THE IMPACT OF KIRI DAM ON LAND USE /LAND COVER DOWNSTREAM IN THE GONGOLA RIVER BASIN, ADAMAWA STATE, NIGERIA

BY

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A THESIS SUBMITTED TO THE POST GRADUATE SCHOOL IN PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY (Ph.D) IN REMOTE SENSING APPLICATIONS, DEPARTMENT OF GEOGRAPHY, SCHOOL OF SCIENCE AND SCIENCE EDUCATION, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

NOVERMBER, 2008

DEDICATION

This thesis is dedicated to my Daughter Aisha.

DECLARATION

hereby declare that this thesis is my own work and has not been presented in any form for ıny qualification at any other tertiary institution. The information derived from the ›ublished works of others has been duly acknowledged in this thesis.

3rd Feb. 2009

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CERTIFICATION

This thesis titled: **The Impact of Kiri Dam on Land use/Land cover downstream in the Gongola River Basin, Adamawa State, Nigeria** by: **Dalil, Musa (Ph.D/SSSE/2001/72)** meets the regulations governing the award of the degree of Ph.D of the Federal University of Technology, Minna and is approved for its contribution to scientific knowledge and literary presentation.

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ABBREVIATIONS

ETM .... Enhanced Thematic Mapper

FCC.......................... False Colour Composite

Landsat .... Land satellite

GIS .... Geographic Information System

MSS .... Multi-Spectral Scanner

NDVI........................ Normalized Differential Vegetation Index

TM .... Thematic Mapper

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

To ensure judicious resource management, it is necessary to measure the impact of human activities on the natural systems. Perhaps this is the reason why geomorphologists, among other scientists, have found themselves involved in a new brand of environmentalism involving a desperate search for productive quality (and how to maintain it) in the environment (Mikesell, 1994). The drainage basin is a suitable environmental unit in which to pursue the search for quality in land and in water, because it is a natural system which man, often than not, manipulates for socio- economic reasons. Mrowka, (1994) has identified several ways in which man manipulates a drainage basin, one of which is direct channel alteration. He contends that man alters natural channels directly through the construction of dams and reservoirs, channelization, bank treatment and irrigation diversion. He believes that because of the linkages between the watershed characteristics and the stream at any point, man's alteration of the watershed attributes should be reflected in changes in the locations throughout the drainage basin (Mrowka, 1994).

But of the various ways in which man manipulates the drainage basin, the construction of dams and reservoirs has received considerable attention, because dams and reservoirs are considered as part of the effective and desirable means of solving the problem of flooding in the humid areas, and of combating water shortage in the sub-humid and arid areas of the world.

The success, which Adamawa State has achieved in its water resource development that rests mainly on the construction of dams, has strengthened the belief in dams and their reservoirs as the best solution to the problems of water deficiency in the savanna areas of Nigeria. Within the last 20 years, not less than 15 earth dams were built, of which up to 10 are now in operation. The construction of dams is a main pre-occupation of several state governments in the savanna areas of the country at present.

The first attempt at dams construction in Nigeria started with the building of small concrete dams in the south – western parts in the 1950s. By the 1960 more than 30 towns and villages in that part of the country were getting their water supplies from these dams. The national sub-committee on National Water Resources Council on Dams (1994) report revealed that Nigeria had about 108 dams with a total capacity of 26, 291 x $106m^3$ and most of these were found in the middle – belt and northern parts of the country. There are about four types of dams in Nigeria; the first type includes the small earth dams built essentially for small-scale irrigation, livestock, veterinary and small-scale fishing. Large agricultural agencies, private individuals and some government parastatals and agencies usually construct this type of dams. The second group consists of municipal dams for water supply to towns, cities and rural municipalities. This type of dams abounds in large numbers in the western states, particularly in Osun and Oyo States. Examples of municipal dams are Erinle and Eleyele in Osun and Oyo States respectively. Others are Kubanni and Gaima in Kaduna State, Kogin Gira, Lamingo and Shen serving Jos municipality in Plateau State, Asejire in Osun State, Ero in Ekiti State, Ojirame in Edo State and Oyan in Ogun State (NEST, 1991).

