

LAND USE IN THE SARKIN PAWA AREA FROM AERIAL PHOTOGRAPHS

BY

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MAY, 1988

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A thesis submitted to the Postgraduate School,  
Ahmadu Bello University, Zaria, in partial  
fulfillment of the requirements for the degree  
of Master of Science in Surveying.

DEPARTMENT OF SURVEYING  
FACULTY OF ENGINEERING  
AHMADU BELLO UNIVERSITY  
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MAY, 1988

DECLARATION

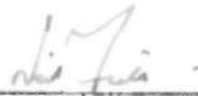
I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous publication for a higher degree.



PUEGEREN, JOHN VICTOR ERUAKPOR

Date 14 June 1988

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PROFESSOR NEIL J. FIELD  
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D E D I C A T I O N

TO

The Beginning and

The End

In Service to

Humanity

For today and

A Better tomorrow

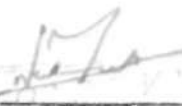
CERTIFICATION

This thesis entitled LAND USE IN THE SARKIN PAWA AREA  
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meets the regulation governing the award of the degree of  
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(MAY, 1988)

ABSTRACT

Aerial photographs at a nominal scale of 1:40,000 of Sarkin Pawa Area were acquired and interpreted to provide data on land use and land facets. Use was made of a general soil map and a geological map. Land use was sampled by dot grids from aerial photograph, and recorded on micro-computer files. Land facet data was acquired in a similar manner.

Interpretations from the geological formations included:

- (1) limitations to land use, and (2) resource opportunities for agricultural and environmental management. Analysis correlation between land use and slope.

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NOMENCLATURE

Unless otherwise stated, the following Codes will convey the following meanings indicated:

Land Use Categories

- 11 Settlements
- 12 Communication
- 21 Cultivated land (less than ten hectares)
- 23 Unenclosed farmland
- 31 Grassland
- 32 Scrub
- 33 Swamps and marshland
- 34 Woodland
- 41 Bare rock and inselbergs
- 51 Rivers and streams

Land Facet Categories

- 1 Rock outcrop and rocky hill (US)
- 2 Ironpan cap (US)
- 3 Interfluvial crest (US)
- 4 Valley-side slope (MS)
- 5 Valley-head (US)
- 6 Floodplain (L.S)
- 7 Terrace (M.S)
- 8 Ridge (U.S)
- 9 Narrow concave valley-bottom (M.S)
- 10 Wide concave valley-bottom (L.S)
- 11 Flat valley bottom (L.S)
- 12 Cliff (U.S)

Facets identified with U.S, M.S and L.S belong to the upland system, midland system and the lowland system respectively

Geology

- 1 Quartz monzonite and Adamallite
- 2 Schists, undifferentiated, including some gneiss
- 3 Quartz Diorite and Grano-diorite
- 4 Migmatite
- 5 Coarse Porphyritic biotite hornblende
- 6 Granite Gneiss
- 7 Pegmatite

## CHAPTER ONE

### INTRODUCTION AND LITERATURE REVIEW

#### 1.1 Introduction

Due to limited natural resources, increasing rates of population growth and subsequent pressure on land resources, shortage of food supplies, timber, energy, water, problems of deforestation and drought and the need for a comprehensive rural development, the rational use and conservation of land resources and the improvement of the management of agricultural lands, forests and environmental protection is indispensable.

Land resources monitoring in accordance with intrinsic land capabilities and limitations is a major tool of integrated resource management. Its application can reduce, if not avert, adverse environmental effects.

In this regard, reliable data are therefore required for land resources capability and long term planning in land use, forestry, grazing and agriculture for a sound land resource base (Whyte, 1976, Schneider, 1977).

The study carried out here was designed to test the the feasibility of a remote sensing approach to land use monitoring.

The rationale of the remote sensing approach was to investigate the application of its techniques as a method of monitoring land resources in the Sarkin Pawa Area. More specifically, the study involved the identification

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and interpretation of land use and land-cover, geology and slope from aerial photographs and maps.

Remote sensing, generally regarded as a data gathering tool, was chosen because of its capability to cover large areas, thus filling gaps between data stations (Savigear, 1977). Moreover, the bird's eye view afforded by such data gathering technique is a great advantage for land use analysis because it presents a holistic view of the spatial relationships between different land uses (Lo, 1976).

## 1.2 The Background of the Study

Due to the economic and social situations as well as the unique terrain configuration in the Sarkin Pawa Basin, particular land utilization practices have developed.

Sarkin Pawa Area is a vast region of considerable resources, most of which are irregularly distributed. In most parts of the area, the land resources are still imperfectly known and the prospects of raising living standards there will depend essentially on the search and development of land resources for the communities.

The most important economic activity in the area is agriculture which absorbs over 78% of the rural population (Tourism in Kaduna State, 1978). About 90% of the population is defined as rural i.e. they live in communities with less than 20,000 inhabitants, very scarce social facilities, poor communication routes, very low technological know-how and very minimal education (Development Plan, 1975).

This indicates that about 4/5 of the population can be said to derive its livelihood directly from agriculture and other primary activities.

Furthermore, the Sarkin Pawa Area is quite rugged in terrain with frequent outcrops of inselbergs. These lands have very steep slopes and few adequate farming areas. Erosion susceptibility is high. The problem of overgrazing, trampling, burning, over-cultivation and stripping of areas of their natural covers for fuel are widespread and are some of the contributory factors to drought and famine in the basin.

According to the Centre for Social and Economic Research Report (1977) 'the theory starts from the cause of population increase and harmful agricultural practices leading to environmental degradation, and then concentrates on the outward push that results. The key is that development in the preferential areas is intrinsically linked to factors and pressure on the land in remote areas'.

Thus, it is apparent from the above quotation that the pattern of land use continues to express itself in the vegetation and the physiognomy of the area.

Given these facts, it is not surprising that over 80% of the inhabitants depend on primary economic activities such as agriculture and livestock which are mostly self employing (Development Plan, 1975).

This is where the paradox lies: the soils are average to poor in quality while away from the hills and river

courses, most land tends to be poor grasslands with many wooded valleys and little perennial water for humans and cattle (Max Lock, 1967). Farming settlements are rare and confined to sites where communication and water coincides.

Moreover, the farming methods are traditional and average soils deteriorate rapidly hence long fallows and shifting systems are practiced (Norman et al, 1982).

The development of irrigation zones are impeded by certain limitations. These include: lack of adjacent farm lands adjacent to the rivers, difficult slope and poor soils (Max Lock, 1967).

But the paradox cannot only be looked at as a problem of potential and actual land utilization but as the consequences that proper land utilization practices have on rural dwellers. As mentioned earlier, over 80%<sup>1</sup> of Sarkin Pawa's population is rural and therefore dependent on primary activities - agriculture and livestock located in scrubland and savanna. These rural inhabitants use the scrub and woodland for firewood, construction materials, food sources and for its agriculture and livestock activities. All these uses and activities have marked signature on the land surface in the test site.

For these reasons, a rational and a reliable method for monitoring land resource is indispensable for the

---

<sup>1</sup> The 1962 Census showed that 88% of the population lived in rural areas i.e. settlements with less than 20,000 inhabitants.

zoning of land use potentials towards enhancing agricultural growth and development of the area. Hence, the resources that still require much further investigations with respect to land resources monitoring are described in this study.

### 1.3 Review of Existing Literature

Various techniques have been advocated and applied to the monitoring of land resources by proponents of land use Surveys. Proposals and arguments for such techniques have arisen out of the need to keep and maintain accurate information about land resources. Such proposals have usually been based on the premise that land use Surveys include any method used to register the different aspects of land use as they exist at the moment of survey (Vink, 1975, Lo, 1976). This is why Vink (1968) defined land use Surveys as part of the land classification that records the present use of the land.

The potentials of remote sensing techniques in the generation of land use data with respect to time, cost and areal coverage has been well documented (Kleckner, 1981). The relevance and the application of remote sensing to land use inventory is discussed by Anderson (1974, 1976, 1977), Loelkes (1982), Esin (1981) and Field and Collins (1986).

Anderson (1976, 1977) comments on the multi-level functional land use classification system developed for use with remote sensor data. He considers the uniqueness of remote sensing relative to other existing data sources

when he argued that the reliability and accuracy of data collected from other sources are often not determined. Even those whose accuracy has been determined are often collected to meet specific needs so that it is almost impossible to aggregate the available data because of differences in classification.

Loelkes (1982) presents a review of the land use and land cover data compilation programme of the United States Geological Surveys which was designed to provide a nationwide systematic and comprehensive land use and land cover maps and data for use by engineers, planners, resource managers etc. According to him, the classification scheme was designed in such a way that evaluation of relationships between graphical and statistical land use and land cover data and other resource data as soil, geology, slope and hydrology is possible.

In a similar context, Esin (1981) investigated the use of aerial photographs in the classification, analysis and mapping of urban environments in developing countries, using Oron (Nigeria) as a case study. His attention was directed towards the determination of accuracy, cost-effectiveness and timeliness of remote sensing technique for land use surveys.

Field and Collins (1986) used aerial photographs to monitor changes in land use in the Nigerian Savanna. In this study, they considered communication, population distribution and agricultural systems as they affect land

utilization practices. From this survey, they established some correlations between accessibility and changes in land use.

Christian and Stewart (1968) recognize land use surveys and assessment as not just a mere inventory and mapping of individual resources with a once - and - for - all determination of development possibilities but as a technique of providing a rapid and direct information through aerial photography of discrete areas of the land surface. They contend that in so far as different areas have different development possibilities, aspirations and problems, the primary objective of land use surveys is the subdivision of land parcels into smaller discrete areas as a means of use registration.

Four papers discussed the use of photo-interpretation for development projects. For example, Hare (1959) described the utilization of aerial photographs in the land use surveys of undeveloped areas in Canada.

Tuley (1972) attested to the use of aerial photographs by the Land Resources Development centre of the Overseas Development Administration of the United Kingdom to survey and map land uses in the former Northern Region of Nigeria.

Francis (1968) and Quinn (1968) in separate papers discussed the application of photo-interpretation to the Antalya Regional Development Project in Turkey, and the provision of natural resource inventory and in monitoring rehabilitation and reconstruction of areas damaged by

earth-quakes in 1960 in Chile respectively. A general conclusion in these studies is the correlation of photo-interpreted data with field checks to test for agreement.

Two papers discussed the relevance of aerial photographs for the provision of land resource information on site selection for engineering projects.

Wey (1981) discussed the basis of aerial photographs in selecting and evaluating sites for engineering projects with particular reference to the Industrial Complex of Indonesia. He confirmed that the lack of resource data pre-empted the use of remote sensing as a stop-gap measure in site reconnaissance, design and construction.

Wright et al (1974) compared various analysis techniques of photographic remotely sensed data as applied to land use classification and inventory relevant to power plant surveys. Similarly, Nedeco and Balfour Beatty and Company Limited (1968) used aerial photography in investigating the Niger Multi-Purpose Development Projects in Nigeria. According to them, preliminary studies based on sound photo-interpretation techniques provided the data for site evaluation and planning. The aerial survey was designed to provide detailed site maps not only for the main base of the engineering design but also for the detailed planning of the construction. The aerial survey was also designed to produce a land use classification scheme of the site in order to facilitate land evaluation as a basis for the payment of compensation to displaced inhabitants.

It is apparent from the aforementioned reviews that monitoring of land resources by a relatively precise remote sensing technique has for many years been considered a feasible alternative to the more costly and time consuming conventional survey methods (Fagerholm, 1968). However, two fundamental questions have to be answered before carrying out any land resources monitoring project.

The first is how the accuracy should be measured or expressed, and the second is how to link this accuracy to land use specifications. Answering these questions permits the monitoring of land resources in a bid towards establishing links and inter-relationships between land use and some of its physical components. Once established, it will then be possible for Surveyors, engineers, planners, resource managers and site developers to adequately map, design and manage land resources to attain optimum benefits.

#### 1.4 Research Objectives

This study considers a technique for monitoring land resources to produce spatially defined data that will be of inestimable benefits for land resources management in the Sarkin Pawa Area.

The specific objectives of this study are:

- (i) Using aerial photographs, develop a methodology for the qualitative monitoring of land use/land cover and slope.
- (ii) Evaluating the effect of slope on land use and land cover as a variable that is dependent on slope variable.

#### 1.5 Test Site Description

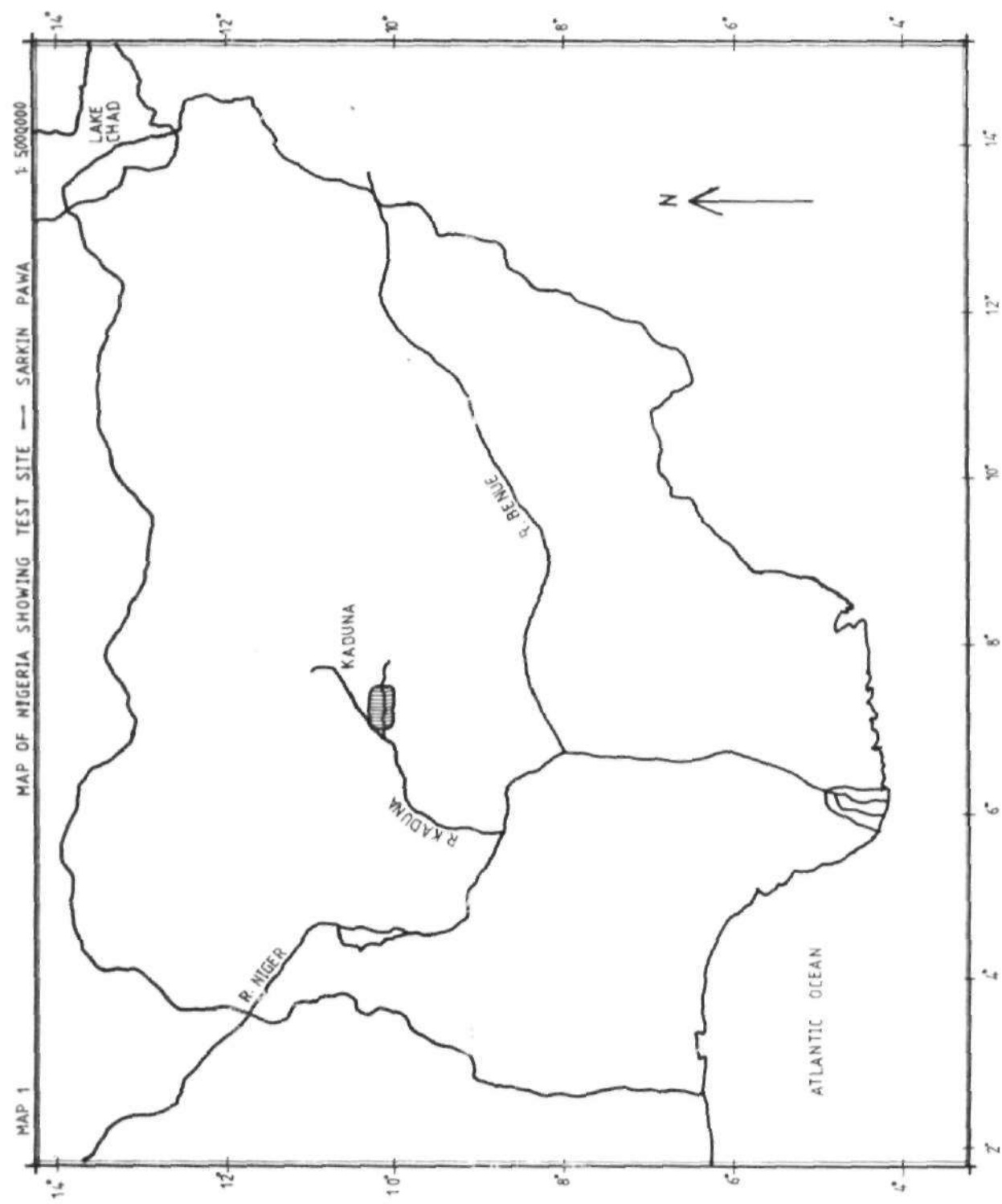
The test site area extends from longitude  $7^{\circ}00'E$  to  $7^{\circ}30'E$  and latitude  $10^{\circ}00'N$  to  $10^{\circ}11'$  as shown in map 1. The area is covered by the national map series of Nigeria 1:50,000 sheet Kakuri 144 S.W. and 144 S.E with an approximate area of about 1125 square kilometres. The shape of the test area is not a perfect rectangle, its boundaries have been 'smoothed' out according to the photo-coverage. The basin is situated South of Kaduna City.

The topography of the area comprise extensive tracts of undulating plains with dissected land of rocky hills and Inselbergs. The western and south eastern margins are more dissected than the eastern margin.

The drainage network is comprised predominantly of distributaries to the Niger via the Kaduna and Sarkin Pawa Rivers. The most extensive floodplains are however associated with the Sarkin Pawa River.

The entire area is underlain by a complex of igneous and metamorphic rocks to form a basement Complex. The basement Complex rocks are essentially granites, gneisses, migmatites, schists and quartzites. The quartzites commonly occur as linear ridges while the granites and gneisses occur as inselbergs.

Population density is low in the Basin while communication is poorly developed. Few settlements are found scattered over hilly terrain.



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The Sarkin Pawa Area is investigated for three reasons.

- (i) The basin, like several others in Nigeria, has no systematic land use information system.
- (ii) The land systems and facets give rise to several types of land use, the influence on which could be interesting to study.
- (iii) The test site is part of the catchment area of the Shiroro Dam Project of which its land use will be interesting to investigate.

#### 1.6 Significance and Limitations of Study

This study is a reconnaissance survey which is designed to provide systematic and comprehensive land use and land cover data for use by Surveyors, project engineers, site planners, resource managers and those who are concerned with integrated rural development. Essentially, this survey constitutes an important land resources assessment for agricultural projects (for example irrigated agriculture and dry farming), environmental impact assessment (for example deforestation and drought) and resource exploration, exploitation and conservation.

As it is a reconnaissance survey, it provides the framework for further detailed resources inventory. Furthermore, the establishment of correlation between land use and other resource factors enables a rapid delineation of resource region which can be used to delineate zones of land use potentials and capabilities.

However, ~~the~~ main limitations of this project are the obsolescence of the sets of photographs used for the interpretation and the scale of photography. Firstly, it was not possible to correlate or cross reference photo-interpreted data with field checks due to obsolete photographs. Secondly, the scale of photography (1:40,000) did not allow detailed information to be extracted from the aerial photographs so that only a two-level classification scheme was utilized in this study as proposed by Avery (1977).

CHAPTER TWO

RESEARCH PROCEDURE

2.1 Materials and Equipment

2.1.1 Material

Black and white panchromatic 9" x 9" (23 cm x 23 cm) aerial photographs were used for the investigation. This set of photographs which were flown in 1962 have a scale of 1:40,000. Topographic maps (1:50,000), geological maps (1:250,000) and soil maps (1:500,000) were also utilized for this study.

