GEOGRAPHY AND REGIONAL PLANNING

Geospatial Modelling of the Obudu Cattle Ranch, Cross River State, Nigeria

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Abstract
This study focuses on environmental problems associated with rugged and complex terrain of the Obudu Cattle ranch, in Cross River State. Utilizing digital terrain modelling (DTM) the work represents the study area in a 3-dimentional model that conforms to orthophotorealism as an aspect of geospatial assessment. Thus geographical information system (GIS) is used to model the terrain of the area digitally. The topographical map of Obudu delineating the study area was scanned into the computer system in the GIS environment. The map was geo-referenced and the values x, y, and z co-ordinates were derived to generate a digital terrain model with a 3-D view of

the area. The arc view and surfer were the GIS software used. In addition, morphometric studies as an aspect of environmental hydrology were defined by numerical methods and quantitatively analyzed. The following morphometric variables computed were basin area = $362km^2$, drainage density = $0.45km/km^2$, stream length = 162.20km, stream frequency = 0.52km, and drainage intensity = 0.23km as well as its various bifurcation ratios.

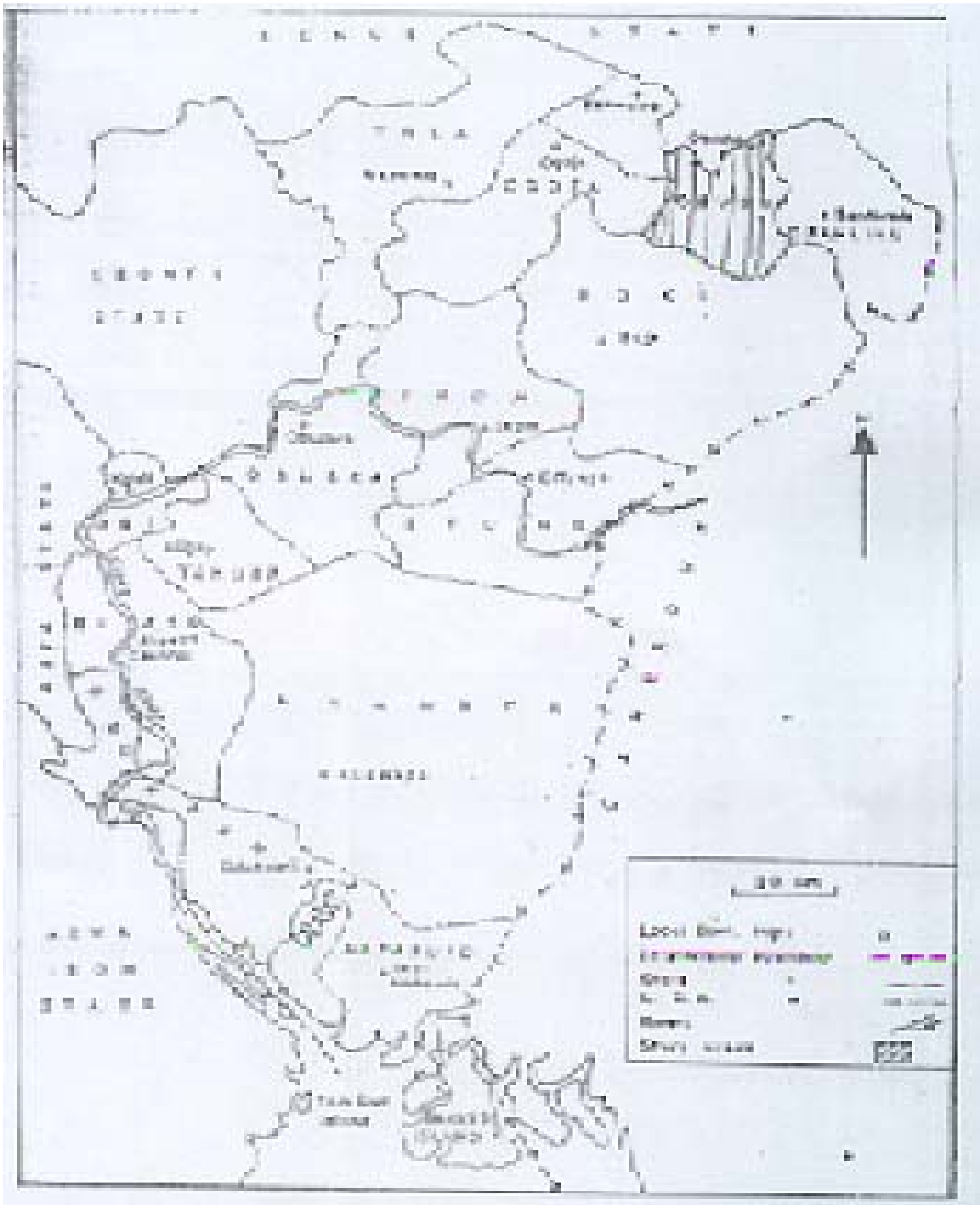
This work enhances and is a viable tool for planners, and other developers in geospatial evaluation particularly in rugged areas to enable them effectively control such environmental problems as gully erosion, landslides, flooding, and other aspects of environmental degradation as well as problems associated with pollution of ground water, sand filling operations, channelization, dredging and several others.

Introduction

The enormous development of computer technology with diverse applications in recent years coupled with their widespread acceptance and availability has led to their adoption in many fields of studies. Geospatial or Digital terrain modelling is the study of ground-surface relief and pattern by numerical methods. As discussed by Petrie and Kennie (1990) there are a number of other names which have been applied to such a representation, for example, digital elevation model (DEM) and digital ground model (DGM). In fact each applies to a slightly different type of surface representation. Interestingly, digital terrain modelling has become integral to hydrology, tectonics, oceanography, climatologic and geohazards assessments. It is also important to non-geographical applications such as land use planning, civil engineering and microwave communications.

