USE OF AERIAL PHOTOGRAPHS IN IDENTIFYING AND MAPPING LAND DEGRADATION TYPES IN THE KUBANNI BASIN, ZARIA

BY

KYARI JOHN DIYA

BSc(Hons) AHMADU BELLO UNIVERSITY, (A.B.U.) ZARIA- NIGERIA

PGDLS (Land Surveying), A.B.U. Zaria, NIGERIA

PGD (Engineering Geology), ITC, HOLLAND

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL,
AHMADU BELLO UNIVERSITY, ZARIA NIGERIA.

IN PARTIAL FULFILLMENT OF THE AWARD OF THE
MASTER OF SCIENCE DEGREE (MSc), GEOGRAPHY.

DEPARTMENT OF GEOGRAPHY,
FACULTY OF SCIENCE
AHMADU BELLO UNIVERSITY, ZARIA-NIGERIA.

JUNE, 1995.

DECLARATION

I, John Diya Kyari do hereby declear that this Thesis has been written by me and that it is a record of my research work. It has not been presented in any previous application for the the award of any higher degree. All quotations are indicated and the sources of information used in the review or in support of my arquements are dully acknowledged in the references.

John D. Kyari

June 1997

Date

CERTIFICATION

THIS THESIS ENTITTLED "USE OF AERIAL PHOTOGRAPHS IN IDENTIFYING AND MAPPING LAND DEGRADATION IN THE KUBANNI BASIN OF ZARIA" BY J. D. KYARI, MEETS THE REGULATIONS GOVERNING THE AWARD OF MASTER OF SCIENCE DEGREE OF AHMADU BELLO UNIVERSITY, ZARIA. IT IS APPROVED FOR CONTRIBUTION TO KNOWLEDGE AND LITERACY PRESENTATION.

DEPARTMENT OF GEOGRAPHY,
AHMADU BELLO UNIVERSITY,
ZARIA-NIGERIA.

DR A. L. BELLO
SUPERVISOR — DATE 18/12/97

DR I. A. JAIYEOBA
SUPERVISOR — DATE 13/12/97

DR D. O. OGBONNA
HEAD OF DEPARTMENT — DATE 13/12/97

PROF. J. Y. OLAYEMI
DEAN OF POSTGRADUATE SCHOOL — DATE 12/6/98

DEDICATION

THIS WORK IS DEDICATED TO MY LATE FATHER, Eng. KYARI DIYA AND TO MY BELOVED CHILDREN, GLORIA, SALVATION, AND STEPHEN. THANKS BE TO GOD FOR HIS LOVE UPON US ALL, Amen.

ACKNOWLEDGEMENT

May the grace of our Lord and Saviour Jesus Christ, the love of God, and the sweet fellowship of the Holy Spirit, abide with us all: Amen.

Grateful acknowledgement is due to everyone who might have contributed in any way toward the successful completion of this thesis.

My indebtedness goes first to our Lord Jesus Christ for His devine sustenance and power bestowed upon me during the course of this work.

I owe much gratitude to all the staff ofmy previous department at the ITC, Enschede-The Netherlands, for their untiring effort in training me especially for the skills and knowledge in computer managememt in Remote Sensing and the GISs. My field experience owe tribute to Prof. Guerricchio, A. of the University of Calabria (Rende, Cosenza), Italy; for his intellectual contribution during my field-work in the Basilicata region, Italy.

My thanks also go to Dr. A. L. Bello and Dr. I. A. Jaiyeoba for their enduring effort in the supervision of this thesis. I am grateful to both of them and indeed, the entire members of the postgraduate committee of the department of Geography.

Mr. Kayode and the staff of the Surveying department of this University were very kind and helpful to me. All the air

photos and tools for the analysis were obtained from their department.

Also appreciated is the expert advice of Dr. S. Patrick of the Department of Geography, Bayero University, Kano. My due regards also go to Prof. I. B. Osazuwa of the Physis department,A. B. U. Zaria. and Mal. Bello of the Cash office (I.A.R), A. B. U. for allowing me the use of their computers.

Finally, I sincerely wish to express my gratitude to Prof. D. O. Ogbonna of the department of Geography (ABU, Zaria) for his moral support and pieces of advise for which he gave me during the entire process of writing this thesis. Surely goodness and mercy shall follow me all the days of my life, and I shall dwell in the House of the Lord, forever and ever: Amen.

ABSTRACT

This work is about the use of aerial photographs in identifying and mapping land degradation in the Kubanni basin of Zaria. Aerial photographs of the panchromatic (black and white) type at the scales 1:40,000 to 1:15,000 were used, including some topographic and geological maps of the study area. These photo series were those taken between 1965 and 1980. Analysis of these photos were based on the techniques of photogrammetry and photo-interpretation.

The aerial photographs were interpreted by the use of some photogrammetry tools which included pocket and mirror stereoscopes, Parallax Bar, Levels, transperent papers, pens and pencils, and rulars. The map interpretation was done in the laboratory, where several photographs were analized and compeared for verification one to the other. A brief field checks was carried out in order to update the interpretation as well as verifying certain features of the terrain. The final maps (land degradation and TMUs), were drawn from the photo-mosaics established from interpreted photo-stereograms. Analysis centred on some terrain mapping attributes, including morphology, slopes, drainage and surface cover characteristics. These terrain attributes formed key elements influencing processes of land degradation. Land dagradation types were identified and mapped through their photo characteristics such as tone, pattern, texture, molting, shape, size, shadow, site,

and situation.

These land degradation were found to be of complex erosion forms and including gullies, rills, sheet wash, debris falls, slumps, erosional scarps, and badland features. It is one's view that the origin of land degradation in the basin can be attributed to increased human activities such as agricultural and construction work, not to overemphasise other factors that are hydroclimatical in nature.

TABLE OF CONTENTS

Page

Tittle Sheet---------- i

Declaration---------- ii

Certification---------- iii

Dedication---------- iv

Acknowledgement---------- v

Abstract----------vii

Table of contents---------- ix

List of Tables---------- xii

List of Figures---------- xiii

CHAPTER ONE

BACKGROUND TO THE STUDY

1.1 Introduction---------- 1

1.2 Statement of the Problem---------- 2

1.3 Aim of the study---------- 3

1.4 Objectives---------- 3

1.5 Justification for the study---------- 4

1.6 Remote Sensing (RS) and Geographic Information Systems (GIS)---------- 5

1.7 Some Definitions---------- 10

1.8 Photo-Terrain Characteristics---------- 13

CHAPTER TWO

THEORETICAL FRAMEWORK AND RELATED LITERATURES

2.1 Theoretical Framework---------- 18

2.2 Review of some relevant Literatures---------- 19

CHAPTER THREE

THE STUDY AREA

3.1 Introduction---------- 24

3.2 Physical Background---------- 24

3.2.1 Geology and Landforms---------- 25

3.2.2 Relief and Drainage---------- 27

3.2.3 Soils---------- 28

3.2.4 Climate and vegetation---------- 29

3.3 Human background---------- 30

3.3.1 Land Use---------- 30

3.3.2 Other Economic Activities---------- 32

3.3.3 Infrastructural Development---------- 33

3.3.4 Population and demographic characteristics------ 34

CHAPTER FOUR

MATERIALS AND METHODS

4.1 Introduction---------- 36

4.2 Materials (Maps and Aerial photograhs)---------- 37

4.2.1 Selection of Materials (maps and air-photos)----- 40

4.2.2 Air-Photo Scales---------- 42

4.2.3 Stereogram Photo Series---------- 43

4.3 Methods (Air-photo Interpretation)---------- 53

4.3.1 Tools of Photo Interpretation---------- 53

4.3.2 Orientation of Stereoscopic Pair of Air-Photos--- 53

4.3.3 Determination of Air Photos Scale---------- 54

4.3.4 Height Measurements using a Parallax Bar--------- 55

4.3.5 Linear Measurements---------- 57

4.4. Mapping---------- 58

4.4.1 Introduction---------- 58

4.4.2 Mapping Terrain Attributes---------- 58

4.4.3 Identification and Mapping Land Degradation Types- 63

4.5 Laboratory Work---------- 69

4.6 Field Work---------- 70

LIST OF TABLES

TABLES:

1.1 Table with minimum sizes of objects to be determined, recognised and identified for various condition of contrast with their background in various types of images---------- 9

3.1 Land Use in the Kubanni Basin---------- 32

5.1 Table-Legend of the TMUs---------- 75

5.2 Slope classes and Associated Land Degradation types---------- 90

6.1 Land Use types and associated types of Land Degradation in the Kubanni basin---------- 95

6.2 Relationship between land uses and physiology in the Kubanni basin---------- 96

6.3 Land Use categories in the Kubanni basin from 1965 to 1995---------- 96

LIST OF FIGURES

FIGURES:

3.1 The Study Area: Kubanni Basin of Zaria and Environs---------- 26

4.1 Schematic Plan of the Study---------- 39

4.2 Sketch map showing the Sampled Areas and their photo series coverage---------(folded) Back cover

4.3(a-g) Stereograms of the Sampled Areas---------- 46

5.1 Terrain Mapping Units(TMUs) in the Kubanni basin (folded) ----------Back cover

5.2 Land Degradation and susceptibility Map (folded) ----------Back cover

CHAPTER 1

B A C K G R O U N D

1.1 INTRODUCTION

This research is about the application of aerial photographs in identifying and mapping the nature and types of land degradation in the Kubanni basin Samaru-Zaria, Nigeria.

Nowadays there is the feeling that land is increasingly being degraded. Conferences such as the 1992 Earth Summit at Rio-de Jainairo (Brazil) and scholars have accumulated tons of literature, centred on deforestation, soil erosion, flooding and desertification (Soeter, 1993).

Land degradation is used here to mean "the general lowering of the surface of the land through erosive processes by running water and wind. The removal of vegetation cover through human socio-economic activities are seen as factors that intensify land degradation (Robert, et al, 1984). Thus, the process is a combined function of man, animal, nature of hydrological factors (i.e. the interactions between meteorological characteristics and ecologically unbalanced human actions, Joachim, 1993). Land degradation develops in various ways ranging from sudden to gradual removal of vegetation cover by man and animal life manifesting in combined geomorphic processes, slope instability, dissection by running water and exhaustion of the soil.

There is hardly any region in the world where land is not suffering from degradation. The degree and repercussions of land degradation may vary spatially. In order to make consented efforts to combat its menace, the United Nation Education, Scientific and Cultural Organization (UNESCO) and the International Institute for Aerospace Surveys and Earth Sciences (ITC - Netherlands) in 1993 embarked on a joint programme which uses Geo-Information Systems (GISs) for environmentally Sound Management of natural resources first in the Andean environment. Also, many agencies such as the Institute Geographic Augustine Codezzi IGAC-Bogota and countries like Italy, Venezuela and Bangladesh have adopted the programme strategies (the UNESCO-ITC programme of 1993) for the study, mapping and documentation of land degradation and environmental hazards monitoring (Rangers and Robert, 1993). These are commendable first steps for redressing environmental degradation.

1.2 STATEMENT OF THE PROBLEM

Literature is full of traditional methods of studying, mapping and assessing various types and degree of land degradation. Practically all of them involve being in contact with the field, surveying, mapping, levelling and measuring using conventional survey instruments and equipment. For example, Ologe (1972); Bello (1973), worked within the upper Kubanni basin identifying and mapping gully erosion and

erosional scarps using measuring equipments such as tapes, Levels, ranging poles and others. Their studies are limited in areal extent because (i) there is a limit to how much time can be spent in covering every square meter of a basin if one is working on a G-Scale lower than 8, (ii) it is laborious and painstaking and (iii) the amount of financial resources and manpower required are enormous. However, with Geo-information systems (GIS) and other advances in earth mapping technology, such as the use of Landsat Imagery, it is possible to have access to information on the nature of the areas that cannot be reached easily. This is the focus of the present study, that is the application of remote sensing(RS) in identifying and mapping types of land degradation in the Kubanni basin.

1.3 AIM

The aim of the study is to apply aerial photographic Remote Sensing technology to identify and map different types of land degradation in the Kubanni basin.

1.4 OBJECTIVES

The objectives of the study are to:

1. identify and classify types of land degradation in the Kubanni basin using aerial photographs;

2. prepare Terrain Mapping Units (TMUs) and describe the evolutionary characteristics of the physical terrain in the basin.

3. prepare spatial distribution map of the types of land degradation recognised in (1) above; including areas susceptible to degradation,

1.5 JUSTIFICATION FOR THE STUDY

Land degradation, especially by run-off and mass movement, is a major threat to settlements, roads development and agricultural land management and conservation in Nigeria, particularly within the Kubanni basin of the Samaru-Zaria region. The severe soil erosion and flowslides here is the inevitable results of a combination of complex factors ranging from nature of relief especially slope characteristics, hydro-meteorological to soil characteristics (Ologe, 1972; Bello, 1973; Thorp, 1971). Changes in land use in the recent past have certainly intensified processes of degradation that were already set in motion (Smith, 1970). Smith demonstrated that man has exercised strong influence over the vegetation cover characteristics in the recent past in the Kubanni, through deforestation, bush fires, over-grazing and fire-wood felling. Indeed, recent changes in land use practices involving increased mechanization and field sizes appear to have had considerable impact in some areas more than in others especially in the traditional forms of human subsistence farming. The continuous loss of crops during high flood to surface runoff in the rainy season (especially during the 1988 rainy season), and the increasing slope instability justifies

the need for further studies in the basin. In this study the application of RS techniques is expected to provide detailed and present state of features of the terrain, their spatial distribution and assessments of the nature of land degradation in the basin. Aerial extent of most geomorphic processes are better assessed on imagery than on field measurements alone, hence the need for the application of RS techniques whenever and wherever possible (Kyari, 1994).

Many soil conservation projects need maps indicating areas of different severity of soil erosion. Such maps will help in determining areas for priority attention and/or treatments of land or environmental degradation. This is what the present study hopes to provide as already stated in objective (3) above.

1.6 REMOTE SENSING(RS) AND GEOGRAPHIC INFORMATION SYSTEMS (GISs) IN LAND DEGRADATION

This section describes in brief the link between Remote Sensing and Geographic Information Systems (GIS) and their uses for land degradation studies.

Remote Sensing (RS) can be defined as the collection of information about an object by a recording device that is not in physical contact with it (Robert L. et al, 1984). The term is strictly used to mean methods that record reflected or radiated electromagnetic energy. The technique employs devices such as cameras, infrared (IR) detectors, microwave

frequency receivers, and radar systems. Any of these pieces of equipment is able to code information about large areas and store in a way that it can be retrieved later. Hence the phase remote sensing. Imagery of objects can be decoded to obtain various kinds of information that can be use to provide maps of different subjects.

Among the different techniques of RS in use, aerial photographs are preferred and employed in this study. Other techniques such as Landsat, radar and SPOT imageries could have been used for comparison purpose but are limited for this present study. Detailed discussions of the advantages of aerial photograph technique over others are given in chapter 4. It is suffice to say that it has high resolution and geometric qualities for quantitative analysis in the study of land degradation and mapping. There is also the added advantage that aerial photography can be flown at any desired scale to suit specific requirements, making them advantageous in specific subject matter. It should be noted that reliable identification of cultural features as well as natural phenomena, requires a ground resolution of 2 to 3 m per pixel. If these features are to be derived from sensor data, the pixel size should be in the order of 1 to 2m. Conversely, this is what makes it impossible for many erosion features to be identified from imagery of present day electro-optical sensors, including SPOT (Naithani, 1990). Besides, where high-performance cameras with (FMC) devices are used mapping of

individual features and other details are enhanced because of the use of lower sensitivity films.

Table 1.1 illustrates the minimum Ground Cell Resolution of the different types of imageries produced by different sensor devices. Indeed the aerial photography, especially those of panchromatic (black/white) films, stands out as a better alternative to any other. For example, for a Landsat (MSS) imagery to be detected it requires a ground resolution cell (GRC) of at least 320 meters. On TM Landsat the GRC needed is at least 120m to detect an object. While SPOT (XS) have GRC OF 80m; SPOT (Pan) will need a GRC of about 40m; but on an aerial photo (AP) at the scale 1:100,000 only a GRS of 40m is needed.

G.I.S. can defined as any manual or computer-based device(s) and procedures used to store, retrieve and manipulate geographically referenced data (Aronoff, 1993). The system involves large data input, management (storage and retrieval), manipulation/analysis; and output in different ways. However, a computer-based GIS is a powerful tool for handling large volume of data in digital format that may not otherwise be possible. Besides, it aids easy retrieval and data may be analysed and manipulated for display in one piece at greater speeds and lower cost than any other manually operated geographic information. In this study it is not possible to use computer-based GIS for lack of equipment and limited finances. Surely application of computer based GIS in

land degradation mapping is enormous ranging from the possibility of super-imposition of a set of factors maps on others and to analyze them in combination with a type of land degradation occurrence map. Also, the combination of maps (map crossing) enables the earth scientist to evaluate the spatial variability of the natural environment and to extrapolate the critical combination of factors found in the analytical phase. Complex computation techniques, necessary in the map crossing of several factor maps and for table calculations, are feasible by the use of a mathematical co-processor. GIS enables the rapid preparation of table showing the area of different factor combinations. Even where most of the available parameter maps are not of the same scale, information or maps to be overlaid can be matched regardless of their original scale by simple manipulations. However it may require statistical analysis of large quantities of variable and algorithmic complexities.

In this study all procedure for data manipulation, storage, and retrieval are done manually. Aerial photographs would be analysed using simple tools such as stereoscopes, parallax bar, rulers, pencils and tracing papers. Interpretations and mapping would be based on manual tracing out of identified attributes/features of land.

Table 1.1: Table with the minimum sizes of objects to be detected, recognized and identified for various condition of contrast with their background in various types of imagery. Values should only be used as an indication of the order of magnitude

		Landsat MSS	Landsat TM	Spot XS	Spot Pan	A.P.*) 1:100 000	A.P.*) 1:50 000	A.P.*) 1:25 000	A.P.*) 1:10 000
GROUND RESOLUTION CELL SIZE		80m	30m	20m	10m	1m	0.5m	0.25m	0.1m
HIGH CONTRAST	Detection	320m	120m	80m	40m	4m	2m	1m	0.4m
Feature Background	Recognition	560m	210m	140m	70m	7m	3.5m	1.8m	0.7m
	Identification	800m	300m	200m	100m	10m	5m	2.5m	1m
LOW CONTRAST	Detection	1600m	600m	400m	200m	20m	10m	5m	2m
Feature Background	Recognition	2400m	900m	600m	300m	30m	15m	7.5m	3m
	Identification	3200m	1200m	800m	400m	40m	20m	10m	4m

*) Without Forward Movement Correction.

(After Rangers et al., 1992)

degradation. This is discussed in detail in chapter 5. Suffice it to say here, that stereo-pair photographs would be interpreted on tracing papers and thereby photo-mosaics are constructed and from which the final maps are drawn.