2.1.2 Equipment

A set of black and white panchromatic photographs flown in 1962 was examined stereoscopically with a folding mirror stereoscope. A binocular high magnification attachment provided an important accessory for identification and interpretation of stereo-models.

Information on land use and land cover, facets and geology was collected in digital format while data analysis was performed by a 48k Apple II micro-computer with a floppy disk storage and a dot matrix printer.

2.2 Definition of Concepts

For the purpose of avoiding ambiguous and application of vague terms, the following concepts have been defined as applicable to this study.

2.2.1 Land Resources

The concept of land resources has evolved over time. To some people, land embraces the atmosphere, the soil, geology

and hydrology and the plants and animals on the earth's surface, together with the result of human activities (Smyth 1971; White 1976, Stoner and Robertson, 1970). This ambiguous definition of land resources led to the conveyance of an Expert Consultation on Land Evaluation for Rural Purposes in Wageningen in 1972 by the Food and Agricultural Organization (FAO) for the main purpose of definition and clarification of land resources (Brinkman and Smith, 1973). According to the report of the Consultation, land is defined in terms of (i) land surface (climate, topography, vegetation cover etc) (ii) Soil profile, and (iii) Sub-surface drainage.

Christian and Stewart (1968) gave a classical definition of land resources in their paper 'Methodology of Integrated Surveys' to the UNESCO Conference on Aerial Surveys and Integrated Studies held in Toulouse in September, 1964. They stressed that the term land resource refers to the earth surface and all its characteristics and attributes of importance to man's existence. It is the integration of such components as climate, topography, soil, vegetation, hydrology etc.

They concluded that land must be considered as a whole vertical profile at a site on the earth's surface - from the aerial environment down to the underlying geological formations and including plants and animal population together with their inter-related activities. Apparently, these various concepts seem to consider land as a resource with

respect to its spatial and physical components and together with the inter-linkage in the man-land relationship.

For the purpose of this study, therefore, these definitions shall be considered significant since the physical components of slope and geology are used to provide the appropriate frame work for monitoring land resources in the Sarkin Pawa Area.

#### 2.2.2 Land Use and Land Cover

Land use has been variously viewed as the human activity on the land or the natural qualities of the land together with its land tenure (Lo, 1976). It is apparent from this brief definition of land use that its classification can be based on morphological, functional or on both characteristics.

The morphological classification is concerned with land cover rather than land use as evident by the use of such terms as arable land, grassland, woodland etc of the First Land Utilization Survey of Britain in 1930 (Becking, 1959).

The functional definition deals with the direct use of the land as shown by the use of terms as cultivated land, grazing land, communications, settlements etc. Under this definition, land use is defined as the use made of the land by man at the time of registration (Lo, 1976).

For the purpose of this study, both terms are used interchangeably for the following reasons:

- (i) there is no sharp distinction between land use and land cover since both are expressions of the same complexes of agricultural activity,
- (ii) both terms have strong ecological connections.

#### 2.2.3 Land System and Land Facet

Bawden (1970) defined a land system as an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation while the smallest unit is termed a facet. Thus, the land system is composed of an aggregate of land facets together with their interrelationships. Hence Hutcheon et al (1974) defined land facets as 'the smallest unit of description and is part of the landscape that has a uniform slope, shape, and position, and is often separated from the other land facets by a break in slope'.

The land system framework provides a common basis for sampling since the scheme provides a simple sampling unit for data collected for slope and geology. This makes the collation and correlation of land use data and other components of land resources possible.

Within the context of this study, therefore, a land system classification has been developed for the Sarkin Pawa Area in order to show not only the basic land types but also in which the land use classes has been cross referenced.

#### 2.3 Classification Scheme

Classification systems for description of land use have been the subject of extensive debate in recent times. This

has led to the view-point that no single land use classification scheme that will serve all users at all times can be established. Hence, Anderson (1974, 1976 and 1977) commented on the incompatible classification schemes adopted by users. He concluded that the accuracy of classification is often not determined and that even those whose accuracy has been determined are often collected to satisfy specific needs so that it is almost impossible to aggregate the available data because of differences in classification systems. This view is equally shared by Avery (1977) and Nunnally (1974). A general conclusion by both studies is that no single classification scheme can be used with all scale and types of imagery.

Rhind and Hudson (1980) enumerated certain conditions which a good classification scheme must satisfy. Firstly, a good classification scheme must comprise of a number of classes which are mutually exclusive, secondly, the classification scheme must cover all the categories of land use likely to be encountered in the site.

Field and Collins (1986) added other conditions for a good classification system. According to them, each class of land use should be capable of clear definition while the criteria used for the classification should be balanced. Moreover, the classification should be applicable over extensive areas and repeatable and repetitive results should be obtainable within the allowable degree of accuracy.

### 2.3.1 Land Use Classification Scheme

The World Land Use Survey Classification Scheme served as a preliminary aid for the study. But it was found to be a general classification scheme and therefore not appropriate for the Sarkin Pawa Area Project because of the difficulty of applying Classes 4, 5 and 6 to the extensive ill-defined boundaries of the savanna farmlands.

Table 1: World Land Use Survey Classification Scheme

1. Settlements and associated non-agricultural lands
2. Horticulture
3. Trees and other perenial
4. Cropland
  - (i) Continual and rotational cropping
  - (ii) Land rotation
5. Improved permanent pasture (managed or enclosed)
6. Unimproved grazing land
  - (i) Used
  - (ii) Unused
7. Woodlands
  - (i) Dense
  - (ii) Open
  - (iii) Scrub
  - (iv) Swamp forests
  - (v) Cut-over or burnt over forest areas
  - (vi) Forests with subsidiary cultivation
8. Swamps and marshes
9. Unproductive land  
(after Field and Collins, 1986)

As a result of the inappropriateness of the World Land Use Survey Classification Scheme, the one developed by Field and Collins (1986) was adopted for this study as shown in table 2 below.

Table 2: Field's Land Use Survey Classification Scheme

| <u>Code</u> | <u>Level I</u>                      | <u>Level II</u>                                                                             |
|-------------|-------------------------------------|---------------------------------------------------------------------------------------------|
| 10          | Settlements and associated features | *11 Settlements<br>*12 Communication<br>13 Industry                                         |
| 20          | Cultivated land                     | *21 Enclosed farm-land (enclosures 10 ha)<br>*23 Unenclosed farm-land<br>23 Tree plantation |
| 30          | Uncultivated land                   | *31 Grassland<br>*32 Scrub and small trees<br>*33 Swamps and marshes<br>*34 Woodland        |
| 40          | Wasteland                           | *41 Inselbergs and bare rock                                                                |
| 50          | Water                               | *51 Rivers and streams                                                                      |

adopted (after Field and Collins, 1986)

Given the background of the test site, only ten level II Classes were interpreted as astericked in table 2. Field's land use classification scheme was adopted for the following reasons;

- (i) It was particularly developed for tropical regions
- (ii) It contained classes which are applicable to the test site
- (iii) The classification scheme has successfully been applied in the neighbouring Kajuru area.

#### 2.3.2 Land Systems Classifications Scheme

This Classification Scheme makes use of the landscape technique as proposed by the Commonwealth Scientific Industrial and Research Organization (CSIRO) while the basic land unit of classification is the land facet (Webster and Beckett, 1970).

The Land System Classification Scheme developed by Bawden (1970) was found to be inappropriate and was therefore modified to suit the test site. In this regard, the test region was divided into three land systems on the basis of slope and elevation. The three land systems are shown in map 2 and are briefly described below.

| <u>SYSTEM</u>        | <u>SLOPE</u>                |
|----------------------|-----------------------------|
| (i) Upland System    | Greater than $20^{\circ}$   |
| (ii) Midland System  | $10^{\circ}$ - $20^{\circ}$ |
| (iii) Lowland System | less than $10^{\circ}$      |

These Systems are composed of the following land facets.

| <u>Code</u> | <u>Facet Names</u>           | <u>Symbol</u> |
|-------------|------------------------------|---------------|
| 1           | Rock out crop and Rocky hill | r             |
| 2           | Iron pan cap                 | I             |
| 3           | Interfluve Crest             | C             |
| 4           | Valley-side slope            | S             |
| 5           | Valley-head                  | H             |
| 6           | Floodplain                   | F             |
| 7           | Terrace                      | T             |
| 8           | Ridge                        | R             |
| 9           | Narrow concave valley bottom | Bvn           |
| 10          | Wide concave valley bottom   | Bvw           |
| 11          | Flat valley bottom           | Bf            |
| 12          | Cliff                        | C             |

It must however, be emphasized that facets that occur in different land systems are not one and the same. Angle of slope, shape, soils and land use may be different.

CHAPTER THREE

DATA ACQUISITION AND PROCESSING

3.1 Data Acquisition

The scope of the study require that a relatively quick and inexpensive methodology be used to correlate land use with slope and geology. For this reason, a stepwise data acquisition procedure was initiated by integrating the geologic, topographic, soil and land use data from medium scale black and white aerial photographs and maps.

In this regard four major constraints were considered in selecting data sources and processing techniques. The constraints were:-

- (i) data availability
- (ii) computer capability
- (iii) ease of data registration after digitization
- (iv) the desired statistical analysis

A set of black and white aerial photographs of medium scale (1:40,000) was used for the study. A topographical map (1:50,000) was also acquired and used as the base map for the project. Geological maps (1:250,000) which served as the main base for the geological data frame were procured from the Geological Surveys in Kaduna and subsequently enlarged to conform to the scale of the base map. The soil unit map (1:500,000) was also procured from the Soil Survey Unit of the Department of Soil Science, Ahmadu Bello University, Zaria, and also subsequently enlarged to make it compatible with the base map.

### 3.2 Sampling Procedure

Observations and measurements were made using dot grids in a systematic manner. Compared with random point sampling, systematic point sampling have the obvious practical advantage of being easier to field check and also easier to use for later analysis. Moreover, systematic point samples have an added advantage of covering the area regularly and serving as data matrices.

Furthermore, dot grids rather than areal sampling was used for the data acquisition for this study for the following reasons:-

- (i) With dot sampling, individual parcel delineation and areal measurements are unnecessary.
- (ii) Simple data sheets are used to record land use information.
- (iii) Any specified level of accuracy may be achieved by adjusting the sample size.
- (iv) Land use change is measured simply by collecting data for the same set of points.
- (v) Data sheet is in a form readily available for computer storage, retrieval, processing and display (after Emott, 1981).

However, the size of the dot-grid was a function of the average stereo-model so that the dots were arranged in relation to the scale of the photographs. In this circumstance, each dot fell in the centre of an area of 4.50 hectares. This unit of area was chosen based on the application of two separate formulae as developed by Bolnor (1975) (a) and Brunt (1966) (b) which estimate the error at 95%

confidence level of a particular sample according to its coverage and dot density.

$$(a) \quad E\% = \frac{153.1}{(AD)^{0.58}} \quad \dots \quad \dots \quad \dots \quad \dots \quad \text{Bornnor (1975)}$$

$$(b) \quad E\% = K \left( \frac{100 - P}{NP} \right)^{\frac{1}{2}} \quad \dots \quad \dots \quad \dots \quad \text{Brunt (1966)}$$

$E\%$  =  $\frac{1}{2}$  the percentage error of a class in a sample at 95% confidence level

$P$  = Percentage area of the class

$N$  = Total number dots

$A$  = Area (in square kilometres) of the class

$D$  = Dot density per square kilometres

$K$  = 196 (a constant based on student's  $T$  taken at 95% level of probability)

Based on these formulae, a pre-sample data analysis was carried out as shown in Appendix 1. It was therefore, decided to use a primary sample of 39 quadrats, one for each of the stereo-models, and a secondary sample of 336 dots to give a total of 13,104 sample points. Using 4.50 hectares as the basic unit, this gave a sample of about 589.68 square kilometres representing 52% of the total area.

It must, however, be stressed that the total number of samples checked (sampling intensity) was based on the amount of time, available resources and the desired level of statistical precision.

### 3.3 Preparation and Measuring Technique

Dot grids (24 x 14) were drawn on transparent acetate paper at 6 mm intervals with each dot representing 4.50 hectares. Altogether about 58,968 hectares out of 1,125,000 hectares have been sampled.

Due to differences in the scale of the photograph (1:40,000) and that of the base map (1:50,000), the base map was enlarged at a ratio of 4:5 to render the interpretation of land use and land facet data compatible with that of the base map.

For the interpretation of land use and land facets from aerial photographs, the dot was placed in such a way on a stereo-model so that only the overlap areas are covered by the dot grids. This is made possible in such a way that data interpretation of the same point is not duplicated.

The land use or land facet that lay directly below the dot were coded in the data sheet. Data were interpreted and recorded column-wise so as to facilitate easy registration, storage, retrieval and analysis by the computer. In the case of geologic data, the same measurement technique was applied with the only difference being that instead of a pair of photographs being the data source, the geologic map is the main source of data.

#### 3.4 Data Processing

Land use units were digitized using the classification code symbol. As earlier mentioned, a transparent acetate grid-paper was fitted to each stereo-model sub-dividing it into discrete data cells.

Using grid overlays, the numeric symbol for each land use was hand-coded (digitized) and data recorded and registered in diskette under the file name VICTOR. Geological and facet data were also digitized and recorded

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in similar manner under the file names J.V.C. Geodata and JEV.P Facets respectively.

Land use was correlated with geology and facets by a Program, BIVAR, designed for the purpose of correlating land use with slope and Geology.

Data analysis included both the visual interpretation and statistical analysis of land use with slope and geology. Statistical analysis consists of simple correlation of non-parametric data. Results are presented in the form of frequencies and histograms constructed there from.

### 3.5 Accuracy of Interpretation

It is important but difficult to define a clear set of criteria for accuracy and precision of this study. Such a definition is necessary so as to give the user not only a good idea of the accuracy and precision of the data but also to allow a reasonable degree of confidence interpreted therefrom.

Regarding this, therefore, only interpretation accuracy is considered. One way to determine accuracy is to field check all data interpreted from the aerial photographs. Even if possible, this is not a feasible approach to the problem. Ground checks of only a few square kilometres in this rugged site would be too costly and time consuming. Moreover, the set of photographs used for the study is twenty-five years out-of-date so that 'ground truthing' is impossible.

Based on these premises, the basic approach to analyse data for accuracy then, was to test for consistency of interpretation over time. This principle was carried out to show that a set of interpretation at one point in time is not significantly different from another set at another point in time. Regarding this principle, an initial sample is used as a reference data against which other subsequent interpretations are cross-referenced. Comparison of the two or more sets of interpretation yields a measure of 'photointerpretation accuracy' usually expressed as an error matrix (Cogalton and Mead, 1981; Benson et al, 1981, Sturdevant, 1981).

#### 3.5.1 The Error Matrix

The error matrix is a square array of numbers set out in rows and columns and it is used to express the number of cells assigned by the photo-interpreter to a particular land use type relative to the actual land use (reference data). The columns represent the reference data and the rows indicate the land use type assigned by the photo-interpreter.

The numbers in the error matrix are tallies compiled by comparing the photo-interpreted data to the reference data on a cell by cell basis.

Application of the error matrix, however, depends on the objective of the researcher or user. Firstly, if the goal of the researcher is to test the degree of similarity

between two or more photo-interpreters, each interpreter is given the same aerial photographs to interpret. An error matrix is then compiled for each interpreter by comparing his interpretation with a reference data (correct interpretation).

Secondly, if the objective is to measure the accuracy of delineations made on different types of photography, a separate interpretation is performed on the same area for each set of photographs by each interpreter and an error matrix is tabulated.

Thirdly, if the objective of the researcher is to test the consistency over time of a single interpreter, the a representative point of selected stereo-models are interpreted at the commencement of the survey (Time A). At some later date, the same set of photographs are interpreted (Time B) and then the two error matrices (Time A and Time B) are compared (Cogalton, 1981).

For example in a stereo-model of 336 grid-points (24 x 14), land use type interpreted from aerial photographs in row (i) is compared with column (i) of the reference data. If column (i) is less than or equal to 14, column (i) is increasee by 1, until the 14th column of row (i) is compared. The rows are processed in the same way i.e. if row (i) is less than or equal to 24, then row (i) is increased by 1 until the land use type in the 24th row and 14th column of the photo-interpreted data is compar@d with the reference data. All correct or consistent interpretation (or classification) are placed on the major diagonal of the error matrix.

Once the error matrices are generated, a discrete multi-variate analysis procedure as developed by Cogalton (1981) may be used to test the degree of similarity between the error matrices of photo-interpreters.

However, in this study, stereo-models of five separate areas were randomly selected to check for consistency. Each stereo-model was interpreted thrice at separate dates. The error matrix deduced from the interpretation of model-17 is shown in table 3.

In this study, as a result of the problems discussed in section 3.5, only relative accuracy was assessed and the assessment was done in three parts according to Sturdevant (1981).

Firstly, overall digital land use interpretation accuracy was calculated. This accuracy indicates the reliability of the final interpretation. It is computed as follows:

$$A\% = \frac{C1}{N} \times 100$$

where A% = Overall accuracy (percentage correct)

C1 = number of correct interpretations of all the land use Categories i.e. the total summation of the diagonal elements of the error matrix.

N = total possible elements in a stereo model i.e. 336  
(after Sturdevant, 1981)

Secondly, the accuracy of interpreting one category of land use against non-members of that particular land use class was assessed. The result of this assessment was used

to indicate the ability to distinguish one land use category from other categories. That is, to say, in a perfect observation and measurement, only the diagonal elements are shown in the error matrix, and the degree of spread or deviation in the matrix is a measure of its accuracy. It is computed by the equation

$$P = \frac{100x}{n}$$

where P = Percentage correct

x = number of correct interpretations in a particular category (i.e. element (i,i) the error matrix) interpreted from the stereo-model.

n = total number of that particular category interpreted from the stereo-model (i.e. the marginal total of row (i) .

Thirdly, the estimated standard error of each particular land use category interpreted from the stereo models are deduced as recommended by Stoner and Robertson (1970) and Sturdevant (1981). The estimated standard error (SP) was computed by using the expression

$$Sp = \pm \sqrt{\frac{P(100 - P)}{n}}$$

P = Percentage accurately or consistently interpreted

n = Number of sample points in a stereo-model.

