GEOINFORMATION FOR EROSION MONITORING AND MAPPING USING MULTI-TEMPORAL AERIAL PHOTOGRAPHS, SIMPLE INSTRUMENTS, AND NUMERICAL DATA PROCESSING
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ABSTRACT

Automated high technology researches in Geoinformation are desirable and commendable; but to achieve "geoinformation for all" educational programmes should be designed to offer training in both the use of sophisticated automated systems as well as low level technologies (of the developing countries).

In Nigeria, financial constraints and lack of equipment have constituted major obstacles to meaningful studies and researches in photointerpretation, remote sensing, and indeed geoinformation application in general. Many of the existing instruments are either obsolete or have since fallen into disrepair. The computer and automated systems technology have been slow to take a firm hold in the country.

The present study sought to "make the best of a bad situation" through the use of available facilities and skillful improvisation. The method thereby developed has been used for monitoring and mapping of the Uyo ravine from multi-temporal aerial photographs dated 1969, 1978, and 1988. Geomorphological interpretation of the photograhs was done by visual image analysis using the mirror stereoscope. Measurement of photo-coordinates of the relevant points was performed using an improvised micro-rule. The photo-coordinates were then transformed to the corresponding ground coordinates of these points by a two-dimensional (2D) conformal coordinate transformation. The area covered by the ravine for each year and the rates of erosion were accordingly computed using the transformed coordinates. All computations were performed with a pocket calculator. The rates compare favourably with those obtained by previous workers who used ground survey methods. This method could facilitate better planning of sustainable land management in erosion prone areas.

RÉSUMÉ

De grandes recherches en technologies automatiseés dans le domaine de la géoinformation sont desirables et louables ; mais pour accomplirla « géoinformation pour tous » on doit preparer des programmes éducatifs gin offent une formation dans l'utilisation des systemes automatisés sophistiqués ainsi que dans les technologies á bas niveau (des pays en voie de developpement).

Au Nigeria, les contraintes financíeres et le manque d equipements constituent des obstacles majeurs a' des études et recherches significatives dans le domaine de la photointerprétation, du sondage eloigné et vraiment de l' application de la géoinformation en général. Beaucoup d' équipements qui existent sont soit obsolétes soit qu' ils sont tombés en nuine. La technologie des systemes informatisés et automatisés n'a pas encore pris de l' envol dans le pays.

La présente étude a servi « de gagner le meilleur dune mauvaise situation » par l' utilisation des aménagements disponibles et de l'improvisation habile, La méthode ainsi développée a servi au monitoring de l' érosion et a' la cartograhic de la ravine d' Uyo a' partir des photos aériennes multi-temporelles dateés de 1969, 1978 et 1988. On a réalisé une interprétation géomorphologique des photos par une analyse visuelle des images en utilisant le miroir stereoscope.

On a su mener á bien le mesurage des coordonnées des photos de tous les points d' intéret en utilisant une micro rule improvisée. On a alors transformé les coordonnées des photos aux coordonnées du sol conerpondantes de ces points par une transformation de coordonnée conformelle bi-dimensionnelle. En utilisant les coordonnées oinsi transforméesées on calcule la surface qui couvre la ravine pour chacune des annees et les níveaux d' érosion. Toutes les calculations ont été faites avec une calculatrice de poche. Les taux se comparent favorablement avec ceux obtenus par les précédents chercheurs qui ont usé des méthodes de metrage du sol. Cette methode pourrait faciliter une meilleure planification de la gestion soutenue de la terre dans des zones prédisposeés a' l' érosion.

1. INTRODUCTION

There is the general tendency of countless persons to associate the name "Geoinformation" with sophisticated automated methods of geodata acquisition, data capture, data analysis, and indeed the entire processes of geoinformation management. Geoinformation technology has changed so rapidly that it is difficult for developing countries to keep the pace; yet they need geoinformation for sustainable development planning. Automated high technology researches in Geoinformation are desirable and commendable, no doubt, but to achieve "geoinformation for all" educational programmes should be designed in such a way as to offer training in both the use of sophisticated automated systems as well as low level technologies (of the developing countries). This is the unique feature of the training programmes at the International Institute for Aerospace Surveys and Earth Science (ITC), the Netherlands.