Geographical information system (GIS) technology further enables terrain modelling results to be combined with non-topographical data and use for analysis. (Moore, 1991; Pike, 1995). Modelling of environmental processes and problems is essentially very essential for the modern engineers and scientists of 21st century and the scope of environmental problems that can be addressed by modelling is truly infinite. There are “off-the-shelf” models or package programmes for almost every conceivable task, be it terrain analysis, water quality analysis, conservative constituents and non conservative constituents, watershed and other environmentally related problems. (Gerard Kiely, 1997).

Fig. 1: Map Of Cross River State Showing Obudu L.G.A.



Terrain modelling by its analytical approach contributes towards understanding landscape, shapes and processes that generate them. The automation of relief's feature extraction is in a transition process leading to present landscape shapes and explains the role of these shapes in current and evolving technology using digital data. This evolving technology is termed Geographical Information System (GIS), which is any manual, or computer based set of procedures used to store, manipulate, evaluate, analyze and model geographically referenced data.

Thus geospatial or terrain surface analysis plays a dominant role in determining the hydrological and environmental characteristics of a landscape. The DTM or DEM otherwise called Orthophotos are needed for very current, accurate and fast acquired technique for coverage 3-dimensional data which can be mapped in various scale for environmental planning, monitoring evaluation and resources management and even in energy supply and surveying purposes.

Statement of the Problem

The problem of planning in rugged and complex terrain is a global concern. Most environmental and/or geographical problems associated with rugged terrain surface are hydrological and geomorphometrical in character. The problems of rocky, complex and rugged terrain surface vary in character and dimensions and include land degradation, floods, gully erosion, loss of soil fertility, runoff problems, slope failure, range of altitude, drainage basin area, drainage density, drainage intensity, drainage frequency, geo-hazards, watershed delineation, stream segmentation.

In this article our interest falls within the domain of generating an orthophotorealism of a 3-D model of Obudu Cattle Ranch terrain in Cross River State of Nigeria using GIS software such as Arc view and surfer. However, modelling of geographical rugged terrain accurately is one of the most difficult problems in surface modelling which GIS can handle very effectively. That is why the technique is adopted to ensure accuracy in this research work. From the foregoing, this work proposes the following research questions:

1. Can a 3-D model be produced from the study area?
2. To what extent can statistical analysis be used in testing the relationship between geomorphometric variables?
3. Can certain properties of the drainage basin be defined in numerical terms?
4. Is there a possibility that by applying GIS technique; we can determine the susceptibility of the Obudu Cattle Ranch terrain to geo-hazards such as soil erosion, flooding etc ?
5. Of what importance will this research work contribute towards resolving societal problems?

6. Can GIS software be used to study the pattern of drainage network?

Aims and Objectives of the Study

The aim of this study is to generate a 3-D model of Obudu Cattle Ranch terrain in Cross River State, using the GIS software. The work seeks to explain and evaluate information about the terrain of the study area for good planning. The study seeks to do this in the following ways:

1. To generate a digital terrain model (DTM) of the study area for effective planning.
2. To derive the digital elevation model (DEM) using GIS software such as Arc view and surfer in the digital framework the planning of the study area.
3. The statistical analysis and comparison of different kinds of terrain possible for the study area.
4. To show the extent to which statistical analysis can be used in testing the relationship between geomorphometric variables.
5. To identify features on the terrain, such as drainage basins and watersheds, drainage networks and channels and other landforms.
6. Modelling hydrologic functions in terms of DTM.
7. To generate a digital terrain model (DTM) of the study area with a view to ascertaining the degree of steepness of the valley-side slope of order 1 – 4 streams in Obudu Cattle Ranch.