Table 3: Error matrix depicting accuracy (Consistency) of photo interpreted data from stereo-model 17.

| LAND USE<br>CATEGORY              | REFERENCE DATA           |    |    |    |    |    |     |    |    |    |    | n   | RELATIVE<br>ACCURACY<br>(%) | ESTIMATED<br>STANDARD<br>ERROR |
|-----------------------------------|--------------------------|----|----|----|----|----|-----|----|----|----|----|-----|-----------------------------|--------------------------------|
|                                   | LAND USE COVER (CLASSES) |    |    |    |    |    |     |    |    |    |    |     |                             |                                |
|                                   |                          | 11 | 12 | 21 | 23 | 31 | 32  | 33 | 34 | 41 | 51 |     |                             |                                |
| PHOTO<br>INTER-<br>PRETED<br>DATA | 11                       | 5  | 0  | 1  | 1  | 0  | 0   | 0  | 0  | 0  | 0  | 7   | 71                          | +2.5                           |
|                                   | 12                       | 0  | 6  | 0  | 0  | 0  | 0   | 0  | 0  | 0  | 0  | 6   | 100                         | -                              |
|                                   | 21                       | 0  | 0  | 2  | 1  | 0  | 0   | 0  | 0  | 1  | 0  | 4   | 50                          | +2.7                           |
|                                   | 23                       | 0  | 0  | 1  | 1  | 0  | 0   | 0  | 0  | 0  | 0  | 2   | 50                          | +2.7                           |
|                                   | 31                       | 0  | 0  | 0  | 1  | 30 | 8   | 0  | 0  | 0  | 0  | 39  | 77                          | +2.3                           |
|                                   | 32                       | 0  | 0  | 0  | 0  | 20 | 209 | 2  | 6  | 0  | 0  | 237 | 88                          | +1.8                           |
|                                   | 33                       | 0  | 0  | 2  | 0  | 0  | 0   | 2  | 0  | 0  | 0  | 4   | 50                          | +2.7                           |
|                                   | 34                       | 0  | 0  | 0  | 0  | 0  | 1   | 1  | 4  | 0  | 0  | 6   | 67                          | +2.6                           |
|                                   | 41                       | 1  | 0  | 0  | 0  | 0  | 0   | 0  | 0  | 5  | 0  | 6   | 83                          | +2.0                           |
|                                   | 51                       | 0  | 0  | 0  | 0  | 1  | 1   | 2  | 0  | 0  | 21 | 25  | 84                          | +2.0                           |

336

Based on the formula developed by Sturdevant (1981), the overall accuracy of data interpreted from Stereo-model 17 is about 85%. Although table 3 shows that errors occurred in interpreting many categories of land use, the errors are probably due to lack of ground truth investigation and simple confusion of categories, such as mistaking grassland for scrubland, and vice-versa.

However, this accuracy satisfy the requirements of planners for river basin planning as recommended by Pelletier (1981).

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## CHAPTER FOUR

### DISTRIBUTION OF LAND RESOURCES

This Chapter attempts to review the distribution of slope, geology and land-use within their environmental setting. Comparison of the distribution of these resources provide a basis for defining the correlation amongst these resources.

#### 4.1 Distribution of Land-use

The distribution of land use in the project site has been mapped on the basis of numerous photo-interpretation. It was found that the occurrence of land use is consistent across vast areas. This allows the distribution to be mapped by a few units of regional extent (Map 3).

Like in several other places, the distribution of land-use in Sarkin Pawa Area is governed by two main factors; (a) regional factors and (b) land factors.

##### a. Regional Factors:

Regarding this the main regional element is climate. The various components of this factor is not treated in this study as only the summary is given.

- (i) The atmospheric and soil temperatures are high  
This high temperature (about 26°C) increase evapo-transpiration in the area to the extent that there is a net-water deficit culminating to drought conditions in most cases.

- (ii) An annual rainfall average of 127 cm in the test area is low when compared with its temporal and spatial spread.
- (iii) Both sunshine and radiation contribute to the high rate of evapo-transpiration in the test site.
- (iv) The North-Easterlies contribute significantly to the drought condition in the test area.

b. Land Factor

The main components of the land factors are topography and geology.

Geological factors consist mainly of the soil characteristics produced from the various geologic formation. These factors are discussed in Section 4.2 and 4.3 respectively.

4.2 Topography and Land Systems

Topography (slope) is a significant component affecting land-use distribution in Sarkin Pawa Area as shown in Section 4.4. It influences the climate, and when combined with the geological formation, the natural drainage of the region is also determined. The influence of the topography (slope) on the land-use in the test site is expressed through the land system.

4.2.1 Distribution of Land Systems

Three land systems have been recognised in the test site on the basis of slope (Map 2). Each has been denoted by a number and their distribution shown on Map 2 at a scale

of 1:100,000. The numbers were allocated as the units were recognized, the order of numbering has no other significance. The summary of the main characteristics of the land systems are described below.

(a) Sarkin Pawa Basin Upland System

Area: 183 sq. kilometres

Physiography: Rugged rocky hills with inselbergs

Slope: Greater than 20°

Altitude: 1600 m - 2430 m

Geology: Basement Complex, mainly older granite.

Predominantly Coarse grained

Hydrology: Drained by seasonal tributaries of the Sarkin Pawa and Godani Rivers.

|      | Facet                      | Land Forms  | Soil      |
|------|----------------------------|-------------|-----------|
| Code |                            |             |           |
| 1    | Rock outcrop and rock hill | Upper Slope | Lithosols |
| 2    | Iron Pan Cap               | " "         | "         |
| 3    | Interfluve Crest           | " "         | "         |
| 5    | Valley head                | " "         | Cambisols |
| 8    | Ridge                      | " "         | Lithosols |
| 12   | Cliff                      | " "         | Lithosols |

(b) Sarkin Pawa Basin Midland System

Area: 612 sq. kilometres

Physiography: Undulating to rolling topography with  
occasional hills or whale - backs

Slope:  $10^{\circ}$  -  $20^{\circ}$

Altitude: 1600 - 1850 m

Geology: Basement Complex consisting of Schists, granite  
gneiss and migmatite.

Hydrology: Drained by slow flowing tributaries and  
distributaries to the Sarkin Pawa, Godani and  
other major rivers.

| Code | Identity                        | Land Forms                                          | Soil                                 |
|------|---------------------------------|-----------------------------------------------------|--------------------------------------|
| 4    | Valley side slope               | Steep Sided Valleys                                 | Cambisols                            |
| 7    | Terrace                         | rolling topography<br>with occasional<br>whale back | Cambisols                            |
| 9    | Narrow Concave Valley<br>bottom | Upper slope                                         | Cambisols<br>with some<br>lithosols. |

(c) Sarkin Pawa Basin Lowland System

Area: 330 sq. kilometres

Physiography: Undulating to rolling plains with occasional hills too small to be mapped. This land system is situated in an inlier<sup>1</sup> of basement rocks in the Sarkin Pawa and the Godani Valleys (Geological Survey, 1963)

Slope: Less than 10°

Altitude: 1300 m - 1700 m

Geology: Basement complex, mainly softer rocks which have been worn down by agents of weathering and erosion.

Hydrology: Drained mainly by the Sarkin Pawa and Godani Rivers.

|      | Facet                      | Land Forms                                          | Soil      |
|------|----------------------------|-----------------------------------------------------|-----------|
| Code | Identity                   |                                                     |           |
| 6    | Flood plain                | Series of undulating plains with broad flood plains | Cambisols |
| 10   | Wide concave valley bottom | Fadama along the Sarkin Pawa River                  | "         |
| 11   | Flat valley bottom         | Gentle Slope                                        | "         |

<sup>1</sup> An Inlier is an exposed mass of rocks wholly surrounded by younger ones commonly occurring when the crest of anticline or an elongated dome is removed by erosion.

#### 4.3 Geological Formation

Geological formation in the project area is considered both in relation to soil formation (edaphic factor) and topography (physiographic factor). This is necessary since the nature of the geologic strata accounts not only for the kind of parent material utilized in soil formation but also to a high degree for the topography and the drainage features. All these conditions have a direct relationship on the characteristics of the soils formed and ultimately on land use.

##### 4.3.1 Rock Types of Sarkin Pawa Area

There are seven main rock types in the test sites, all of which except the schist are of granitic (Igneous) origin.

Schist are formed from the metamorphism of Sandstone.

Granitic rocks of the sub-region consists mainly of ferromagnesian mineral content as biotite and hornblende which tends to form in clusters.

Other important rock types are: (1) Quartz monzonite (2) Quartz diorite, (3) Migmatite (4) Coarse porphyritic biotite (5) Granite Gneiss and (6) Pegmatite.

Five minor rock types have also been recognised (Map 4). The relationship of the rock types in the geological map is complex, thus making soil relationship and mapping very difficult.

The characteristics of the geological formations of the test site is summarised in table 4.

Table 4: Attributes of the main rock types in the Sarkin Pawa Area

| Code | Rock Types                 | Areal Coverage sq km | %    | Parent Material        | Soil              | Comment                                                                                                                                                                                                                                   |
|------|----------------------------|----------------------|------|------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1    | Quartz monzonite           | 53.68                | 4.8  | Granite (Igneous)      | cambisols (stony) | Coarse grained intermediate igneous rock                                                                                                                                                                                                  |
| 2    | Schist                     | 393.20               | 34.4 | Sand stone metamorphic | Cambisols         | Characterised by scattered pebbles and cobbles. The rocks of this formation are not hard but their imperviousness and consequent resistance to weathering and erosion results in their composition of moderate to strong relief features. |
| 3    | Quartz diorite             | 49.14                | 4.4  | Granite (Igneous)      | Cambisols (Stony) | Coarse grained intrusive igneous rocks with much plagioclase and feldspar.                                                                                                                                                                |
| 4    | Migmatite                  | 405.38               | 36.0 | Granite (Igneous)      | Cambisols (Stony) | Characterized by strong mineral banding of ferromagnesian and feldspar and quartz. They are less resistant to weathering and erosion hence they are characterised by a relatively low relief of few exposures and residual land forms.    |
| 5    | Coarse Porphyritic Biotite | 30.7                 | 2.7  | Granite (Igneous)      | Cambisols (Stony) | Biotite is one of the minerals of granitic rock.                                                                                                                                                                                          |
| 6    | Granite Gneiss             | 137.48               | 12.2 | Granite (Igneous)      | Cambisols (stony) | Generally, coarse grained except at the flanks near their contact.                                                                                                                                                                        |
| 7    | Pegmatite.                 | 56.24                | 5.0  | Granite (Igneous)      | Lithosols         | Consists of stony weathered or unweathered rock fragments. They form the crest of hills and ranges and occurs in association with Schists.                                                                                                |

#### 4.3.2 Effects of Geology and Topography (Slopes) of Sarkin Pawa Area on Soil Association

It is obvious from the fore-going discussion on the geology of the test site that the relationship between the rock types is very complex, more so than is shown on Maps 4 and 5.

The boundaries between the major rock types are transitional and this will affect the properties of the soils formed there from. Even rock properties within the major rock types vary with regard to texture, structure and foliation properties. For example the Granite Gneiss is coarse grained within the main body of the out crops than in the region of their contact within the surrounding migmatite and schists (Fagbami, 1976).

Another significant character of the geology of the area is the association of the main rock types with the minor ones. The properties of the minor rock types are different mineralogically, lithologically and stratigraphically from the major rock types. This difference may cause variations in the different properties of the soil. Thus mapping of soil in such an area of complex geological relationships is not easy so that the lumping together of soils of widely differing characteristics is inevitable.

This problem is compounded by the fact that similar soils can develop on different rock types depending on the other factors of soil formation.

Consequently, it is not easy to establish a relationship between the rock types and the soils derived from them particularly in a Savanna region. And for these reasons, a great deal of information has been inferred about the soil properties from knowledge about the lithology of the rock types and their weathering characteristics.

#### 4.4 Evaluation of the Distribution of Resource Factors

##### 4.4.1 Land-use and Slope

Topographic effects on land-use are particularly noticeable in their impact on hydrology, erosion, deposition and soil processes which are mostly evident in vegetation gradient from upland slopes to lowland slopes. Hence, this study has demonstrated the following relationships between land-use and slope in the Savanna region of Nigeria.

Table 5: Relationship Between Land Use and Land System

| Land-Use Class | Upland System | Midland System | Lowland System |
|----------------|---------------|----------------|----------------|
| 11             | 58 (96.67)    | 2 ( 3.33)      | - ( - )        |
| 12             | 102 (94.45)   | 6 ( 5.55)      | - ( - )        |
| 21             | 237 (94.80)   | 12 ( 4.80)     | 1 (0.4)        |
| 23             | 46 (97.87)    | 1 ( 2.13)      | - ( - )        |
| 31             | 1980 (92.05)  | 158 ( 7.35)    | 13 (0.6)       |
| 32             | 7836 (88.43)  | 979 (11.05)    | 46 (0.52)      |
| 33             | 5 (62.5)      | 2 (25.0)       | 1 (12.5)       |
| 34             | 839 (89.16)   | 101 (10.75)    | 1 (0.11)       |
| 41             | 106 (94.75)   | 4 (3.51)       | 2 (1.76)       |
| 51             | 212 (38.47)   | 296 (53.73)    | 43 (7.8)       |
| TOTAL          | (87.26)       | 1561 (11.92)   | 107 (0.82)     |

Values in bracket indicate the percentage of the land-use in that particular land system.

With reference to table 5, 87.26% of land use points was observed in the upland system, 11.92% in the midland system and 0.82% was observed in the low-land system.

From detailed analysis of the various land systems, it is evidently clear that no land use is equitably distributed within the systems. Equally apparent in the table is the unequal distribution of the various categories of land-use within the same system.

Also with regard to table 5, in the upland system about 0.51% is occupied by settlements, 0.89% by communication, 2.07% by cultivated farmland less than ten hectares, and 0.4% by unenclosed farmland. Others include grassland (17.33%), scrub (68.60%), Swamp and marsh 0.04%, woodland (7.34%) bare-rock and inselbergs (0.95%) and rivers and streams (1.86%).

For the midland system, the following observations are made. Settlement was observed at 0.13% of the total land use observed in the system. Other observations are communication (0.38%), cultivated land less than ten hectares (0.77%), unenclosed farmland (0.06%), grassland (10.12%), scrub (62.72%), swamps and marshland (0.13%), woodland (6.47%), barerock and inselberg (0.26%), and rivers and streams (18.96%).

And for lowland system, the following percentages of land use was observed:

Cultivated land less than ten hectares occupy 0.93% of the land uses in the lowland system while grassland and scrub occupy 12.15% and 43% respectively. Others are Swamp and marshland (0.93%), Woodland (0.93%), bare rock and inselbergs (1.87%) and rivers and streams (40.19%).

#### 4.4.2 Land Use and Geology

The distribution of the major geological formations is indicated in Map 5 and their areal extent and local features catalogued and described in Section 4.3.1. Details of distribution of land use in each geological formation is contained in this Section.

Table 6 portrays the general relationship between land use distribution and geology.

Table 6: Relationship Between Landuse and Geology

|       | Frequency | Percentages | Areal Coverage<br>(hectares) |
|-------|-----------|-------------|------------------------------|
| 1     | 642       | 5.72        | 2889.00                      |
| 2     | 4305      | 38.52       | 19372.50                     |
| 3     | 445       | 3.98        | 2002.50                      |
| 4     | 3981      | 38.62       | 17914.50                     |
| 5     | 112       | 1.00        | 504.00                       |
| 6     | 1277      | 11.43       | 5746.00                      |
| 7     | 414       | 3.70        | 1863.00                      |
| TOTAL | 11176     | 100.00      | 50292.00                     |

The table reveals that quartz monzonite occupies 5.75% of the land-use observed in the Sarkin Pawa Area while schists and some gneiss occupy 38.52%. Other land uses occupied by geological formations are: quartz diorite (3.98), migmatite (35.62%), coarse porphyritic biotite (1.0%), granite gneiss (11.43%) and pegmatite (3.70%).

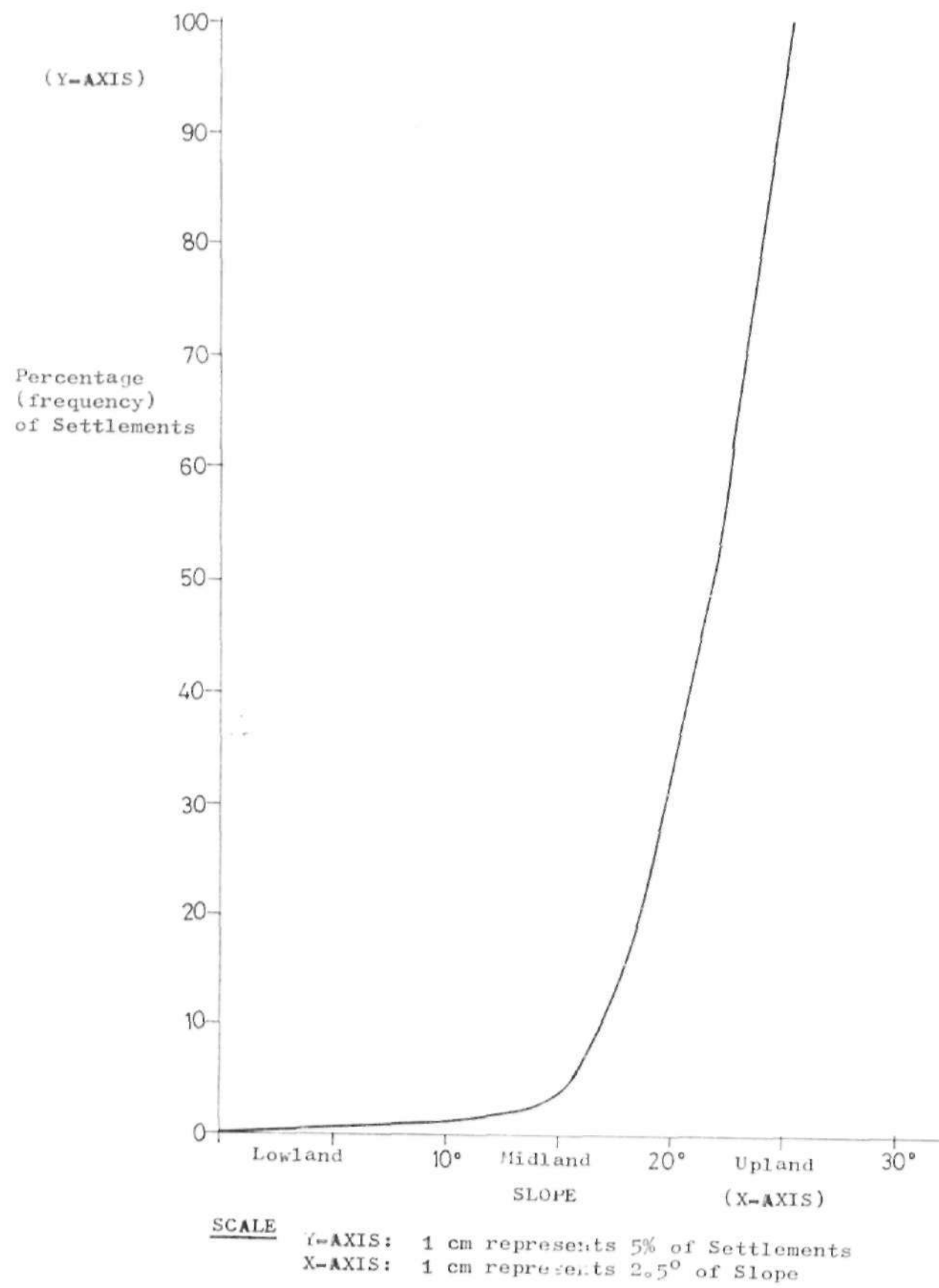


FIGURE 1: CORRELATION BETWEEN PERCENTAGE OF SETTLEMENTS AND SLOPE

Table 7: Relationship Between Settlements and Facets

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 33               | 55.00          |
| 2            | 4                | 6.67           |
| 3            | 21               | 35.00          |
| 4            | 1                | 1.67           |
| 5            | -                | 1.67           |
| 6            | -                | -              |
| 7            | 1                | -              |
| 8            | -                | -              |
| 9            | -                | -              |
| 10           | -                | -              |
| 11           | -                | -              |
| 12           | -                | -              |
| TOTAL        | 60               | 100.00         |

Amongst the various facets rock outcrop and rocky hill (U.S) accounts for 55% of settlements observed while 6.67% were observed on ironpan cap (U.S). The relationship of settlements and other facets are: Interfluve crest (U.S) (35%) Valley-side slope (M.S.) and terrace (M.S.) accounts for 1.67% each of settlements.