The third type of dam found in Nigeria comprises the multipurpose dams constructed essentially to serve two major objectives: irrigation and water supply. This type of dams exists in Kano, Kaduna, Bauchi, Sokoto and Borno states. Kano state has about 20 of this type of dams with the Tiga dam being the largest. Other dams that fall under this type include the Kiri Dam in Adamawa State, which is the focus of this study and the largest in the State. The type of this dam also exists in other towns, including Kafin Zaki, Misau, Dindima and Kirfi in Bauchi State. Kangimi and Matari in Kaduna State, Dutsinma and Jibia in Katsina State, Zoba in Nasarawa State, Bakolori and Goronyo in Sokoto State.

The fourth type of dam is the large multipurpose dam designed essentially for electricity generation. Dams in this group include the Jebba dam on River Niger, the Shiroro Dam on River Kaduna and the Kainji Dam also on River Niger.

Globally, there has been a dramatic increase in the number of dams over the last 20 years. The utilities of the dams are immense, and include irrigation and industrial uses, protection against flooding, hydroelectric power generation, water supply and creating artificial lakes for recreation.

However, it is only recently that some doubts are being expressed as to the best solution to water management problems. For example, Maigioi, et al (1997) quoted an Emir, as saying that the land in Guyuk is dying, following the operation of the Kiri dam. However, it is observed that the fadama agriculture could not have been more rewarding in terms of socio–economic cost than the construction of gigantic dams. More recently, Edenton and

Edenton (1999) have contended that the "benefits derived from impoundment schemes are frequently associated with undesirable side – effects".

In the light of these statements, it is apparent that the construction of dams constitutes some problems not only to the socio – economic systems, but also to the quality of natural systems as well. It is envisaged therefore, that environmentalists would help towards finding solutions to some of the associated environmental problems by identifying, describing and interpreting the characteristics of the problem of impoundment.

1.2 **Statement of Research Problem**

Construction of the Kiri dam offers some prospects and introduces some problems that can be divided into two categories, the first of which are effects on the river basin hydrology and, the second, the socio-economic activities. It is known that dams and their reservoirs affect channel morphology, sediment and soil characteristics and vegetation; in short the entire ecosystem of the downstream (Olofin, 1980). Many of these effects are known to be negative. For example, channel erosion is common downstream of dams while the migratory movements of some species of fish and other aquatic organisms are curtailed. Also, species of flora and fauna are often drowned out of existence under impounding reservoirs.

Channel erosion and other human activities associated with the construction of hydraulic structures increase the array of pollutants that are transported in affected river systems. Such pollutants, which may include pathogens and toxic materials from cultivated valley side slopes, affect the utilization of the affected water for domestic, industrial and agricultural purpose.

The problems with the Kiri dam are not limited to natural ones. It is known that large scale irrigation with its concomitant dam construction leads to the displacement and land dispossession of many peasants; changes in land use and tenure, adverse changes in occupations such as fishing and small scale fadama cultivation; unsatisfactory compensation and haphazard resettlement schemes. Infarct, dam construction projects have brought so much socio-economic distraction in certain areas that many writers (Palmer, 1987) has wondered why such projects are embarked upon at all in developing countries.

The aquatic ecosystem is also affected by the creation of dams and artificial lakes. They become perennial water bodies that serve as media for aquatic life alien to that ecological zone. Dense algae growth and aquatic weeds choke and invade channels and distribution systems that are rich in organic matter. Natural vegetation, flora and fauna are disturbed. Some of these changes could be highly devastating. It is not uncommon for health problems associated with the coming into existence of those dams to be considered too late and more often rushed efforts are made to combat these health problems only when they have attained epidemic proportions. Many of these are debilitating and chronic, for example, schistomiasis. Management of these dams could also lead to the formation of stagnant ponds, which accentuates the breeding and transmission of typhoid fever and malaria, among others.

1.3 Aim and Objectives

The aim of this study is to assess the changes in land use/land cover along the lower reaches of Gongola River as a result of the impact of Kiri Dam.

To achieve the above aim, the following objectives were pursued:

a) analyse the environmental condition of the land use/land cover for the pre-dam period (1975) and the post-dam period (between 1975 and 2007) in terms of aerial extent and percentage coverage.

b) identify the magnitude of change that has occurred on the land use/land cover condition during the post dam period.

c) determine some major impacts of Kiri Dam on the socio-economic activities in the study area as viewed by the inhabitants.

d) assess the impact of the Dam on landuse/landcover and socio-economic activities in the basin.

e) make recommendations appropriate to the findings.