In Nigeria, financial constraints and lack of equipment have constituted major obstacles to meaningful studies and researches in Aerial Photo-interpretation, Remote Sensing and indeed geoinformation application in general. Many of the existing instruments are either obsolete or have since fallen into disrepair, without being replaced. The availability of imageries (or more appropriately the non-availability) further compounds the problem.

The present study sought to "make the best of a bad situation" and face up to these constraints through skillful improvization and use of available facilities. The method thereby developed was then used to contribute to the study of accelerated erosion that has ravaged this part of the world for the past three decades. It is interesting to note that accurate enough result was achieved even with the rudimentary facilities.

2. THE STUDY AREA

The study area is the portion of the "Uyo Ravine" to the north east of the former University of Cross River State (now University of Uyo), afflicted by gapping erosional gullies, otherwise known as ravines. The ravines deviate sharply from the general landscape of Uyo urban and pose immense environmental problems (Fig. 1).

Uyo itself is situated roughly on latitude $5^{\circ}03'$N and longitude $7^{\circ}55'$E, and is believed to have been first settled as a Military Camp in 1903 (Ituen, 1988, 2). Uyo became Provincial Headquarters in 1959; Divisional Headquarters in 1970, and Local Government Headquarters in 1976. In 1987 it was made a State Capital, on the creation of Akwa Ibom State by the Federal Government of Nigeria.

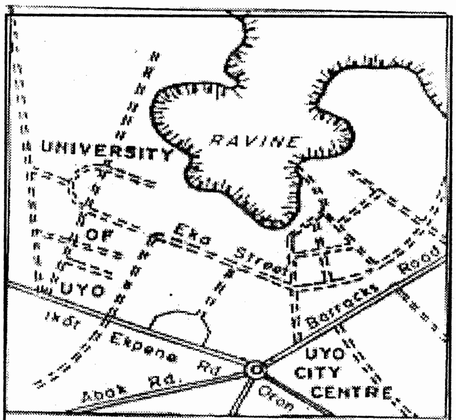

Figure 1. Location of Study Area

The area is generally less than 60m above mean sea level with the slope of the land surface seldom exceeding 5° - 10°, except in and around the ravines. Geologically the area is underlain by Coastal Plains Sands of late Tertiary Period. This geological formation consists of unconsolidated to semi-consolidated coarse to medium grained sands with gravels, and local concentrations of clay.

Uyo has a typical tropical type of climate with heavy rainfall, high temperatures, and high relative humidity almost all year round. There are two main seasons, namely: the Rainy or Wet Season from April to October, and the Dry or Hot Season from November to March. The heavy rainfall constitutes the dominant geomorphic agent responsible for the accelerated erosion in the area. Uyo is supposed to have tropical rainforest vegetation by virtue of its location; however most of the land is under cultivation or construction, thus removing the original forest cover.

3. EQUIPMENT AND MATERIALS

Very simple equipment and materials were involved in this study, and some have even been improvized. These include the mirror stereoscope, photogrammetric needle, lens magnifier and plastic ruler, aerial photographs and transparent overlay.

3.1 **Mirror Stereoscope**

The Mirror Stereoscope (fig. 2) is a device for viewing pairs of overlapping photographs so as to obtain a "three dimensional optical impression" (Stereomodel) of the photographed terrain and objects. The mirror stereoscope provided with binocular attachment forms the principal equipment in this study. The mirror stereoscope is a very familiar piece of equipment and will therefore need no further elaboration here.

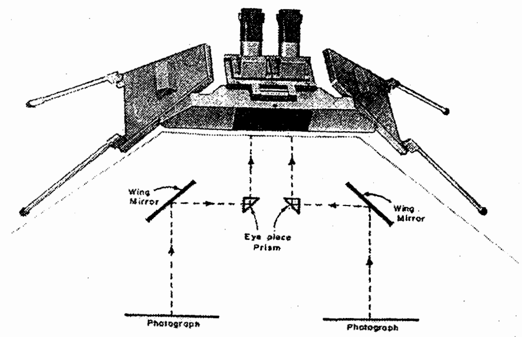

Figure 2. Mirror Stereoscope

3.2 **Photogrammetric Needle**

The photogrammetric needle is a simple device for marking fine points on paper prints of aerial photographs. It consists of a hard plastic stem roughly cylindrical in form and about 10cm long (Fig 3). The stem carries a sharp needle point at one end, and tapers at the other; the needle is replaceable.

