent upon the mineralogy of soils.

In the soil of the study area, the fine fractions are negatively correlated to acidity as opposed to the coarse sands which are positively correlated. Soil acidity is negatively correlated to clay and silt because these soil fractions are laden with base cations. Organic carbon is negatively correlated to coarse sand, acidity and positively correlated to total nitrogen and available phosphorus. Coarse sands are subject to wash processes which take away the fine fractions leaving the large sand fractions which are still being dissolved and silica which is acidic released more into the soil complex. Organic carbon is directly related to soil nitrogen and phosphorus which are released by organic matter decay.

Principal Component Analysis Results

The properties extracted from the soils in the laboratory were subjected to the Principal Component Analysis. The results of the principal component analysis are contained in Tables 2 and 3**.** Table 2 contains the total variation explain by the components extracted by the model, while Table 3 contains the components matrix showing the significant variables in each component.

Table 2: Rotated Component Matrix of Principal Component Analysis

Code		Component		
		1	2	3
A1	CLAY	-775	-.382	-.003
A2	SILT	-677	-.578	.022
A3	FINE SAND	-.082	.652	.164
A4	COARSE SAND	-.855	.366	-.096
A5	PH/H_2O	-.741	-.367	.462
A6	PH/KCl	-.720	-.273	.519
A7	OC	.821	.378	.267
A8	CM	.819	.378	.269
A9	TN	.275	.159	.666
A10	Av.P	-.129	.596	-.096
	Eigen Value	**4.302**	**1.915**	**1.117**
	% of Explained Variance	**43.021**	**19.146**	**11.168**
	Cumulative %	**43.021**	**62.167**	**73.336**

Source: Authors Computation

Table 3: Total Variance Explained of Principal Component Analysis of the Soil Properties

Component	**Initial Eigenvalues**			**Extraction sum of square loading**		
	Total % of variance Cumulative%			**Total % of variance Cumulative%**		
1	4.302	43.021	43.021	4.302	43.021	43.021
2	1.912	19.148	62.167	1.915	19.146	62.167
3	1.117	11.168	73.336	1.117	11.168	73.336

Source: Authors Computation

The results of the Principal Components Analysis of the soil parameters I of the study area are contained in Tables 1 and 2. The tables show that the model assigned 63.71% level of explanation to Component I, 19.17% to Component II and 13.13 % to Component III. The model offered a total of 73.336% explanation of the variation in the soil properties of the soils in the study area. This level of explanation is good and indicates that the soil parameters measured are derived from the soils in question. Additionally they indicate the accuracy of the observations and analysis.

The 10 variables observed were reduced to three significant components. The limit of significant loading was put at 0.5 which is common among researchers.

I. **Component 1** has an eigenvalue of 4.302 and accounts for 43.021% of the total explained variance. This component has very high positive loadings on clay (0.775), silt (0.67); organic carbon (0.821); and organic matter (0.819). It also has high negative loadings on coarse sand (-0.855); soil acidity pH/H_2O (0.741). This component is indicative of the dominance of clay and silt fractions, they indicate their properties coming from wash processes and deposition. These are soils found at the toe slopes in the study area; they are wet soils thus weathering is continuous within them leading to the presence of fine fractions in the soils. They are deep, well-drained loam soils which have high mineral nutrients and are widely cultivated for the production of crops such as pigeon peas, beans, maize, vegetable, yams, cocoa yams, plantains and bananas.

II. **Component 2** has eigenvalue of 1.915and accounts for 19.146% of the variance in the data set. With Component 1 both account for 62.167% of the variance in the data set. Component2 is loaded strongly positively on fine sand (0.652) silt (-0.578) and available phosphorus (0.596). pH/KCl is the dominance of sand fractions and high quantum of available phosphorus. This component describes soils left after the fine fractions have been washed down slope by overland flow. They characterize soils on the middle slope component. They are relatively shallow when compare with soils on the toe slopes. They are not intensively cultivated because they can only support crops which tolerate high acidity for example oils palms, cassava, some vegetable. Thus, they have limited agricultural use. They are shallow and sandy.