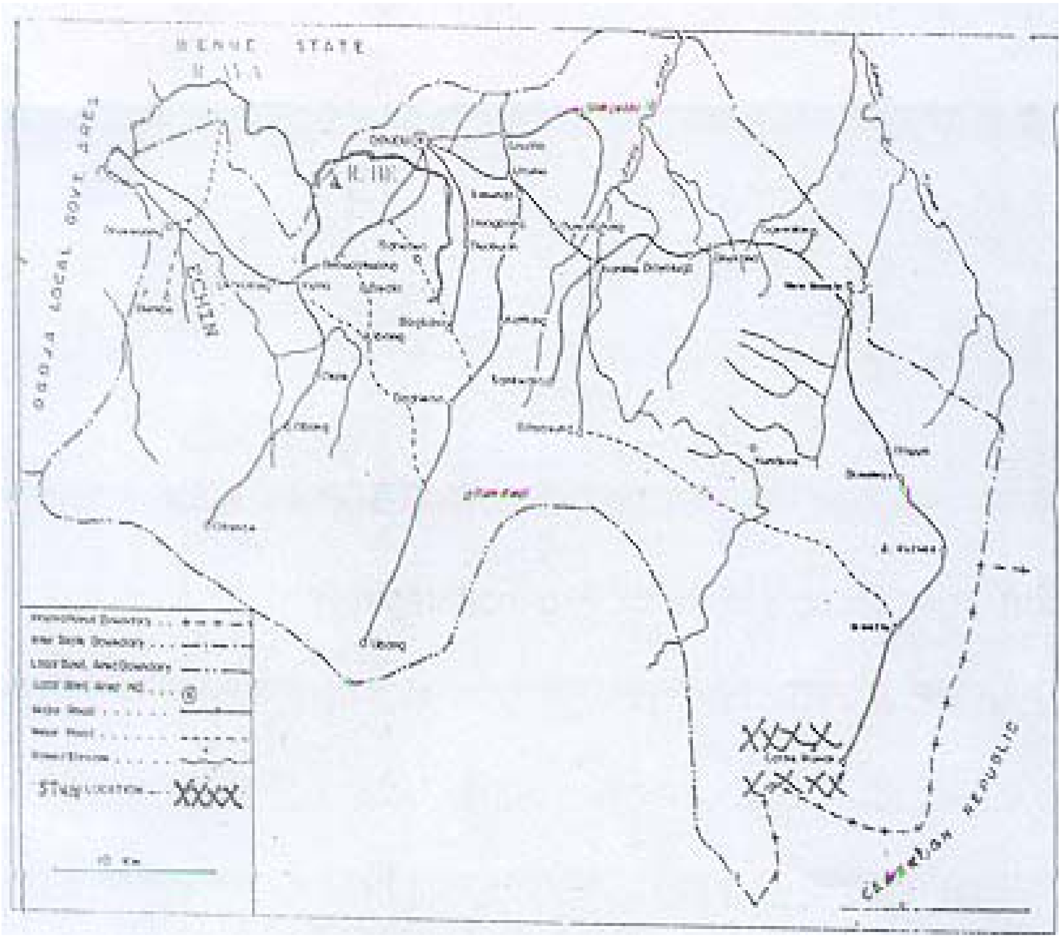
The Study Area

Location:

Obudu Local Government Area of Cross River State lies between latitude 6^0 33' to 6^0 44' 'N and longitude 9^0 0' to 9^0.12' E of the Greenwich Meridian. It is located on the western part of Obudu main town and bounded to the west by Umaji, Banyosung, Bayongor, Bassingo, Boghi, Bagga, Kureke, Bengeta, Sankwala, etc.

Climate; geology and vegetation

The Obudu Cattle Ranch generally is situated within the tropics and has a climate that is characterized by semi temperate in nature. The Obudu altitude slightly modifies a rarity in tropical Africa, makes it relatively cooler than most parts of the state. The mean annual temperature is about 14^0 to 28^0 centigrade (Mabogunje, 1983); while the mean annual rainfall is about 2000 – 3000mm (Diye and Ojo 1997). The dominant winds are the North-east trade winds, which bring dry stable air that causes harmattan during the dry season from November to March, and the South-west monsoon winds that bring warm unstable air from the coast from April to October.



The Obudu Cattle Ranch is a part of the basement Complex of Nigeria, and consists of a host suite of grade gneiss, pegmatite, dolerites, aplites and quartz veins cut this suite.

The vegetation pattern of the study area from the map shows that it is mainly Savannah. This is so because of the combined effort of bush burning and shifting cultivation, which has degraded the original or initial forest vegetation, making it a derived Savannah. In some areas, only isolated stands of a few trees remain as evidence of the original forest.

Methodology of Study:

A base map of the study area was used. A map is a two dimensional (2-D) scale of a part of the surface of the earth. This model is a systematic description or presentation of the part of the earth, generally using symbols to represent certain objects and phenomena. Maps are effective ways of representing a great deal of information about objects and the spatial relationship of objects. The representation of information and relationships and presenting them for visualization are areas where there is a great deal of overlap between a GIS and computer cartographic system (Fabiyi, 2001). In the same manner, Demers (2004) defines a map as the fundamental language of geography and environmental studies. It is therefore, the fundamental language of automated geography. This graphic form of spatial data abstraction is composed of different grid systems, projections, symbols libraries, methods of simplication and generalization and scales.

Thus, a base map is the major instrument for data collection in this work. The methods adopted are aimed at first converting existing or analogue paper topographical sheet or map of the study area into digital format, and then generating a DTM or DEM.

The base map is the toposheet of Obudu, in Cross River State of Nigeria, published by Federal Surveys, Nigeria in 1968. It is a fourth order basinal area and the detailed geomorphometric parameters are computed.

Data Collection Procedure

The study area is traced out from the base map on a tracing paper and the streams are ordered on the basin overlay (tracing paper) . After which the measurement of the geo morphologic attributes of the basin are carried out. These include the stream length, drainage basin area, drainage density, drainage intensity and stream frequency.

A topographical sheet (map) on a scale of 1:50,000 was used to extract information on relief. The sampling technique reflected progressive sampling principle in which the density of the sample points was adjusted to the complexity of the terrain surface. The base map was attached to an A4 12" x12" summa sketch digitizing tablet, Arc view and surfer, GIS software, were used for digitizing the topo map.

The digitizing tablet was calibrated to accept the transverse Mercator projection. The unit is in feet since the base map was produced in 1968 and the unit will not affect the accuracy of the results. The model was then traced with the stylus of the four-button mouse as appropriate. After digitizing and editing, the model was generated. The user-friendliness of the GIS software version endeared it for adoption and its facilities for the input, display and analysis of geographic data all these give it an added advantage.

Method of Data Analysis

The method used in generating a DTM of the study area is known as "Contour matrix height sampling". Its major advantage is that it is an effective and efficient means of producing digital terrain models.

Morphometry is defined as the measurement of shape. Morphometric studies in the field of hydrology were first initiated by R . E. Horton and Strahler in the 1940s and 1950s. The main purpose of this chapter is to quantitatively analyzed morpometric indices such as: Stream length, stream frequency (Fs), drainage density (Dd), drainage intensity (iD) and drainage basin areas as well as bifurcation ratio.

In this way, channel segments are ordered numerically using Horton's and Strahler's approaches. By this, the analysis of these indices would reveal some interesting relationships as we will see soon.