This equipment is used in marking points by pricking through the paper prints with the sharp needle at the required locations. The fine needle point enables accurate measurement; however it is made more legible by circling around with colour grease pencil.

Figure 3. Photogrammetric Needle

3.3 **Lens Magnifier and Plastic Ruler**

A typical device for accurate measurement on aerial photographs is the micro-rule. However, in the absence of the micro-rule an improvized device has been fashioned out in the present study. This consists of a transparent plastic ruler about 30cm long, graduated in centimetres and millimetres, and provided with a lens magnifer (Fig 4). With this improvized device it is possible to obtain enhanced measurement of coordinates on aerial photographs, up to the fraction of the millimetre.

Figure 4 Lens Magnifier and Plastic Ruler

3.4 **Aerial Photographs**

Aerial photographs as the name implies are taken from airbone platforms, usually aircrafts. In aerial photography the environment is imaged with radiation in the visible portion of the electromagnetic spectrum within the 0.4-0.7 micrometre wavelength range. The resulting imagery is a perspective (central) projection of the terrian and objects. For the presen study, wide angle, black and white (panchromatic) aerial photographs of standard format (23 x 23cm) covering the study area were used. Three different sets of photographs, taken in 1969, 1978, and 1988, were involved.

3.5 **Overlay Material**

Overlay material is used on the photograph to enable annotations to be made during interpretation, thereby protecting th surface of the photograph. There are different types of overlay materials; kodatrace paper is the one commonly used, bu acetate paper is better and more transparent, and of course more expensive. Where these are not available tracing pape could be used as overlay though with difficulty. For the present study tracing paper was used as overlay.

4. PRACTICAL PROCEDURE

Erosion mapping necessarily involves a number of interrelated operations, the overall aim of which is to identify, investigate, and present information on erosion within a given portion of the earth's surface. The procedure in erosion mappin may be rather complex, depending on the method used, but invariably includes the following operations among others.

The erosional features and landforms must be identified, defined and/or delimited on the terrain. The geodynamic processes involved must be investigated and the impact of each assessed. The delimited erosional features and landforms must then be described, measured, and presented in the appropriate format, which necessarily always includes maps.

The resulting maps can be geomorphological maps, geomorphometric maps, or even specialized engineering geological maps depending on the purpose and scope of the mapping; or they may simply be called "Erosion Maps". Erosion mapping and monitoring have generally been done by ground survey methods; however a method based on the use of multi-temporal aerial photographs and numerical data processing is hereby proposed. The practical procedure includes geomorphological interpretation of the sets of aerial photographs, the measurement of coordinates, and appropriate processing of the data so obtained.

4.1 Geomorphological Interpretation

The purpose of the geomorphological interpretation is to identify and delineate the outline and form of the portion of the ravine under study, as well as associated geomorphological features. It also includes the description and codification of the features.

The geomorphological interpretation was performed by visual image analysis using the Mirror Stereoscope, and with transparent overlays placed on the photographs for annotations. For each date three consecutive photographs covering the ravine area were selected. The principal point and conjugates on each photographs, and the observed features were marked on the transparent overlay and subsequently compiled for each of the years 1969, 1978 and 1988 (Figs. 6, 7, 8)

4.2. Measurement of Coordinates

The outline of the ravine obtained by geomorphological interpretation is highly irregular. To this irregular outline the best fitting polygonal shape was constructed. In effect the irregular outline of the ravine was converted into a series of intersecting straight lines and the coordinates of the points of intersection then measured in the photo-coordinate system.