An attempt is made to perform a manual map crossing of the land use types and degradation types/Terrain Units (TMU). This is achieved by first carrying out detailed interpretation/mapping of the individual attribute maps on tracing paper thereafter they are laid upon one another for final mapping.

1.7 SOME DEFINITIONS

Some terms are used here with specific meanings, different from the way they are conventionally used. Hence, it is necessary to define them as used in this study.

1. Aerial photograph (air photo): A photograph of parts of the earths' surface taken from the air. It is usually taken from a moving air-craft in a systematic pattern and at a desired attitude. A mosaic of such air photos is often made and used for mapping land divisions and physical attributes e.g. geology, soil, vegetation, topography of the area;
2. Brightness and Contrast: Brightness (as applied to remote sensing) refers to attribute of sensation by which an observer is aware of differences of luminance; and contrast refers to the ratio of two adjacent scene

radiances expressed as a number equal to or greater than one;

3. Contrast Ratio: On an image, the proportion of reflectance of the brightness to darkest parts of the images;
4. Digitization: Process of converting an analog display into a digital display;
5. Digitizer: Device for scanning an analog image and converting it into numerical format;
6. Digital Terrain Model (DTM): are data commonly provided in a grid format in which an elevation value is stored for each of a set of regularly spaced positions. Each datum point represents the elevation of the grid cell in which it is located;
7. Geographic Information System (GIS): are computer-based systems that are used to store and manipulate and retrieve geographic information;
8. Imagery: a visual representation of energy recorded by remote sensing instrument;
9. Landsat: an unmanned earth-orbiting NASA satellite that transmits multispectral images in the 0.4 to 1.1 um region to the earth receiving stations. It was formally called Earth Resource Technology Satellite (ERTS);
10. Map Crossing: A process (mostly computer-based) for overlaying two or more maps of different factors, in order to calculate or derive new values or units for some

specific purposes;

11. Multispectral Scanner (MSS): an instrument (sensor) used to obtain imagery from different portions of the electromagnetic spectrum;
12. Panchromatic (film): black and white film that is sensitive to all visible wavelengths.
13. Pixel: A picture element having both spatial and spectral aspects;
14. Resolution: the ability of a remote sensing system to distinguish signals that are close to each other spatially, temporally, or spectrally. It refers to the pixel diameter (pixel diameter is the equivalent pixel size);
15. Sensor: device that receives electromagnetic radiation and converts it into a signal that can be recorded and displayed as either numerical data or an image;
16. Terrain: the character of a tract or region of the earths surface.
17. Terrain Mapping Unit (TMU): unit of a tract or region with similar characteristics such as slope, drainage and geomorphic condition. They are defined as units of land on the basis of geomorphologic origin and physiographic characteristics, lithology, morphometry and soil that can be verified on the ground (Meijerink, 1988). The TMU approach allows the identification of units with similar terrain conditions that result from the inter-

relationships between geology, landform and soil with unlimited number of legends of conventional thematic map. Quantitative, parametric or statistical description of relief, drainage, and slopes are also incorporated. On stereo aerial photographs TMU is differentiated on the basis of the following: geomorphic origin (genesis and process), specific origin within the main origin, lithology; morphometry (internal relief, valley density, slope forms, length, steepness); sub-units.

1.8 PHOTO-TERRAIN CHARACTERISTICS:

The following set of definitions relates to some special characteristics of the terrain which a photo-interpreter would need to be familiar with on photographic images. These have been used in chapter 5 and need to be emphasized. These photo characteristics are tone, pattern, texture, mottling, shape, size, shadow, (topographic) site, and situation (geographic site). A systematic study of the these characteristics will help the photo-interpreter in his classification.

1.8.1 **TONE:** the black-to-white range of a panchromatic photograph. Different prints of one photograph are not necessary equal in tonal density. Several phenomena are defined by their typical tone (e.g. a pine forest is black, a meadow medium grey, unvegetated dry sand deposit white, etc.). Reflection of sun may cause a body of water to appear white on

one photo, whereas on another photo-where there is no reflection-it appears black. Within one photo, tonal differences may occur because of random loss of light, hot-spot effects, etc.

1.8.2. **PATTERN:** the spatial arrangement of the various features in a repeated sequence and/or in a characteristic order within the interpreted area. Trees in a cultivated landscape may display a pattern (e.g. a forest reserve plantation in lines). The arrangement of vegetation in a natural landscape may indicate geomorphic conditions and features. Pure geomorphic forms may also be associated with a pattern (e.g. a sand desert with longitudinal dunes). Also drainage can be classified according to certain patterns (e.g. dendritic, parallel, etc.). Man-made features often display a pattern (e.g. buildings are often rectangular and streets in lines).

1.8.3. **MOTTLING:** a covering of spots which may be of darker or lighter tone than the main surface; they appear in an irregular pattern and are of irregular shape and size. Thin eolian sand deposits frequently display a mottled photo image. Sheetwash also may have a mottled appearance.

1.8.4. **TEXTURE:** the product of an aggregate of uniform features which are too small to be clearly discerned individually; texture is depicted as repetitions of tonal changes. Large trees appear coarse. The photo-scale affects

texture (e.g. small scales reveal finer texture). Texture differences are often indicative of the vegetation and edaphic differences which are the distinguishing attributes among geomorphic units.

1.8.5. **SHAPE:** form or topographic expression as observed in a two-dimensional photo-image. The photo-interpreter should become accustomed to identifying features by their shapes in an aerial photograph phenomena that he is already familiar with in the field. Road types can be classified by width and culture. Shapes alone do not provide sufficient information for the identification of all objects.

1.8.6. **SIZE:** the volume dimension of an object as observed in a three-dimensional photo-image. Knowing the dimensions of an object, alone, is not always enough for classification. Comparison with other known objects enables the interpreter to gauge or measure volume. Also understanding photo-scale is very important in size analysis. Note that near the edges of air-photos, displacements caused by tilt, relief and lens distortions may lead to an incorrect interpretation.

1.8.7 **SHADOW:** obscurity within the area or space from which direct rays from a light source (normally the sun) are excluded by an interposed opaque body; i.e. terrain obstruction. Shadow can obscure important phenomena which thus cannot be interpreted. Shadow facilitates three dimensional perception. The best stereo view are obtained

when the shadows fall towards the observer. When they are not, the observer may have the impression of relief reversal. Shadow makes it possible to analyze the height of an object. The position of objects casting shadows in relation to the principal point of an aerial photograph is an important consideration. Because of radial displacement, the objects themselves can obscure their own shadow.

1.8.8. **SITE (TOPOGRAPHIC):** the position of a place with reference to the surrounding district or locality. In practice, it is the smallest unit in a system of morphologic regions influenced by a number of "site factors". In principle, the highest point of a given terrain receives more precipitation and is colder than the surrounding area. Hence height differences can result in differences in the morphology of the terrain, not only by causing differences in vegetation, but also by producing differences in processes which are reflected in different landform. It must be noted also that differences in slope steepness influence (slope) processes as well as land use. Slopes exposed to the prevailing winds are different from those on the lee-ward side.

1.8.9. **SITUATION (GEOGRAPHIC):** the place, position or location of an area or region in relation to its surroundings. Zonal circumstances affect the geomorphologies not only through forms and processes but also in intensity at which these processes work. However, under the same climatic conditions, a completely different morphology can be found

where lithologic circumstances differ. Situation can be characterized both by climate and regional or local topographic and geologic circumstances. Similarly, there are zonal (local) circumstances. For example the presence of a river can result in differences in geomorphic processes and subsequent landform under the same climatic conditions. Fluvial forms and processes in a purely desert environment (where the water comes from a humid source area) demonstrate such a situation.

CHAPTER 2

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Theoretical Framework:

In many environmental management situations the most useful contribution of the geomorphologist is the provision of a terrain map. This is particularly true where information is required on the distribution of landform characteristics and soil types including operational surface processes; such maps have been used to considerable advantage for engineering, planning, and management projects. While the concept of making a terrain map is not a difficult one, the task of actually making one makes it to so.

Landforms are varied and many on the earth surface ranging from broad plains, plateaus, high hills and rugged mountain ranges to valleys and warped basins. Landform development is due to both internal and external forces. These forces are continually shaping the face of the earth. Man's influence on the development of landform can be seen through his socio-economic activities which subjects the earth's surface to constant degradation.

Land degradation varies from one region to another in accordance with the forces and processes including hydrometeological factors and influence of man and animal life.

The Kubanni basin is influenced by rapid urban sprawling, poor agricultural and land management practices and hence subjected to rapid degradation. As already stated conventional field survey may be used to map the nature of and assess the extent of the degradation. However, these conventional methods can only be used in smaller areas (its coverage is limited) and extrapolation is strenuous and may result in over simplication. Thus, better techniques are needed, hence the focus of this study which is the use of air-photo application of remote sensing (RS) techniques to identify and map land degradation and their susceptibility in the basin.

2.2 REVIEW OF SOME RELEVANT LITERATURE

Studies of land degradation in the Kubanni have been investigated but using conventional field observations over a limited area. These involved measurements of a few selected parameters, i.e. gully length and morphology (e.g. Ologe, 1972; Bello, 1973). However, similar studies elsewhere have been carried out using mapping techniques that minimize contact with the field or objects.

Smith (1970) using aerial photographs in the upper Kubanni basin demonstrated the possibility of identifying land degradation resulting from the influence of man on vegetation cover characteristics in recent past through farming activities, bush fire, overgrazing, deforestation and fire-

wood falling.

Ritchter (1978) carried out a research on soil erosion in Germany and Czechoslovakia and found that there are two types of soil erosion mapping (i) mapping of actual damages concentrating on soil damage and visible soil erosion features and (ii) mapping of potential soil erosion hazards. Ritchter based his work on the traditional field measurements and so was restricted only to areas that were accessible due to the ruggedness of the terrain. The application of RS/GIS techniques would have minimized such limitations.

Hosomura's (1993) work in Thailand is on application of remote sensing techniques (using both air photos and Satellite imageries) in assessing land cover changes. The result showed that the techniques proved quite effective as a tool especially by the use of multi-temporal images.

Keech (1978) holds the view that remote sensing can provide clear synoptic view of the distribution of factors which influence land degradation and planning information. The technique is advantageous since vast tract of land can be viewed at a glance using Satellite imagery on small scales which means great expanse of land is represented with ease on the imagery.

Damen (1991) observed that some features such as gullies, are generally more visible than rills or sheet erosion (in fact, the later may have no stereo). He further noted that indications of the presence of rills on aerial photographs are

the patterns (linear photo-tone) varying sizes (about 30cm wide), and position on the terrain. This implies therefore that such features can be mapped on air photos which is why they are preferred to satellite imagery.

Rendell (1982) working in Southern Italy measured and discovered that over 50,000km^2 of land was subjected to severe land degradation (due to soil erosion by water and mass movement especially sliding). The result is considerable damage to settlements and infrastructure. Such vast expanse of land would only be possibly covered using Remote Sensing data.

Chen, et al (1994) working in the Agri-River Basin of Basilicata, Italy, applied remote sensing and GIS techniques in assessing landslides hazards. He noted that the application of RS/GIS provide assessments of present rate of land degradation and the features of the terrain and spatial distribution of their hazards.

To demonstrate how earth mapping technology (EMT) has edge over traditional field method, Soeters, et al., (1991) confirmed that many erosion features are better recognised (using stereo pairs or triplets) on aerial photographs by their sizes, pattern and photo tone than the traditional field measurements especially in rugged topography and inaccessible areas.

Carrara, et al (1978) were able to define the hazard level of degradation in Southern Italy by using GIS together with multivariate analysis of the data sets obtained in the

field during the survey.

Examples of land degradation studies carried out in the Kubanni basin are those of Ologe (1972), Dada (1972), Bello (1973), Chaga (1989), Ahmed (1989), Bello (1991), etc.

Ologe (1972) assessed gully headscarp recession in the Kubanni basin. Gully headscarps recession were mapped in the field and with the aid of topographic maps of different dates calculated mean rates of recession of 3 gullies (i.e. 4.27 meters, 5.18m and 4.79m per annum) were obtained. He also suggested that headscarp recession were dependent on storm surface runoff. The efficiency with which material is removed from the foot of the wall and the nature of the regolith materials .such as their degree of compaction or induration were also found to be important factors of the land degradation in the basin.

Bello (1973) also worked within the same upper Kubanni basin but employed direct field measurement and survey methods for mapping erosional scarps along the main stream channel. He identified erosional scarps as important land degradation element. The erosional scarps were adduced to gradual rejuvenation which made the Cabana river to cut into spurs and carved bluffs. The study showed that the steep erosional scarps were developed on thick weathered regolith. Other features mapped were large and small residuals, micro-pediments, large amphitheater-like embayments alternating with long narrow strips of head-lands on the erosional scarps.

However, all these occurred on a piece of land of not more than 10km^2.

Dada (1972) working within the upper Saye basin of Zaria (a major tributary of the Galma River as the Kubanni also is) found that deep gully incision of the river channel is associated with either drop in the base level or climatic change which initiated rejuvenation and two-level terraces is the ultimate result of this process. He revealed further that gullies occurred were on steep valley side slopes and on interfluves with steep slopes and where vegetation is sparse.

Other studies include Ahmed (1989), Bello 1991) and Makeri (1989) which showed that because of significant increase in the intensity of land use, gully erosion density and areal coverage also increased. Also the rapid urban sprawling plus intense agricultural practices and poor management of the land within the basin has been shown to result in severe soil erosion and deep gully incision.

CHAPTER 3

THE STUDY AREA

3.1 Introduction:

This chapter presents the general physical background of the Kubanni basin. Figure 3.1 shows the study area. There are several published and unpublished texts/literature on the general geography of the study area especially regarding geology and landform, relief and drainage, soils, vegetation and climate. The detail given in this chapter include information obtained from field observations, air-photo interpretation, in addition to relevant information already published. Figure 3.1 presents the sketch diagram of the study area.

3.2 Physical Background

The study area (Samaru-Zaria, 11°3'N, 7°42'E) is located on the high plains of the Hausa highlands. It is drained by the Kubanni systems and covers c.118 square kilometers. It is bounded by the Institute of Agricultural Research (IAR) and the Samaru Village to the north. On the West the limit is Ungwan Barau and Ungwan Maigamo Village settlements. Its southern boundary is the Kufena Hills and Ungwan Zarumi. On the east is the Ahmadu Bello University and the Nigerian College of Aviation Technology (NCAT), Zaria (Figure 3.1). The basin has an average altitude of C.680m a.s.l. with the

Kufena Hills towering up to a height of c.820m a.s.l.

3.2.1 **Geology and Landform:**

Samaru-Zaria and its environs is underlain by three groups of rocks, all belonging to the Precambrian Basement Complex of Nigeria (Jeje, 1978; Wright, 1971). These are summarized below:

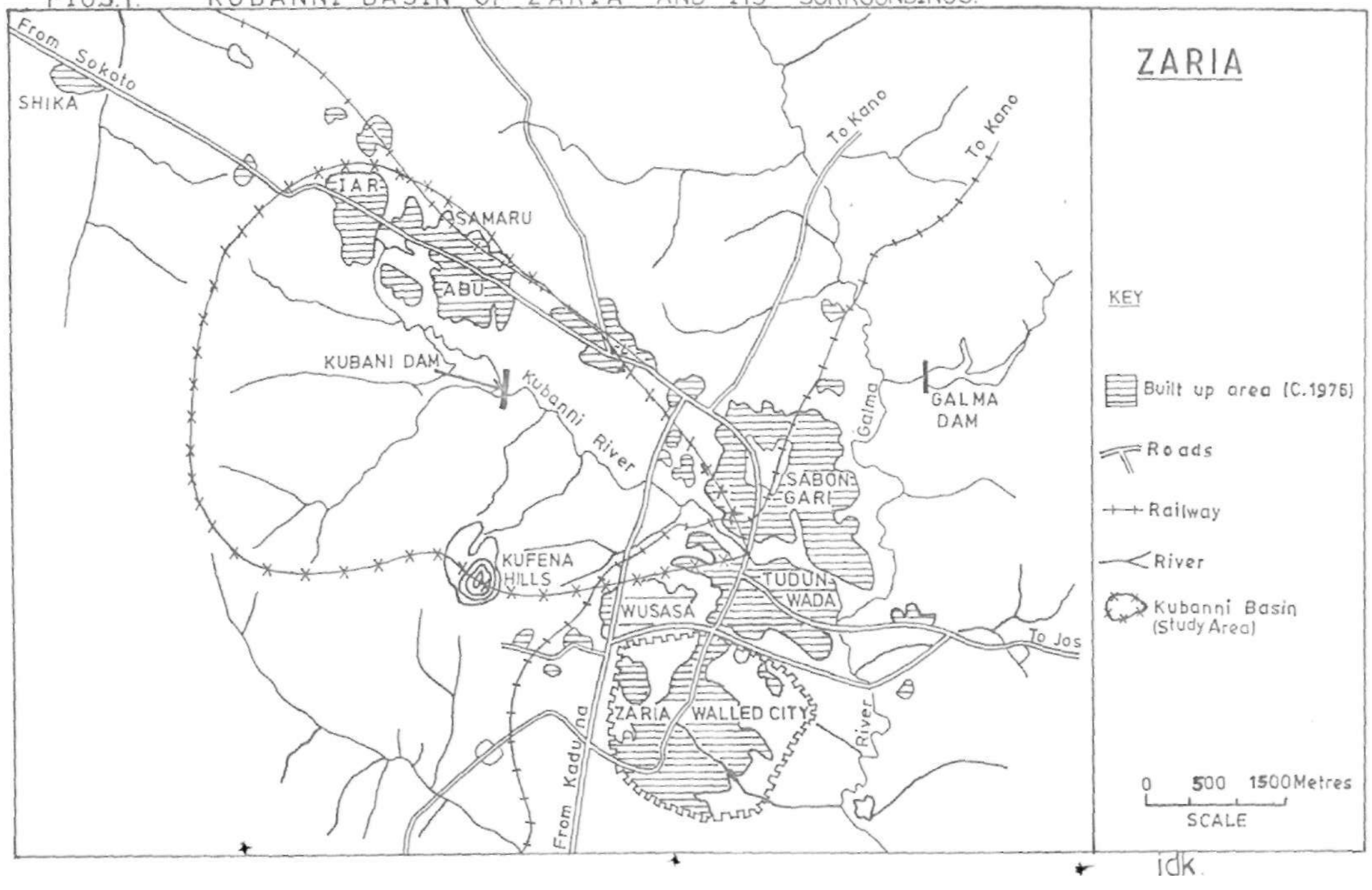
(i) Gneiss of variable composition including granitic, pegmatitic or schistose thoroughly weathered to varying depths and covered with superficial materials called drift;

(ii) Quartz Schists and quartzite form a narrow belt of low, rounded, hill and valley topography;

(iii) Gneisose porphyritic granites characterized inselberges of drift shapes and sizes. These are often referred to as the older Granites to distinguish them from the Jurassic Younger Granites. They cover a small area with the largest out-crop forming the Kufena groups of Inselberges.