Drainage Network Analysis of Obudu Cattle Ranch

The study area is a fourth order basin and the aspect of drainage basin analysis of the rivers would be analyzed as follows:

Stream length

The stream length for various respective orders are measured using the topographical map of Obudu; in which the Obudu Cattle Ranch area was delineated from the base map. Also, a white thread and a 30cm ruler, a tracing paper, tracing pins, a mathematical set and a graph sheet as well as a scientific calculator are used to obtain the data for the result as shown below.

Table 1 Stream Lengths In Respective Order Of Category

S/n	1st Order (cm)	2nd Order (cm)	3rd Order (cm)	4th Order (cm)
1-20	∑ = 203.35cm			
1-30		∑ = 58.50cm		
1-22			∑ = 39.38cm	
1-17				∑ = 23.17cm

Source: Researchers' Fieldwork (2006)

∑ total stream length for orders 1-4 respectively
= (203.35cm + 58.50 +39.38cm + 23.17cm)
= 324.40cm

Now, to convert the actual distance of total stream length for orders 1-4 from cm to km.

$$= \frac{\text{Scale X Distance in Cm}}{100{,}000}$$

$$= \frac{50,000 \times 324.40}{100,000}$$

$$= 162.2km$$

Therefore, the total stream length is 162.2km. From the calculation, it implies that the discharge is high since the stream is up to 162.2km. This means that the basin area is highly mountainous.

Drainage Basin Area

Hence the area of the basin of the study area is analyzed and computed using tracing paper and graph sheet by the use of square method due to lack of equipment such as opisometers.

Thus after superimposing the traced out delineated basin on a graph sheet, the number of complete and incomplete squares are counted and recorded.

It follows therefore that:

(a) Scale of the map is 1:50,000

(b) The number of complete Squares = 376

(c) The number of incomplete Squares = 2144. In converting the incomplete squares to complete squares = 2144 ÷ 2 = 1072. So, total numbers of complete squares are = (376 + 1072) = 1448. Hence, the area of the basin is calculated based on the scale of the topo-map used:- Which is (1: 50,000). The areas of the drainage basin in Km becomes: ¼ X1448/1 = $\frac{1448}{4}$ = $362km^2$

In getting the individual area of stream order: = (120 + 30 + 21 + 16) = 187 / Area

Thus, basin area for 1st order stream, $= \frac{120}{187} \times \frac{362}{1} = 232.30km^2$

Basin area for 2nd order stream $= \frac{30}{187} \times \frac{362}{1} = 58.07Km^2$

Basin area for 3rd order stream $= \frac{21}{187} \times \frac{362}{1} = 40.65Km^2$

Basin area for 4th order stream $= \frac{16}{187} \times \frac{362}{1} = 30.97Km^2$

Total area (232.30+58.07+40.65+30.97) = $361.99km^2$

Total area = $361.99Km^2 \cong 362km^2$.

Hence, the total area of the drainage basin remains $362km^2$. Approximately.

Drainage density

This is the ratio between the total length of the streams in a drainage basin and the area drained by them. It can be expressed numerically as:

$$Dd = \frac{\sum \text{Stream Length}}{\text{Basin area}}$$

Where Stream length = 162.20Km

Basin area = $361.99km^2$

$$Dd = \frac{162.20km}{361.99km^2} = 0.45Km/km^2$$

The drainage density of the above can be expressed numerically such as (162.20:362.99) km/km^2, where 361.99 refers to the area of the drainage basin and 162.20 refers to the length of streams in the area. Generally, (Adejuyigbe 1982) describes that slow flowing rivers are denoted by widely spaced contours or may be meandering, while fast flowing rivers have closely spaced contour lines or may not be meandering (i.e. its river courses are straight). Therefore, the drainage density in Obudu Cattle ranch could be described as slow flowing and its contours widely spaced. The contours map of the study area widely spaced and has low density and/or coarse density. This is convincingly true as it can be seen from calculations that:

(a) The drainage basin area is very large of the value $361.99Km^2$.
(b) The stream length is also large which is 162.20km and so it takes streams or rivers a long time to channel per unit area of drainage basin.
(c) Again, the 3 – D model generated from the study area also reveals that the terrain is rugged and complex; but with a relatively flat top surface. Therefore reduces drainage density of the area to $0.45km/km^2$.

Hence, the following characteristics can, for example be mentioned of the study area:

1. The prevalence of drowned valleys.
2. Directions of flows of streams particularly the major ones.
3. The presence of contorted deranged drainage
4. Relatively straight courses of streams in the hilly region.
5. Both High land and low land are well drained.

So, the drainage density is $0.45km/km^2$. And the low drainage densities of range 0.5 – 1.5 Km have been reported over the Nigeria basement complexes both in the rain forest and Savannah area which Obudu Cattle Ranch falls within the domain (Wigwe, 1966, Jeje,1970: Thorp,1970). Hence, it could be said that the low drainage density in the study area is thought to probably reflect the widespread occurrence of deep regolith with infiltration capacities low enough to absorb a large portion of precipitation (Thomas,1974). This makes through flow interflow, and base flow poor which constituted the major drainage and erosion problems. Thus, the study area is very prone or susceptible to flooding and soil erosion.

Stream frequency **(Fs)**

The stream frequency for the watershed is also calculated using the formula

$$Fs = \frac{\sum \text{ total number of streams}}{\text{Basin Area}}$$

Where, Fs = Stream frequency. ∑ total number of streams (1st to 4th) = 120 + 30+ 21+ 16

= 187Km. Now, Fs 724Km^2 - $\frac{187Km.}{362km^2}$ Fs = 0.52km

The empirical explanation and quantitative importance of this calculation is similar to that discussed for drainage density in (Faniran and Jeje 2002). Thus, it can be inferred from the above calculation that about 187 of streams occupy a basin area of 362km^2. Hence, the value of total number of streams per unit basin area is almost half. That is the value of drainage density and stream frequency are 0.40Km and 0.52Km. Since, stream frequency is one of the factors that control the speed of runoff and infiltration rate. It therefore implies from the calculation that there is poor speed of runoff as it is evident with the value of drainage density (0.45Km) and stream frequency. (0.52Km).