To establish the photo-coordiante system the principal point and conjugates marked on each photograph and transferred onto the transparent overlay were used. For each set of photographs the line joining the principal point and conjugate on the first photograph of the strip defined the flight line, and this was adopted as the x-coordinate axis. Another line through the same principal point and perpendicular to the flight line defined the y-coordiante axis. These two perpendicular lines, with the principal point of the first photograph as origin, constitute the coordinate system for measurement on the photographs. Thus for the 1969 set of photographs the principal point numbered 172 was the origin and the coordinate axes as indicated (Fig. 6).

All points marking the outline of the ravine were then measured in the above coordinate system. Also measured were three control points A, B, and C with known ground coordinates. These control points were used to compute the parameters necessary to transform the coordinates of all other points measured on the photograph to the ground coordinate system. The coordinates were measured directly to half a millimeter, and by estimation to a quarter of the millimetre using the transparent plastic ruler with lens magnifier, this serving as an improvized micro-rule.

5. DATA PROCESSING

Data processing necessarily involves performing a set or series of mathematical operations on data so as to obtain the required information. In the present study, data processing includes transformation of coordiantes, computation of areas, and computation of the rates of erosion.

5.1 Transformation of Coordinates

The coordinates of all points of interest measured in the photocoordinate system must be transformed to the corresponding ground coordinates of these points in order to give them geodetic significance, and relate the points to their correct positions on the terrain. This was done by two dimensional conformal coordinate transformation . The advantage of the two dimensional conformal coordinate transformation is that true shapes, are preserved after transformation (Efiong-Fuller, 1979, 16) and the mathematics involved simple enough to be performed with a pocket calculator.

The transformation involves scale change, rotation, and translation. The mathematical details of the transformation, including the derivation of the transformation equations, are outside the scope of this presentation. Nevertheless the transformation equation is given below (equation 1) and this was used to compute the ground coordinates of each point from its measured photocoordinates.

$$E = ax - by + T_E \quad (1a)$$
$$N = ay + bx + T_N \quad (1b)$$

Where

E	=	Eastings Coordinate of point in the ground system
N	=	Northings Coordinate of point in the ground system
x	=	X - Coordinate of point measured on the photograph
y	=	Y - Coordinate of point measured on the photograph
a, b, T_E, T_N	=	Transformation parameters

For the two dimensional comformal coordinate transformation a minimum of two control points are required; but where more than two control points exist (as in the present case) then a "least squares" solution could be obtained, yielding more accurate values of the transformation parameters as well as offer a check on observational errors. First the transformation parameters were computed using the known ground coordinates and measured photocoordinates of the control points. The transformation parameters were then used to compute the ground coordinates (E, N) of all other points defining the outline of the ravine, from their measured photocoordinates (x, y).

5.2 Computation of Areal Extent of the Ravine

After the transformation, ground coordinates were obtained for all points defining the outline of the ravine. The ground area covered by the ravine for each of the years was accordingly computed from these coordinates using the following formulae (equation 2). The computations could be performed and the same result obtained using the procedure shown in table 5.

$$E_1N_2 + E_2N_3 + E_3N_4 \ldots E_{n-1}N_n + E_nN_1 = C_1 \quad (2a)$$
$$N_1E_2 + N_2E_3 + N_3E_4 \ldots N_{n-1}E_n + N_nE_1 = C_2 \quad (2b)$$
$$\tfrac{1}{2}(C_1 - C_2) = A \quad (2c)$$

Where:

A	=	The required area
E	=	Easting Coordinate of points
N	=	Northing Coordinate of points

The area covered by the portion of the ravine under study in 1969 was 5.94 hectares; in 1978, 11.76 hectares; and in 1988, 17.03 hectares.

5.3 Computation of Rates of Erosion

By differential analysis the total land area encroached upon by the ravine, and the annual rate of encroachment between 1969 and 1988 could be obtained. Thus by simple subtraction it was deduced that a total land area of 5.82 hectares was lost to that portion of the ravine between 1969 and 1978; this gave an average rate of 0.582 hectares per annum. By differentiating the area with respect to the length the total distance encroached upon between 1969 and 1978 was obtained; and from this a linear rate of 26.80 metres per annum was computed.