The overlying superficial drifts are found on the uplands and valley side slopes. Likewise alluvial and colluvial deposits are found on valley bottom lands and bordering terraces. Ologe (1971) has observed that solid rock outcrop occur only over a small proportion of the landscape around Zaria. Thus the landscape is developed on regolith materials of variable depth

FIG 3.1. KUBANNI BASIN OF ZARIA AND ITS SURROUNDINGS.



idk.

and composition, which strongly reflects the recent geomorphological processes (Higgins 1965).

The importance of the solid and surficail geologic arrangement plus the nature of the regolith is seen in the undermining tendency of gully headscarps retreating on to steep valley sides slopes. The drift also tends to become stripped on poorly compacted bedrock materials.

Distinctly banded sands, silts, and clays along stream channels are cut to form bluffs which Higgins (1965) described as having a very typical eolian drift appearance, being vertical and of a stable nature.

(b) **Relief and Drainage**: By virtue of its location on the High Plains of Hausaland (elevation is between 620 and 690m a.s.l.) just south of the primary watershed separating the Chad inland drainage system from the Nigeria drainage system. Samaru Zaria has a subdued relief characterized by monotonous undulating landscape broken only by the occurrence of grouped or scattered single inselberges, the largest being the Kufena groups.

The study area is drained by a sixth-order stream, river Kubanni which is a tributary of the Galma River i.e. Shika, Kubanni and the Saye tributaries. The Kubanni and Saye flow roughly West-East to join the Galma river but the Shika, like the Galma itself, flows a circuitous course, first flowing north-wards and then curving round to join the Galma just north of Zaria (Mortimore 1971).

The river system is ephemeral and assumes a dendritic pattern. The streams have severely and deeply incised their beds causing dissection by numerous and large axial gullies (Bello 1973; Thorp 1971).

3.2.2 **Soils**: Although a considerable variation exists in the soil types, it is however generally described as the (leached) tropical ferrugineous type. Topographical factors appears to play vital role in determining their detailed characteristics. For instance, around the Kufena Hills is the young coarse or weakly developed soils (regosols). The soils in the valley bottom lands (Fadama) belong to the intra-zonal group especially hydromorphic soils or vertisols (Klinkenberg 1970) due mainly to accumulation of both organic matter and fine alluvium.

Extensive wide valley bottom lands is a typical feature of the Zaria area. The soils here are mostly dark-grey clays (vertisols), poorly drained. Most of these soils have been formed in alluvial material and some variation in textures can therefore be expected. The 'fadama' are of special importance. They are fairly rich in nutrients and have a good to ample water supply, which persists far into the dry season.

Generally, the character of the soils is such that as soon as rainfall starts, infiltration could be quite high but the pores soon get sealed up with fines and further infiltration is impeded resulting in overland flow, sheet flow

and channel initial (Makeri, 1989).

3.2.3 Climate and Vegetation: Samaru-Zaria possesses a tropical continental climate consisting of pronounced long dry season alternating with a distinct but short rainy season. Temperatures are high. Daily maximum temperature rises generally from allow of 13°C in January to its peak 35°C in April/May. A secondary high is often encountered in October. Also, the mean minimum temperature rises from is lowest value in December/January (28°-30°C) to its highest (35°-40°C) in July/August. Thus, the area is appropriately described as a tropical savanna (AW climate). The rainy season occurs in the high-sun period (May-September) with an average annual total rainfall of a c.110cm (Jeje, 1978). The dry season begins in October and is very hot but cool and dusty during the January/February months (the Harmattan).

This seasonal characteristics of rainfall makes its mark on the vegetation of the area which assumes various shades of green in the wet season and turns brown, pale or yellow in the dry season. The vegetation of Samaru-Zaria region is described as the Northern Guinea Savanna type. The term connotes a wood-land vegetation type characterized by the presence of Isoberlinia doka and other genera of Isoberlinia plus grasses.

This vegetation patterns shows that a pattern owes its existence largely to land use management practices over a very

long period of time (Ologe, 1971). Thus though the area lies within the Guinea Savanna zone, there is very little natural or climax vegetation and the area has become derived savanna characterized by sparse shrubs/trees in grass and tuff cover and clusters of trees along water courses. Near major settlements efforts are being made to plant cover trees in order to protect the land/soil resources.

3.3 Human Geography

3.3.1 Land Use: The major activities over the area are intensive but scattered cultivation during the rainy season and grazing with some construction works. Market gardening takes place on the terraces along the stream channels. "Fadama" cultivation which is the type of farming activities on the marshy land, is very common in the valley bottom lands after the cessation of the rains. This type of cultivation can last throughout the dry season period. This land use encourages rapid changes in the morphology of the channel and probably area.

Virtually all cultivated land within several square kilometers was under cultivation or short fallow (Ologe, 1971) in the past. The entire basin is today subjected to intense cultivation, and rapid urban sprawl due to increase in population. The land no longer enjoys bush fallowing which was the common practice in the past. These fallow lands were known to carry a vegetation of open shrub woodland; however,

these shrubs have little chance of achieving climax status as they are regularly grubbed for firewood, grazed and, sometimes burnt over the dry season (Bello, 1994). Trees of economic value were allowed to stand on farms or fallow lands and they provide a certain amount of shade from the sun and rain. These trees include Parkia, Clappertoniana, Vitex, Doniana, Afezelia, Afucana, Dabueka, Oliveri, Mangifera, Indiana, and Tamarindus Indica (Ologe, 1971).

From the cultivated areas orchard bush gives way to open canopy savanna woodland and recently, the Forest Reserves. Even then there is evidence of frequent cutting for firewood as well as burning and grazing. Taking Zaria area as a whole, Ologe (1971), summarized the vegetation and land use of the area into the following:

(i) half the total area was under permanent or semi-permanent cultivation;

(ii) Fallow land covers perhaps just over a quarter of total area and is used for grazing;

(iii) Open savanna woodland with a good cover of grasses, covers the belt of schist and quartzite ridges and valleys, within which there was very little cultivation.

Thus, land use in the study area has probably changed since 1963 when the air photos were taken. Table 3.1 shows the estimates of the categories of land uses in the basin.

Certainly the changes would have influenced or intensified geomorphic processes and consequently land degradation (Chaga, 1989, Shenyin, 1989).

Table 3:1 **Land Use in the Kubanni Basin *(1971)**

Land Use Category	% of Basin Area
Open Savanna Woodland	07
Shrub regrowth	17
Cultivation and recent fallow land	46
Gully area	12
Rock outcrops	03
Built-up areas	12
Total	97

* Estimated from 1:40,000 aerial photos, taken in 1962 (After Ologe, 1971).

3.3.2 Other Economic Activities

Kubanni basin is occupied by some major settlements such as the Samaru, Shika, Palladan, ungwan Maigamo, ungwan Kubanni, ungwan Lumbayi, ungwan Rafin Magaji, Kudingi, Tukur-Tukur, ungwan Barau, ungwan Zarumai, the University, the Nigerian College of Aviation Technology, and other hamlets.

Although farming activities seem dominant, not withstanding, there are other economic activities for which recent urban sprawl has brought along. Previous studies shows that while the rural land use declined from 93.24% in 1965 to 62.22% in 1995, the urban land use rose from 06.74% to 37.28% during the

same period, respectively (Chaga, 1989, and field investigation, 1995). Going by such a rapid urban development within the basin, economic activities which often goes with human resources are found. Economic development are concentrated along the north and north-eastern axis of the basin. Most common of such economic development are some commercial activities as the Samaru market, automobiles, banking institutions, educational institutions at all levels, construction works, sand and stone quarrying for the construction industry.

It is not probable that such urban pressure upon rural land would leave its imprints in the basin. Increasing economic activities in recent years by way of grzing has resulted in intensity of gullying (Ahmed, 1989).

3.3.3 INFRASTRUCTURAL DEVELOPMENT

The basin has witnessed a dramatic change in infrastructural development over the years. Interpretation of air photos of 1965 revealed that very few infrastructural facilities were in existence. However, the present day situation is quite different. Recent changes in urban land use includes roads, networks, recreation facilities, electricity and development of water resources in the basin. Also construction of residential building for staff in several institutions located in the basin. These structures demands that there should be provision of road network. It also means

changes in land uses. Some roads have been renovated or re-constructed recently. The Kaduna-Kano road is now (1990) a dual carriage road. More recreation facilities both private and public have been developed. Indeed the recreation of a new local government (Sabon Gari) has served as an impetus towards establishment of new infrastructures in the basin.

3.3.4 POPULATION AND DEMOGRAPHIC CHARACTERISTICS

Population constitutes a vital component of the potentials for land use and impact on the terrain in the basin. Most relevant elements of the population are its size, rate of growth and spatial distribution.

There are no accepted population figures as yet. However, estimate of the population in the basin can be put at about 80,000 people. The rate of growth (10.4% per annum) follows a similar trend to that of the state during the 1991 census. Population concentration in the basin is not even. Reconnaisance surveys showed concentration in major settlement along the major roads in north and eastern parts of the basin. Most urban development are concentrated also along the same axis. Farther away from the road we have scattered or isolated small settlements of between a few tens and 150 people mainly fulani herdsmen and sedentary farmers/fishermen.

The rural areas are consists of agricultural population living on the other valley side slopes. It is probably due to to the activities of the people that have caused severe

erosion being felt along these areas. There literacy level is low. Health and social welfare services are available. The main health service centre being the University Sick Bay with several other private ones.

CHAPTER 4

MATERIALS AND METHODS

4.1 Introduction

The nature of the field work, data collection and analysis are described in this chapter. Section 4.2 explains the organization of field work. In section 4.3 the selection and collection of data together with the criteria for choice of sampled areas and reference points are described and explained. Section 4.4 discusses the choice of scale and maps for the study.

Geomorphological mapping is an important tool for recording information concerning the nature of surface forms, materials (soil and rock), surface processes, and geomorphic history. The maps provide useful basis for terrain assessment and for monitoring environmental problems. Usually the approach to such mapping combines field inspection with air photo interpretation (Soeters, et al, 1993).

Deterioration of vegetation condition is usually the stage indications of land degradation. When it occurs it is usually a reflection of deteriorating soil condition and/or erosion hazards. Hence deterioration in vegetation conditions constitutes the core element used in this study for detection of land degradation on air photos. Land degradation mapping also involves delineating types of mass movement as seen on air photos and those that are occurring or may occur in the

future.

An alternative method to land degradation mapping involves the use of computers which employs the use of Digitizers for map compilation and production, and several other aided machines such as printers. This method has the advantage of rapid map-crossing. By using the Digital Terrain Model (DTM), all forms of morphometric data can be presented in digital forms and stored and reproduced on maps for subsequent use. It also has the capacity of converting data stored in the "Raster" module into "vector" module and vice versa (Aronoff, 1993). In this study it was not possible to use the computer based method because of lack of funds and equipment.

4.2 MATERIALS AND GENERAL STUDY ORGANIZATION

This section presents the working procedure for the study and is summarized in a schematic diagram Figure 4.1.

A. The first phase involes the gathering of relevant information from maps and texts. Preliminary air photo interpretation was made at this stage to be used as a tool for a general guide.

B. The second phase of the working procedure involves brief field inspection of the sampled areas. The inspection is meant to verify the relationships of landform, relief lithology, and note the processes in operation observed earlier on the air photos. It is also meant to up-date, make adjustments, and extrapolate the terrain unit boundaries.

C. Mapping and reporting forms the third and final stage of the research in which land degradation types, susceptibility map and the TMUs map are produced on a scale of 1:15,000. Using the elements of photo-interpretation (i.e. topography, drainage, pattern and texture, erosion, photo tone, vegetation and land use), different terrain conditions were identified and the boundaries between them determined. Also information obtained from secondary sources about geologic origin and formation, soil and bedrock characteristics, land uses, and those obtained from field inspection were also used. The characterization of the terrain mapping units (TMUs) is done using the 1:15,000 photographs via stereogram and mosaics which were not geometrically corrected. Detailed hazard analysis were also carried out using the 1:15,000 photographs as well. These provided the degradation hazard maps.

Table 4.1: SCHEMATIC PLAN OF THE STUDY

MATERIAL	ACTION	OUTPUT
A: PRELIMINARY AND LABORATORY WORK		
TOPO MAPS, GEOLOGICAL MAPS LITERATURE/SECONDARY DATA	TERRAIN CLASSIFICATION INFRASTRUCTURE MAPPING (for use in the field) FIELD WORK PLANNING	PRELIMINARY TERRAIN CLASSIFICATION MAP OF THE AREA (KUBANNI BASIN) INFRASTRUCTURE/ROUTE MAP
AERIAL PHOTOGRAPHS OF APPROX. SCALE 1:40,000 1:15,000	DIFFERENTIAL OF ENVIRONMENT OF THE SUB-UNITS OF THE TMU MAP, DESCRIPTION OF THE ATTRIBUTES OF THE TMU'S	SPATIAL DISTRIBUTION OF SUB-UNITS IN THE TMU'S AND CHARACTERIZATION OF THE TMU'S
B: FIELD WORK		
CHECKING AND UPDATING PRELIMINARY MAPS COLLECTION OF ATTRIBUTING DATA USING REMOTE SENSING DATA (Air Photo) IN THE FIELD AS TOOL.		
C: MAPPING AND REPORTING		
FINAL PHOTO ANALYSIS	PREPARATION OF FINAL MAP GIS MANIPULATION (Manual) REPORTING/WRITING	TERRAIN CLASSIFICATION MAP OF THE KUBANNI BASIN, LARGE SCALE MAPS GIVING SUB-UNITS FOR THE TMU MAPPING DETAILED HAZARD ANALYSIS, ETC.

4.2.1 SELECTION OF MATERIALS (MAPS AND AIR-PHOTOGRAPHS)

The materials selected for this study comprises information coded on aerial photographs, topographic and geologic maps and from previous research work on the Kubanni River basin, parts of Sabon Gari and its environs. To obtain information the photograph series were acquired from both the Department of Surveying, A.B.U., Zaria and Kaduna Polytechnic. The air photo series covered the main Kubanni river channel and its tributaries. A few air photos and maps were also obtained from the Geography Department (ABU). These air photos were arranged into series of stereo-triplets to form a mosaic to cover the study area (appendix A). In view of the large area to be covered representative sample areas were selected for use bearing in mind major topographic/terrain characteristics. The selection was also based on:

(i). location and type of land use: For instance considerations were given to differences between rural land use types. The nature of land degradation reflects the nature of land use system. Proper farm land management system checks sheet wash or riling menace. Conversely, over grazing and bush burning of open fields or farm lands often result in different forms of degradation hazards.

(ii). Indications of geomorphic process such as gullying, sheet wash, riling, observable and identified on air photos. Observable differences from area to area were used in selecting reference points.

(iii). availability of air photograph series that covers the study area including sample area and the reference points. Details of the air photo coverage and the stereograms of sample areas are given in figures 4.2 and 4.3a-g series respectively.

Sample area and reference points are given in Appendix A. Each reference point covers an average radius of 60 meters and all observations made within the circle are used for both TMUs up-dating and land degradation hazard susceptibility analysis. The appendix shows the air photo series from which the reference points were carefully chosen based on the availability of aerial photos coverage. Also some selected localities were considered for sampling e.g. headscarps, or areas of intense geomorphic processes as seen on the photos and since such areas represent land degradation type(s). However, a few reference points had to change during the brief field inspection because they no longer exist following the construction of the Kubanni Dam.

The use of the terms 'sample points' and 'reference points' are synonymous. They are simply points 'pricked' on air-photos to mark locations on the ground which helps the observer to orient the photos during field inspections. They are also sometimes referred to as 'base points'.

4.2.2 AIR PHOTO SCALES

The choice of the scale of maps of land degradation to be produced is as important as the photo types that may be available. For instance, large scale maps have more details and, at such, yield more information than medium and small scale maps.

In this study, however, because of difficulties in obtaining air photos covering the area under study at the same scale and for the same period, different air photo scales had to be used and they range from 1:40,000 to 1:15,000.

For preliminary air-photo interpretations the scale 1:40,000 was the choice used to help in reconnaissance surveys and analysis. The air photos at such a scale cover greater land space with more detail and can be viewed at a glance for the purpose of establishing TMU outline. Also the air photos at a scale of 1:40,000 were considered good enough because they are nearer the scales of the available topographical and geological maps which were both at 1:50,000.

The detail and final interpretation and production of maps were done on the 1:15,000 scale. The reason for this is that certain features of erosion such as rills, slope wash cannot be seen on medium scale air photos say 1:25,000 or less. Also the final maps were produced from photo mosaics of the interpreted stereogram. Similar scales for the final TMUs and susceptibility have been used in order to facilitate easier use of both maps and the possibility for map-crossing

later in the study.

The land use and susceptibility maps were produced from stereogram of photos on the 1:15,000 scale. This is because at such scales greater perception of details can be viewed and their land use pattern appreciated with ease.

4.2.3 STEREOGRAM PHOTO SERIES

Air photo series of stereo-triplets and pairs used for the study area and the sampled area are presented below and can be seen in appendixes A and B respectively.

The photo series used for the entire study area are those of 1965, 1970, 1974, and 1980. The 1965 series are in two categories: (i) 65109-38 to 56 covers the Forest Reserves at Tukur-Tukur, Ungwan Lanbayi, the A.B.U. Kubanni Dam, and parts of the southern half of the basin area; and (ii) 65113-11 to 28 covers the IAR, Samaru Village, ABU (Main Campus), Ungwan Mallam Tsofo, Civil Aviation Quarters, Hanwa Village. Both categories are panchromatic at the scale of 1:15,000 taken during dry season.

Photo series B of 1970 are coded 70705: 1-24 at a scale of c.1:15,000. The runs of this series overlap most areas covered by the 1965 series indicated above excluding parts of Tudun Wada. However, unlike the 1965 series 1970 series were taken during the wet season.

The 1974 Series are coded 74194 - 143/146; with at a scale of c.1:24,000. Again, this series were taken during the wet season and cover the Hanwa Village Southwards enclosing

Tudun Wada; Zaria City, Tudun Jukun, Sabon-Gari.

1980 Series, coded 052-058, at a scale of c.1:40,000 cover the Kubanni Village, Civil Aviation Air-Strip, Hanwa Village, Sabon Gari, Tudun Wada, Zaria City, Kufena Hills, and Ungwan Rafin Magaji.

Appendices A and B present the areal coverage of the stereo-triplets of the study area and the sampled area, respectively. The reasons for their choices have been explained in section 4.2.2. Figure 4.2 presents a sketched map of the sampled area (after the appendix), indicating all the sample points and their air-photo series coverage as recorded in appendix A.

All the photographs which cover the sampled areas are presented in stereogram and illustrated in Figures 4.3(a-g).