Drainage intensity

Mathematically speaking, it is computed as the product of drainage density (Dd) and stream frequency (fs). Thus, it is given as : ID = Dd X Fs = 0.45Km X 0.52Km. ID = 0.234Km. iD = ≅ 0.23Km This index of morphometric studies in the field of hydrology is used to refer to the combined textural effect of drainage density and stream frequency of the study area. It gives a more quantitative assessment of the extent to which the surface has been lowered by agents of denudation (Eze and Abua,2002). Hence, the value of the index calculated is 0.23Km . It is of a very low value. This implies that the combined textural effect of drainage density and stream frequency has had very little effect (of the index value of 0.23Km) on the extent of surface lowering. This convincingly agrees with the initial calculations that the drainage density of value 0.45Km is low and the stream frequency of value 0.23Km is also low; thus the combined textural effect of drainage intensity of value 0.23Km is very low. This means there is more or less no good drainage system in the surface lowering in the study area.

That means the drainage system in the study area is not intense and as such it does not have a very strong effect or felt very strongly. Hence, the study area is highly susceptible to gully erosion, flooding and denudation as well as possibly landslide.

Bifurcation ratio

The bifurcation ratio of the basin is calculated using the formula as thus:

Rb = N

N + 1

Where;

N = No of streams of one order. N + 1 = No of streams in the next higher order, thus the bifurcation ratio. (i) Between order 1 and 2 is given as No of streams in order 1 = 120. No of streams in order 2 = 30

$$Rb = \frac{120}{30 + 1} = \frac{120}{31} = 3.87$$

ii) Between order 2 and 3 is given as: No of streams of order 2 = 30
No of streams of order 3 = 21

$$Rb = \frac{30}{21 + 1} = \frac{30}{22} = 1.36$$

iii) Between order 3 and 4 is given as: No of streams f order 3 = 21
No of streams of order 4 = 16

$$Rb = \frac{21}{16+1} = \frac{21}{17} = 1.24$$

Table 2: Bifurcation Characteristics of the Fourth Order Basin

Order	Number	Bifurcation
1	120	
2	20	3.87
3	21	1.36
4	16	1.24

Source: Researchers' Fieldwork, (2006).

Table 3: Morphometric Variables Of Stream In The Basin

Order	**Number**	**Total Stream Length (Km)**	**Basin Area (Km^{2-})**	**Bifurcation Ration**
1	120	203.35	232.30	
2	30	58.50	58.07	3.87
3	21	39.38	40.65	1.36
4	16	23.17	30.97	1.24

Source: Authors' Fieldwork, (2006).

Discussion

From empirical findings, the result reveals that there are as much as 3.87 times first order stream segments than second order stream; there are also as much as 1.36 second order stream segments than third order stream and for every one fourth order stream there are 1.24 streams.

It is from these computations that the laws of stream numbers, length and area respectively coined by Horton (1945). The law of stream numbers states that stream number decreases as the order category of a basin increases. In other words, there are many more streams of order one category than there are for order two and there are many more order two streams than order three until the last order category which is unity (Eze and Abua,2002). That simply means that the law of number states that stream order is related to the number of stream by a simple geometric relationship. Also, the law of stream length states that the average length of streams in a drainage basin forms a geometric series while the law of area states that there is a linear exponential or geometrical relationship between stream order and drainage area.

To prove these laws, morphometric variables need to be tabulated and indicated as shown below. Now, the value in Table 4 can be graphed and plotted as show above.

Having plotted the graphs, they produced straight lines for the stream number, length and area respectively. Hence, for all river systems irrespective of the nature of the underlying rock, there exist a geometric relationship between the stream number and stream order, stream length and stream order as well as basin area and stream order. It can thus be inferred that Obudu Cattle ranch river systems have fulfilled Horton's laws of drainage composition. This answers critical research question number 2 and 3 of this work.

That is, Horton's law of drainage composition has been successfully proved and achieved and certain properties of the drainage such as bifurcation ratio, basin area, drainage density, drainage intensity and stream length and stream frequency have been defined in numerical terms.

The Digital Terrain Model (DTM)

The digital terrain model (DTM) of the study area has been generated using GIS techniques and methodologies. DTM was generated using the following steps:

(a) The topographical map was scanned into the computer system
(b) The map was geo referenced; i.e a process of allotting co-ordinates to the points.
(c) The values of X, Y and Z were picked in the GIS environment.
(d) The DEM / DTM was generated using arc view and surfer (Soft wares) which shows 3-D surface profile of the study area, the picture elevation (Pixel) values, row picture elevation (pixels) and column picture elevation (pixels) are all indicated