1.4 Justification for the Study

The problem of inadequate data for planning in Nigeria remains the most important bottleneck militating against sustainable development in all sectors of the nation's economy. Nduaguba (1996), while commenting on the solid minerals development policy draft, observed that no adequate earth resources data management system has been put in place anywhere in Nigeria to ensure sustainable economic planning for the nation's vast natural resources. The committee on solid minerals policy in its draft report (1996) expressed dismay in finding that "data emanating from Nigeria is contradictory." The utilization of such data by resources personnel complicates the situation, in that wrong tools are often applied (e.g. use of single item data set such as satellite data for E/A studies) without due consideration to their limitations, attributes and characteristics.

This study is justified for the fact that resources data are not readily available in the country, even if they are, certainly not in a usable format accessible to the intending users. On this note, users must appreciate the shortcomings of the data sets they intend to use before venturing to apply them for any scientific study.

Kiri Dam has been in existence since 1976, yet it has never been subjected to a thorough post implementation environmental impact assessment. After the design and construction of a dam, many environmental problems arise, some of which can be highly devastating. The problems could at best be tackled by resorting to a thorough Environmental Impact Assessment, through a sustainable environmental management and acquisitions of information on existing patterns and the dynamic situation over-time.

This study is therefore justified in the sense that if Enhanced Thematic Mapper data set is found valuable for environmental impact assessment, we can be assured that we have a powerful tool for assessing and planning the environment.

1.5 **Scope of the Study**

The study covers the lower part of Kiri Dam to River Benue, consisting of three Local Government Areas: Shelleng (with seven villages), Guyuk (with sixteen villages) and Numan (with five villages) as presented in Table1.1. This allows for different classes of land use\land cover to be included in the analysis. The research concentrates mostly within the downstream of Kiri Dam predominantly used for irrigation activity. The study also covers the socio-economic impacts of the dam on the people as well as on the environment. In this context, ten (10) villages were selected for study as shown in Table1.1.

Table 1.1: The existing villages located at the lower course of Kiri Dam

S\N	SHELLENG L.G.A(Villages)	GUYUKL.G.A(Villages)	NUMANL.G.A(Villages)
1	Sabewa	Wuro Waziri Gadawa*	Bungudu
2	Wuro Munchi	Bare	Linga Tassala*
3	Wuro Jauro Atiku*	Ndasso	Bilachi
4	Dukolichi	Jigawa	Mbalang*
5	Anderu*	Wuro Jauro Sheduri*	Kapalakan
6	Bariel	Gelode	
7	Kabawa	Ndasso Kiri	
8		Kiri*	
9		Ken Mai-kasuwa*	
10		Garin Obasaya	
11		Zangen	
12		Opalo	
13		Shumun*	
14		Kwanar Kuka	
15		Ndasso Bachema	
16		Wuro Jauro Ahmadu*	

* The selected Villages

1.6 **Organization of the Thesis**

The thesis is divided into five chapters. Chapter one focuses on the introduction and background information on the evolution and types of dams including people's perception on dam construction. The problems in the study area that prompted this research were discussed in this chapter. The chapter also focuses on the aim and objective of the research and the general overview of the geography of the study area.

Chapter two focuses on review of related literature, comprising of literature on rationale for using remote sensing as a tool for earth's resources investigation; review of studies on environmental impacts of reservoirs and application of remote sensing in land use/land cover studies. Chapter three is committed to research methodology. It discusses the research methods and procedures of collecting and processing field survey data and satellite image data.

Chapter four is devoted to results. The chapter presents results arising from the methods, analyses of satellite image data and field survey data. Chapter five focuses on discussion of results, summary of findings conclusion and recommendations.

1.7 **The Study Area**

1.7.1 **Location of Adamawa State in the Context of Nigeria**

Adamawa State was created in 1991 out of the old Gongola State. It is located in the extreme eastern part of Nigeria as presented in Fig. 1.1. Adamawa is bounded at the North by Borno State, west by Gombe State and south by Taraba State. The Cameroon Republic bounds the entire eastern flank of the state. The State stretches from approximate Latitude 9^0 14^1N in Ganye to Longitude 12^0 38E in Madagali L.G.A. The state has total land coverage of about 42,158sq.km (Mirchaulum, 1994).

1.7.2 **River Gongola and Kiri Dam Location**

River Gongola, the major right-hand tributary of River Benue has a catchment area of 56,000km^2. The study area covered a stretch of 35km from the Kiri dam to the confluence of the River with River Benue at Numan. The channel is located within latitudes $9^0 35^/$ to $9^0 41^/$ N and longitudes 12^0 to $12^0 5^/$ E. Also included within the study area are settlements of Kiri, Wuro Jauro Boderi, Ndasokiri among others, as can be seen in Fig.1.2.