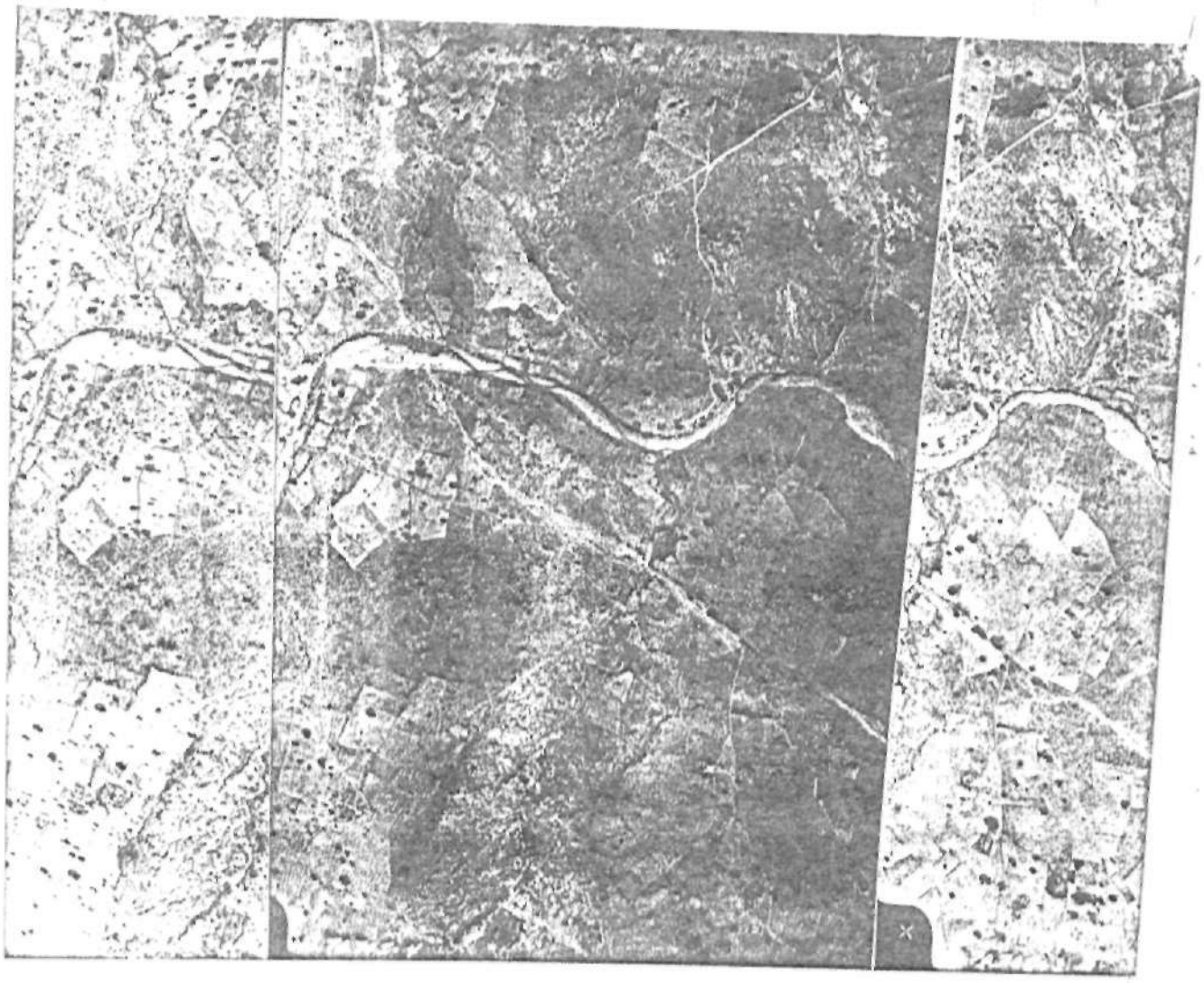
The choice of sampled areas were necessary as stated already (section 4.2.2). Altogether 7 paired (stereo triplets) photos were selected which cover the sampled areas. From photo series of 1965 stereo-striplets numbers 48,49,50 cover the sampled area south of Ungwan Dan Mako, Kubanni, and the Kudingi Gully. Stereo-triplets 50/51/52 within the same photo series cover south of IAR; west of the Kudingi Gully and parts of the headwaters of Kubanni. Thus the sampled areas in this photo series cover approximately 25 square kilometers.

Three sets of stereo-triplets from photo series B of 1970 series (3/4/5; 5/6/7; and 22/23/24) were selected and covered about 38 square kilometers of Ungwan Mallam Tsofo; the Air

strip and surrounding A.B.U. Dam (main campus); Samaru Village, College of Agriculture; Area BZ (A.B.U.); Veterinary Medicine Department (A.B.U.), Ribadu Hall (A.B.U.); etc.

From photo series D of 1974 (144-146) stereo triplets were chosen and cover the sampled areas of Tukur-Tukur Village, Wusasa, parts of Tudun Wada and Sabon Gari; Hanwa Village; GRA Quarters and Layin Zomo Village. The sample areas is the largest and cover approximately 32 square kilometers. Finally from the 1980 photo series stereo triplets (052/054/056/058) covering c.42km^2 were used as sampled area. These areas included the Kufena Hill, the Forest Reserves (near Tukur-Tukur), Zaria City, Ungwan Rafin Mallam, Lumbayi and Wusasa Village. It should be noted however that all the photo series described here overlapped one another at various locations.

Fig.5-2a. STEREO-TRIPLET (Panchromatic Black-White), 1:15,000. 70705-3/5.
AREA: Ung.Mal.Tsofo, Mal.Mako, Lumbayi, etc.



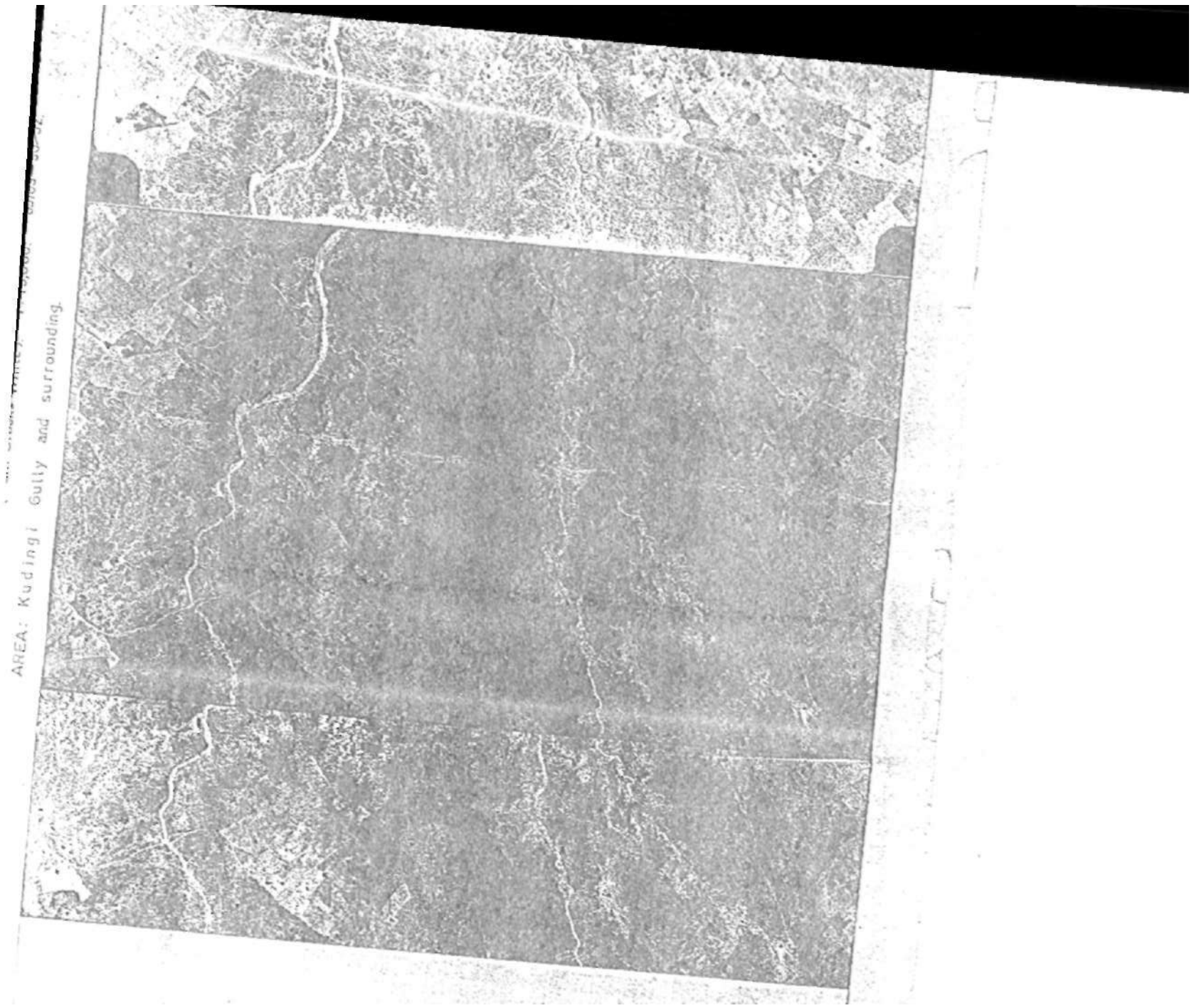

AREA: Kudremukh Valley and surrounding

Fig. 5-2 a. STEREO-TRIPLET (Pan. Black/White) 1:24,000. 74194—44/46

Fig.5-2 b. STEREO—TRIPLET (Pan. Black/White). 1:40,000. 1980—054/058.

AREA: Kufena Rocks, Civil Aviation, Forest Reserves, Zaria City.

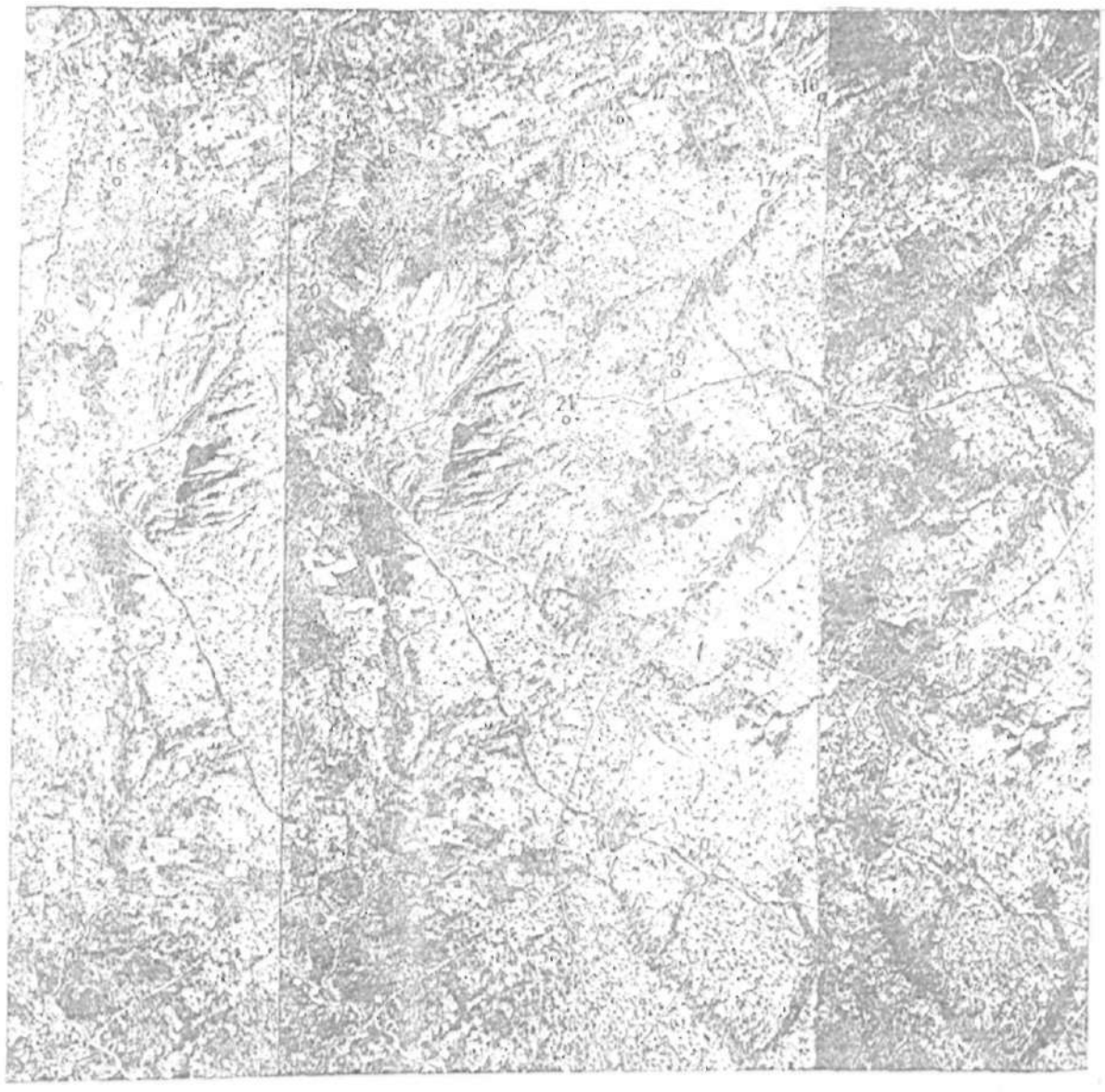


Fig.5-2b STEREO—TRIPLET (Pan. Black/White) 1:15,000. 70705—5/7.
AREA: Kubanni Dam, Ung.Dan Mako and surrounding.

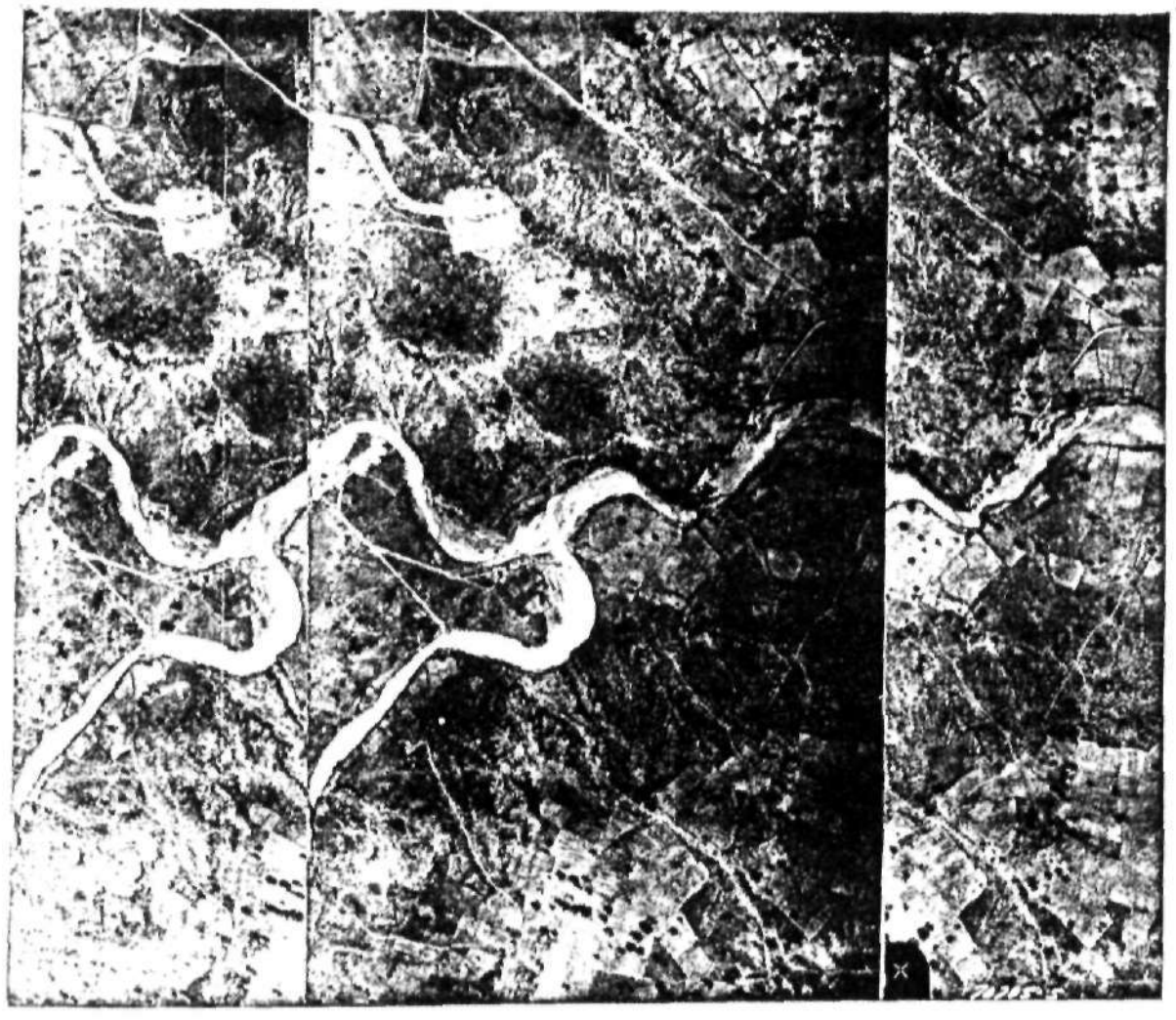


Fig 5.2c: STEREO—TRIPLET (Panchromatic Black/White). 1:15,000.
AREA: Samaru/Gulley, A.B.U. (Dan Fodio hall Vet. Med.), Etc.
—Series 70705-22/24.