The situation was slightly different with the 1988 computations; this is because one of the control points (Point B) had been removed by erosion and its location now formed part of the ravine. However a total area of 17.03 hectares was obtained for the ravine's extent. The net area of about 5.27 hectares was lost at an average rate of 0.480 hectares per annum, between 1978 and 1988. The linear rate for the same period was calculated as 20.87 metres per annum.

Point No.	E - Coordinate	N-Coordinate
1	E_1	N_1
2	E_2	N_2
3	E_3	N_3
4	E_4	N_4
n - 1	E_{n-1}	N_{n-1}
n	E_n	N_n
1	E_1	N_1

Table 5. Computation of Area Using Coordinates

Multiply along the dashed lines and find the sum; this is C_1. Then multiply along the full lines and find the sum; this is C_2. Required Area=A= ½ $(C_1 - C_2)$.

6. DISCUSSION AND CONCLUSION

The result of this study has shown that erosion mapping and monitoring could be performed using aerial photographs and very simple instruments; the areal extent and the rates of erosion could be determine quantitatively. Such quantitative parameters are important and useful in two main respects. Firstly, it is possible to predict future trends of the erosion activity using the computed rates, and necessary warning issued in advance. Secondly, remedial measures could be planned accurately and timely, thus avoiding the damage to property that would have been caused. This will also enable better and sustainable land management policies to be formulated.

Furthermore the result shows that the portion of the ravine to the north east of the University of Uyo has been encroaching at the rate of about 0.6 hectares or 26.80 metres per annum between 1969 and 1978; and at the rate of about 0.5 hectares or 20.87 metres per annum between 1978 and 1988. These rates compare favourably with previously obtained estimates for different parts of the ravine. For instance a rate of 32.90 metres per annum was obtained by Usoro (1977) using ground measurement. De Silva (1980) obtained rates of 23.45m and 30.04m for different parts of the ravine; he used a combination of aerial photographs and ground measurements.