1.7.3 **Relief, landform and Drainage**

The relief of the Gongola catchments ranges from I,200m on the Jos Plateau (the source region of the river) to less than 300m above mean sea level at its mouth (confluence of the river with River Benue) at Numan. On the Plateau, south and west the landform is a clear escarpment but on the Gongola side, the Plateau merges indistinctly with the high Bauchi plains (Fig. 1.3).

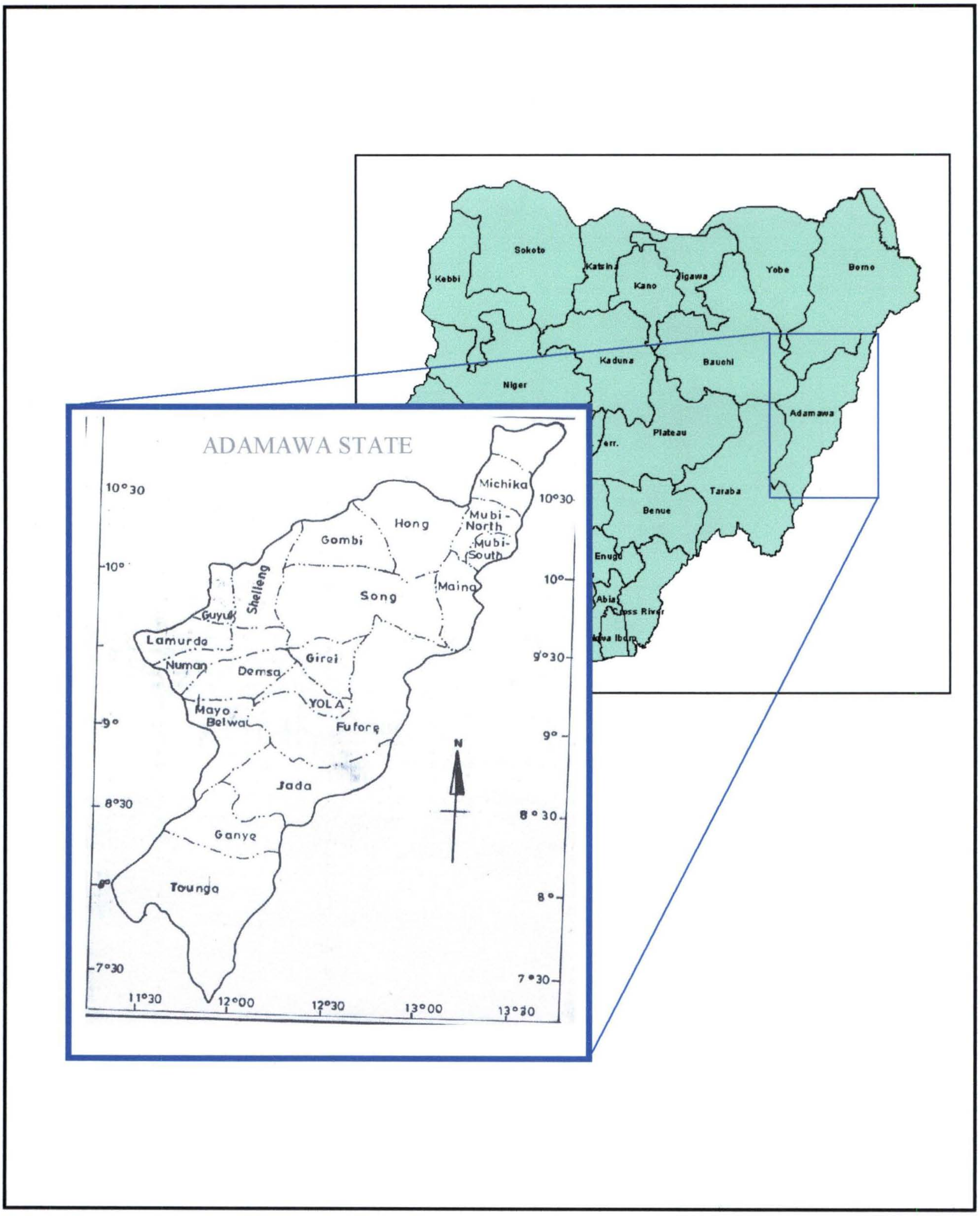


Fig.1.1: Nigeria showing the location of Adamawa State

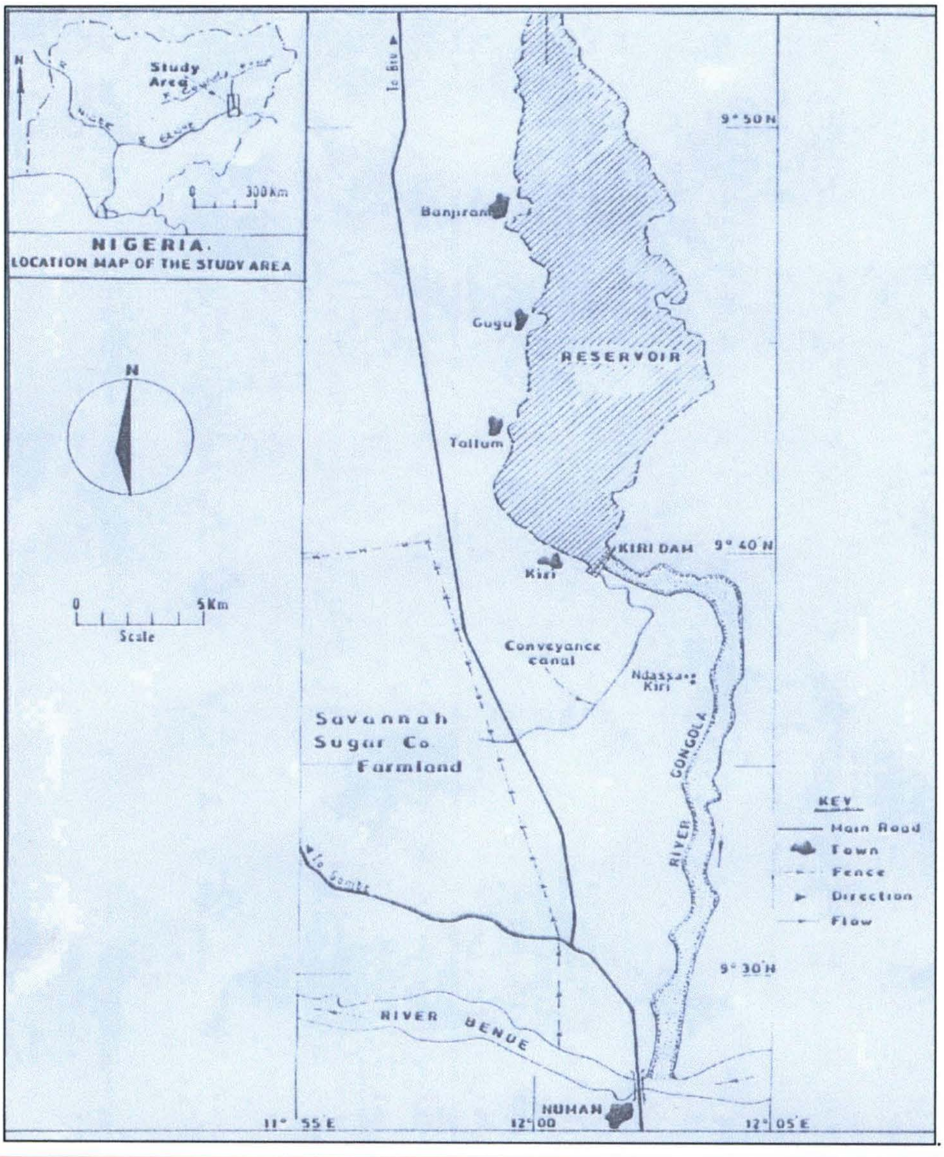


Fig.1.2: Kiri Dam and Lower Gongola - the Study Area (Source: Mubi, 2001)

Stepping down in elevation as the mature Gongola river cuts through the crystalline pre-Cambrian and much weathered rock known as Basement Complex, the successive lines of hills on the edge of the Jos plateau are replaced by isolated outcrops (inselberg) standing up to 300m above the plains. The Gongola continues to flow northeast to Dindima and the Kenken sandstone plateau, which has even lower relief than the Bauchi plains. Being particularly permeable, the sand stones add little to the Gongola River. No major tributary enters the river until it turns east, passes through Nafada and bends southward (Cater et. al, 1977) to form the section which constitutes the study area. Most parts of the study area are liable to flooding and water logging or are swamps running parallel to the river channel. This is because of the low lying nature of' the area and the nature of the mineral constituents of rocks being clay, shale and limestone. Drainage is a problem during the rainy season. The post dam sediment transported by the river, none availability of data on land practices and changes within the river basin, are the known determinants of the quantity of sediment yield in the basin catchments. These limitations made it impossible to identify and establish spatial and temporal patterns of the channel plan form.