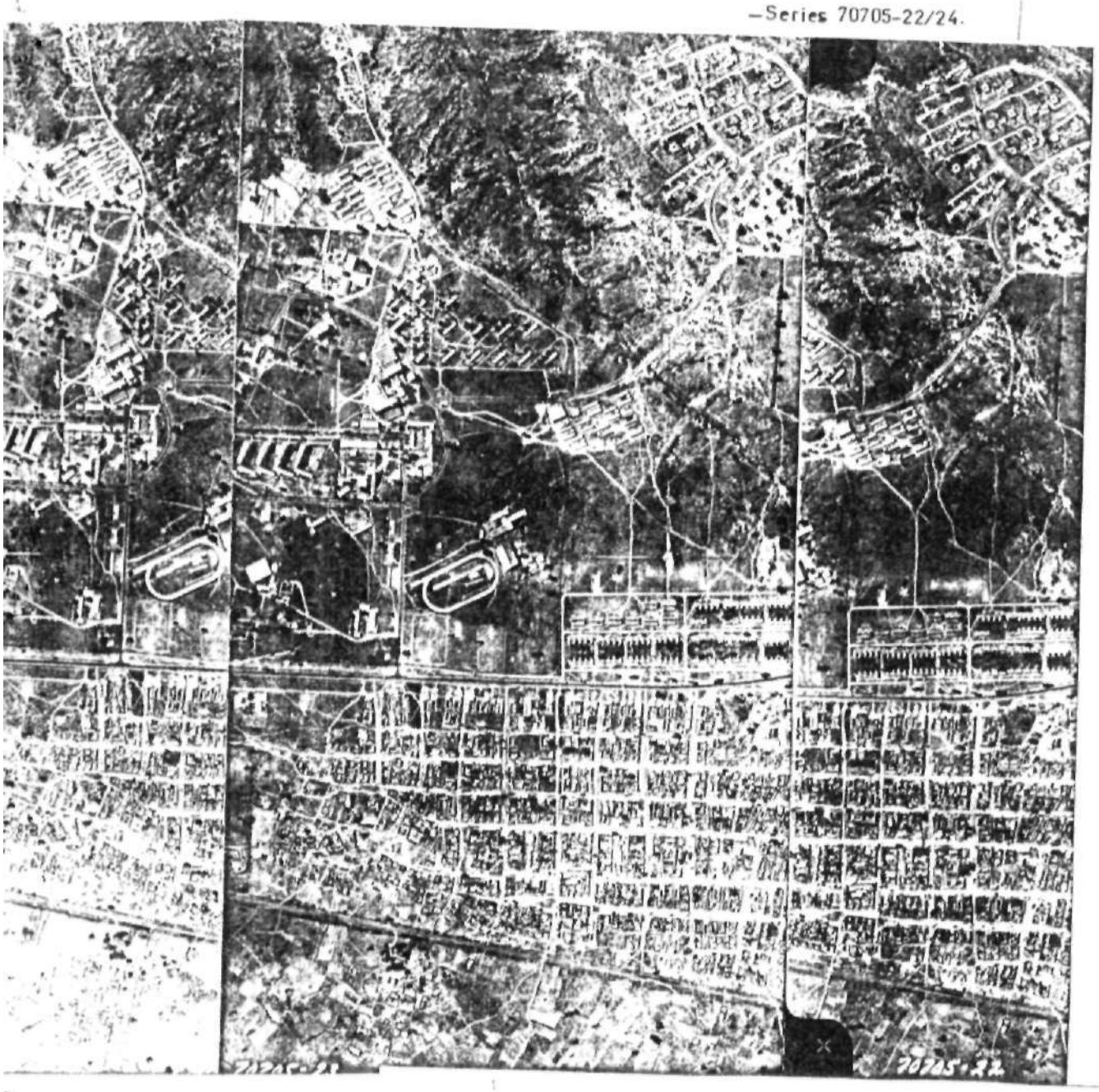


Fig.5-2 d. STEREO-TRIPLET (Pan. Black/White). 1:15,000. 65109-48/50

AREA: Ung. Maigamo and Up stream Kubanni Dam.

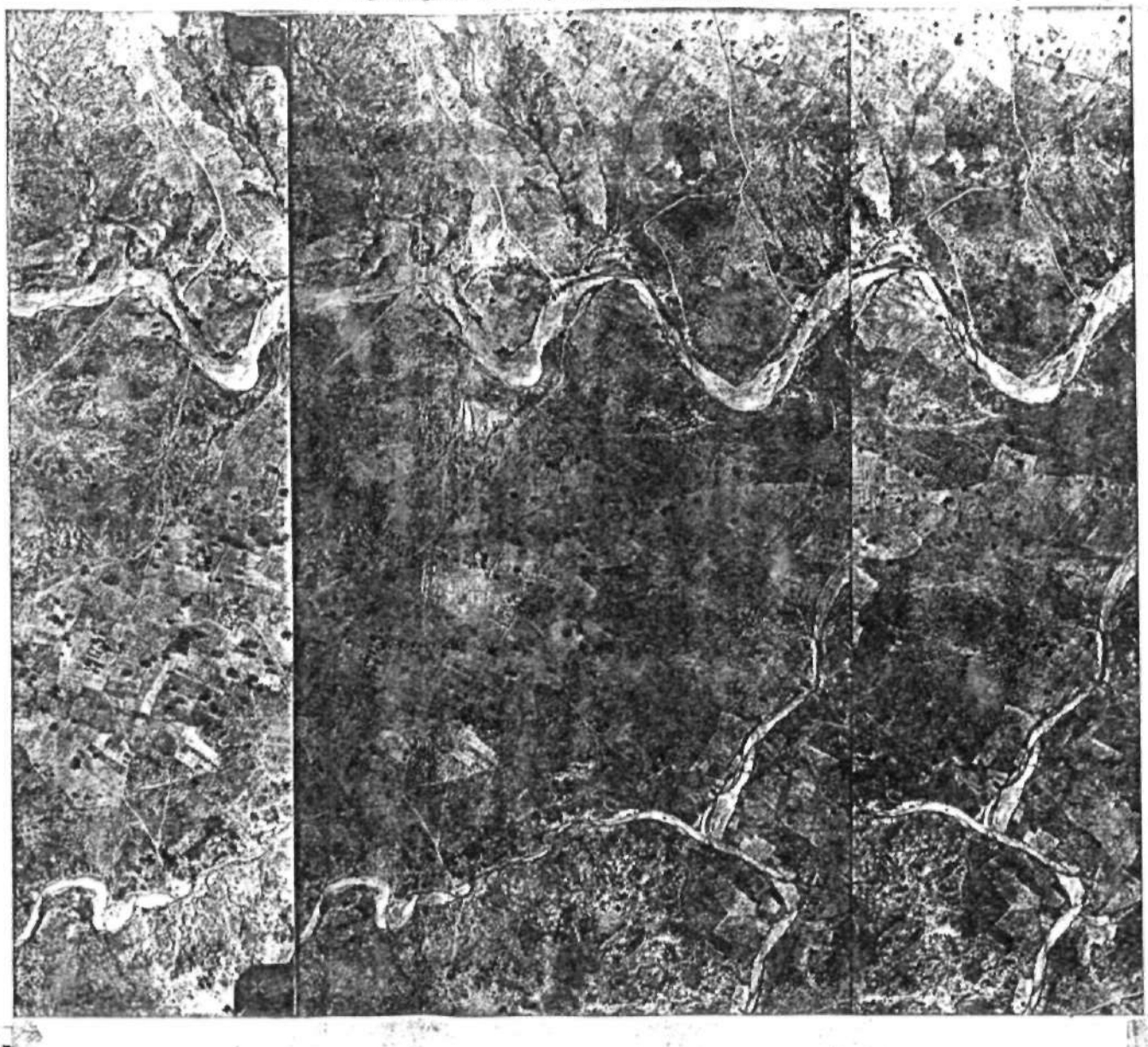
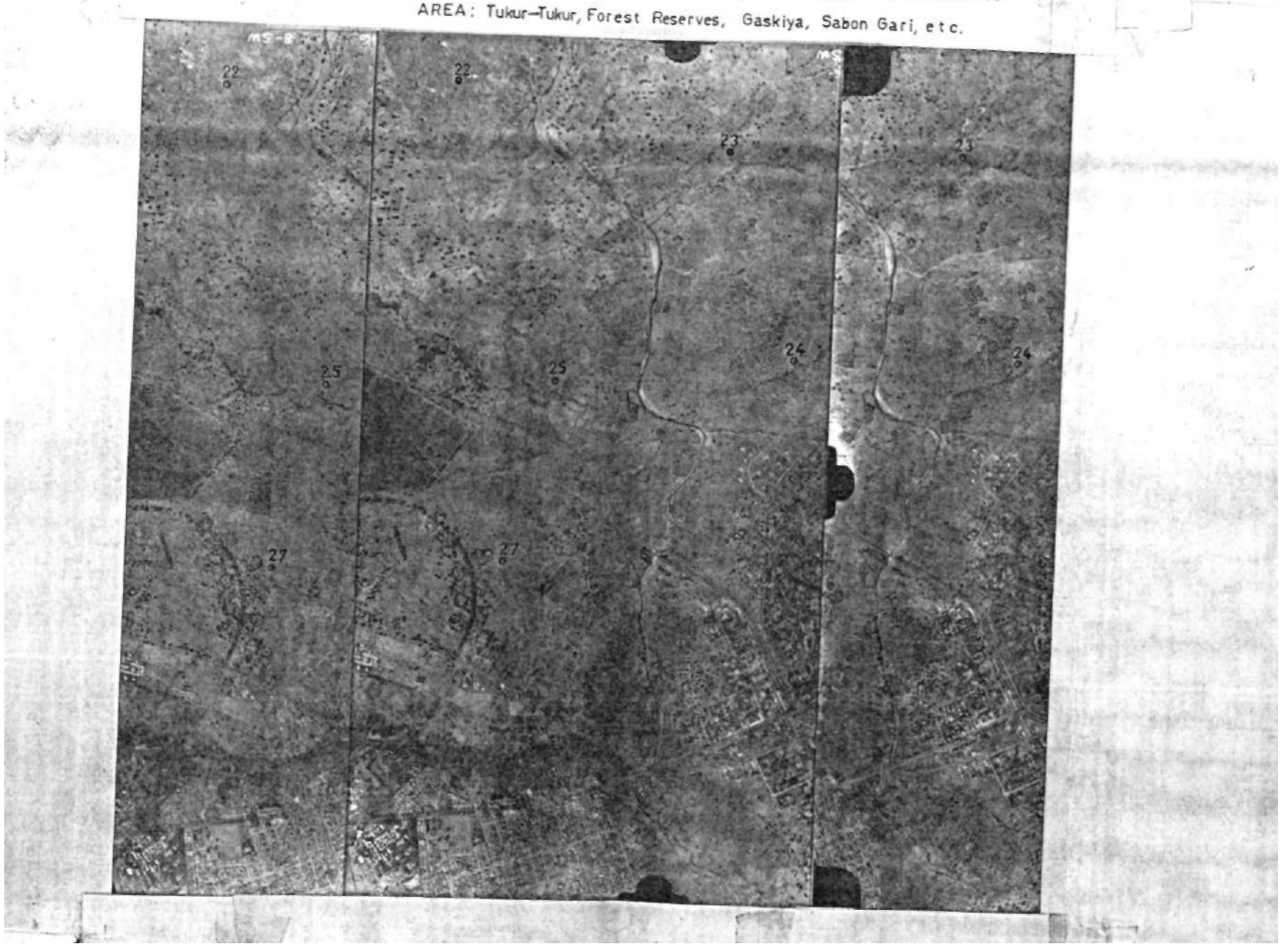


Fig. 5.2g. STEREO-TRIPLET (Pan. Black/White) 1:24,000. 74194—44/46
AREA: Tukur-Tukur, Forest Reserves, Gaskiya, Sabon Gari, etc.



4.3 METHODS (Air Photo Interpretation)

In this section the techniques of photo interpretation and procedures are descriped.

4.3.1 TOOLS OF PHOTO INTERPRETATION

The type and range of tools and instruments used have already been mentioned. This section describes the ways and manner in which each tool or instrument was used with particular reference to:

(i) Orientation of a Stereoscopic pair of photos;

(ii) Determination of Photo Scale;

(iii) Height Measurements using a Parallax Bar;

(iv) Linear Measurements.

4.3.2 Orientation of Stereoscopic Pair of Air-Photos:

The instruments used here were the pocket and mirror stereoscopes, stereo-pairs photos, ruler, wax pencil, masking tape and color tapes, transparent paper, rotring pens, and pencils.

Good stereo vision using pocket stereoscope was obtained by making the principal points on both photos to form one line with the two corresponding transferred principal points. Next the distance between the principal points were measured along the Stereoscope base; this was larger than the distance between the two transferred principal joints. Also, corresponding images were separated by a distance equal to or slightly smaller than the Stereoscope base. Lastly, the

shadows visible in the photos are falling towards the observer's side of the flight line.

For Mirror stereoscope, first two air photos were positioned in such a way that the shadows visible on them fall toward the observer.

Secondly, one photograph was superimposed on the other such that it covers the area they have in common to create zone of overlap. The next step was separation of the photographs properly and putting them under the transparent material in such a way that (1) the lines drawn on each photo (flight lines) coincide with the line through A and B, (2) images of the same point in each photo are at a distance AB apart. Then the photos were fixed securely in position with masking take over the corners and the transparent sheet removed. Lastly the mirror stereoscope was placed over the photo pair with its base parallel to the flight lines to view the three dimensional model of features without eye strain.

4.3.3 Determination of Air Photos Scales

Photo scale for aerial photographs can be determined in two ways. One of the methods involves the use of the data strip of the aerial photographs and a given elevation of the terrain. The other requires the aid of a topo-map. To determine photo scale (average along the flight line) of aerial photographs the following procedure was used:

First, the principal points were marked on three consecutive aerial photographs (h'_1, h''_2, h'''_3). These points

were transferred to the adjacent photos and label accordingly. Second, the principal points on the topo map would be identified and marked as H_1, H_2, H_3. Then the segmented line in between H_1, H_2, and H_3 are measured to get the total distance on the map: d_m.

$$d_m = \overline{H_1 H_2} + \overline{H_2 H_3}$$

Third, the flight line segment is measured and the average length of the flight line on the overlap d_p is calculated.

$$d_p = \frac{h'_1 h'_2 + h''_1 h''_2}{2} + \frac{h''_2 h''_3 + h'''_2 h'''_3}{2}$$

The final stage is calculation of the photo scale.

Mp = 1:Mp using the ratio.

$$\frac{d_m}{d_p} = \frac{m_p}{m_m} \qquad \text{..... (Eqn. 1)}$$

However, some aerial photos have the scale written on them.

4.3.4 Height Measurements using a Parallax Bar

Some elevations were measured in order to determine aspects such as internal relief, depth of gullies and rills, etc. The procedure followed is described here.

The first step is to orient and fix the photographs correctly on a drawing table. Then the objects to be measured were identified and where necessary holes are pricked and

grease pencil circles of 0.1cm diameter were drawn around them. Using a long ruler the distance between the foot of the object (a') in the left-hand photography and the foot of the object (a") in the right-hand photo (a'a") was measured. Also measure the distance between the two principal points (h'_1 and $h"_2$) of the photos (h'_1 $h"_2$). The difference between these two distances is the Stereoscopic parallax (Pa) of point "a". Next, you place the bar and land the floating mark on the foot of the object (a) and note down the parallax bar reading (Ma). Also land the floating mark on the top of the object (b) and note down the parallax bar reading (Mb). Subtract the reading Ma from the Mb reading to determine the differential parallax (p) between the top (b) and the foot (a) of the object.

$$p = a'" - b'b" = Ma - Mb$$

Next is to determine the flying height (Za) over the ground surface of the point "a"

$$Za = Zo - hm$$

where Zo = flying height over sea level. This is read from altitude or data strip on the photograph; hm - height of terrain with respect to sea level.

The height difference (h) is then computed between the top (b) and the foot (a) of the object is meters using equation 2.

$$h = \frac{p}{pa + p} \times Za = X\text{metres.} \qquad \text{.....(Eqn. 2)}$$

4.3.5 Linear Measurements

Two different types were involved, i.e. linear measurements in flat areas and, those on hilly areas.

(a) On flat areas, the procedure followed are described below. The tools needed are the mirror Stereoscope, pair of Stereo photos, parallax bar, ruler, needle and drawing materials. First, the photo scale (mp) was determined as described earlier. Second, measure the distance between the selected points a-b in millimeters. Third, is to multiply the measured distance (a-b) between the selected points by the photo scale number (mp), which gives the distance of the points in the field; a-b:

$$\text{therefore: } ab = mp \; \frac{---}{ab}$$

(b) On a hilly area the following procedure was used. Using the same instruments listed above:

- determine the height differences of the selected points, this gives the values h_{ab}, etc. in meters;
- next, use the slope between the selected points, this gives the values, d_{ab}, etc.;
- calculate the slope length in the field (ab, etc.) using the results of the first two steps, i.e.

$$ab = \frac{h_{ab}}{\text{Sin } d_{ab}} \qquad \ldots\ldots\ldots \text{(Eqn. 3)}$$

4.4 MAPPING

4.4.1 Introduction: This section describes the principles that guided mapping of terrain attributes and various types of land degradation from air-photos. Terrain mapping attributes considered include morphology, lithology, drainage, surface cover characteristics, and genetic origin. Land degradtion attributes used include gully, rills, sheet wash, slumps, debris falls, block falls and 'badland' phenomena.

4.4.2 Mapping Terrain Attributes

First, the entire air-photo mosaics of the study area was divided up into segments based on uniform character of the landscape; second, each segment was carefully studied and specific land attributes mentioned above were used to determine areas of similarities and/or differences. The terrain attributes used are those that were identified on the air photos during the preliminary laboratory examination of the materials (Section 4.1).

The terrain atributes mentioned above have been chosen because they form the key elements influencing processes of land degradation (Meijerink, 1988). These terrain attributes are preferred in this study for the following reasons.

Lithology has a strong relationship with landform. For instance various main rock types are associated with certain lithologies (ie. sedimentary rocks are associated with heavy clay, unconsolidated sand, gravel, pebble, silt; ect.). So

knowledge of the lithology of a terrain unit facilitates to a great extent the ease to determine likely geomorphic processes that operate on the various units. Also, morphology of the area gives a clear idea of the size, types and associated features and the terrain slopes. These, and the nature of the slope (length and steepness) play important role in determining rate and magnitude of land degradation. For instance, in principles, convex part of the terrain are susceptible to soil wash and rills, consequently the thickness of the weathering zones is diminished. Similarly, drainage characteristics (pattern, density) provide opportunity to see the terrain in patterns easily identifiable on air photos. Indeed, it gives expressions of wholeness to segments of the terrain since the network of channel tie all parts of the drained area together.

Surface cover characteristics of a terrain also determine, the nature and intensity of geomorphic processes and consequently land degradation. For instance, bare surfaces are more prone to severe erosion than areas under good pasture or grass cover.

Khan (1992), used geologic structure such as lineaments (joints/fractures), slope, strike and presence of ground water (but does not include surface cover characteristics, etc.) in his work in the Ganges basin (Bangladesh) to identify nature of land degradation including earthflow, and slides, creeps, and the like.

Also Yang (1993), in his work in South-Western China considered some of the terrain attributes used by Khan (1992) and included surface cover and lithology.

In this study ground water movements and lineament of the bedrock were not considered as important since earthquakes and tremors are not a common phenomena in Samaru-Zaria area. Besides detailed geologic maps for the study area were not available.

Lithology was determined based on the existing relationships between it and soil as well as with hydrology (Section 4.2).In land degradation studies surface lithology is of prime importance especially for soil erosion.

On air photos sedimentary rocks display prominent beddings and jointings as well as resistance to erosion. They are stratified in appearance on photographs. The photo tone is generally light-toned. The interbedded ones appear with distinct stair-stepped terrain. Igneous rock outcrops were identified on the air-photos with the use of stereoscopes. They were found to appear in variable summit elevations. For instance, hardpan (concreted ironstones) were found to form plateaus-like surfaces; granitic microfeatures appeared rounded and formed most of the ridge-like landform with broad surfaces.

Drainage system (pattern) appeared on the air photos as dissected wavy lines on the terrain. Principal drainage lines were identified also by their sizes and direction of channel

flow as controlled by the maximum valley slope of the terrain once proper orientation of the stereogram has been made with images casting their shadows towards the observer. Another guiding principle towards identification of drainage on air photos is the type and density of vegetation. Where there is high vegetation clustering some sort of drainage (presence of water) is most likely. Also they are indicative of the type of lithology, and the geologic structure. Drainage density was determined by a semi-qualitative method of approach rather than absolute values. In this case sample photo circle (coins) were used to classify the various degrees of densities (i.e. high, very high, low, very low density).