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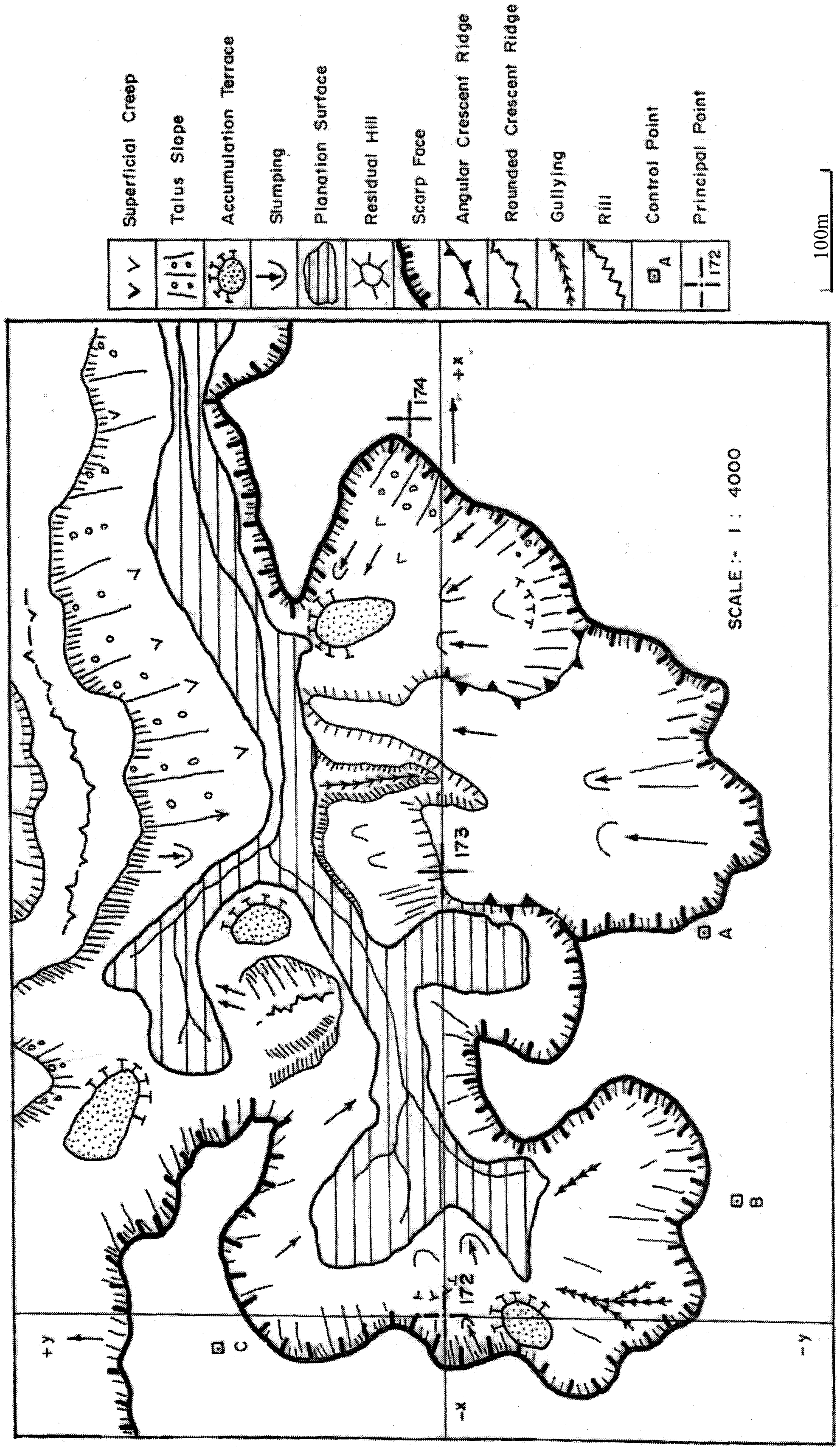
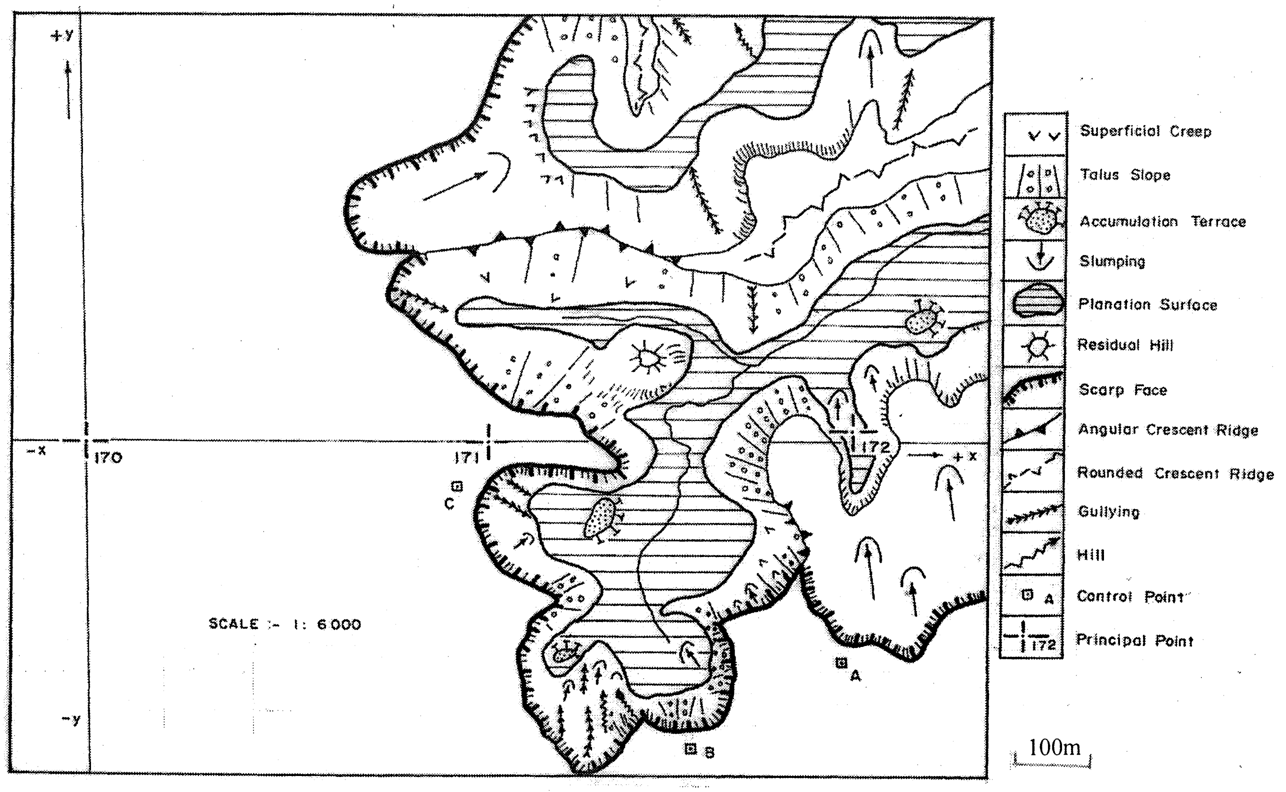