1.7.4 **Geology**

The river takes its source from a crystalline rock that is described geologically as alkaline anorogenic complexes of the Jos Plateau, which was emplaced during the Jurassic period. The rock is also referred to as Younger granite of Nigeria and it consists mainly of volcanic rocks in form of trachytes, rhyolites and ignintrites and also those of plutonic origin consisting of granites and synites (Cater et al, 1977).

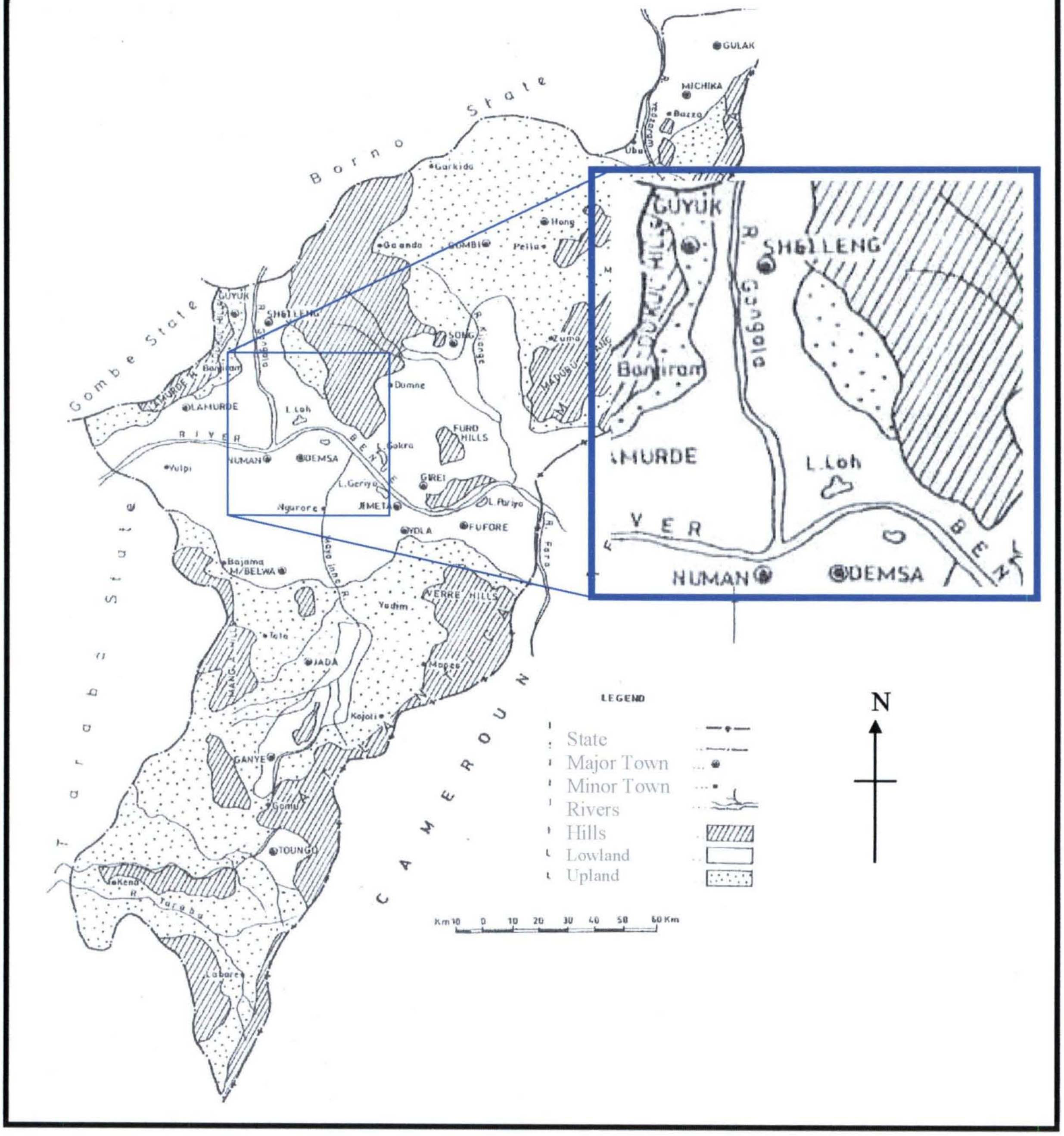


Fig.1.3 Landform types in Adamawa State and the study area (Source: Tukur, 1999)