The difference in relief (internal relief) was determined by finding the average height difference (in metres) between the local drainage divides of hill tops and the valley floors of the terrain units using the Parallax Bar and ruler (see Section 5.5). Here again the classification is based on semi-qualitative rating rather than absolute values.

In mapping slopes from air photos a qualitative rating was used rather than the point network method due to lack of photogrametric maps. Looking through the stereoscopes on to the stereogram of the air-photos the following semi-qualitative rating is use, ie. flat, gently-sloping moderately steep, steep sloping, very steep sloping, and, vertical for Cliff-like, types.

For surface cover characteristics, different vegetation cover were observed on the stereo-pairs/triplets ranging from grasses, shrubs, trees to farm crops. In some of the stereogram (of photos taken in the dry season) some areas are bare or seen as patches of shrubs intersparsed. This was confirmed during the reconnaissance field inspections. In stereogram of photos taken during late dry season land cover is virtually non existent. Here, the vegetation has been "stripped" although and without any evidence of form of land-use (especially to the South-west of the basin). Open natural vegetation, grassland, shrubland-savanna forms the land cover in undisturbed areas (but very small indeed and is located to the north-west of the headwater area). Farm fields (crops cultivation) were also observed on air-photos. Photo tone, shape of cultivation and the regularity of pattern helped in mapping this attribute. For instance, bare land is depicted by light-tone on air-photos because of high reflectance of soil when dry; or dark;grey-tone when wet. Vegetation covers were identified by their shapes, sizes, pattern and tone of the clustered or sparseness usually in dark or grey colour. Different vegetation pattern indicates different plant species, e.g. conservation using tree plantation. Man-made features, such as buildings, roads, bridges, etc. often display a pattern of lines or squares i.e. elongated rectangular pattern.

Morphology (or relief shape) as a terrain attribute was also considered using height (Spot height and water divide), slope steepness, slope length, break of slope, slope form, of land features.

Genetic origin as a terrain attribute was considered in the study based on the fact that it relates to dominant exogenous or endogenous processes responsible for the occurrence of certain land degradation features. For instance, landform of fluvial and denudational origin are terraces, gullies, floodplains and are quite different from those of say structural or eolian process by influenced topographic origins were identified on air photos (i.e. Denudational/structural and fluvial). The principle applied in the identification of these genetic origins was based on the fact that units of denudational origin consist of gently undulating slope, little dissected terrain with deep soils on soft sedimentary (weathered) rocks; but more resistant rocks are steep hills. Whereas, units of structural origin are usually highly dissected, steep slopes, etc. Units of fluvial origin are usually aggraded or erosional landforms.

4.4.3. Identification and Mapping Land Degradation Types

Analysis of photographs using the above different terrain attributes revealed the following phenomena as the processes in operation which results to land degradation; i.e.:

Gully erosion
Soil wash

Rill erosion
Erosional scarps
Slumps
Debris fall
"Badlands" topography.

The important photo characteristics taken into consideration and which aided identification of land degradation features mentioned above included:

tone
pattern
texture
molting
shape
size, shadow (topographic) site, and
situation (geographic site).

as already defined (Section 1.7)

The remaining part of this section describes the application of the photo characteristics in identifying and mapping the land degradation features observed in the study area on individual basis. The main tools used for the identification and mapping are the stereoscopes (pocket/mirror), Stereogram copies of air-photos covering the study area, ruler, rotring pens, pencils, greased pencils, transparent papers and masking tapes. The method of instrumentation of these tools are discussed in Section 4.4.

i) Gully erosion can be discerned on air-photos through examination of the depth, drainage density and absence of vegetation cover. The more intense the activity the deeper and more abundant are the gullies and the sparse the vegetation. Field inspection showed that where the soil

material appears granular the gullies are short, and closely spaced. Gully shapes are a guide to the type of lithology, surface material (i.e. V-shaped denotes occurrence in sands and gravel, and U-shaped in silts or clays. Thus, on air-photos, gullies were readily recognised by their shape, size and depth and vegetation cover and drainage density. Drainage systems and their relationship with the surrounding vegetation were identified through their tone and pattern. A dark-toned concentration of plants along trench like courses can be picked-out with confidence and mapped as gullies (Kingma, 1993).

ii) Rill erosion and braids are associated with clayey/silty soils and sandy soils respectively. Rills are usually only a few centimeters wide and deep (i.e. 50cm maximum for both width and depth) and their dimension controlled by fine soil. A single braided channel is typically 1-10cm deep and 5cm to 50cm wide but without limited length. On air-photos they may appear in pattern similar to bare farm ridges or furrows but can be distinguished from their unique longitudinal lengths, and widths. Rills were hardly perceptible on medium and small scale air-photographs (because of their small sizes which are hardly discernable); they were however, detected on the 1:15,000 photos, combined with some field checks.

iii) Occurrences of sheet wash were identified on air-photos on basis of differences in grey tone by mottling. Sheet erosion on air-photo stereo pair were identified by their

tonal, pattern, shape, size, etc. characteristics. They appeared in light-grey tone, patchy pattern, bare ground surface and not widespread in area. Eroded parts of the landscape generally showed a lighter grey than the areas of accumulation which exhibited darker tones. Tonal difference is related to the fact that fine grained material of higher (now eroded) areas have been washed away leaving the erosional areas with a less moist coarse textured top-soil depleted of organic matter.

iv) Slumps and "terracetts": Drainage is also sometime distorted or blocked by the slumped material. Slumps were easily identified on air-photos by their steep-like terracetts surfaces. Somewhere, the drainage was seen to be distorted or blocked. They were picked out on air photos as masses of rocks or blocks of unconsolidated material along the slopes or parallel to the cliffs from which they descended.

v) Creeps were identified only by other evidences (i.e. leaning position of trees or fences/poles). On air-photos trunk of trees and pole lines showed bent position ; the surface cover vegetation however can hardly be perceived to change. They were recognised and mapped only where some erect features were found to slant or leaning.

vi) Mudflows in the study area were observed only along stream channels and usually at the middle or lower stages of the main streams. They displayed dark-grey tones on air-photos when wet but are grey-light toned when dried. They are

usually bare surfaces with little grass cover. The soil material was difficult to identify on air-photos, but was however, made possible only after the field inspection. The materials were those of silts/clays, sometimes mixed with sands.

vii) Debris falls were found to be common along the undercut banks of streams. The fallen materials (unconsolidated) can be seen directly below the stream bank cliff/bluff. They appear to occur where the soil is marl and clayey on photos. The tone is usually light-grey on panchromatic (black and white) photographs.

viii) "Badlands" topography in this study referred to highly dissected, bare surfaces. Badlands here refers to valley-slopes or areas which have been subjected to severe (intense) stream incision by erosive agents. They appeared irregular in shape, bare, and without defined channels. There is no form of land use practice and gullies are steep-sided. The surface tone is light-grey. Such topography were seen to be of less or no economic use. Good example is the area within the Kudingi Gully. On air-photos they were depicted by their pattern (denobitic and irregular); tone (light); mottling (irregular shapes and size); shape (irregular). There is absence of vegetation cover and lack of clear channel flow direction.

ix) Rock falls were identified on air photos usually where there exists isolated inselbergs or steep bedrock

scarps/outcrops and were found to be lying at the base. There is usually the lack of vegetation cover. The flow-direction is normally along slope direction and occur usually on convex parts of slopes. Block (falls) were identified by the appearance of blocks beneath some major scarps and channel banks. Major joints (may be due to plant root systems) were observed (during field inspection), on such scarps and banks where the lithology was silty-clays. They were without vegetation cover.

x) Bare land fields were characterized by lack of vegetation cover of any intensity or value; lack of soft or unconsolidated materials, such fields were spotted to be subjected to severe dissection, sheetwash and riling. Lack of grass cover denoted overgrazing or bush fires.

Other specific forms of land degradation identified and mapped out include the following:

i) Footslopes: These were identified on aerial photographs by their appearance, i.e. gently inclined planated surfaces. They are generally veneered with debris (strewn with rock fragments). They are mostly undissected (however, accumulattional footslopes may be slightly darker-toned and with braids). It was however, difficult to distinguish between thinly covered erosional surfaces and accumulational surfaces since in either case the bedrock is invisible and surfaces may be covered by vegetation;

ii) Inselberge (residual hills) stand out clearly and were

viewed through stereoscope as isolated hills surrounded by lowland surfaces of erosion and appeared dark-grey in tone. They were sometimes vegetated or not.

iii) Fans (accumulation of debris brought by rivers). These were identified on aerial photographs by their shape (fan-like), situation (usually on the plains), tone (light-grey). Little vegetation cover could be seen;

v) Infilled valleys were viewed in valley bottom areas. They were identified by their gentle slopes to flattish surface and by the absence or evidence of runoff. They were dark-grey in appearance because of the presence of vegetation and, or wet soils.

4.5 LABORATORY WORK

This involved collection of background information such as maps and texts of previous research and work done in the study area. Laboratory work also involved both preliminary air photo interpretation to delimit the extent and have a synoptic view of the study area to determine how to go about the classification and characterization of the terrain units as well as the final adjustments and updating of maps. Also at this stage the traverses to be made were considered.

The actual selection of data and of scales to be used were decided following a more detailed interpretation of the photos to determine TMU, sub-units and hazard susceptibility. maps.

4.6. .FIELD WORK

A brief field inspection constituted the second phase of the working procedures. The field inspection was meant to varify the relationships between the landform, relief, lithology, and to note the processes in operation observed earlier on the air photos. It was also meant to update, make adjustments, and extrapolate the terrain unit boundaries. Some measurements were also carried out using the Abney Level for slopes measures, and the tapes for linear measurements. Other instruments used included ranging poles, pocket stereoscope, maps and air-photographs.

CHAPTER 5

PRESENTATION OF RESULTS

5.1 INTRODUCTION:

Using photo interpretation techniques described in chapter 4, different types of terrain units (TMUs) were mapped and land degradation types identified and described as section in 5.1. In section 5.2 classification of the types of TMUs are presented, while section 5.3. discusses the spatial distribution of the land degradation types in the basin.

5.2 THE TERRAIN MAPPING UNITS (TMUs) AND LAND DEGRADATION

(i) This section of the chapter describes the terrain mapping units (TMUs) and land degradation types identified in the Kubanni basin (figs.5.1 and 5.2). The terrain mapping units (TMUs) attributes and approach has already been discussed in section 4.4. The concept makes use of land surface conditions which express evolutionary relationships among land attributes such as surface geology, landforms and their slope, drainage, soils and their vegetation cover characteristics.

(ii) The aerial photograph series used for the TMUs mapping were selected from air photo series of 1965, 1970, 1974 and 1980 as described in chapter 4. Specific ones used included:

- 1965 photos of the series - 65109 and 65113 at 1:15,000;
- 1970 photos of the series - 70705 at 1:15,000

Thus, the final TMUs that emmerge describe in detail the various units contained in the basin. Each TMU is represented by combinations of subscripts to identify and dsecribed it. Table 5.1 illustrates it.

F. Units of Fluvial Terraces.

F1- fluvial terraces of the lowest level (first order) usually filled atimes with sand bars and other eroded materials from the main channel always affected by even minor floods. Sample points are 13 and 14.

F2- fluvial terraces of the second order in elevation affected by subsequent floods. Sample point is 14.

F3- fluvial terraces of the third order in elevation, in most cases they are not flooded. Sample point sre 15 and 16.

F4- the higher fluvial terraces usually not affected by the main channel processes but experience rilling and gullying. Sample points include 13, 15 and 16.

F5- the highest fluvial terraces often located far away from the influence of the main channel; they may be valley side slopes, erosional scarp recognised by Bello 1973. Sample point location are 16 and 17.

SD Units of Structural-Denudational origin:

SD11- highly dissected elevated flat (Plateau-like) surfaces of the highest elevation. Point location is 9 and 4.

SD12- moderately dissected plateau-like surfaces of the second order. Point location incudes 3, 8 and 13.

SD13- plateau-like surfaces of less dissected nature and usually densely inhabited or settled. Point location includes 1 and 3.

SD21- Ridge-like terrain with sharp crested edges and very steep sided slopes. Point location includes 16.

SD22- Ridge-like terrain with broader surfaces and gently sloping slopes. Sample points includes 15 and 17.

SD23- Rounded broad-like hills with smooth looking surfaces, less dissected. Point location is 19.

SD24- Rounded broad-like hilly surfaces but highly incised terrain. Point location 10.

SD31- Hill slopes greatly incised, steep-sided and less cultivated or put to any economic use. Sample point is 14.

SD32- Hill slopes of moderate incision, moderately sloping slopes, and partially cultivated;

SD33- Hill slopes with less incision, gently sloping slopes, and with intense cultivation and other economic uses such as buildings. Sample point is 11.

SD41- Valley slopes moderately incised with streams, moderately steep sided slopes, some forms of land use activities, well drained. Point location is 18.

SD42- Valley slopes moderately incised with gullies, moderately steep sided slopes, some forms of land use activities, well drained. Point location is 23.

SD43- Valley slopes less incised with gullies and gently sloping slopes, highly cultivated and poorly drained. Sampled point location is 24.

IH- Isolated Hills, highly eroded and/or dissected; e.g. the Kufena Hills. Point location is 21.

D Units of Denudational Origin:

BD- Badlands, highly eroded and/or dissected, no form of land use activities. Sampled point locations includes A and B, 15 and 16.

TABLE 5.1 LEGEND OF TERRAIN CLASSIFICATION (TMU) OF THE KUBANNI BASIN, ZARIA.

MAIN TMU	SUB-Unit	Code	Geomo. origin	LITHOLOGY	Surface material	Slope Form	Slope steepness	Slope Length	DRAINAGE Pattern	Densi.	Inter. Relief	Geomor. Process Type	Act.	Area	Vegetation Type	Dengi	REMARKS AND DESCRIPTION
STRUCTURAL DENUDATIONAL	Highly dissected Plateau-like	SD11		gravels over Iron pan, laterites	gravel,sand rocks,	convex-broad	very steep cliff-like	mod, long	parallel, sub-dendritic	high	mod.	gully. soil erosion	very high	slopes	shrubs, trees, grass	low	Plateau-like surfaces where denudation processes deeply weathered ,evidence of human influence upon the terrain, severe gully incision, soil erosion.
	Moderately dissected Plateau-like	SD12		laterites, sands,clays	gravels,clay sands,silts	*	moderate	mod-long	dendritic irregular	high	low-med.	rilling gully.	very mod.	top-surface	trees, shrubs,	high	Plateau-like surfaces where erosion processes has not been quite severe yet, gullying and sheet erosion are prominent;there are evidences of human impact.
	Flat -top Plateau-like	SD13		*	sands, silts gravels	table-like	gentle, moderate	long	Parallel-dendritic	medium-low	low	sheet rills	active	top-slope	trees, grasses shrubs	very high	These are plateau -like surfaces with flat-top topography, less stream incision and erosion, some cultivation and grazing are common.
	Sharp-crest Ridge-like	SD21		Iron pan silt,sands	sands, silt clays	sharp	very steep	mod-long	sub-dendritic	medium	mod-high	gully, rills	active	slopes	shrubs grasses	mod-low	Severe geomorphic processes and stream incision, soil erosion is quite evident; little vegetation growth, steep slopes.
	Broad -surf. Ridge-like	SD22		*	gravels, sands, silts.	broad-sharp	moderately steep	*	sub-Dendritic	Medium	moderate	gully rills	little	surf	shrubs, grasses trees,	medium high,	These are broad-like surfaces where the land has not yet been severely incised by streams and human influence not so prominent to cause erosion
	Flat-top Ridge-like	SD23		laterites, iron-pan	sands,silts gravels,	flat-undulating	gentle	long	*	low	moderate	rills sheet.	low	top-surf.	trees, shrubs, grass.	high	gullying and rilling in some areas; some cultivation and grazing on these surfaces can be seen to result to rilling and sheet wash.
	Hill-slopes Less dissec	SD31		gravels, clays, silt	sands,silts clays,	conver-concave	steep	short	dendritic	med.	high	gully rill sheet	very active	slope	shrubs grass.	medium	These hill slopes are less dissected and much of it being cultivated and grazed; gullying and rilling are in effect.
	Hill-slopes mod. dissec	SD32		*	*	concave	gently-slopping	short	sub-dendritic	high	high	gully rills	very active	slope	trees shrubs	*	There is severe gully erosion due to human influence of clearing bushes leaving the soil bare; some cultivation and grazing are common in most parts.
	Hill-slopes highly dissected	SD33		sandy-clays	gravels, silts,clay	broad	moderately gentle	mod-long	*	high	mod-high	gully rills	very activ	slope	trees grass.	med.	Highly dissected hill slopes where severe gully erosion is evident and scarp recession most spectacular all over; human influence evident.
	Valley-slope highly dissected	SD41		laterites-iron-pan	clays,silt sands,	concave, cliff	very steep	long	parallel dendritic	med.	high	deep gullys	very active	slopes	trees shrubs	mod-low.	Little cultivation can be seen on these valley slopes due to severe gully erosion; in some cases they are almost a waste land as the soil has been eroded.
	Valleyslopes moderately dissected	SD42		*	*	concave-straight	gently-slopping	long	*	high	mod-high	*	*	*	grass. shrubs trees	*	These are valley slopes which are moderately dissected but intensive cultivation recently has shown that gully erosion is on the increa.
	Valleyslopes less dissec	SD43		lateritic iron-pan, sandy-clay	sandy-silts gravels, clays	concave-conver	gentle	long	parallel dendritic	medium	moderate	slumps gullies	*	mostly slope	*	*	Intensive cultivation of the slopes and constant grazing by animals has severely accelerated erosive processes.
FLUVIAL AND DENUDATIONAL	Alluvial/ Colluvial Fans	AF	sedimentation	silty-clay gravels	gravels, sands, silty-clays	broad-concave	gently-slopping	short	distributary, parallel	medium	low	rills, sheet,	low	surface	grasses shrubs	low	mostly made of gravels and sands, are cultivated in some cases.
	Lower Terraces	F1	*	silty-clays	sands,silts clays,	flat	gentle	short	*	*	*	*	Mod.	*	*	*	Intensive cultivation of the terraces even on to the river banks, this has greatly influenced the rate of erosion.
	Low Terraces	F2	*	*	*	*	*		*	low	*	sheet wash	*	all	*	*	"fadama" cultivation quite intense and this is a serious threat to rilling and gully erosion
	High Terraces	F3	*	*	*	broad-flat	undulating	mod-rate	parallel distribu.	medium	modera-te	rills sheet	acti-ve.	slopes	trees grasses	medium	severe rilling and some gulling and sheet wash. farming activities of the "fadama" type.
	Higher Terraces	F4	*	*	*	*	gently-slopping	*	straight, distri-	*	*	gully, rills	very active	*	trees, shrubs,	*	shallow gully erosion and scarp recession, rilling and sheet erosion also common.
	Sadland*	SD	erosional	Iron pan, lateritic	clays,silts sands,	Irregular, cliff-like	very steep	short-long	Irregular	high	mod.	gullies rills,	*	*	shrubs grasses	low	evidence of deep gullying and head-scarp recession, erosion processes of all kinds at great depth.
Structural Denudational	Isolated Hills	IH	SD	gravels,	conglomerates gravels,	cliff-conver	very steep	-	Parallel straight	mod.	-	erosion with.	very active	all	shrubs grasses trees	low	subjected to severe cracks and jointing processes, rock falls are common , evidence of weathering and erosive processes pronounced.