FIG. 1: GRAPH OF STREAM ORDER AGAINST STREAM NUMBER

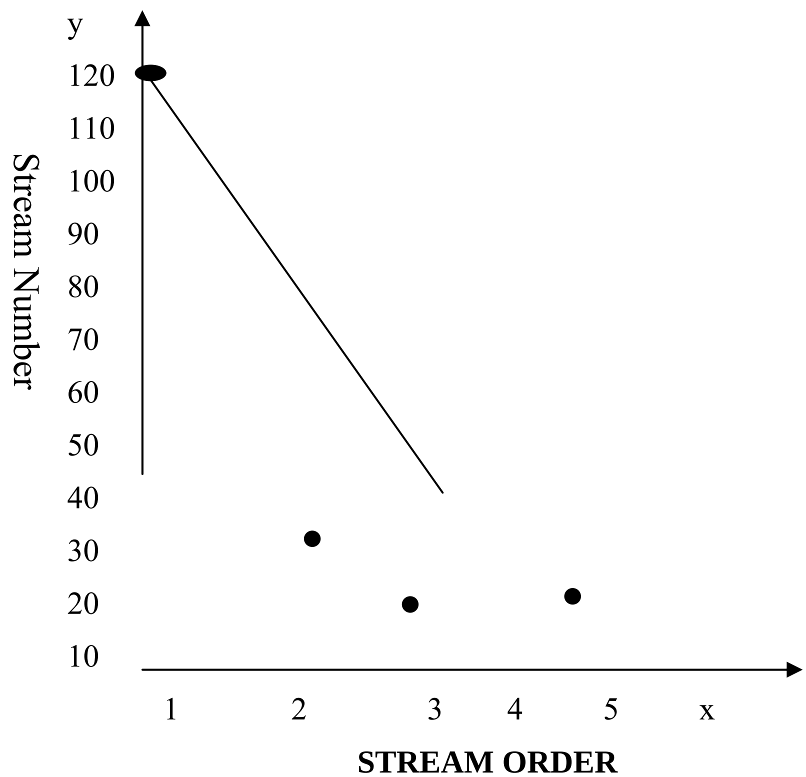
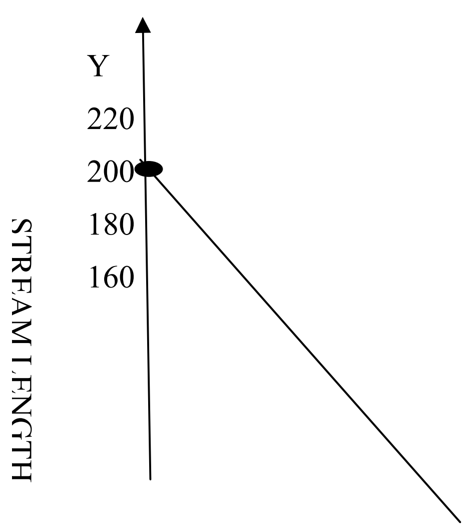


FIG. II GRAPH OF STREAM ORDER AGAINST STREAM LENGTH (KM)



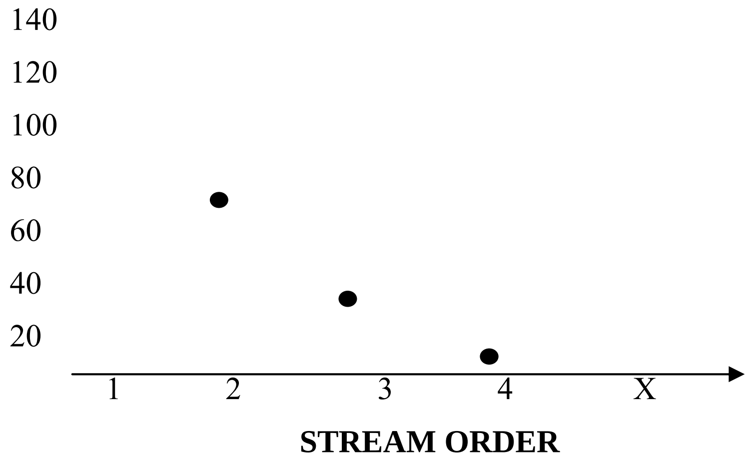
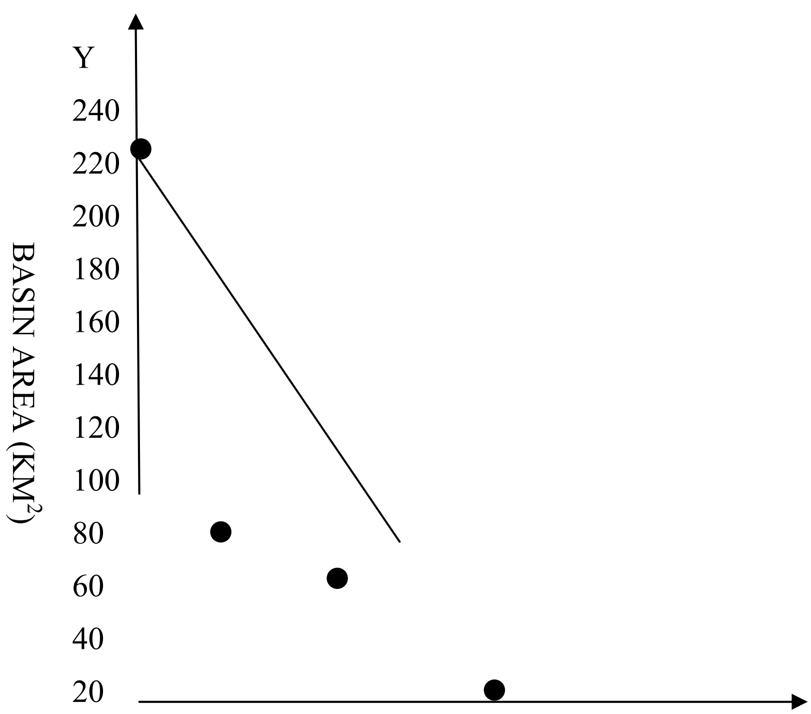


FIG. III GRAPH OF STREAM ORDER AGAINST BASIN AREA (KM^2)