Figure 6. Geomorphological map of part of Uyo ravine for 1969

Figure 7. Geomorphological map of part of Uyo ravine for 1978



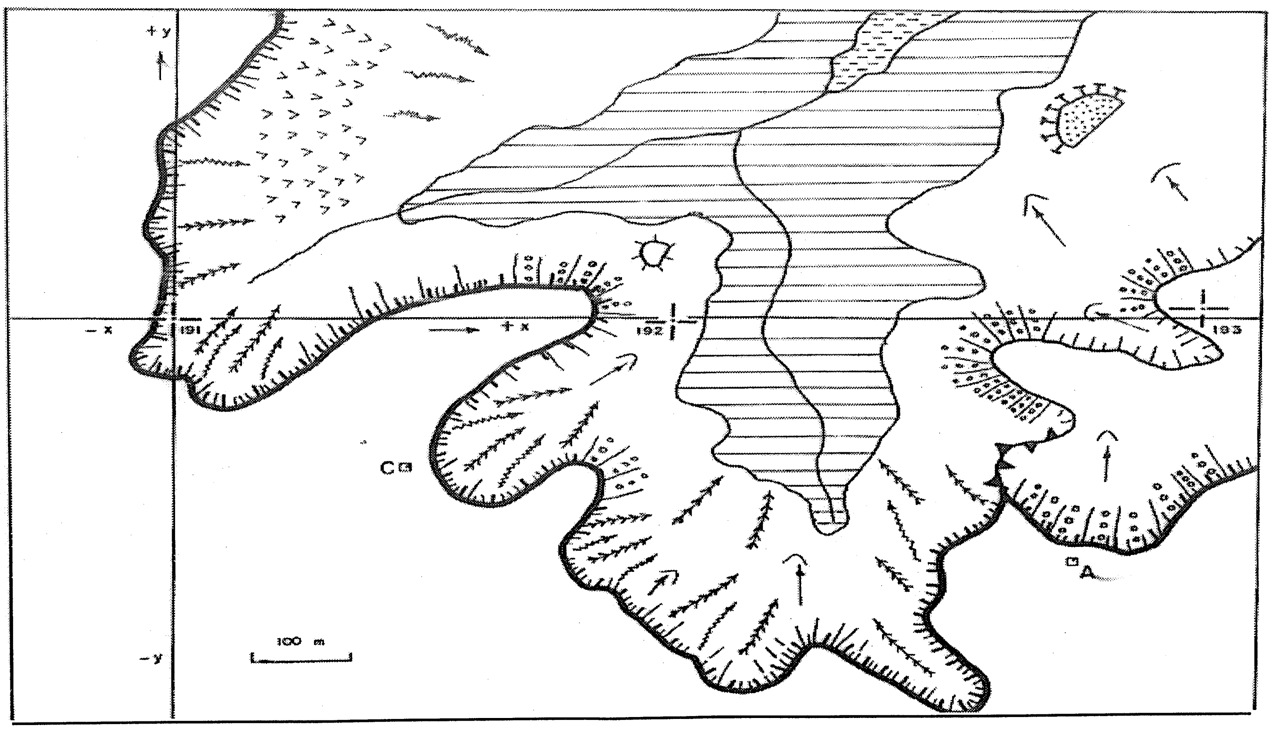


Figure 8. Geomorphological map of part of Uyo ravine for 1988