*CLASSIFICATION BASED ON SEMI-QUALITATIVE AND QUALITATIVE METHODS

5.2.2 Sample Points Description

The choice of sampled areas and points of reference have been described in sections 4.2 and 4.3 respectively. Here results of the detailed analysis of the aerial photographs are explained.

Points 1 and 2: Shows removal of surface vegetation probably due to overgrazing and resulting in intense sheet and rill erosion. This is illustrated by the visible differences between the air photos of 1965 and those of 1970. There were a number of shrubs during the 1965 aerial coverage but by the 1970 coverage of the same season, most vegetal cover were absent. The presently field observations show deep gully incision, increase sheet and rill erosion; in fact, the ground is virtually bare (aerial photo coverage codes are 65113 (13/14) and 70705 (10/11)).

Point 3: is characterised by extension of the gully headscarps and some increase in width between the period 1965 and 1970. Some few measurements from air photos give an extension of average of about 1.34m of the headscarp over a period of 6 years. Also during the past twenty five years sheet and rill erosion have increased on bare slopes and on slopes of >7 but <15 degrees. Where the slopes are >20 degrees gullying activity were observed. Aerial photo coverage codes are 65109(14/15) and 70705(10/11).

Point 4: The predominant forms of degradation between 1965 1970 were the removal of surface soil through sheet wash, following destuction the shrub-like of vegetation cover. Today deep gully incision and the widening of headscarps have developed. Aerial photo coverage codes are 65109(51/52) and 70705(10/11).

Points 5 and 6: Between 1965 and 1970 removal of vegetation cover due to grazing and fuel wood harvesting resulted in sheet erosion and gully initiation on gentle slopes. However, that have since developed into sleep scarp-like slopes due to increase animal gazing and trampling. Aerial photo coverage for these points are 65113(16/17) and 70705(22/23).

Points 7 and 8: Common of all forms of degradation were found to be on the increase in the area affected by sheet and rill erosion from the period 1970 to 1995). These areas were found to be set out for animal passage for daily grazing routine, thus, riling is on the increase due to constant animal trampling. Little or no effort is being made by farmers around to control this activities and so sheet erosion by runoff process is dissecting the upland terrain and erosion of top soil during little down pour especially on slopes less 15 degrees. Aerial coverage are 70705(13/14) and 70705(12/y13) respectively.

Point 9: Located on a lateritic capped residual (Area II of the university). surface wash and gully/stream incision have developed through time from 1970 to 1995. Presently changes

have taken place, slopes have become with slope angles within the range .of 5-25 degrees with associated gully initiation. Gully recession was found to be on the increase. Scarp failure and block collapse was found to be common and were attributed to the lithology on the one hand and scarp material "breakingaway" the erosion process on the other. Aerial photo coverage are 70705(7/8).

Point 10: Here active sheet and rill erosion were found to be common with intense grazing and farming activities around. The present situation is that of stream incision and increase riling activities. The field is gradually being degraded by the increasing mismanagement of the land through poor agricultural practices.

*Note that points 1,7,8, and 10 are open fields where animal tramping is common; hence, the events of rill erosion and sheet wash become active processes thereby rendering the land into a waste land. Photo-interpretation and subsequent field checks have revealed events of severe gully erosion over the period of 25 years and the terrain has changed dramatically from what it use to be.

Point 11: This point was at a erosional scarp as found on aerial photo of the 70s coded 70705(25/26). The position of that same point no longer exists today as the eerosional scarp has since retreated for over a distance of about 2.35 meters and widen in width to an area of about 15 squaremeters for the period between 1970 and 1994. The road construction over the

scarp appears to have both positive and negative effects on it, the erosional processes seems to have been controlled on the one hand because of the concrete works over the scarp. But on the other, the lack of adequate drainage channels for flood water during times of high floods has led to further gully incision and lateral spread down-stream, of the head-scarp. Predominant degradation process to this day are severe gully erosion, head-scarp recession, and some sheet wash.

Point 12: As at the time of the 65113(19/20) and 70705(6/7), coverage of the area no significant changes took place. However, now the period of over 30 years (1965 to 1995) field observation showed large areas dissected; for instance, the point no .longer exist today because its position is now occupied by a very deep gullies. Active stream incision and erosional scarp recession are all clearly identified. Aerial photo measurements of some gullies combined with field checks showed an average scarp retreat of about 3.2-8.75 meters between 1970 and 1995. This point is located just adjacent to the Center for Energy Research and Training (CERT), A.B.U.,Zaria. Average slope angles over the reference point were between 10-25 degrees.

Point 13: This point lies just down-stream of the Kubanni Dam to the (right). Sheet wash and rill erosions are the characteristic. Sedentary farming activities have degraded some of the erosional scarps to gentle sloping-flat smooth valley side slopes or upland. Now there is a gentle gradation

of the valley side slope from the bottom lands or "Fadama" area. Aerial photo coverage code is 70705(5/6).

Point 14: Located on a erosional scarp of the second stream (up-stream) from the Air-strip of he Civil Aviation, Zaria. Photo-interpretation of the 1965 and 1970 coupled with some field checks, shows remarkable changes in the extent of gully incision and vast area of sheet erosion. The situation today is that the same point of reference no longer exists due to erosion. The erosioal scarps have been reduced greatly to irregular shapes, and, the terrain, for most parts along the steep slopes (>25 degrees), have been lowered into an almost gentle (flat)-but-rough surface. The head-scarp was found to have retreated far beyond the foot-path up to a distance of about 0.36km over the period of 25 years. The presence of rills on the gently-sloping terrain (6-10 degrees) is evident along paths as can be viewed on aerial photos. Likewise, block collapse as evident on the floors of major scarps revealed the type of lithology common in the area for which clayey materials were discovered to be overlained by heavier sandstone and conglomerates. There is a rapid degradation of the terrain in-between the first stream just after the Air-strip and the second stream where the point of reference is located. The lateral spread of the gully incision of the two stream has almost dissected the terrain from that of a smooth rounded ridge (D22) by 1970, to the present status of a narrow strip of dissected sharp crested one (D21). Aerial

photo coverage have the codes 65113(22/23) and 70705(3/4).

Point 15: Highly incised gullies close to Ungwan Lumbayi. There is clear evidence of active gully incision and sheet erosion. Block collapse, and slumps are also evident. yThe terrain can be regarded as "badlands". Most of the land have been greatly dissected and rendered wasteful and bare. The period of 1970-1980 saw major changes on surface erosion, slope retreat and scarp retreat as well. Its aerial coverage are 70705(4/5) and 1980-054/056).

Point 16: Sheet erosion is widespread here. Many changes have taken place since 1980. Some measurements of erosional scarps on aerial photos and field checks showed some erosional scarp-retreat of up to 3.42 meters over the period of 15 years (1980 to 1995). Aerial photo coverage code is 1980-056/058.

Point 17: Located on very steep valley side slope (>30 degrees) and along the 'Rafin Magaji' stream. Aerial photo interpretation covering: 65109(43/44), 70705(2/3) and, 1980-054/056, showed some contrasting terrain features. First, the degrading status of the terrain through deep gully incision and erosional scarp retreat; then the events of intense sheet erosion and riling activities. Secondly, a diversion of a tributary stream from the point of reference has its head scarp about 1km away as of 1970 but today, the situation is that the head- scarp has retreated over a distance of 0.8km. Farming activities have resulted to some erosional scarp retreat and massive sheet wash of the top-soil. Most

discouraging is the poor farming method of farming that is aiding severe gully activities.

Point 18: Located at the foot of the Air-strip (about 0.5km away), has the following aerial photo coverage: 65113(22/23), 70705(3/4), and 054-056. A major gully incision of the Air-strip is active at present and progressing at an alarming rate. Photo interpretation of the 1960s and '70s revealed only the impact of severe sheet and rill erosion and the presence of vegetal cover which has since been removed or reduced. The presence of rills and subsequent stream incision is attributed to intense animal tramping and other land-use activities. The 1980 aerial photo has revealed intensive cultivation around the Air-strip thereby subjecting the terrain to other form of degradation such as gully dissection and soil creep.

Points 19; 20; and 21 were noted to shear similar terrain characteristics but with limited diversities. Point 19 (1980-054/056) is located at the erosional head-scarp of Ungwan Rafin Magaji, at the foot of the Kufena Hills. Point 20 (1980- 056/058) lies on a smooth gently-sloping valley slopes at the foot of the Kufena Hills the point was located close to a erosional head-scarp; while point 21 (1980-056/058) is located at foot of the Kubanni hills. Field investigation and phot interpretation revealed some remarkable changes in the rate of sheet and rill erosion in terms of their widespread nature (up to 15sq metres or even 30sq metres in some cases),

for the period of between 1980 and 1994. The light tone of the photographs scattered all over the place is an indication of widespread sheet wash. Intensive land-use today is a major threat to the stability of the slopes Bello (1973). The terrain has since been reduced to an incised valley-wall and continuous erosive processes are on the increase, more especially on point 19; whereas sheet wash is the dominant process of degradation on point 20. Presence of many streams from the Kufena hills results to severe runoff over the terrain. On point 21, the predominant degradation processes are sheet-wash and rill erosion. Over the period of 15 years the terrain has changed immensely as massive erosion of the top-soil has rendered the terrain bare and almost wasteful. Fresh erosional surfaces can easily be seen from photographs as light-tone and are bared in most cases.

Point 22: The surrounding area revealed some changes in the terrain especially of the slope gradient as observed from the 1974 and 1980 photos and the present day. The period between the '70s and '80s saw slight tonal changes which indicated surface erosion as the vegetation cover was removed through over grazing and/or bush burning. Photo-interpretation of the 1974 series revealed an average slope gradient ranging between 15-25 degrees for most moderately steep valley-slopes. However, recent field checks (1995) of the same spot revealed the following: (i) that the slopes have been degraded immensely through stream incision and (ii) the slope gradient

ranges between 20-35 degrees. Aerial photo coverage codes are 74194(145/146) and 054-056.

Point 23: Located almost directly across point 22 but on the other side of the river, was on a steep valley slopes as viewed from the 1980 photos. The valley below the point was then not so active and some forms of farming was going on then. The present condition of the terrain as analysed during field checks revealed great changes in terms of the rate of dissection of the topography by gullying. The valley slopes have been rendered wasteful by intense stream incision and sheet erosion. The valley sides slopes have been observed to be undergoing active gullying and erosional scarp retreat. Aerial photo coverage are 74194(145/146) and 054/056.

Point 24: Located down-stream of the Hanwa settlements when viewed from the 1980 photos, the point was on valley slopes which no longer exist. The settlement and its activities has greatly distorted the topography of the area. The valley and stream channel has been reduced to a narrow one of just about 1.5 meters wide from its former width of about 4.3 meters as interpreted from the 1980 photographs. Aerial photo coverage codes are 74194(144/145) and 054-056. Slope measurements showed an average slope gradient of between 12-36 degrees.

Point 25; 26; and 27 are located respectively as follows; first, point 25 (74194-145/146) is located about 1km just before the Forest Reserve at Tukur-Tukur village; whereas

point 26 (74194-145/146) and 054-065, lies at a confluence of two head streams just before the Forest Reserves at Tukur-Tukur. Point 27 (74194-145/146) is located to the south of Tukur-Tukur and adjacent to the Gaskiya Corporation showed little degradation of the terrain as viewed from the photos All three point bears similar characteristics. The 1980 photo-interpretation showed a gently sloping smooth topography with intensive cultivation of the surroundings up to 70m radius on the average. The smooth-surface topography indicated limited dissection of the terrain. However, the terrain condition today has revealed great topographical changes; the surfaces are rough, highly dissected, bare and, removal of top soil by severe sheet wash and riling. Deep gully incision and its head scarp retreat of about 3.6 meters (between 1980 and 1995) were measured. Two erosion surfaces (old surfaces) were identified from points 25 and 26. Measurement of the present erosional scarps retreat for most of them were approximated at about 3.6 meters on the average. Evidence of the rate of dissection can be seen from the construction works on the road as a culvert had to be constructed to channel overland flow (runoff) during wet seasons. Average slope gradient was measured to range between 6-35 degrees for point 26. The most affected slopes (by stream incision) are those slopes less than 22 degrees.

5.3 DISCUSSIONS:

5.3.1 Land Degradation types: Interpretation of the aerial photographs described in chapter 4 revealed that prominent land degradation types that occur in the basin are erosional in origin and complex in type. All existing and past forms of land degradation in the basin were identified, delineated, and classified on Stereogram. The classification was based on assigning of codes to all the types of land degradation identified; thereafter a final map of the degradation types in the entire basin was drawn after a photo-mosaic had been established (Figure 5.2).

A careful analysis of some parameters and terrain attributes revealed that there exists some relationships between the attributes and occurrences of land degradation in the basin. The types of land degradation that were identified and mapped included:

- surface/soil wash
- rill erosion
- erosional scarps and erosional scarps of different magnitudes
- debris fall
- creep
- slump
- Mudflow
- block collapse
- "badlands" phenomenon, and

- gully erosion

Each of these degradation types listed above were mapped out as discussed already in section 4.5. Here, their spatial distribution and theirevolutionary nature are brieflyn discussed.

5.3.2 Spatial Distribution of Land Degradation in the Kubanni basin

The spatial distribution and pattern of land degradation in the Kubanni are influenced by certain factors at specific locations. These factors are lithology, slope, altitude, slope aspect, and, human activities /land uses. Figure 5.2 shows the spatial distribution map of the forms of land degradation in the basin. The relationship between slope classes, terrain units and degradation types are also described. Point samples descriptions of land degradation types are given in the final part of the section.

5.3.2.1. Factors of Distribution of land degradation in the Kubanni basin

The following parameters were found to be directly and indirectly related to the distribution of land degradation in the basin.

(i) Lithology: Surface lithologies rather than bedrock geology were found to affect the nature of land degradation of particular locations. The use of the geological map (Zaria 102. S.W.) and relevant texts assisted the air-photo interpretation in determining the lithologies of the terrain

units. Most common of all lithologies of the basin are sands, silts, clays, gravel, sandstones, conglomerates, laterites. The rate of land degradation of a particular type was found to depend partly on the type of lithology. For instance where surface lithologies are those of soft and/or unconsolidated materials (e.g. silt, sand, gravel), the tendency for a severe soil erosion of sheet wash, creeps or gullying to occur were high. Most surface erosion impact were found where the soil is loose, unconsolidated and/or bare. Field checks revealed seepage and sheet erosion on terrain units with clays as the lithology.

(ii) Slope: The influence of slope steepness on land degradation occurrences was found to be prominent in the basin. Table 6.1 clearly explains the relationships. In general, the steeper the slope the more severe were the types of land degradation taking place. The slope classes measured on air photos (section 4.3.4) are grouped below:

(i) < 1 degree;

(ii) 1-5 "

(iii) 5-10 "

(iv) 10-15 "

(v) 15-25 "

(vi) 25-30 "

(vii) 30-35 "

(viii) 35-40 "

(ix) 40-45 "

(x) 45 "

These slope classes were measured based on different terrain units. It should be noted however that, slope alone does not determine the type of land degradation that operates within a terrain unit and neither is it a rule that all slope with similar gradients are associated with such degradation types.

(iii) **Elevation and Slope Aspect**: The distributiton of land degradation types was observed to be associated with altitude in the basin. This can be supported by the fact that elevation is positively correlated with rainfall and humidity regime of soil (Damen, 1993). The topo-sheet (Zaria 102, S.W.) gives the elevations points of the basin and the use of the parallax bar technique (section 4.2) revealed the following elevations, i.e.

Elevation above sea level	Ref. point	TMU
> 2000m a.s.l.	13	F1/2
> 2000 - 2100m a.s.l.	19	D41
> 2100 - 2200m "	2	SD42

etc. (at intervals of 100m).

Table 5.2: **Slope Classes and Associated Land Degradation Types**

Slope Class	Associated Land Degradation	TMUs	Degradation Activity
1 degree	accumulation glacis flooding, planation, sheet wash, lateral erosion.	F1-F4, AF	very active
1-5 "	sheet, rill erosion soil creeps,	AF,SD11-SD33	very active
5-10 "	sheet, rill erosion gully incision	SD11-SD12, SD21-SD22	active
10-15 "	debris slides,gully slumps, riling	SD22-SD23 SD31-SD33	very active
15-25 "	gully,block slides slumps, debris slide	SD31,SD41-SD42	very active
25-30 "	scarp retreat, head-scarp erosion, gully	SD33, SD41-SD43	very active
30-35 "	head-scarp erosion, runoff, rock fall	SD41-SD42, SD31	active
35-40 "	rock fall, scarp-retreat, debris slides	SD41-SD42	very active
40-45 "	rock fall, headword erosion, debris slides	SD41-SD42	Very active
45 "	rock/block slides, debris slides	SD41-SD42	active

Note: Mapped from some terrain units. The grouping the TMUs is based on general characteristics of the terrain measured. (Source: Field work 1995)

The aspect classes were grouped according to compass point direction, (as: NNW, NEF, SWW, etc). It was discovered that

there were intensive gully erosion on the lower elevations, sheet wash and rill erosion intensifying on midslopes and high elevations. The sun-facing (face slopes) were subjected to severe degradation of the gullying and erosional and sheet wash types than the 'back slopes'.

(iv) **Human Activities and impact**: In addition to natural factors is the influence of man. Man's influences upon the terrain in the basin ranges from construction, agricultural, fuel-wood felling and animal grazing to sand gravel mining in the valley bottom. It was observed on aerial photographs how man's influenced and accelerated the rate of occurrence occurrence of different types of land degradation. For instance, deep gullying was observed to occur on terrain units where man has dug ditches earth movement/sand mining or cleared the land for farming (especially on hill-slopes and valley side slopes). Sheet wash and rill erosion were observed to occur where the vegetation cover have been greatly stripped off. Indeed, where urban settlement encroached on rural fringes land degradation was intense in form of deep gullying and erosion scarps.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The study aim, i.e. application of the use of aerialphotographs and related geoinformatics data such as maps and other relevant texts has been achieved. The types of land degradation identified classified and mapped were complex erosion forms (i.e. gullies, rills, sheet erosion, debris falls, block collapse, slumps, badlands features, and erosional scarps). A spatial distribution map of the types of land degradation and the generalized classification map of the terrain units (TMUs) were prepared (Figures 6.1 and 6.2 respectively).