#### 5.1.2 Communication and Slope

Table 8 expresses the relationship between communication and slope.

Table 8: Relationship Between Communication and Slope

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 59               | 54.63          |
| 2            | 3                | 2.78           |
| 3            | 38               | 35.19          |
| 4            | 4                | 3.70           |
| 5            | 2                | 1.85           |
| 6            | -                | -              |
| 7            | -                | -              |
| 8            | -                | -              |
| 9            | 2                | 1.85           |
| 10           | -                | -              |
| 11           | -                | -              |
| 12           | -                | -              |
|              | <hr/>            | <hr/>          |
| TOTAL        | 108              | 100.00         |

Analysis of the table and appendix 3 tend to relate about 94% of communication routes to the upland slope while about 6% is related to the midland slope. Again no observation of communication was made in the lower slope. About 54.63% of communication was observed on rock outcrop and rocky hill. This value is very similar to the 55% of settlements observed on rock outcrop and rocky hill (upland system). About 2.78% and 35.19% were observed on ironpan cap (upland system) and interfluvial crest (U.S) respectively. Again the value of 35.19% observed on interfluvial crest is quite close to that of settlements (35.0%) observed on the same facet. Others include valley side slope (M.S) (3.7%), valley-head (U.S) (1.85) and narrow concave valley bottom (M.S) (1.85%).

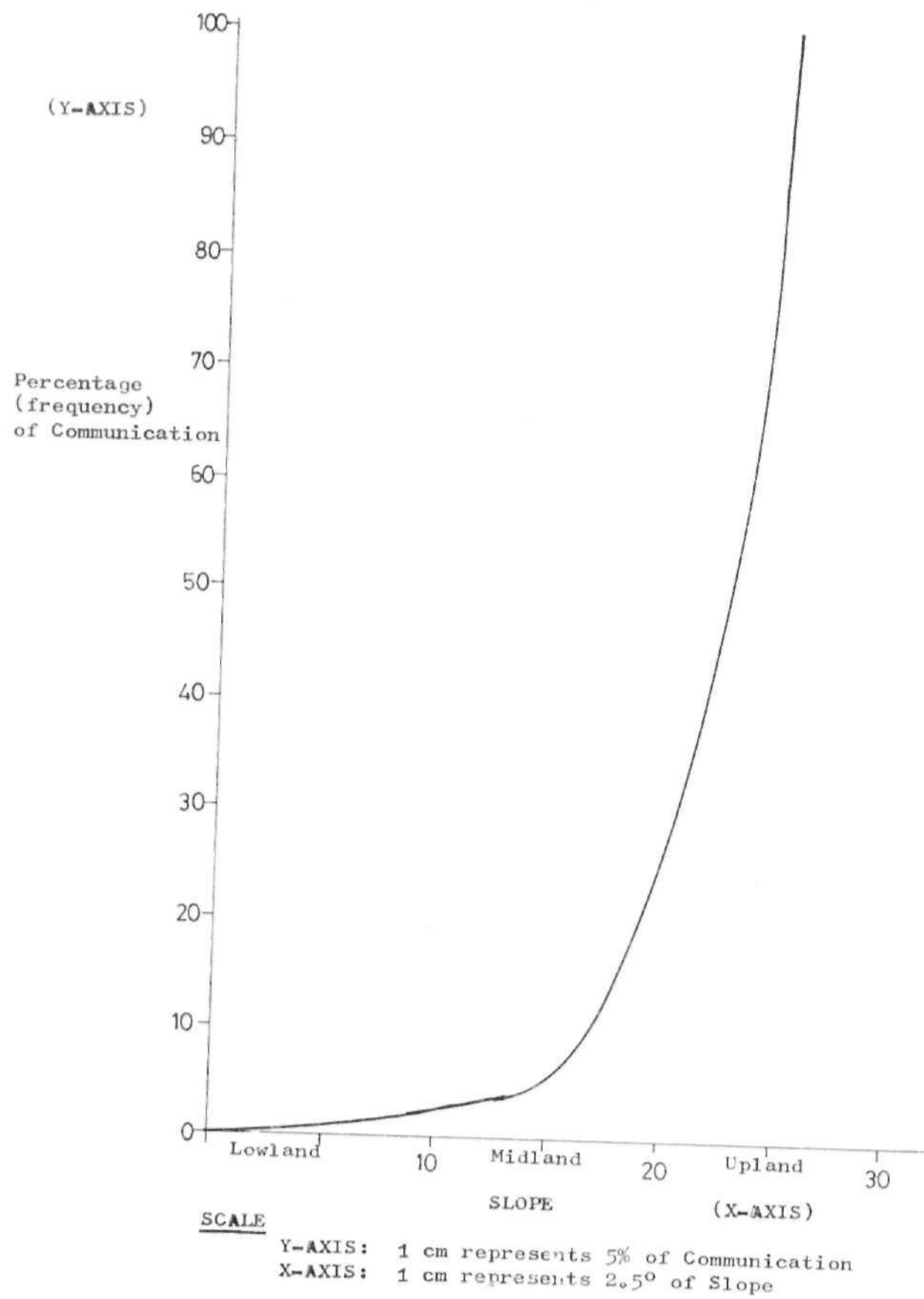


FIGURE 2: CORRELATION BETWEEN PERCENTAGE OF COMMUNICATIONS AND SLOPE

The relationship of communication to slope is quite similar to that between settlements and slope as depicted in figure 2.

5.1.3 Cultivated Land (Less Than Ten Hectares) and Slope

A positive relationship seems to exist between cultivated land (less than ten hectares) and slope. This is shown in table 9 below. From the table, about 94.8% of cultivated land (less than ten hectares) was observed in the upland slope, 4.8% in the midland slope and 0.4% in the low-land slope. Of these distributions, about 55.6% was observed on rock outcrop and rocky hill (U.S) while 5.2% was observed on ironpan cap (U.S). Other observations are interfluvial crest (U.S) (31.6%), valley-side slope (M.S) 0.8%, valley-head (U.S) (0.8%) terrace (M.S) (1.6%), ridge (U.S) (1.2%), narrow concave valley bottom (M.S) (2.4%), flat valley bottom (L.S) (0.4%) and Cliff (U.S) (0.4%).

Table 9: Relationship Between Cultivated Land (Less Than Ten Hectares) and Facet

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 139              | 55.60          |
| 2            | 13               | 5.20           |
| 3            | 79               | 31.00          |
| 4            | 2                | 0.80           |
| 5            | 2                | 0.80           |
| 6            | -                | -              |
| 7            | 4                | 1.6            |
| 8            | 3                | 1.2            |
| 9            | 6                | 2.4            |
| 10           | -                | -              |
| 11           | 1                | 0.4            |
| 12           | 1                | 0.4            |
|              | <u>250</u>       | <u>100.00</u>  |

The relationship between cultivated land (less than ten hectares) and slope is well exemplified in figure 3 and appendix 4

#### 5.1.4 Unenclosed Farmland and Slope

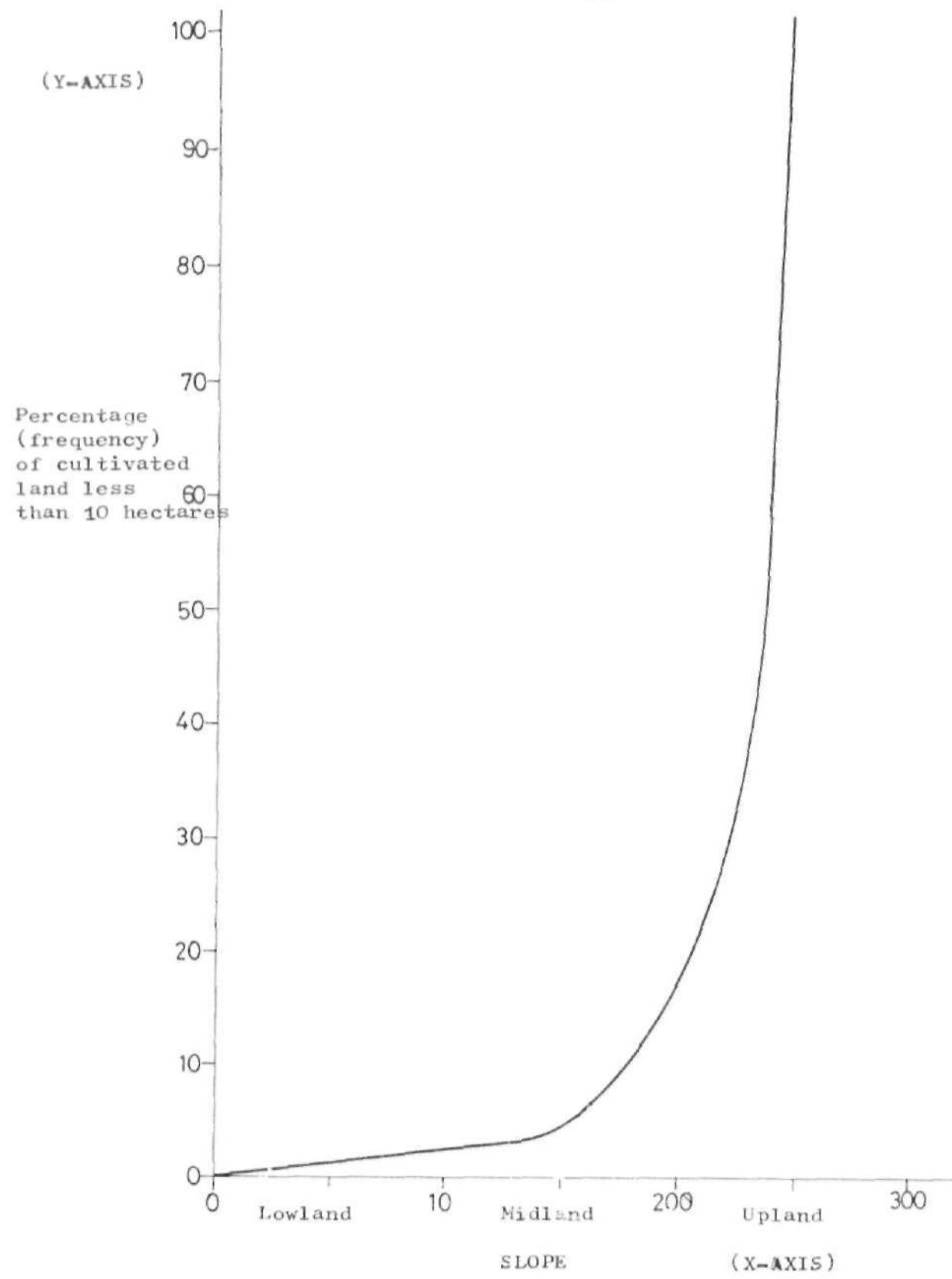
Table 10 reveals the relationship between unenclosed farmland and slope. The table shows that over 97% of unenclosed farmland was observed in the upland slope while only 2.13% was observed in the mid-land slope. None of the unenclosed farmlands was observed in the lowland slope. Rock outcrops and rocky hill (U.S) accounts for only 27.65% while interfluvial crests accounts for only 68.85%. The valley-side slope (M.S) and valley-head (U.S) accounts for only 2.13% each respectively. The relationship between uncultivated farmland and slope is shown in figure 4 and appendix 5.

Table 10: Relationship Between Unenclosed Farmland and Facets

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 13               | 27.65          |
| 2            | -                | -              |
| 3            | 32               | 68.085         |
| 4            | 1                | 2.128          |
| 5            | 1                | 2.128          |
| 6            | -                | -              |
| 7            | -                | -              |
| 8            | -                | -              |
| 9            | -                | -              |
| 10           | -                | -              |
| 11           | -                | -              |
| 12           | -                | -              |
|              | <u>47</u>        | <u>100.00</u>  |

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SCALE

Y-AXIS: 1 cm represents 5% of Cultivated land less than ten hectares  
X-AXIS: 1 cm represents 2.5° of Slope

FIGURE 3: CORRELATION BETWEEN PERCENTAGE OF CULTIVATED LAND (<10 ha.) AND SLOPE

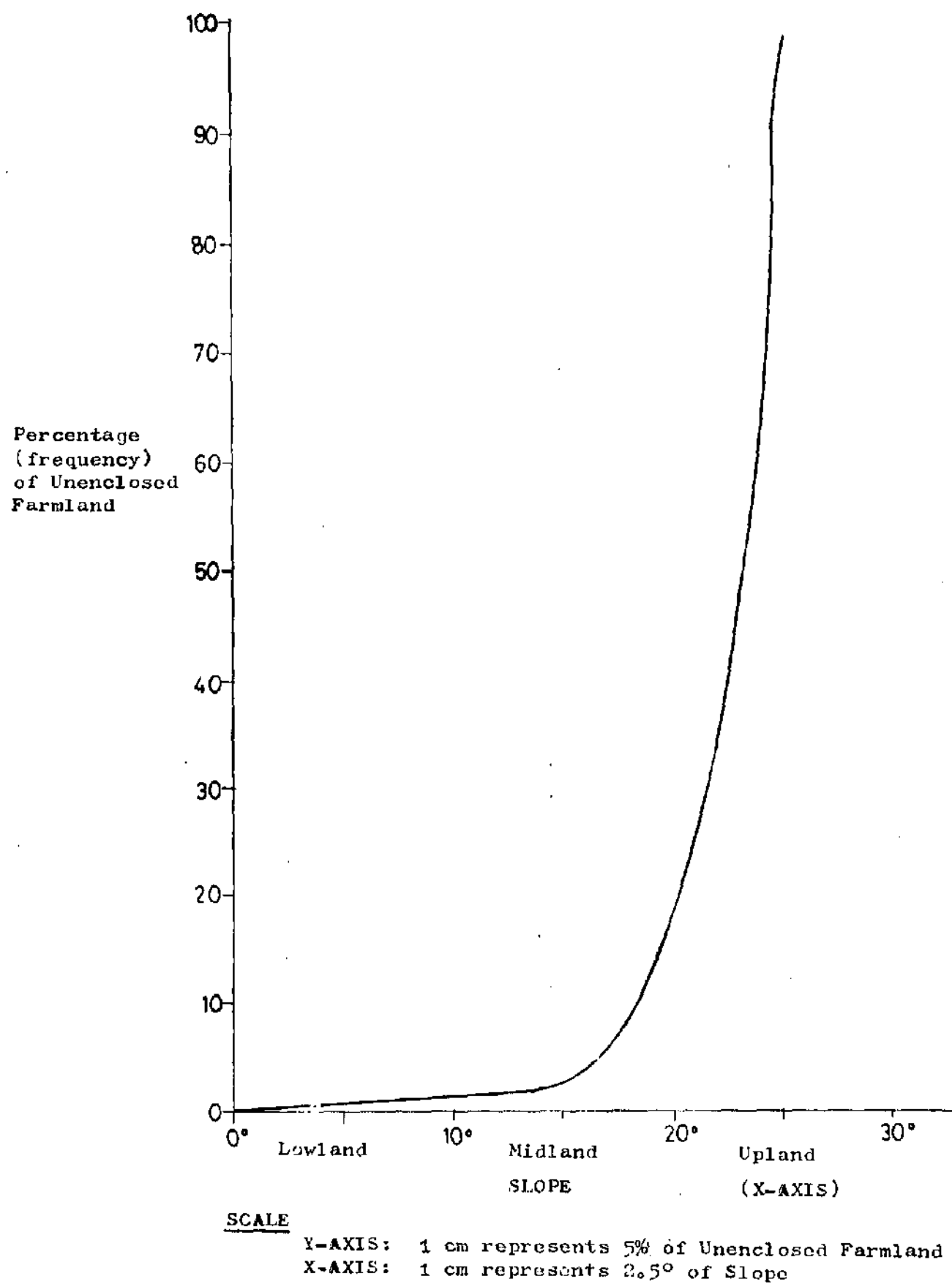


FIGURE 4: CORRELATION BETWEEN PERCENTAGE OF UNENCLOSED FARMLAND AND SLOPE

#### 5.1.5 Grassland and Slope

Grassland has a widespread occurrence among the three slopes. The upland slope accounts for 92.05%, the midland slope accounts for 7.35% while 0.6% was observed in the lowland slope. This relationship is well illustrated in table 11 and figure 5 and appendix 6. Analysis of the table and the histogram reveal that over 50% of grassland was observed on rock outcrop and rocky hill (U.S), 37.75% on interfluvial crests (U.S) and 1.86% on ironpan cap (U.S). Other observations were valley-side slope (M.S) (2.789%), valley-head (U.S) (1.255%) and narrow concave valley bottom (M.S) (3.58%). The remaining facets account for less than 1.0% each of grassland.