1 2 3 4 X

STREAM ORDER

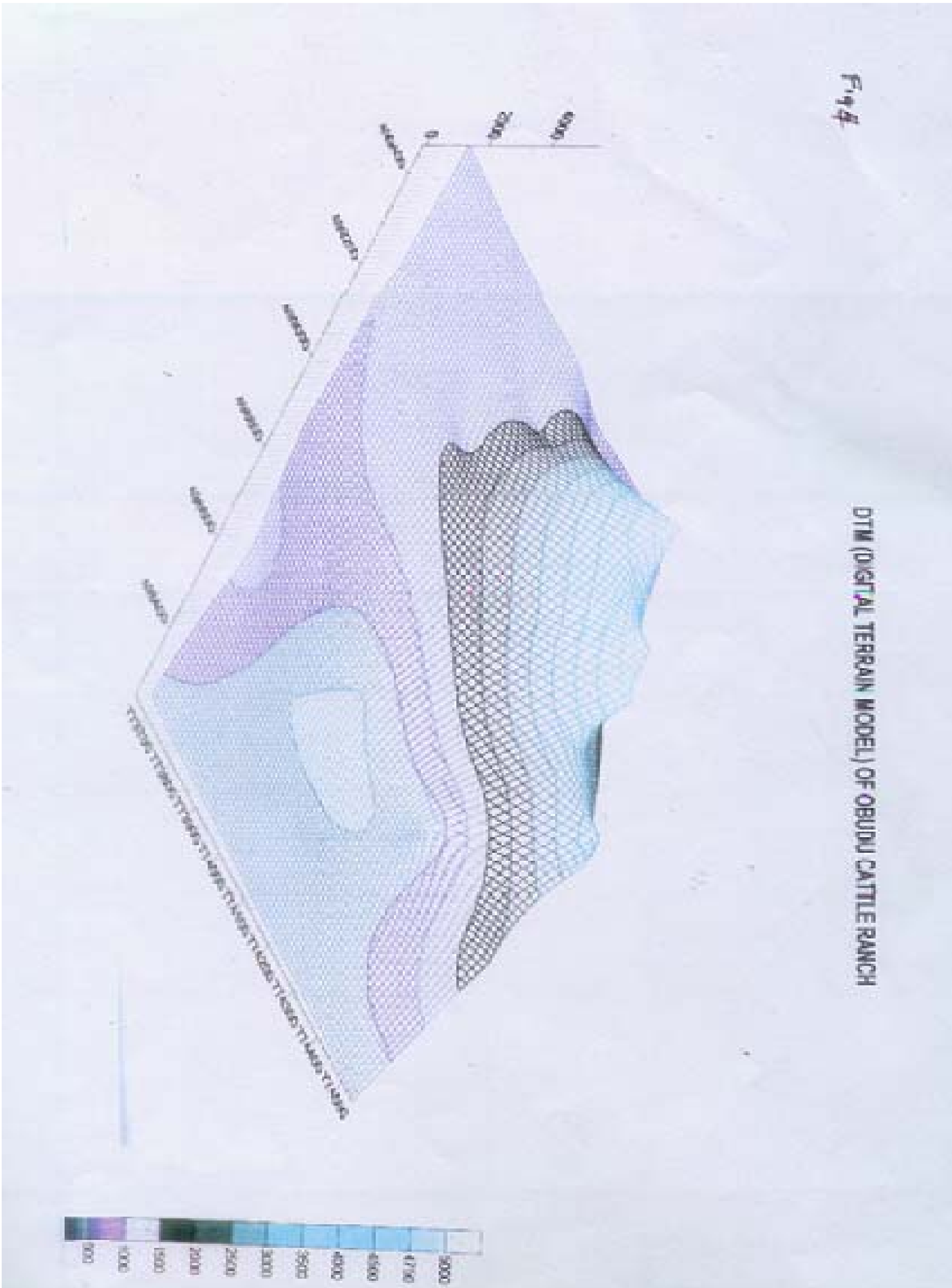
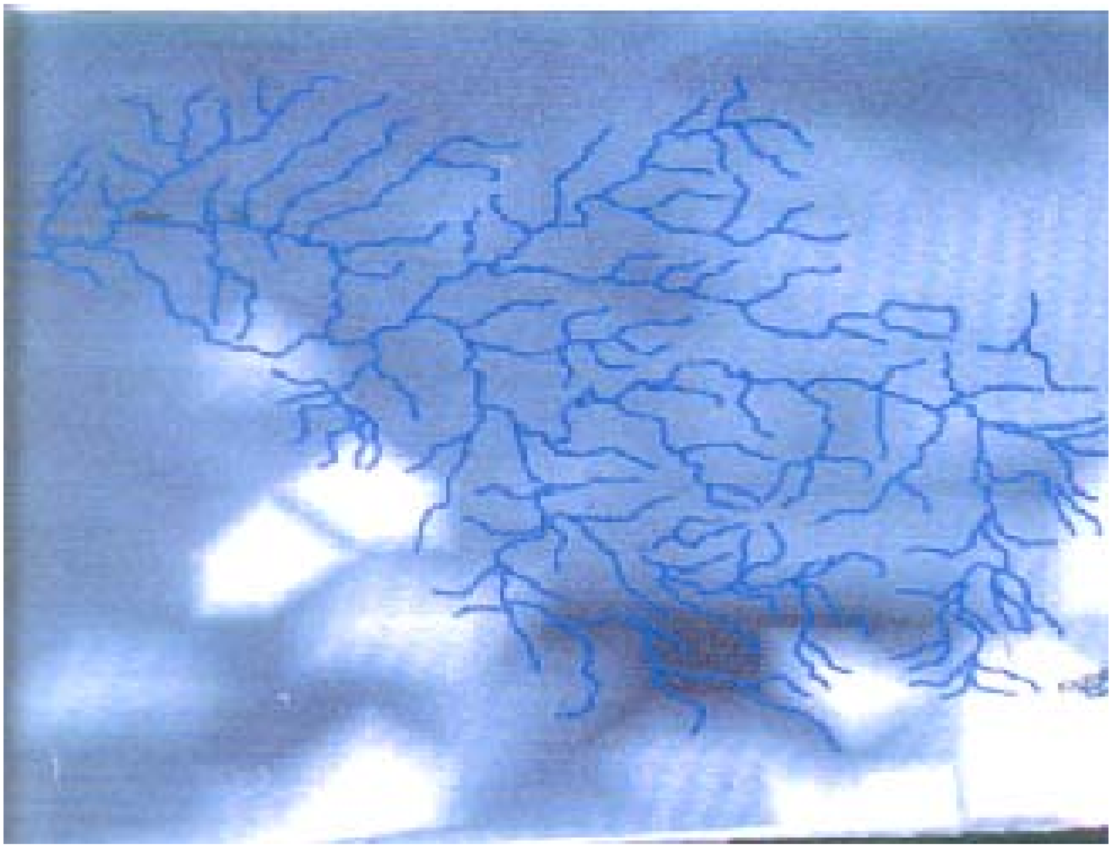