The river juts into a tertiary terrain of the Upper Benue trough sedimentary basin. The formation encountered is known as Keri-Keri formation. The formation is a continental sequence of sandstone deposited during geologic time as locustrine and deltaic sediment (Cater et al,. 1977). The river moves down into the cretaceous formation of the Upper Benue trough where it encounters the Bima and Pindiga formations. The Bima formation is the oldest cretaceous sedimentary deposit consisting of large class of' materials; surface sand and shale formations, it encourage subterranean flow of tinder ground water, so that water table drops very low during the dry season.

1.7.5 **Climate**

The climate of the upper course of the Gongola basin lies in the Guinea savanna and consists of Jos Plateau and lower Hawal catchment which has high rainfall. While the lower course of the Gongola lies in the Sudan savanna with less rainfall. The rainfall regime in the area is a tropical type with distinct wet and dry seasons.

The climate of the study area is determined by two air masses, namely, the equatorial maritime air mass and the tropical continental air mass. The boundary where the two air masses meet is termed Inter-Tropical Discontinuity (ITD). The equatorial maritime air mass is associated with rain-bearing south-west winds from the Atlantic Ocean while the tropical continental air mass is associated with the dry and dusty hamattan from the Sahara desert. With a south-ward movement of the sun in winter, northeasterly hamattan winds from the Sahara are drawn into this area. These winds have a dehydrating effect on the skin from the Sahara are drawn into this area. These winds have a dehydrating effect on the skin and often bring about poor visibility and last from November to March. This is accompanied by low relative humidity. The north-ward movement of the sun from March brings about a reversal of the wind direction.

The rainy season begins in the study area as from April with rain increasing progressively, reaching its peak in August and September and subsiding in October to early November. The average annual rainfall ranges from 605mm in lower Gongola Basin (Table 1.2) to over 1040mm in the upper Gongola basin.

Throughout the year there are considerable variations of the amount of the rainfall as well as diurnal ranges in temperature and relative humidity. The coldest temperature is about 18^0C, recorded between December and January. The potential evaporation, which is a function of temperature, is high throughout the year. The relative humidity is also a reflection of the temperature, and it is high between May and October, (rainy season) when it ranges from 60% to 70%. The lowest values are recorded during dry season when it drops to between 27% and 35% (Yavala, 2006).

Table 1.2: Variation in annual rainfall between stations in the study area

Year	Station		
	Numan 9^0 20′N 12^0 07′E	**Guyuk $9^0$45′N 11^0 45′E**	**Shelleng 10^0 10′N 11^0 20′E**
1990	773.0	645.0	695.5
1991	876.0	675.0	695.5
1992	839.7	783.3	683.4
1993	602.0	877.3	702.6
1994	480.0	596.6	506.3
1995	1013.0	987.2	956.1
1996	850.0	1043.2	82107
1997	656.0	618.8	599.4
1998	865	686.7	843.8
1999	637	730.6	850.3
2000	949	786.0	648.0
2001	686	777.5	887.7
2002	1089	835.5	790.7
2003	909	NR	972.3
2004	605	968.2	942.3
2005	985	907.7	828.8
2006	995	709.0	857.9

(Source: Yavala, 2006)

1.7.6 **Type of Soil**

The texture of the surface soil of the study area is mainly clay, which contributes towards water logging during the rainy season. The soil of the area falls into the hydromorphic group of Nigerian soils (Mirchaulum, 1994). Such soils are developed on alluvial marine and fluviomarine deposits notably along river flood plains.

1.7.7 **Vegetation and Forest Resources**

The major vegetation formations in the state are the southern guinea savanna, northern guinea savanna and the sudan savanna (Mirchaulum, 1994). Within each formation is an interspersion of thickets, tree savanna, open grass savanna, and fringing forests in the river valleys. It is however, necessary to note that large-scale deforestation resulting from indiscriminate extraction of wood for fuel and expansion of agricultural land area within each vegetation type with few indigenous woody plant species has occupied. Most area, especially those close to the settlements, is covered with exotic species such as the *neem* and *eucalyptus* trees.The Benue valley, which cuts Adamawa State into almost two equal parts, consists dominantly of marshy land grasses.