Table 11: Relationship Between Grassland and Facets

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 1088             | 50.58          |
| 2            | 40               | 1.86           |
| 3            | 812              | 37.75          |
| 4            | 69               | 2.79           |
| 5            | 27               | 1.25           |
| 6            | 1                | 0.05           |
| 7            | 21               | 0.98           |
| 8            | 10               | 0.46           |
| 9            | 77               | 3.58           |
| 10           | 7                | 0.33           |
| 11           | 5                | 0.23           |
| 12           | <u>3</u>         | <u>0.14</u>    |
|              | 2151             | 100.00         |

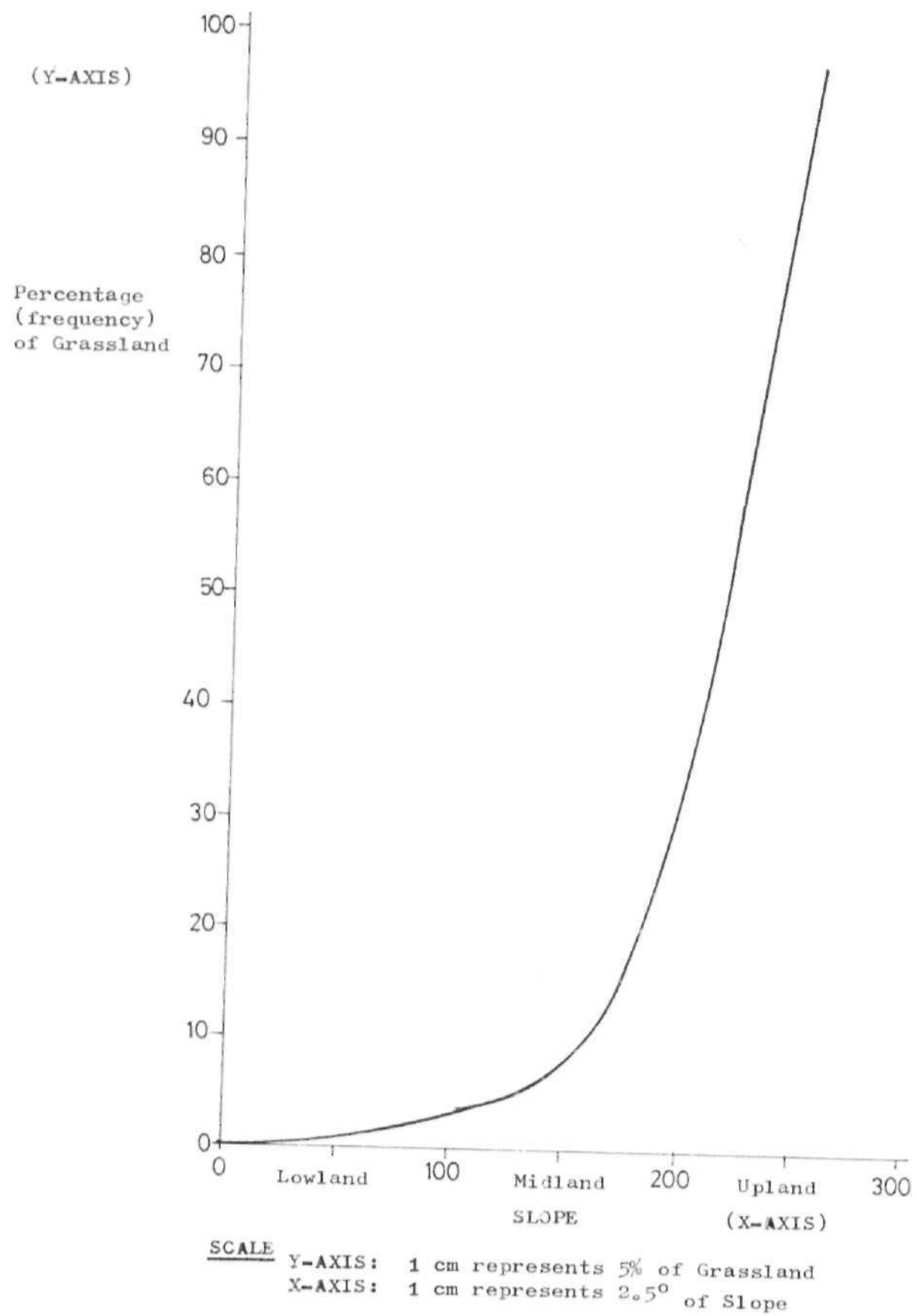


FIGURE 54 CORRELATION BETWEEN PERCENTAGE OF GRASSLAND AND SLOPE

#### 5.1.6 Scrubs and Slope

Scrubland represent the transitional zone between the woodland and the true grassland. And the following observations of scrubs regarding slopes were noted: upland slope (88.42%) midland slope (11.05%) and lowland slope (0.52%). These relationships are expressed in table 12 and in figure 6 and appendix 7.

Table 12: Relationship Between Scrub and Facets

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 3158             | 35.64          |
| 2            | 167              | 1.88           |
| 3            | 4262             | 48.10          |
| 4            | 392              | 4.42           |
| 5            | 126              | 1.42           |
| 6            | 11               | 0.12           |
| 7            | 29               | 0.37           |
| 8            | 56               | 0.63           |
| 9            | 558              | 6.30           |
| 10           | 40               | 0.34           |
| 11           | 5                | 0.06           |
| 12           | <u>67</u>        | 0.76           |
|              | 8861             |                |

Examination of the table indicates that over 35.6% of scrubs was observed on rock outcrop and rocky hill (U.S), 1.88% on ironpan cap (U.S) and about 48.10% on interfluvial crest (U.S). Others include 4.42% on valley-side slope (M.S) 1.42% on valley-head (U.S) and 6.30% on narrow concave valley

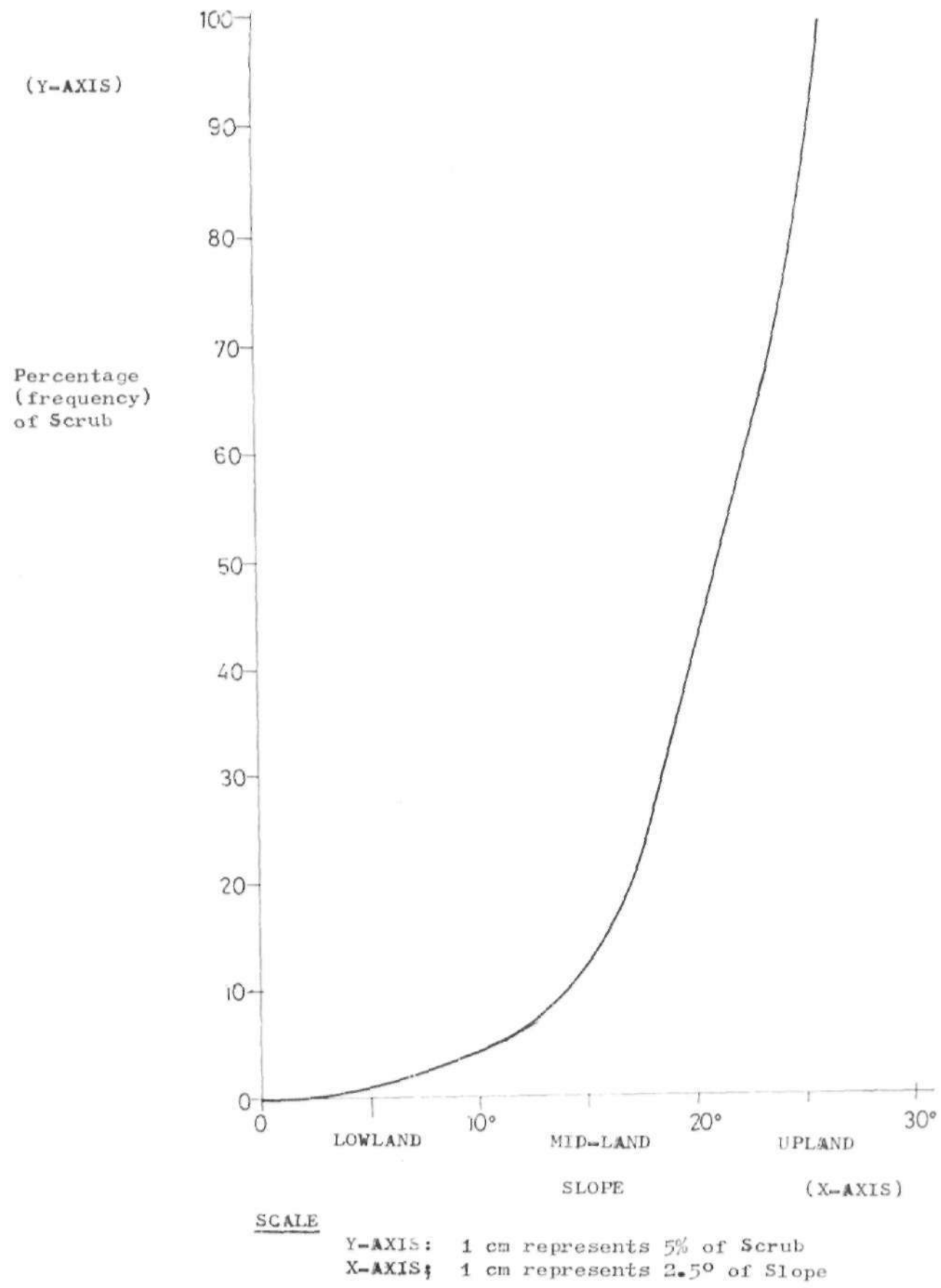


FIGURE 6: CORRELATION BETWEEN PERCENTAGE OF SCRUB AND SLOPE

bottom (M.S). As in the case of grassland, the remaining facets account for less than 1.0% each of scrubland.

5.1.7 Swamp/Marshland and Slope

Observations of table 13 reveals that over 60% of swamp/marshland occur on the upland slope, 25% in the midland slope and about 12.5% on the lowland slope.

Table 13: Relationship Between Swamp/Marshland and Facets

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 2                | 25             |
| 2            | -                | -              |
| 3            | 3                | 37.5           |
| 4            | 2                | 25.0           |
| 5            | -                | -              |
| 6            | -                | -              |
| 7            | -                | -              |
| 8            | -                | -              |
| 9            | -                | -              |
| 10           | 1                | 12.5           |
| 11           | -                | -              |
| 12           | -                | -              |
|              | <hr/> 8          | <hr/> 100.0    |

Of these occurrences, rock outcrop and rocky hill (U.S) account for 25%, interfluvial crest (U.S) (37.5%), valley-side slope (M.S) (25%) and wide concave valley bottom (L.S) 12.5%. The relationship between swamp/marshland and slope is demonstrated in figure 7 and appendix 8.

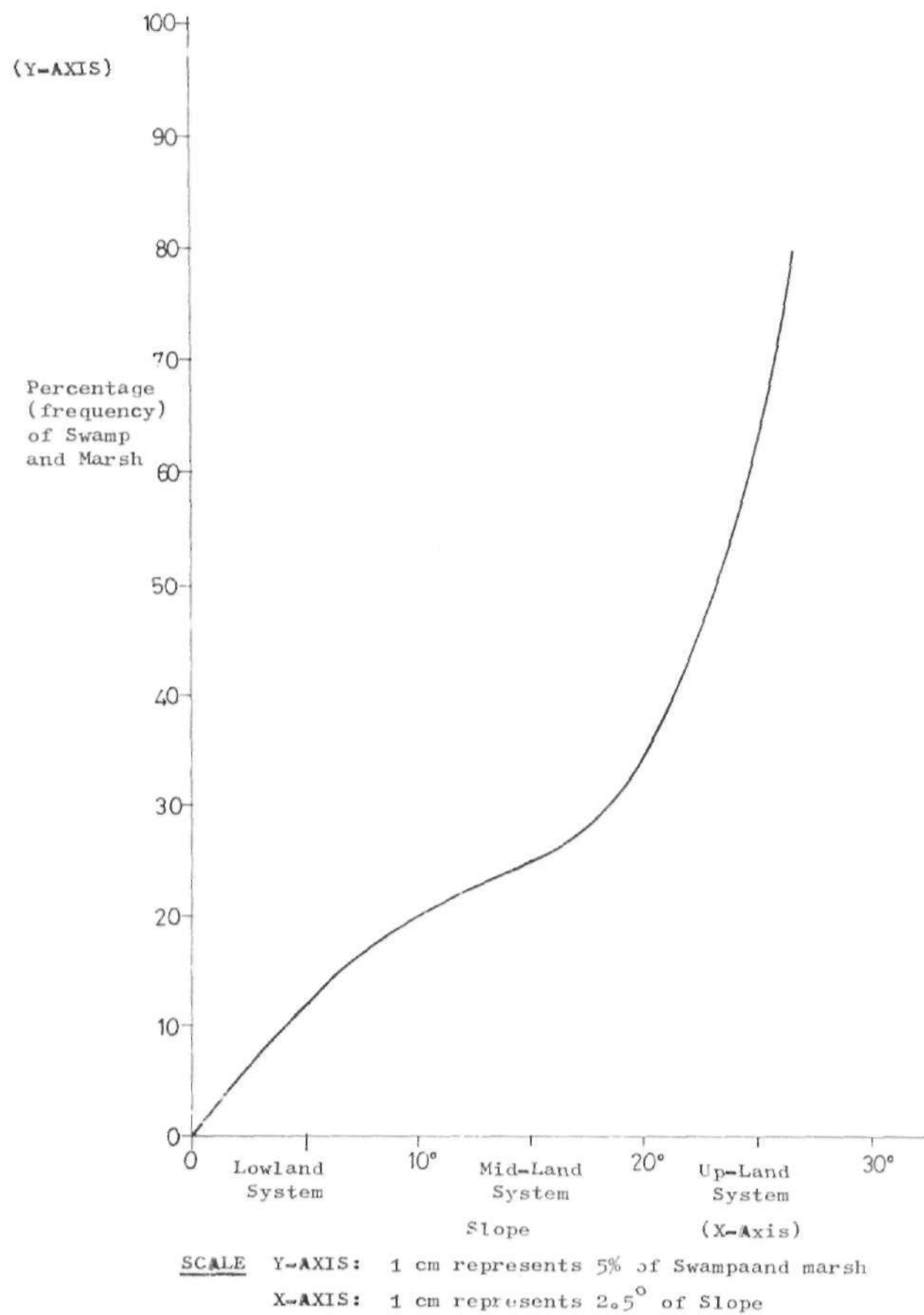


FIGURE 7: CORRELATION BETWEEN PERCENTAGE OF SWAMP/MARSH AND SLOPE

5.1.8 Woodland and Slope

From analysis of table 14 and appendix 9, a defined relationship seems to emerge between the occurrence of woodland and slope. For instance, about 89% of woodland was observed on upland slopes, 10.7% on midland slopes and a very insignificant percentage (0.11%) on lowland slopes. This skewed relationship between woodland and slope is shown in figure 8.

Table 14: Relationship Between Woodland and Facets

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 214              | 22.74          |
| 2            | 3                | 0.32           |
| 3            | 573              | 60.89          |
| 4            | 35               | 3.72           |
| 5            | 20               | 2.12           |
| 6            | -                | -              |
| 7            | -                | -              |
| 8            | 21               | 2.23           |
| 9            | 66               | 7.01           |
| 10           | -                | -              |
| 11           | 1                | 0.11           |
| 12           | <u>8</u>         | <u>0.85</u>    |
|              | 941              | 100.00         |

The table shows that about 22.7% of woodland was observed on rock outcrop and rocky hill (U.S), 60.89% on interfluve crests (U.S) and about 3.72% on valley-side slope (M.S). Others include valley-head (U.S) 2.12%, ridge (U.S)

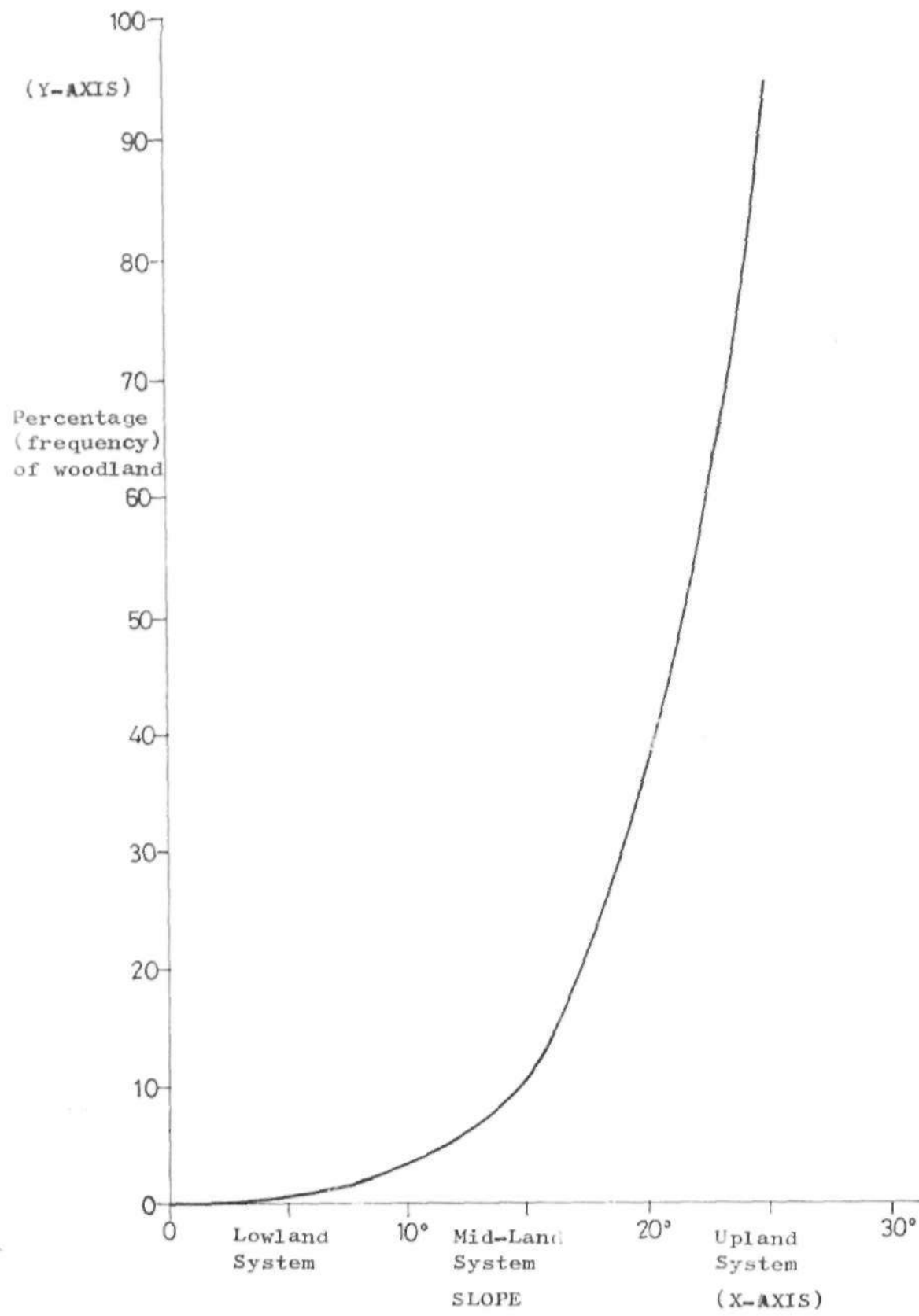


FIGURE 8: CORRELATION BETWEEN PERCENTAGE OF WOODLAND AND SLOPE

(2.23%) and narrow concave valley-bottom (M.S) (7.01%). Ironpan cap (U.S), flat valley-bottom (L.S) and Cliff (U.S) account for less than 1.00% of woodland each. No woodland was observed on flood plain (L.S), terrace (M.S) and wide concave valley bottom.