Fig 4
DTM (DIGITAL TERRAIN MODEL) OF OBUDU CATTLE RANCH

Fig. 5: Overlay of Stream Channels on the DTM



From inspection and comparison, one drainage pattern is radial due to the geologic structure of the pre-Cambrian basement complex of the study area. the drainage is beautifully highlighted in blue colours, while the areas of low lands are minimized to a shade of dark greenish-grey: which the peaks or highlands areas are also enumerated by the highlighted hexagonal blocks.

One of the aims of this research work was therefore to generate a digital terrain model (DTM) of the study area with a view to ascertaining the degree of steepness of the valley – side slope of order 1 – 4 streams.

From empirical researching, the researchers found out that the DTM so far generated can be construed and demonstrated the fact that valleys which generally run South-East in the study area are termed convex-rectilinear – concave. The overall shape of the valleys in the study area revealed that they are U-like (widen) and a very few are V- like (narrow). This is true. Hence, the study area is a plateau, at the top and a mountain from the bottom. It is therefore not a hill (see the DTM in Fig. 4).

The basin is underlain by basement complex, thus giving rise to a rugged terrain with various peaks. From the DEM, the highest elevation value is above 5000 depicting that the terrain of the study area is mountainous and complex. Meanwhile, the lowest elevation value is below 500 (See Fig. 4).

Overlay of Stream Channels on the DTM

The GIS techniques – overlay and buffer operations were employed to assess the nature of drainage system. This combines several data sets based on certain criteria. Therefore, the topo map of the study area of scale 1: 100,000 was overlaid superimposed over the 3- dimensional surface profile (DTM) as shown in Fig. 4

From Fig. 5: it shows that overlay operations with other attributes could be successfully achieved with GIS software such as arc view and surfer to reveal the pattern of drainage networks in the study area. This analysis also answers research question number 6; that can GIS software be used to study the pattern of drainage network?. It worth while to note that all the research questions asked have been answered.

Conclusion

This study focused on digital terrain modelling (DTM), in Obudu Cattle Ranch in Cross River State of Nigeria. The work also described morphometry. Studies of hydrological indices such as: (a) stream length, (b) basin area, (c) drainage density (d) stream frequency and (e) drainage intensity and (f) bifurcation ratio have been defined by numerical methods. Also, these morphometry indices have been quantitatively analyzed and the relationship among them have helped to forecast and explain drainage patterns, and geomorphic processes of weathering, erosion, mass wasting, flooding, deposition runoff, problem infiltration crises, sand filling operations, and eutrophication of streams. Relations between and/or among these indices in the study area have revealed some interesting facts which hold true for Horton's laws of drainage composition. Horton's law of stream length suggested that a geometric relationship existed between the numbers of stream segments in successive stream orders. This is agreeable with the mathematical relationship preformed in this work. Again, the law of basin areas indicated that the mean basin area of successive ordered streams formed a linear relationship when graphed. This relationship also holds true for this work. (Pidwirny, 2005)

The work provides an environmentalist, a hydrologist, a geomorphologist and geologist as well as other related earth sciences with a useful numerical measure of landscape dissection and runoff potential in the rugged and complex terrain. As observed and recommended by Gerard Kiely (1997), the scope of environmental problems that can be addressed by modelling is truly infinite. He also added that there are "off-the-shelf" models or package programmes for almost every conceivable task, be it physical or social phenomena. Therefore, it is true that modelling is central and pivotal to most other disciplines. This can be supported by what Demers (2000) remarked that GIS is now a mainstay for solving environmental and geographic problems not only for natural resources, but for a myriad of physical and human endeavours such as:

- Crime
- disease analysis and prevention
- emergency vehicle
- business
- industrial location analysis
- urban and regional planning
- scientific research
- spatial data exploration
- utilities inventory and management
- military simulations.

The potential applications of geographic information system are enormous and still growing: From this study we recommend that:

- The studies of GIS techniques and its applicability to societal problems should be pursued vigorously. Maps of various kinds and scales should be digitized to enable modellers carry out empirical findings with ease. While experts in the field should be employed in the Universities to promote automated geography.
- Staff and students should develop interest in researching GIS related areas and those with research interest in this field should be encouraged through scholarships and fellowships. This will

create awareness and renewed interest among researchers in the discipline. Z

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