III. **Component 3** has an eigenvalue of 1.117 and account for 11.168% of the variance. With components 1 and 2 they offer 73.336% of explanation in the loading of the data set leaving 26, 664% of the variance in the data set unexplained. Component 2 is positively loaded on soil acidity pH/KCl (0.519) and total nitrogen (0.666).

These loadings indicate high soil acidity and soil nitrogen and constant wash. They are soils at the top of the low residuals in the study area. The soils are generally shallow and are underlain by impermeable lateritic crust. Vegetation on them is relatively scantly and they are not really agricultural soils except where the local conditions have favoured the creation of patches of deep soils. The principles indicated are shallowness and coarseness of soil.

Analyses of the Engineering properties of the soils

Field tests on the load bearing capacities of the soils in the three topographic units discerned in the study area within which the soils fall reveal that the toe slopes have relatively low load bearing capacities with a mean load bearing capacity of 6.5%. This value is generally below the accepted minimum load bearing capacity stated by Karol (1961) and Brady and Weil (2000). The acceptable minimum load bearing capacity is 7% which is the value that is considered safe for housing (Nwokocha, 2009).

The soils recognized under the engineering considerations are five units. The valleys have clayey and deep soils which are subject to extreme condition of wetness, softness and mobility during the rainy season and dryness and hardness during the dry seasons. No stable layer could be found at depth of 1.0 metre beneath the surface thus eliminating them as normally suitable for any permanent fixtures. In the field, the roads that cross the valleys are built on embankments of borrowed stable lateritic soils. The construction engineers informed this researcher that the foundations of the culverts were commenced at 1.7 to 2.0 metres where fairly stable soil conditions were encountered. They are under slopes of 0^o - 2.99^o. They are followed as one moves upslope by soils in the colluviation zone which are under slopes of 3^o – 4.99^o sometimes up to 6^o. These soils have low load-bearing capacities. These low load bearing soils are found over shale's which occupy the valleys and low lands in the study area. Shale's are problematic engineering soils (Muntohar, 1999; Ewing, 2011).

The soils of the middle slopes come next. They have marginal load bearing capacity that vary from 9% at the lower end of the slopes to 13% at the upper end. This translates to a mean load –bearing capacity of 11% which is satisfactory. The problem of the soils due to their topographic positions is erosion due to the relatively steep angles. Thus, apart from the sheet wash problem they were found to be marginally suitable for emplacement of engineering structures.

The soils at the residual tops and relatively higher grounds were found to have values of 15% - 21% with a mean value of 18%. They are very suitable for any type of construction. In the course of the field work, it became obvious to this researcher that the summits of the residuals and relatively higher grounds were formed on lateritic concretions or duricrusts with shallow top soil. All the settlements in the study area started on top of these residuals where the lateritic concretion underlies the earliest sites.

The PCA approach has recognized three soil units in the study area. The soil units have topographic correlation with the surface features and slope angles and strongly suggest a soil slope relationship which has been advanced by Ofomata (2008).

Geomorphological Analysis and Terrain Characterization

The function to which every tract of land is put is a function of the attribute of the land (Ndulue, 2018). The attribute of the lands in the study area were obtained from the results of the analysis carried out in the area and the findings are thus:

The Lower Coal Measure: The lower coal measure is exposed in Omor and conform to a regional dip of 3- 5^oc (Nwachukwu, 1976). The lithology is made up of sandstone, shale, mudstone, sandy shale and coal streams. Exploration reports by Shell BP (1974) between Amikwe Omor and Umerum in the study area revealed considerable changes in thickness within each unit; a thin coal band when traced laterally passes into shale. This view is held to show mild, unstable, conditions of earth movement during their formation (Nwachukwu, 1978).

The False-Bedded Sandstone: These sandstones are exposed in Igbakwu within the study area (Ofomata, 1967) and are called the Igbakwu Sandstones (series). These sandstones are found exposed mainly in riverine areas which have been incised into by stream thus creating scarp slopes. They are permeable with occasional shale partings. They are unconsolidated and have medium to poor sorting. The alternation of coarse and fine grains in a continuous laminae suggest fluctuating conditions of deposition and by analogy these alternations are believed to indicate the alternation of periods of flood and normal sedimentation in the Niger Delta during each marine transgressions (NEDECO, 1961).