#### 5.1.9 Bare rock/inselbergs and Slope

The widespread occurrence of bare-rock/inselbergs occupying large areas in the test site is not extensively developed and the topography often reflects the geology of the underlying rocks (Trustwell and Cope, 1963). Steep sided inselbergs, usually developed on porphyritic granites are commonly found in migmatites. For this reason, the distribution of bare-rock tend to follow the slope and the geology. For instance, while about 94.7% of bare-rock/inselbergs was observed on the upland slope, only 3.51% was observed on the mid-land slope. The lowland slope accounts for 1.76%. These relationships are expressed in table 15, and figure 9 and appendix 10.

Table 15: Relationship Between Bare-rock/Inselbergs and Slope

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 17               | 14.91          |
| 2            | 46               | 40.35          |
| 3            | 36               | 31.58          |
| 4            | 1                | 0.88           |
| 5            | 3                | 2.63           |
| 6            | 1                | 0.88           |
| 7            | 1                | 0.88           |
| 8            | 2                | 1.75           |
| 9            | 2                | 1.75           |
| 10           | -                | -              |
| 11           | 1                | 0.88           |
| 12           | <u>4</u>         | <u>3.51</u>    |
|              | 114              | 100.00         |

A significant relationship can be inferred from the above table between bare rock/inselbergs and ironpan cap (U.S) where about 40.35% of bare-rock/inselbergs was observed. About 31.58% was observed on interfluvial crest (U.S), 14.91% on rock outcrop and rocky hill (U.S). Other significant observations were valley-head (U.S) 2.63%, Cliff (U.S) 3.51%, and ridge (U.S) and narrow concave valley bottom (M.S) 1.75% each. The remaining facets have less than 1.0% each respectively.

5.1.10 River/Stream and Slope

Analysis of table 15 has revealed an interesting feature about the relationship between river/stream and slope in the Sarkin Pawa Basin. According to the table,

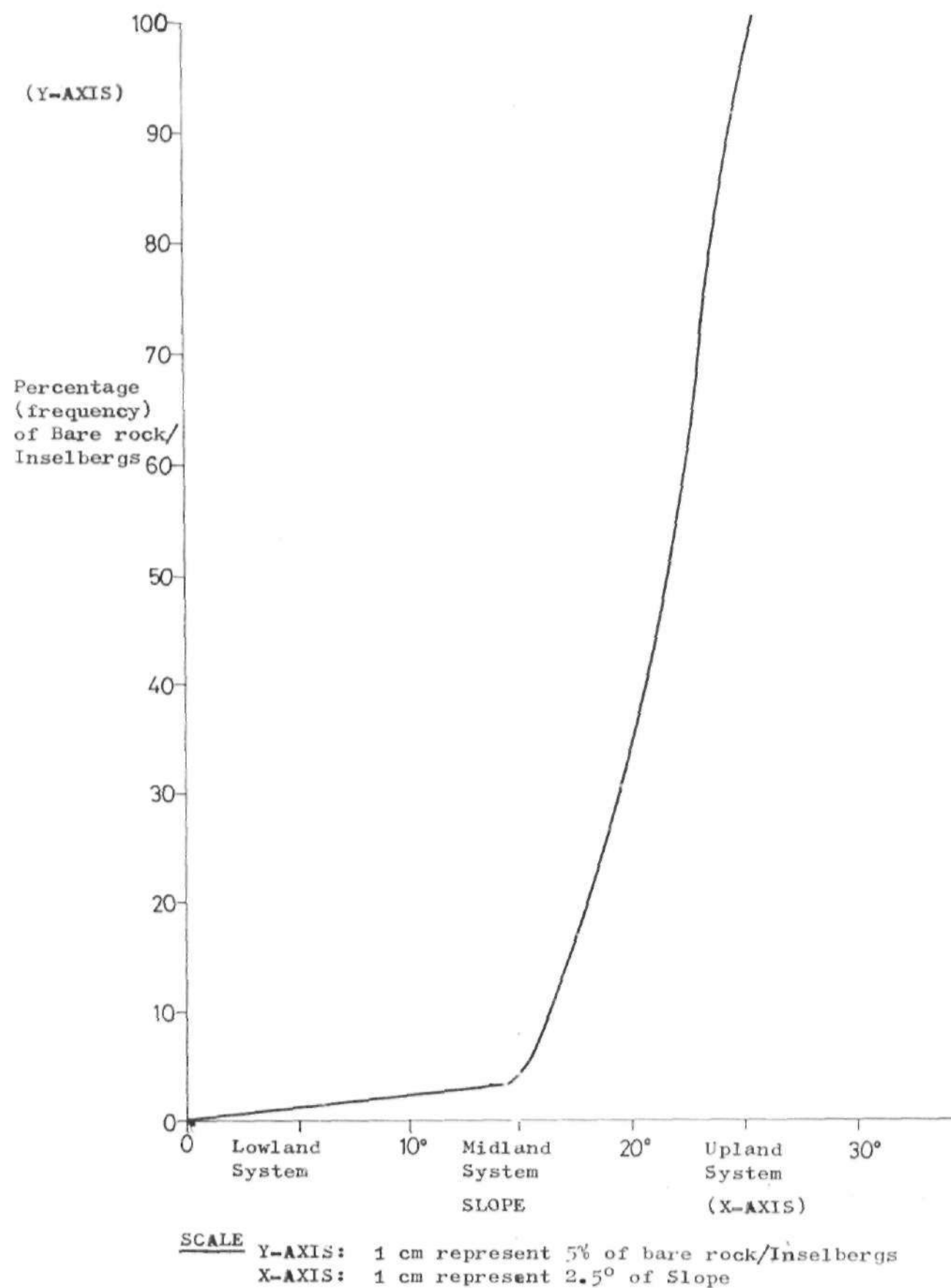


FIGURE 9: CORRELATION BETWEEN PERCENTAGE OF BARE-ROCK/INSELBERGS AND SLOPE

about 42.5% of the rivers/streams in the test site was observed on narrow concave valley bottom (M.S) and 10.53% on valley-side slope (M.S). Others include rock outcrops and rocky hill (U.S) (25.4%), interfluve crest (U.S) (9.98%), Wide concave valley bottom (L.S) (5.44%), and valley-head (U.S) and floodplain (L.S) (1.63%) each.

Table 16: Relationship Between Rivers/Stream and Slope

| <u>FACET</u> | <u>FREQUENCY</u> | <u>PERCENT</u> |
|--------------|------------------|----------------|
| 1            | 140              | 25.41          |
| 2            | 5                | 0.91           |
| 3            | 55               | 9.98           |
| 4            | 58               | 10.53          |
| 5            | 9                | 1.63           |
| 6            | 9                | 1.63           |
| 7            | 4                | 0.73           |
| 8            | -                | -              |
| 9            | 234              | 42.47          |
| 10           | 30               | 5.44           |
| 11           | 4                | 0.73           |
| 12           | <u>3</u>         | <u>0.54</u>    |
|              | 342              | 100.00         |

Although appendix 11 shows that about 38.5% of rivers/streams was observed on the upland slope, 53.8% on the mid-land slope, and 7.8% on the lowland slope, the correlation of rivers and streams to slope in the Sarkin Pawa Basin is inconclusive. This relationship is expressed in figure 20.

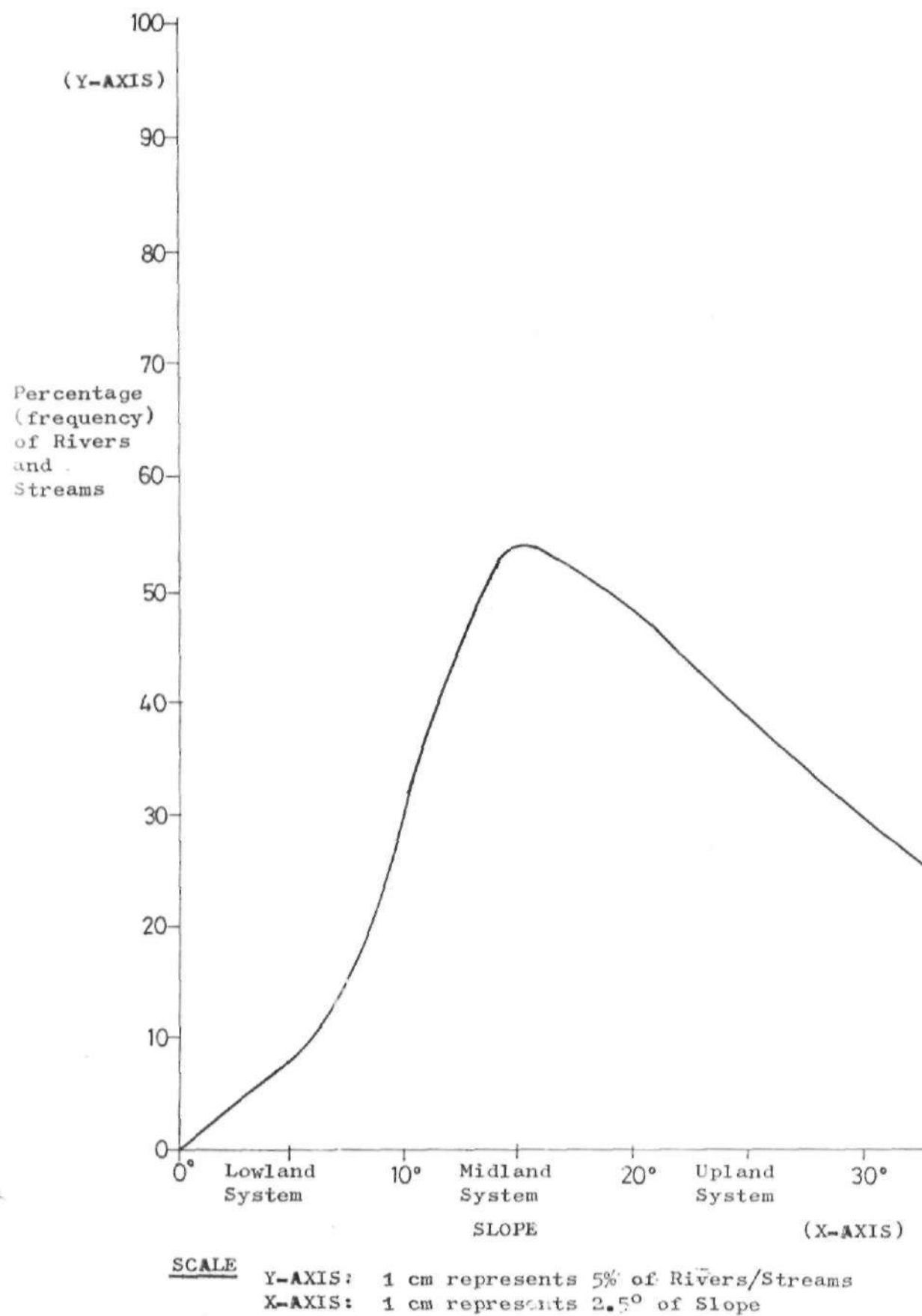


FIGURE 10: CORRELATION BETWEEN PERCENTAGE OF RIVERS/STREAMS AND SLOPE

## CHAPTER SIX

### SUMMARY AND CONCLUSIONS

The objective of this study has been to present as complete as possible a picture of the project area from the available data of the land resources of Sarkin Pawa Area.

In addition quantified estimates of the main parameters have, wherever possible been provided. The study of the project area has facilitated the establishment of the following land use correlation with slope.

- (i) The occurrence of settlements is predominantly more on higher slopes than on lower slopes.
- (ii) Communication pattern tends to follow the occurrence of settlements and farmlands.
- (iii) Cultivated land less than ten hectares are more concentrated in the upland system than in the lowland system.
- (iv) Unenclosed farmland is positively related to the occurrence of high slopes.
- (v) Of all the land use in the test site, grassland vary significantly according to their position on the slope and to the degree of tree shading, but are otherwise almost uniform over the whole area.
- (vi) The occurrence of scrub in the test site also vary according to the degree of slope.

- (vii) The correlation between swamp/marshland to high slope is caused mainly by geological factors. This is, however, not necessarily suggesting that the geological pattern controls the distribution of swamp/marshland in some absolute sense as some salient factors may also be involved.
- (viii) Woodlands are positively correlated with slope.
- (ix) Geological and climatic factors have tended to correlate barerock/inselbergs with slope
- (x) The relationship between rivers/streams and slope has proved inconclusive but, nevertheless, some geological factors have been associated with this relationship.

The area is fairly representative of the Nigerian savanna region. The land use and land cover categories are newly described and their relationships fairly established. The economic importance of the basin has been emphasized and the potential for resource monitoring were discussed.

Finally, this study has raised some interesting problems which require closer examination. It may not have resolved all the problems, but it has directed attention to a significant aspect of our development problems which has been neglected because of the general lack of data. It is therefore hoped that with this

introduction to the area, and the increase in the acquisition of remote sensor data, land resources monitoring will be open to more detailed study both for its academic and economic interests.

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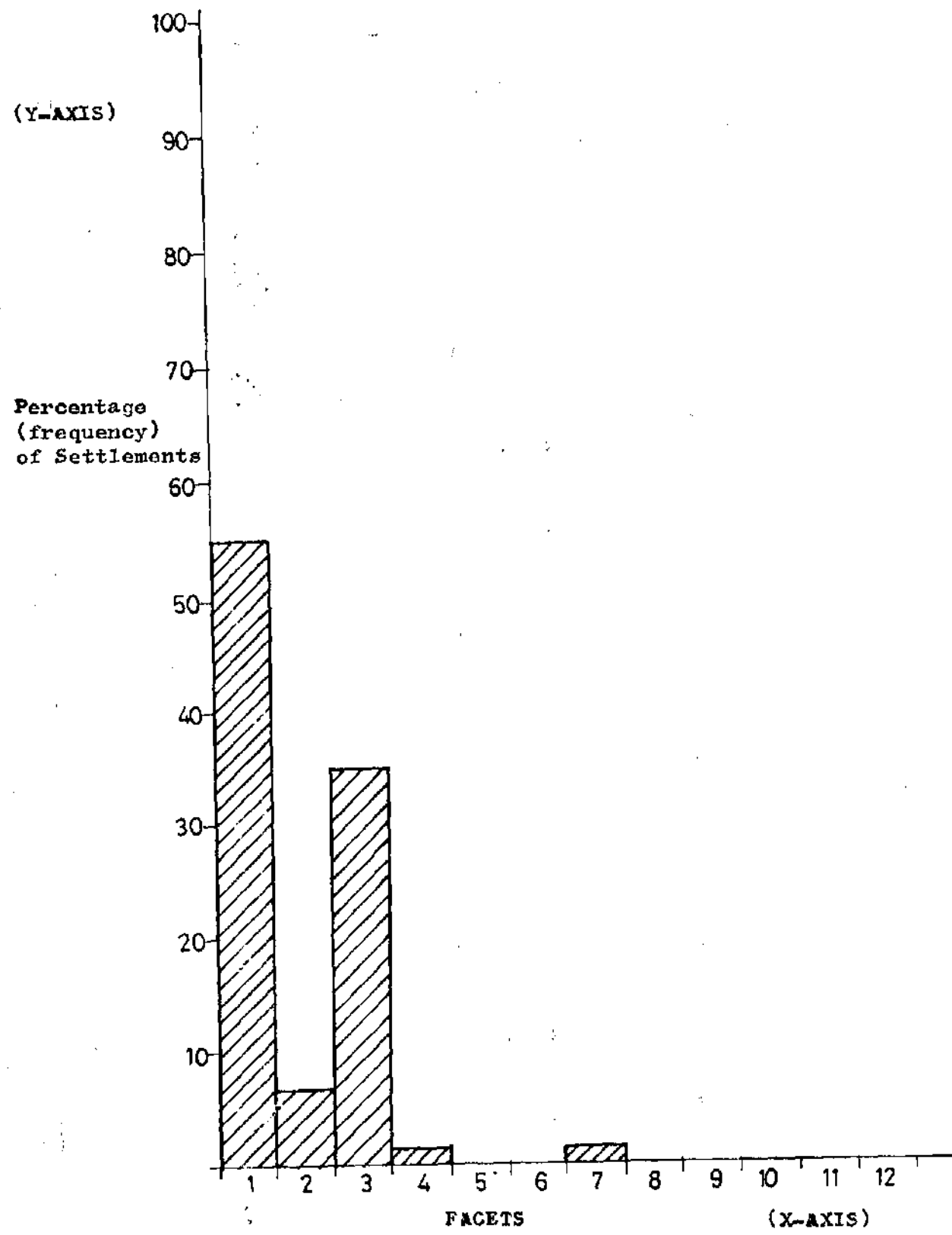
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ERROR ESTIMATES IN DETERMINING SAMPLE SIZE APPENDIX I

| PERCENTAGE OF<br>TOTAL AREA | CLASSIFICATION<br>CODE | TOTAL NO OF<br>DOTS IN<br>SAMPLE | AREA/km <sup>2</sup><br>(1) | 1504<br>(2)          | 3009<br>(4)          | 4513<br>(6)         | 6017<br>(8)         | 7521<br>(10)       |
|-----------------------------|------------------------|----------------------------------|-----------------------------|----------------------|----------------------|---------------------|---------------------|--------------------|
| 1.207                       | 11                     | 39                               | 9.080                       | (22.862)<br>28.489   | (16.163)<br>19.058   | (13.198)<br>15.065  | (11.430)<br>12.749  | (10.223)<br>11.202 |
| 0.959                       | 12                     | 31                               | 7.214                       | (25.680)<br>32.556   | (18.155)<br>21.779   | (14.824)<br>17.215  | (12.839)<br>14.569  | (11.483)<br>12.800 |
| 1.177                       | 21                     | 38                               | 8.854                       | (23.154)<br>28.909   | (16.370)<br>19.339   | (13.367)<br>15.286  | (11.576)<br>12.937  | (10.354)<br>11.367 |
| 0.712                       | 23                     | 23                               | 5.356                       | (29.841)<br>38.694   | (21.097)<br>25.885   | (17.226)<br>20.461  | (14.919)<br>17.316  | (13.343)<br>15.214 |
| 29.133                      | 31                     | 941                              | 219.153                     | (3.941)<br>4.495     | (2.786)<br>3.007     | (2.275)<br>2.377    | (1.970)<br>2.012    | (1.762)<br>1.767   |
| 56.378                      | 32                     | 1821                             | 424.104                     | (2.222)<br>3.065     | (1.571)<br>2.050     | (1.283)<br>1.621    | (1.111)<br>1.372    | (0.994)<br>1.205   |
| 0.031                       | 33                     | 1                                | 0.233                       | (143.5)<br>238.403   | (101.453)<br>159.483 | (82.841)<br>126.061 | (71.744)<br>106.688 | (64.171)<br>93.737 |
| 2.384                       | 34                     | 77                               | 17.934                      | (16.17)<br>19.197    | (11.432)<br>12.842   | (9.334)<br>10.151   | (8.083)<br>8.591    | (7.231)<br>7.548   |
| 0.062                       | 35                     | 2                                | 0.466                       | (101.454)<br>159.483 | (71.727)<br>106.688  | (58.568)<br>84.330  | (50.723)<br>71.371  | (45.368)<br>62.706 |
| 4.025                       | 41                     | 130                              | 30.278                      | (12.339)<br>14.168   | (8.724)<br>9.478     | (7.123)<br>7.492    | (6.169)<br>6.341    | (5.518)<br>5.571   |
| 3.932                       | 51                     | 127                              | 29.578                      | (12.490)<br>14.362   | (8.830)<br>9.608     | (7.210)<br>7.594    | (6.244)<br>6.427    | (5.585)<br>5.646   |