Terrain unit analysis and the classification of the types of land degradation requires the compilation of various terrain attributes. This was used to predict terrain properties at sites not visited but observed on air photos to having similar characteristics and qualities as seen were sampled elsewhere. The assumptions were based on the following as put by Way (1973), and Ollier(1977); that

-every site belongs to a terrain class,

-the user can identify the terrain class at every site,

-all sites within one terrain are sufficiently similar so that it is reasonable to predict terrain conditions of all from observations of a few. The genesis of the terrain features was

found to be related to a number of factors namely: geology, structure, climate and the influence by man (past and present).

The study also revealed that major factors responsible for land degradation in the basin were largely due to land use systems (bush burning, grazing cultivation methods, fuel-wood cutting), and hydrometeorological factors. It was discovered that the severity of one form of degradation or the other depended upon the intensity of land use type as well as the surface lithology of the soil. For instant, in areas (such as points 20 and 21) where the surface materials were those of loosed and unconsolidated soils and being subjected into intensive cultivation or grazing, the tendency for severe rilling and even gullying erosion was high. Man's agricultural practices and urban construction works and sprawling were found to have exacerbated the nature and intensity of land degradation especially on the fringes of rural areas (Table 6.1). A relationship was found to exist between land use and morphological units (Table 6.2). Major erosional scarps were observed to be bare and unvegetated land areas. While badlands features found to be common on valley side slopes and hillslopes. An increase of about 3.24% in rural land use was noted between the period 1980 and 1989 (Table 6.3). This shows a decline of the same amount in urban land use over the period. However, between 1989 and 1995, a reversal phenomenon was the case as there was an increase of about 5.75% in the

urban land use within a period of just 7 years. Thus, results of the 1989 and field inspection in 1995 clearly revealed the effects of urban sprawling upon incease in gully erosion. Photo-interpretation of the 1980 photos and field inspection in 1995 also proved the impact of urban land use on the terrain.

Interpretation of the 1980 air-photos and field inspection in 1995, revealed massive gully headscarp encroachment along closely settled areas of the basin. This phenomenon was found to be common around the Kudingi, Ungwan Dan-Magaji, Samaru, and the Shika suburbs. The existence of rills in most parts of the basin was found to be attributed to the farming pattern on the one hand and on the other due to animal trampling.

Stripping of vegetation resulting from such land use types exposes the land to direct heating effects of the sun, raindrops impact and runoff. Man's construction and mining activities was 'observed to contribute immensely to erosional headscarp retreat and deep gully incision especially in the Samaru, Tukur-Tukur,Kudingi, and the College of Agriculture settlements. Land degradation triggered by agricultural practices was common but appeared to be more in areas with marked by specific lithologies such as clay, hence characterised by cracking. They are particularly widespread in densely settled, and intensely weathered soils where prolonged excessive land-use has destroyed vegetation, exposing deep, highly erodible soils.

Table 6.1 Land use types and associated types of land degradation in the Kubanni basin.

Land use	Processes	Types of degradation	Activity level
Farming	runoff,sheetwash gullying	gullies, sheet erosion,riils, erosional scarps,'badland s	very active
Fadama	runoff,sedimenta -tion	rills, floodplain badlands gullies slumps	active
Fallowing	sheetwash runoff	rills, sheet- erosion	less active
Grazing	riling	rills, sheet- erosion,gullies erosion scarps	very active
Residential	runoff,sheetwash gulling	gullies, erosion scarps	very active
Commercial	sheetwash,runoff	rills, sheet erosion	active

Source: Field work, 1995/96.

Table 6.2 Reletionship between land uses and physiography in the Kubanni basin.

	Physiography	Land use system
1.	Major scarps	barren land
2.	Hillslopes	barren, sparsely vegetated
3.	valley slopes	sparse to dense vegetation, grazing, some cultivation
4.	River terraces	cultivated,vegetated, grazing
5.	Flood plains	cultivation, grazing

Source: Field work, 1995/96.

Table 6.3 Land use categories in the Kubanni basin (1965 to 1995)

Land use(%)	*1965	**1974	***1980	+1989	++1995
Rural	93.24	8.21	75.23	78.47	62.22
Urban	06.74	11.79	24.77	21.53	37.28

Note:
*1965 Air-photo interpretation estimates
**1974 Air-photo interpretation estimates
***1980 Air-photo interpretation estimates
+1989 Results from field measurements (after Makeri,1989)
++1995 Results from field inspection estimates (research study)

Source: Field work ,1995/96.

Little effort has been made to combat the severity of land degradation in the basin, some of which are afforestation, fallowing, and construction of some drainage systems. These attempts have yielded limited success. A better approach probably would be to re-vegetate the slopes with scrub vegetation which will at least ensure reasonable ground cover and may provide a first step toward eventual

afforestation. This idea has been applied in the Agri-River basin of Basilicata, Italy and found to be quite effective (Soeters, 1993). One other method that can control land degradation in the basin is by 're-grading' the some of the areas already incised by gullies including those susceptible to over land flow. This method though can be quite expensive. Lastly since it has been noted that man's activities has exacerbated land degradation problems in the basin, then the first step to take should be to check such land use pattern that threatens the stability of the terrain.

In conclusion, the use of air-photos in mapping land degradation types over the Kubanni basin was a difficult process indeed. First, lack of up-to-date air photos especially those of the 1990s made comparison almost impossible since what was available were those of the 1960s, 1970s and 1980s. As such some form of partial field inspection had to be carried out for updating of of the present terrain characteristics which could have been achieved within a short time in the laboratory if air photos of the 1990s were available. Next was the lack of 'good' and adequate photogrammetry equipment such as the electrified mirror stereoscopes and overlays which made interpretation so labour intensive and tideous too. The lack of 'digitizers' and computer aided photo-interpreter was another aspect of the problems encountered; for the availability of these equipments would have ease the photo-interpretation as well as effecting

much level of accuracy.

The use of air photos should be encouraged as this forms one of the simplest techniques of quick and accurate large scale mapping available even in this age of satellite technology. Satellite images are only available and useful for small scales mapping as they are taken from far distances in space. Effort should be made to carry out air coverage of the terrain at least once in every five year period. By this it is possible to clearly monitor genue land degradation processes that encroaches daily due to man's economic activities.

REFERENCES

1. Ahmadu, M.I. 1989
   Assessment of Gully density in relation to land use upper Kubbani of Zaria, (B.Sc. Thesis, Dept. of Geography, A.B.U., Zaria).

2. Aronoff, S. 1993
   "Geographic Information Systems" A management Perspective, Wld. Publishers, Ottawa, Canada.

3. Bello, A.L. 1973:
   The Morphology of an erosional scarp south of A.B.U., Zaria (B.Sc. Thesis, Dept. of Geography, A.B.U., Zaria).

4. Bello, A.L. 1994:
   "Discussion based on field trip and analysis" on the River Kubanni and Environment (unpublished).

5. Bello, G.A. 1991:
   Variations in gully morphology within the Kubanni basin system, Zaria (B.Sc. Thesis, Dept. of Geography, A.B.U., Zaria).

6. Burrough, P.A. 1986:
   "Principles of Geomoorphological Information Systems for Land Resources Assessment" Clarendon Press, Oxford, UK, 194p.

7. Carrara, A.; Soeters. R. 1978:
   "Analysis of land-slides form and incidence by statistical techniques, Southern Italy" -Z. Geographical N.F., Vol.9, pp.35-62.

8. Chaga M. I. 1989:
   Geomorphological implications of the nature of landuse within the upper Kubanni basin, Zaria. (B.Sc. Thesis, Dept. of Geography, A.B.U., Zaria).

9. Chen, L.; Guillermo, A.C.; Kyari, J.D. 1994:
   Analysis of Landslides in the bad lands of S. Arcangelo, Itay (Unpublished report, ITC Seminar Paper, Holland.

10. Cleaves, A.G. 1961:
    Landslide investigation: A field handbook for use n highway location and design", U.S. Bur. of Publ. Roads, 67pp.

11. Cooke, R.U. and Doornekamp, 1990:
"Geomorphology in Environmental Management:, Clarendon Press, England.

12. Crozier, M.J. 1973:
"Techniques to morphometric analysis of landslide". Z. Geography, N.F, 171, pp.78-101.

13. Crozier, M.J. 1986:
"Landslides: Causes, Consequences, and Environment", Croom Helm Publishers, Longman.

14. Dada, F.O.A. 1972:
A geomorphology of the Upper Saye Basin. (B.Sc. Thesis, Dept. of Geography, A.B.U., Zaria).

15. Damen, M. 1991:
Introduction to soil erosion by water (ITC Enschede, Holland).

16. Damen, M. 1992:
Personal communication on the landslides: Agri-River Basin Basilicata-Italy.

17. DeGraaff, LWS (et.al.) 1987:
"A Geomorphological mapping system at scale 1:10,000 for mountainous Zeitschrif fur Geomorphologie, Vol.32/2, Stuttgart, June 1987, p.229-242.

18. Drury, S.A. 1987:
Image interpretation in geology; (First Edition). 1987.

19. Florez, A. 1986:
Geomorphologia del ara Manizales-Chinchina, Central, Colombia, University of Amsterdam, 158p.

20. Hansen, M.J. 1984:
"Strategy for classification of landslides", in chapter 1. Slope Instability, Brunsen and Prior (Eds), John Wiley & Sons Ltd., p.1-25.

21. Higgs, G.M. 1965:
Upland soils of the Samaru and Kano area; (Unpublish report Institute of Agric. Research, Ahmadu Bello University, Zaria, Nigeria).

22. Hore, P.N. 1970:
In: Mortimore M.J.(ed) Zaria and its Regions: An occasional paper number 4.

23. Hosomura, T. 1994:
Remote Sensing Techniques for land cover detection. (unpublished) Asian Institute of technology, Bangkok, Thailand.

24. Hutchinson, J.N. 1988:
"Morphological and geotechnical parameters on landslides in relation geology and hydrology", Proceedings from the 5th International Symposium on landslides. Lausanne, Switzerland, 10-15 July 1988, Vol.1, 3-35p.

25. Jeje, L.K. 1978:
"Aspects of Geomorphology of Nigeria", In: Oguntoyinbo, J.S. (et al.) Ed. A Geography of Nigerian Development; Second Edition, Heinnemann Educational Books, Nigeria, p.17-44.

26. Joachim, H. 1993:
Mapping and Modelling (unpublished report on application of Remote Sensing in Environmental management, Inst. for Remote Sensing and Environmental Studies, Ispra, Italy.

27. Keech, M.A. 1978:
Remote Sensing in Planning the control of erosion: National col. of AGric. Engineering Silsoe, Bedford, England.

28. Khan, S. 1992:
Soil erosional in Bangladesh (unpublish report, Dept. of Geol. Studies, Decca Bangladesh.

29. Kingma, N.C. 1993:
ITC. Lecture Notes on Geomorphological photo-interpretation; ITC., Enschede. The Netherlands, 1993: (unpublished).

30. Klinkerberg, K. 1970:
"Soils" In Mortimore M.J. Ed.) Zaria and its Regions, Occasional Paper, No. 4, Geography Dept./, ABU, Zaria, p.55-71.

31. Kyari, J.D. 1989:
Secular changes in the growing season structure over Northern Nigeria, B.Sc. Thesis, Department of Geography, (A.B.U., Zaria).

32. Kyari, J.D.; Chen, L. 1994:
Project research on the Agri-River Basin, Basilicata, Italy. (Unpublished, ITC PROJECTS, Enschede, Italy). Project research.

1-463087

33. Kyari, J.D. 1994:
Mapping of Terrain Units and Landslides in the Agri River Basin, Basilicata.

34. Meijerink, A.M.J. 1988:
"Data acquisition and data capture through terrain mapping units". ITC Journal, Vol.1, pp.23-44.

35. Mortimore, J.M. (ed) 1970:
"Zaria and its Region", An Occasional Paper No.1, Department of Geography, Ahmadu Bello University, Zaria, Nigeria.

36. Naithani, K.K. 1990:
"Can satellite imagery replace serial photographs?" A photogrammetrists's view. ITC Journal, 1990-1, pp.29-31.

37. Oliver, C.D. 1997:
'Terrain classification methods: Application and principles, J.R. Hailo (ed), Appl. Geomor., Elerv, New York, p.277-316.

38. OLoge, K.O. 1972:
"Gully in Zaria Region" Headscarp Recession - a preliminary study of headscarp recession: SAVANNA, Vol.3, No.1, 1972.

39. Ololobou, Y.F.S. 1982:
"Some aspects of river channel morphology in the Zaria Area, Northern Nigeria" (Ph.D. Thesis, dept. of Geography, A.B.U., Zaria, Nigeria).

40. Oyedun, F. 1991:
An assessment of erosion: Upper Kubanni Basin, B.Sc. Thesis: Dept. of Geography, A.B.U., Zaria.

41. Rabelo, R.M. 1980:
Landslides Occurrence in the Agri River Basin, Basilicata, Italy, M.Sc. Thesis report: ITC, Enschede, Holland.

42. Rendell, H.M. 1982:
"Landslides: Occurrence and mapping". In: J.L. Van Genderen (et al.) (Ed). Operationalization of Remore Sensing, Vol.3, (1993). Conference paper, ITC, Holland

43. Rengers, N., Soeters, R. and Westen van, C.J. 1992:
Remote Sensing and GIS applied to mountain hazard mapping. Episodes, Vol.15, No.1, pp.36-45.

44. Rengers N.; Robert, S. 1993:
"Satellite Remote Sensing and Geographic Information Systems for Landslide Hazard Zonation", In: J.L. Van Genderen (et. al.), Ed. Operationalization of Remote Sensing, Vol.3, p133-140, International Conferences on RS/GS, ITC, Holland.

45. Rib, N.J.; Liang T. 1978):
"Recongition and identification": Landslides, Analysis. In: Special Report 176 (cont.), Transportation Research Board, National Research Center, National Academic Sciences, Washington D.C., p.34-79.

46. Ritchie, C. 1978:
"Recognition and Identification of landslide" from Landslides and Engineering Practice Highway Research Board Special Report 29, Eckel E.B. (edited), p.48-68.

47. Richter, C. 1958:
Soil Erosion in Germany and Czechoslovakia (Physiche Geographie Universitdt Trier).

48. Robert, L.; Julia, A.J. 1984:
Dictionary of Geological Terms. (Third Edition). American Geological Institute, Anchor Books.

49. Selby, M.J. 1993:
Hillslope Materials and Processes: (Second Edition).

50. Sheyin, T. 1989:
Gully intensity in relation to soil characteristics in the upper Kubanni River Basin. (BSc. Thesis, Dept. of Geography, Ahmadu Bello University, Zaria.)

51. Sissaskian, D. 1986:
"The Study of mass movement from aerial photographs", Symposium on Remote Sensing for Resources Development and Environmental Management, Enschede, The Netherlands, August, 1986.

52. Soeters, R. 1991:
"Remote Sensing and Geographical Information Systems as applied to mountain hazards analysis and environmental monitoring" 8th Thematic Conference on Geological Remote Sensing, Denver Colorador, U.S.A. Apr. 29-May 2, 1991.

53. Soeters, R. 1993:
Field lectures on effects of flooding and soil erosion in the south-western region of the Netherlands,(unpublished).

54. Soeters, R. 1994:
Personal Communication in the AGri River basin of Basilicata, Italy (unpublished).

55. Strandberge, C.A. 1967:
"Aerial discovery manual", John Wiley and Sons, Second Edition.

56. Terzaghi, K. 1960:
"Mechanism of Landslides". From the Geological Society of America, Harvard University Press, pp.83-123.

57. Thorp, M.B. 1967:
"Landscape Evolution" In Mortimore M.J. (ed.) Zaria and its Regions, Occasional Paper No.4, Geography Dept., A.B.U., Zaria.

58. Thorp, M.B. 1971:
"Landforms" In Mortimore M. J.(ed.). Zaria and its Regions, Occasional Paper No. 4, Geography Dept., A.B.U., Zaria.

59. Van Western K. 1992:
"Medium Scale Landslide hazard analysis using a PC based GIS - A case study Chinchina, Colombia", The first international symposium on the use of remote sensing in geographical information systems for the study of natural hazard, 8-15 March, 1992, Bogota, Colombia.

60. Varnes, D.J. 1984:
"Landslide Harzard Zonation"" a review of principles and practices, published by UNESCO, Paris, France, QE599.A2., 61p.

61. Veder, C. 1981:
"Landslides and Their Stabilization", Springer-Verland Publishers, New York.

62. Way, D.S. 1973:
"Terrain Analysis", A guide to site selection using aerial photographic interpretation. Dowden. Hutchinson and Ross, Stroundsburg, p.1-35.

63. Wright, J.B., P.McCurry, 1971:
"Geological", In: Mortimore M.J. (ed.) Zaria and its Regions: Occasional Paper No.4, Geography Dept., A.B.U., Zaria. p.5-12.

64. Yang, X. 1993:
Frequencies of Landslides in Southern China. (unpublished report, Inst. of Geography Chinese Academy of Sciences; Beijing, China).

APPENDIX A

Sample and Reference Points and their Photo Coverage

Reference Point	Photo Series	Reference No.
1 and 2	65113	13 - 14
	70705	10 - 11
3	65113	14 - 15
4	70705	10 - 11
	65209	51 - 52
5 and 6	70705	1- - 11
	65113	16 - 17
7	70705	22 - 23
8	70705	13 - 14
9	70705	12 - 13
10	70705	7 - 8
11	70705	13 - 14
12	70705	25 - 26
	65113	19 - 20
13	70705	6 - 7
14	70705	5 - 6
	65113	22 - 23
15	70705	3 - 4
	70705	4 - 5
16	1980	054 - 056
17	1980	056 - 058
	65109	43 - 44
	70705	2 - 3
18	1980	054 - 056
	65113	22 - 23
	70705	3 - 4
19	1980	054 - 056
20 and 21	1980	054 - 056
22 and 23	1980	056 - 058
	74194	145 - 146
24	1980	054 - 056
25, 26 and 27	74194	145 - 146
	1980	054 - 056
	74194	145 - 146
	1980	054 - 056

APPENDIX B

Aerial Photo Coverage of the Stereo-triplets

	Triplet No.	Photo Series	Photo Type	Aerial Coverage
Figure	4.7a	70705-3/5	Pan(B/W)	Ung.Mal.Tsofo,Mako, Lumbyaiyi, etc.
	4.7b	70705-5/7	"	Ung.Dan Mako, Kubanni Dam and surroundings
	4.7c	70705-22/24	"	Samaru Village Gully, A.B.U. (Vet.Med., Dan Fodio Hall, etc.)
	4.7d	65109-48/50	"	Ung.Maigamo, Upstream Kubanni
	4.7e	65109-50/52	"	Kudingi gully and surrounding
	4.7f	1980-054/058	"	Kufena Rocks, Aviation Run-way, Forest Reserves
	4.7g	74194-44/46	"	Tukur-Tukur Village, Gaskiya, Sabon-Gari.