The Imo Clay Shales: These shales are found in Omor, Umumbo, Igga, Umueje, Ojjor, Anaku, Omasi and Umerum (Jungerius, 1965; Ofomata, 1965, 1967). This formation is made up of the dark grey shales that were weathered into stiff clay, occasionally intercalated with sandstones. Pebbly sandstone bands are locally present. The fauna discovered in the deposits are comparable to the Upper coal Measures and this finding led Reyment (1965) to report the presence of a marine transgression which got to the top part of the Upper Coal Measures. Kogbe (1974) also took up this problem and put the boundary towards the top of the upper coal measures. The difficulty is fixing the boundary of this transgression is attributed to the absence of the Danian era in Nigeria sedimentary records.

Soils

Description of soils of the study area are drawn from the earlier works by Obihara, et. al., (1965); and (Ofomata; 1964, 1965, 1967, 1973, 1975) which show that the soils in the study area correspond to the geologic formation of the study area, the site conditions and their related landscape features. Ofomata (1965) class them as litosols which are young soils derived from recently deposited materials. The ferralitic soils and hydromorphic soils also present are associated with different geological formations. The associations of soils with geologic formation indicate as follows. Soils Developed over False-Bedded Sandstones, soils developed over Imo Clay Shales, soils developed form Terrace materials and soils developed from Alluvium.

Soils Developed from False-Bedded Sandstones

These soils are found on the ridges along the Anambra-Du Rivers. They are the Igga-Ogwari associations developed on the summits of the ridges overlain by the Igbakwu Sandstones. The greater part of this association is covered by the well-drained, deep, red sandy clay Igga series. The Ifite series is similar to that of Igga but varies in colour, brown to reddish yellow due to the presence of water and greater wetness the texture has more sandy contents.

Soils Developed over Imo Clay Shales

Obihara, et. al., (1965) showed that the soils in this zone are highly mottled with red and white specked colour due to periodic water-logging. The drainage of the soils developed from these materials is so poor that grey mottling is found within 30cm of the surface. They are typified by the Umumbo series. According to Ofomata (1978), the motling is caused by the water-logging of Umumbo during rainy season. Other soil series found in the Imo Clay Shales are the Omor and Ogurugu series Obihara, et. al., (1965).

Soils Developed from Terrace Materials

These are soils found along the lower courses of the rivers. Two series are identified on the terraces of the Du, Ezu and Obinna rivers. Their textures range from loam to clay, the sand fraction being mainly derived from the False-Bedded Sandstones. They are also present in Asaba on the Obina-Anambra plains. They are brownish and also molted at about 30cm – 40cm below the surface (Ofomata, 1978).

Soils Developed from Alluvium

These soils are found on the flood plains of the rivers. The Umulokpa series is held to represent this soil series. The soils are loamy and mottled. They are derived from the False-Bedded Sandstones, and the Imo clay Shales. At the lower courses of the streams and tributaries of Du-River, a system of levees and swamps exist Obihara, et. al., (1965).

5. Conclusion

This study establishes that the developmental value of any region is primarily rooted in the combined values of the geology, climate, geomorphology, soils, vegetation and human factors. This is why Dylik (1957) and Mozie (2011) asserted that in the end, geomorphological surfaces are translated to economic surfaces by human beings based on their inherent characteristics or qualities. The search for or the verification into the characteristics and qualities of land is the exclusive presence of quantitative geomorphology christened terrain or land evaluation by Stewart (1968), Nwokocha (2009) and Ochege (2009).

In this work, the Principal Components Analysis collapsed the ten soil parameters into three principal components which represent three major soil classes existing in the study area.

This study is a meso-scale study and is of greater detail than the works of Obihara, et. al., (1965). It is a further demonstration of the relevance of geomorphology to human society. It is hoped that the results of this study will help the local governments of the study area to make informed decisions in development matters because this study presents a regional development blue-print for the study area which provides a justification for the sustained study of Applied Geomorphology.

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