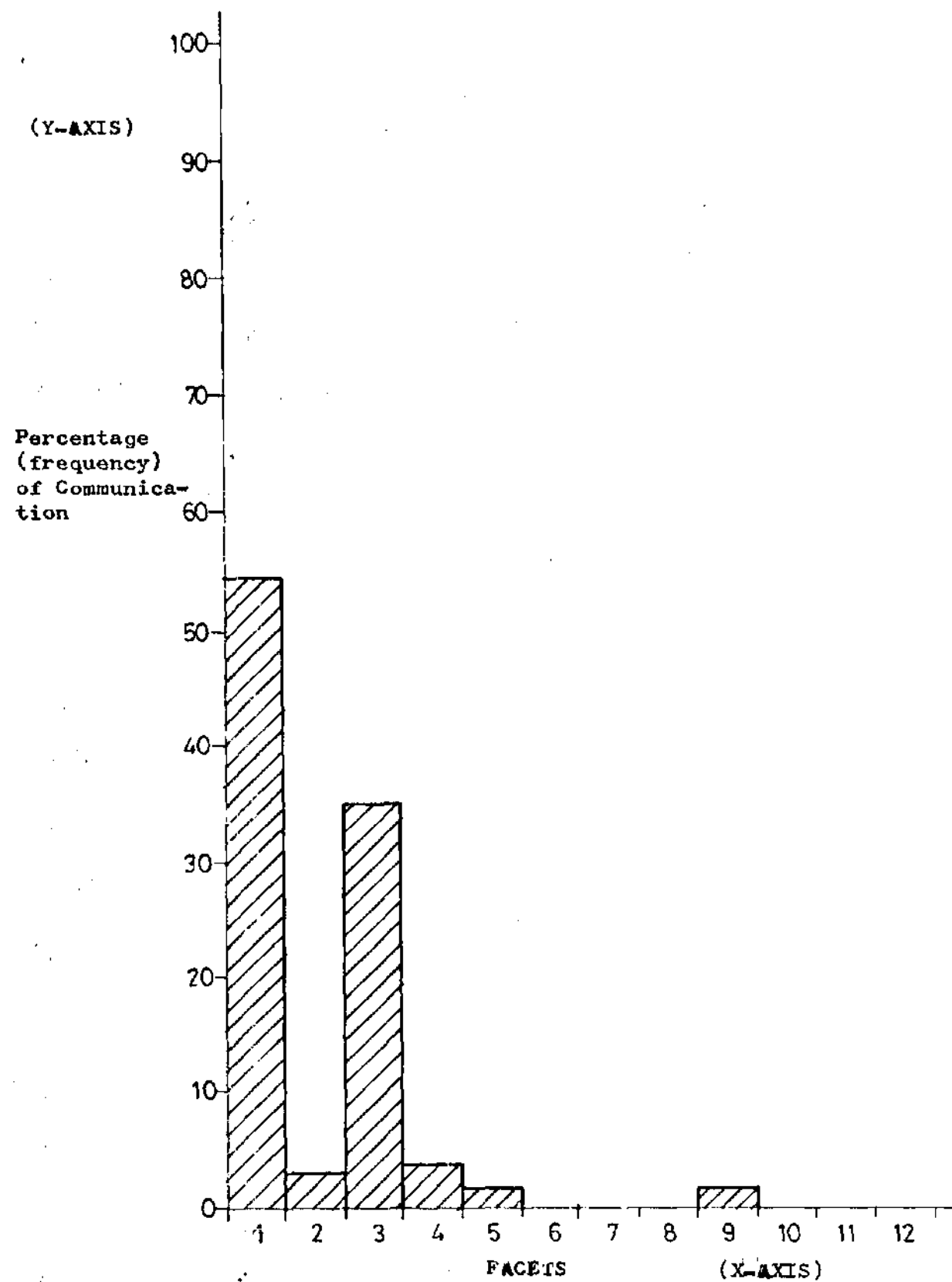


SCALE

Y-AXIS: 1 cm represents 5% of Settlements

X-AXIS: 1 cm represents one category of Facets

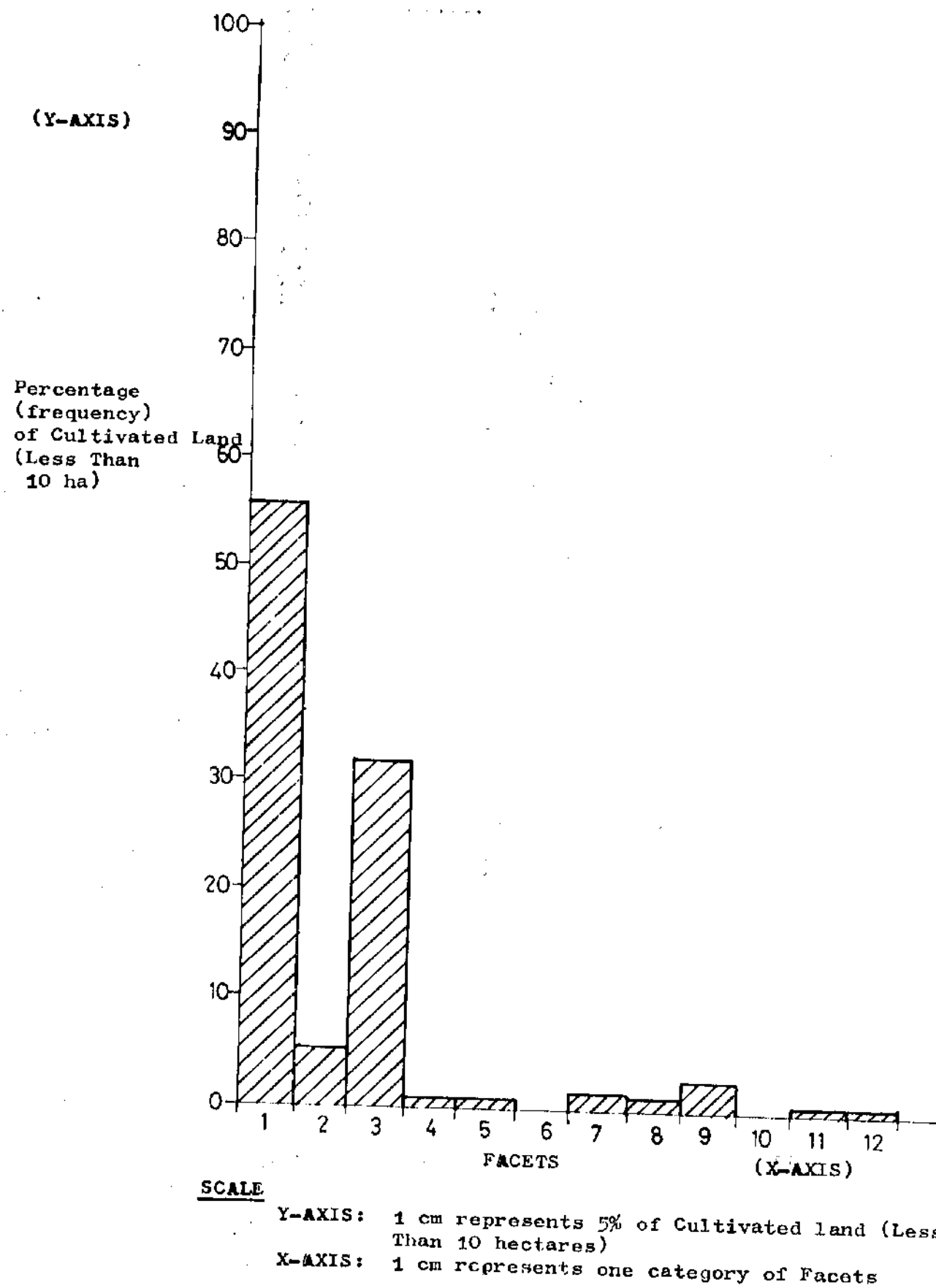
APPENDIX 2: RELATIONSHIP BETWEEN SETTLEMENTS AND FACETS



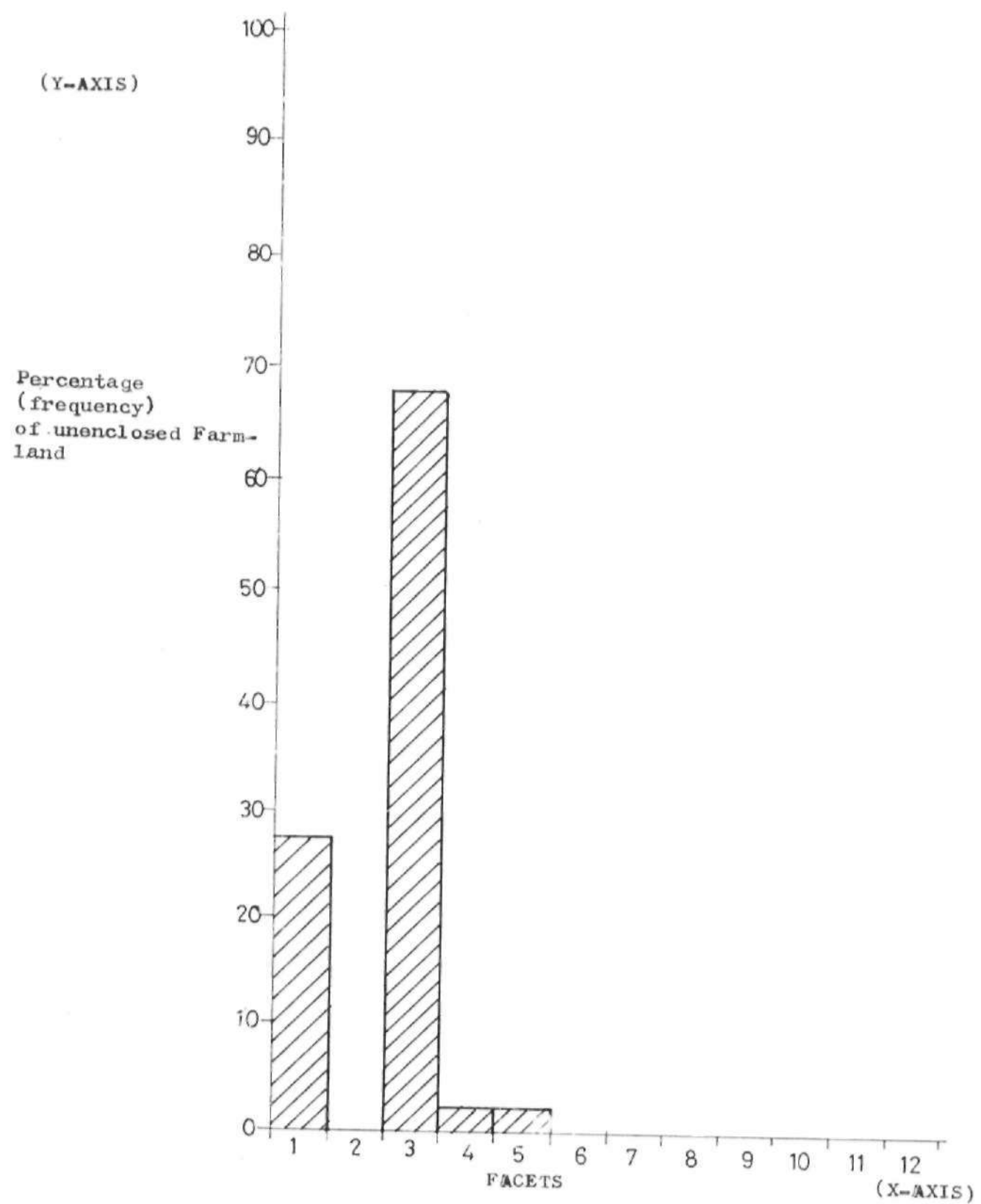
SCALE

Y-AXIS: 1 cm represents 5% of Communication  
X-AXIS: 1 cm represents one category of Facets

APPENDIX 3: RELATIONSHIP BETWEEN COMMUNICATIONS AND FACETS



APPENDIX 4: RELATIONSHIP BETWEEN CULTIVATED LAND (<10 ha.) AND FACETS

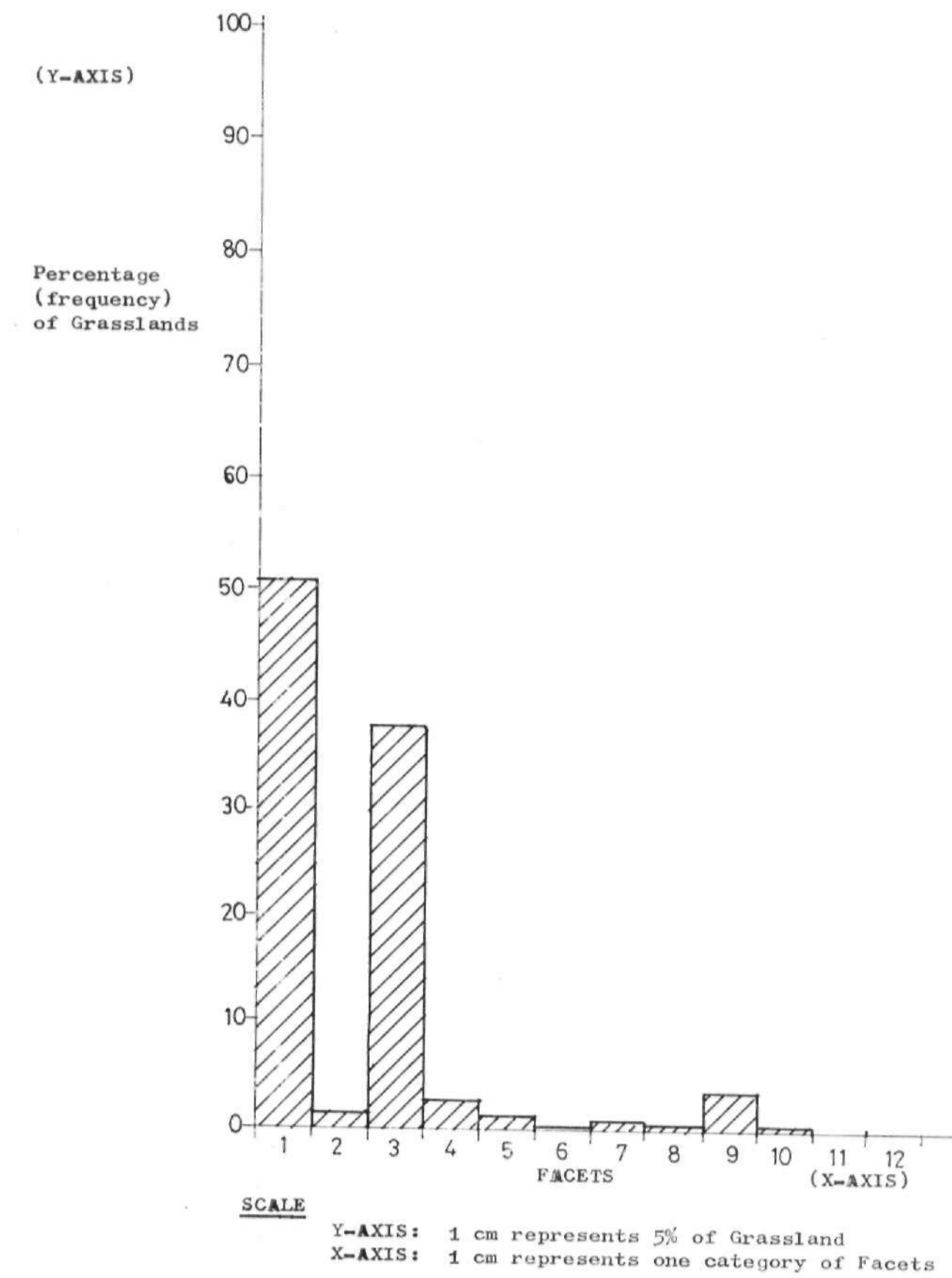


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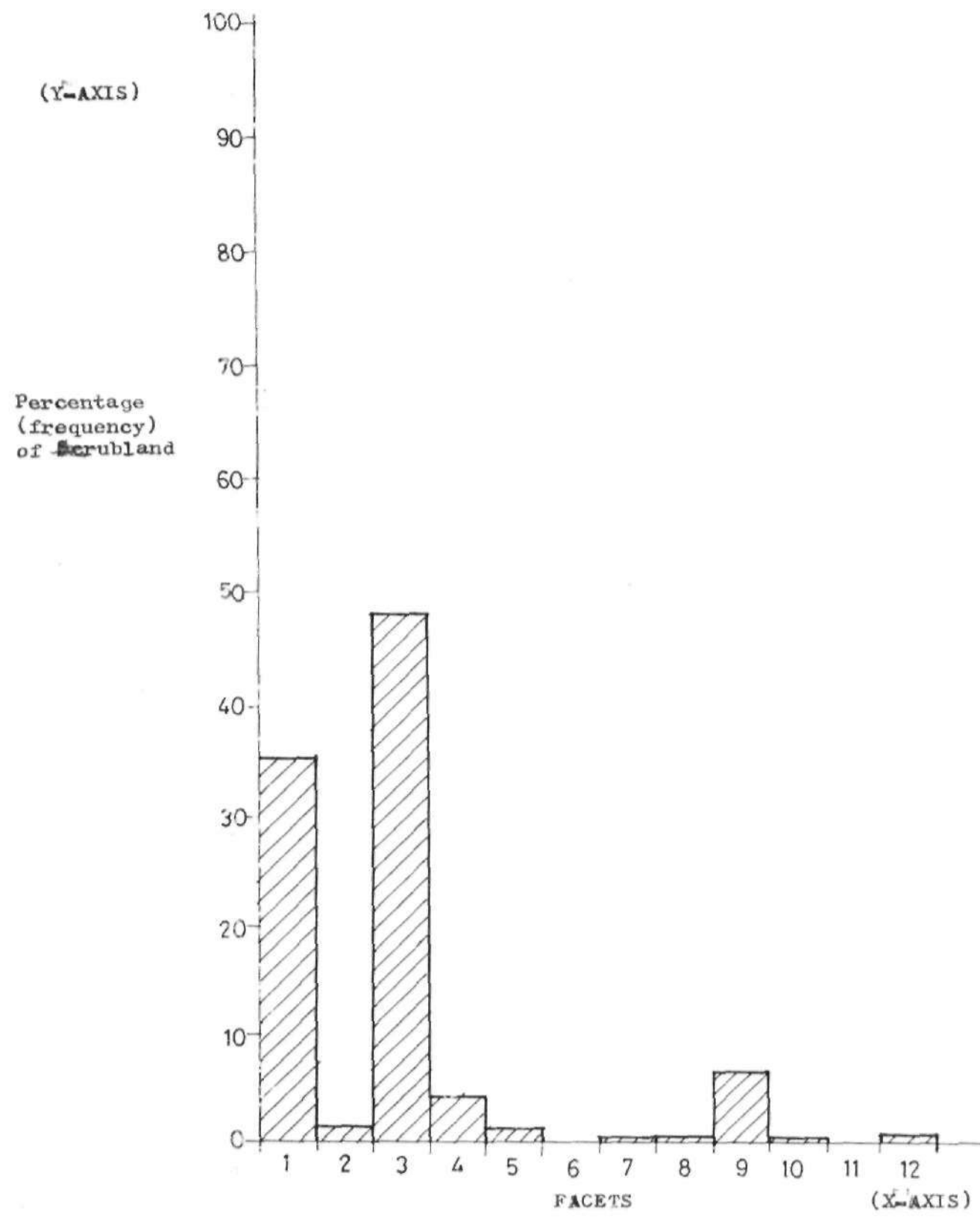
Y-AXIS: 1 cm represents 5% of unenclosed farmland

X-AXIS: 1 cm represents one category of Land Facets

APPENDIX 5: RELATIONSHIP BETWEEN UNENCLOSED FARMLAND AND FACETS

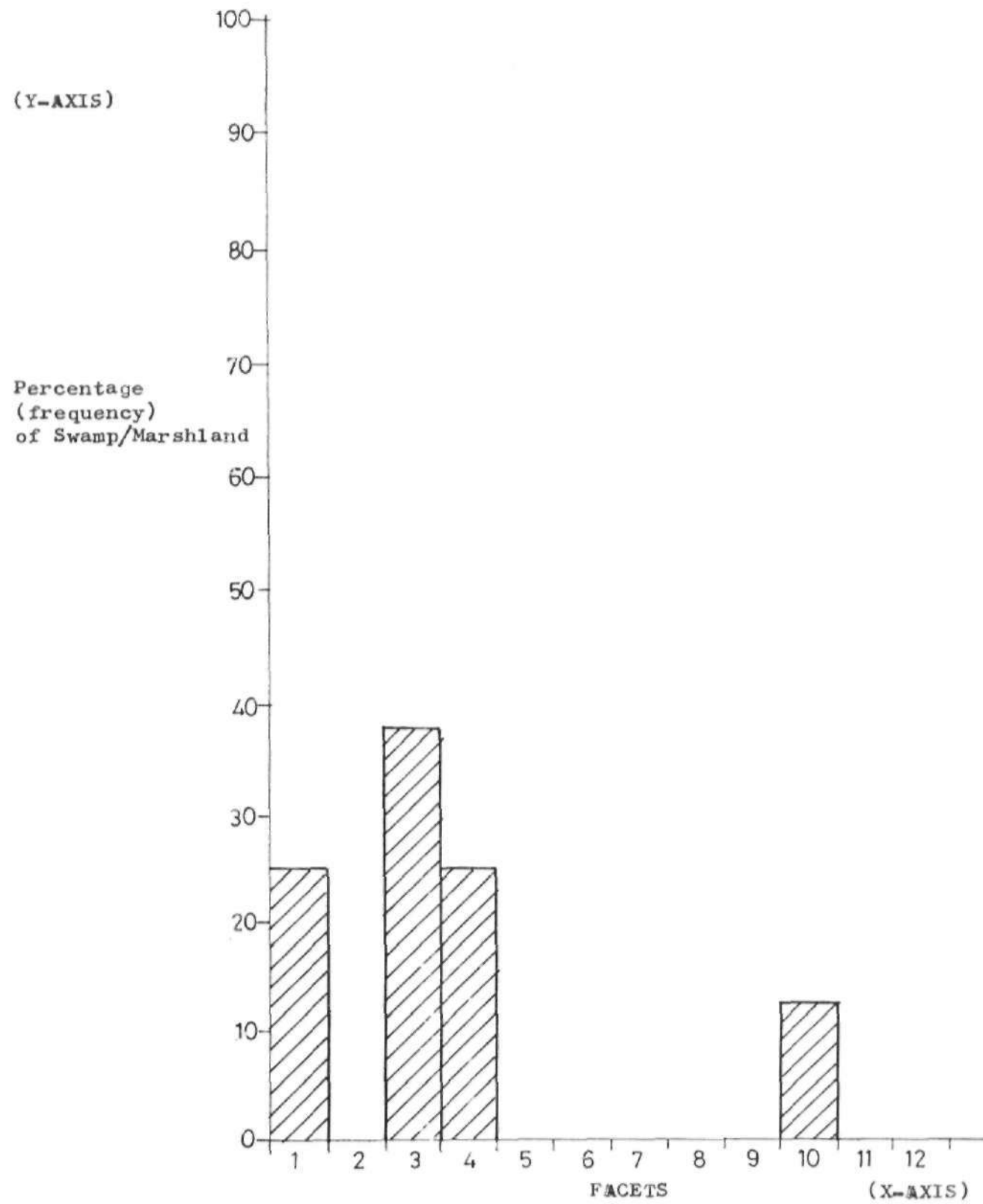


APPENDIX 6: RELATIONSHIP BETWEEN GRASSLANDS AND FACETS



SCALE Y-AXIS: 1 cm represents 5% of Scrubland  
X-AXIS: 1 cm represents one category of Facets

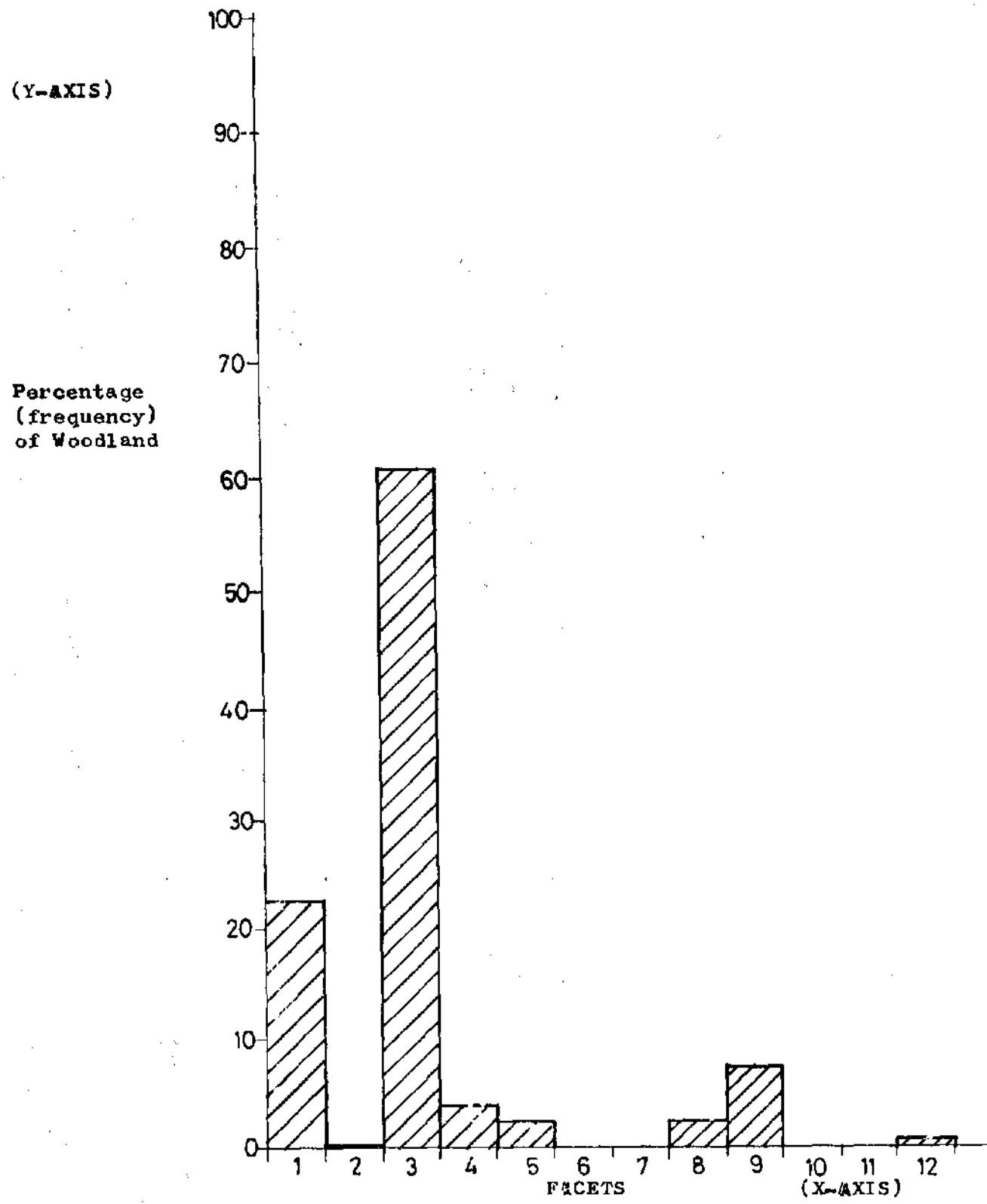
APPENDIX 7: RELATIONSHIP BETWEEN SCRUBLAND AND FACETS



SCALE

Y-AXIS: 1 cm represents 5% of Swamp/Marshland  
X-AXIS: 1 cm represents one category of Facets

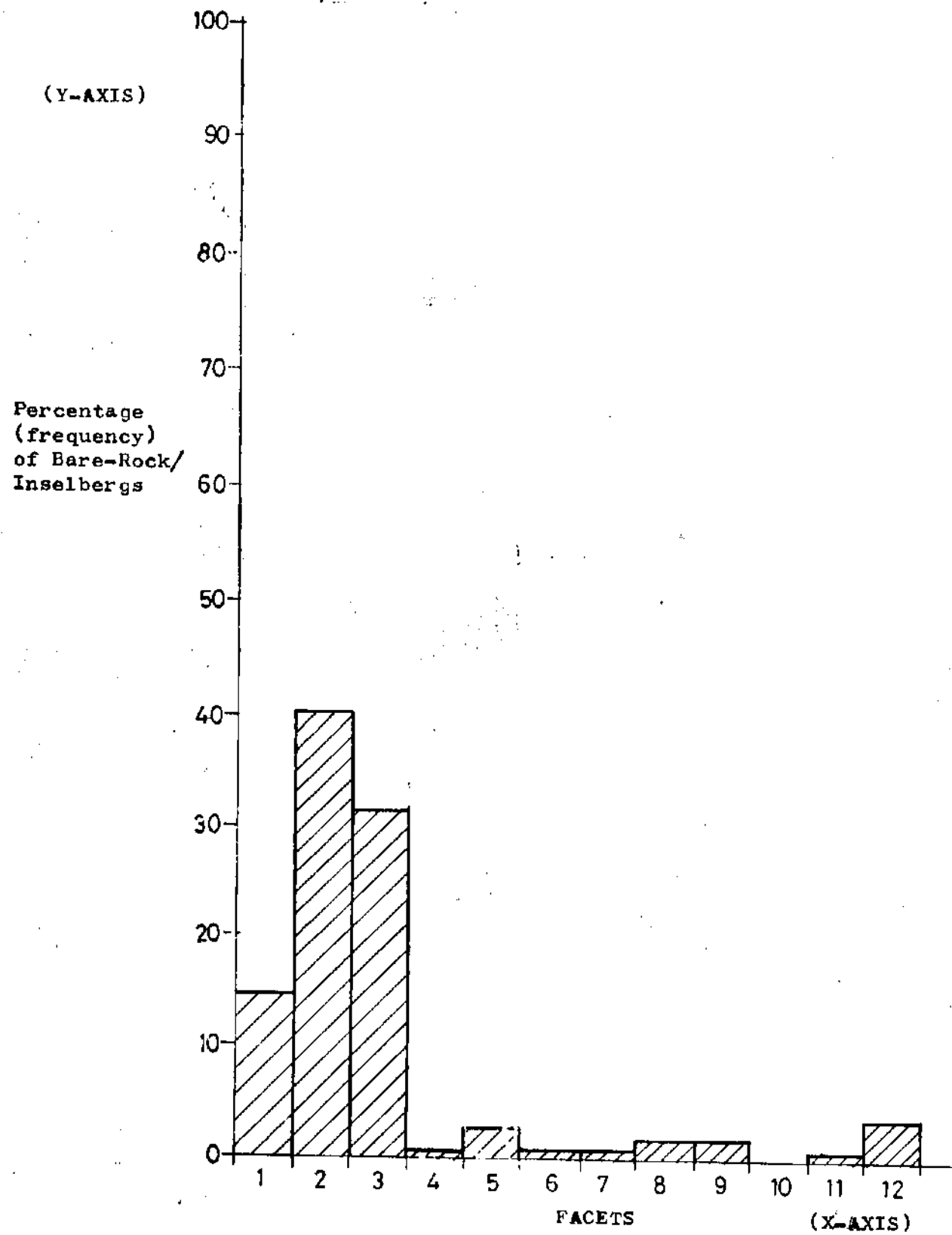
APPENDIX 8: RELATIONSHIP BETWEEN SWAMP/MARSHLAND AND FACETS



SCALE

Y-AXIS: 1 cm represents 5% of Woodland  
X-AXIS: 1 cm represents one category of Facets

APPENDIX 9: RELATIONSHIP BETWEEN WOODLAND AND FACETS

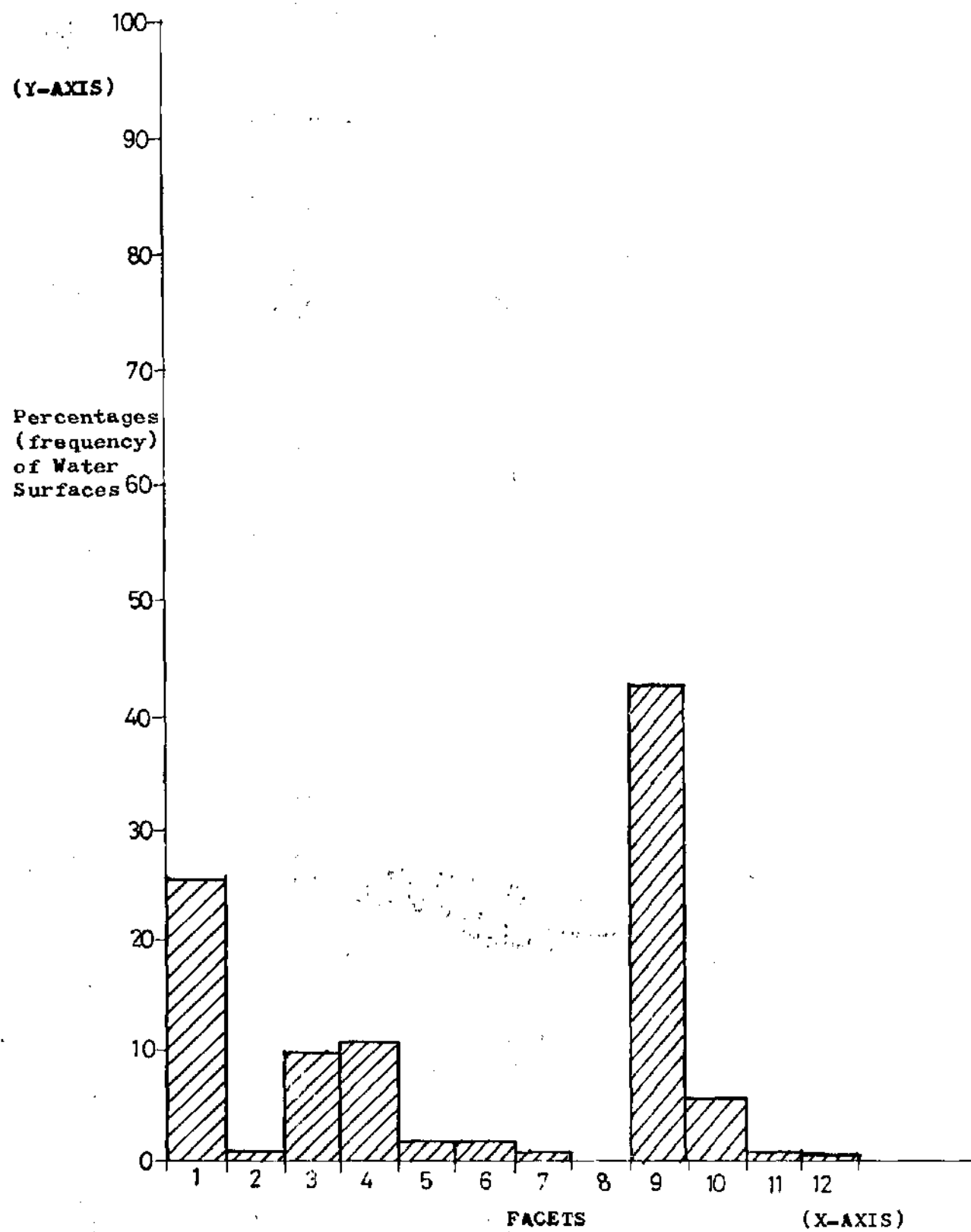


SCALE

Y-AXIS: 1 cm represents 5% of Bare-rock/  
Inselbergs

X-AXIS: 1 cm represents one category of Facets

APPENDIX 10: RELATIONSHIP BETWEEN BARE-ROCK/INSELBERGS AND FACETS



SCALE

Y-AXIS: 1 cm represents 5% of Water Surfaces  
X-AXIS: 1 cm represents one category of Facets

APPENDIX 11: RELATIONSHIP BETWEEN WATER SURFACES AND FACETS