The natural vegetation in which the study area lies is termed by the plant geographers as the Sudan savanna zone, a distinction which implies a grass land vegetation inter-sparsed by short trees. The nature of the vegetation over the area reflects the activities of man and his livestock. The availability of natural vegetation of greater stands of trees in the study area is not common. The most widely spread species in the area include *Acacia*

Seibberiona, Adensonia Degitata, Albeizia, Chevolieni, Parkia, Clapertoniana to mention but a few.

1.7.8 **Population Density**

Excessive human population levels may build up in particular areas because of political direction and this can lead to land degradation (Goudie, 1990). It is for this reason that an assessment of the population distribution of Adamawa State may not be considered out of place. Table 1.3 gives the distribution of population on local government basis. The size of the local government has no relationship with the population size. While Ganye and Song Local Government Areas boast of having the largest land areas, their populations are less than the 200,000 mark each as at 1991. Yola and Mubi, however, which have relatively small land areas, have population sizes about 24,000 each. Three local government areas can be said to have population densities that are high enough to raise fears on land degradation. These are Mubi, Yola and Numan Local Government Areas. Places like Fufore, Ganye and Song that seem to have relatively high populations have correspondingly large land areas. All the other Local Government Areas have populations less than 120,000 while Mayo Belwa is having the highest with 125,073 and Guyuk having the lowest with 70,526 (National Population Commission, 2006). Population density since the time of Thomas Malthus has been blamed for the exhaustion of natural resources. In the case of land degradation, it is believed that an increase in the demand for wood is a major factor. It can also be blamed for constant clearing of land for farming. It follows therefore that an increase in the demand for wood and other agriculture related activities will result into an increase in the depletion of vegetal cover, which ultimately results in land degradation.

1.8 **The Kiri Lake Basin**

The Kiri Dam constructed on the River Gongola in 1976 lied within the northern Sudan Savanna vegetation zone of Nigeria. The Kiri lake region is a part of the wide zone known as the middle belt running west to east across Nigeria. The belt encloses the broad valleys of the Gongola and Benue rivers as well as the Jos Plateau and the northeastern highlands. The region has low population density with high degree of ethnic fragmentation. The inhabitants of low lying, often-marshy areas of the Kiri Islands and banks of the middle Gongola Basin include Lao, Ndasso, Kursa and Fora. Their main occupations are fishing and farming. The downstream inhabitants comprise the Jenjo, Mapo, Sukur and Hausa, occupying the Fadama area of the Gongola River. A wide range of food crops comprising both the root tubers such as yam and cassava and cereals such as guinea-corn, millet and maize are produced. Others include sugarcane and a variety of vegetables and fruits. The Kiri lake basin comprises of three (3) main resources commonly investigated for impact assessment which include aquatic, terrestrial and wetland resources.

Table 1.3: Population distribution by local government areas

	LGA	POPULATION (1991)	POPULATION (2006)
1	MADAGALI	90,159	101497
2	MAIHA	83192	93653
3	MICHIKA	117684	132483
4	MUBI-NORTH	56477	63577
5	MUBI-SOUTH	188983	121744
6	GOMBI	88635	99781
7	GIREI	78605	88490
8	HONG	117240	131983
9	SONG	119869	134940
10	FUFORE	158137	178023
11	GANYE	115285	129786
12	JADA	124856	140557
13	MAYO-BELWA	125073	140801
14	TOUNGO	31550	35515
15	YOLA-NORTH	146501	164924
16	YOLA-SOUTH	111205	125190
17	DEMSA	81525	91769
18	]GUYUK	70525	79395
19	LAMURDE	66635	75015
20	NUMAN	77441	87181
21	SHELLENG	52447	59076

(Source: National Population Commission, 2006)

1.8.1 **Kiri Reservoir**

The variation in the lake water level is controlled by a number of factors, which include:

a) An inflow into the lake from the area surrounding the lake basin (white flow) between August and November and also the upper catchments of the Gongola River (black flood) which occurs from December to March.
b) Rainfall within the lake area;
c) Evaporation losses from the water surfaces;
d) Seepage through the underground fault across the reservoir beneath the dam.
e) Spilling (mainly during high flood) to satisfy storage and downstream commitments.
f) Domestic water supply; and
g) Irrigation water use

Although Kiri Lake is not very large, it has a variety of characteristics, which makes it stand out from most man made lakes in Africa. These include:

a) The wide fluctuation of its water level from the maximum high level in November and March and dropping about 12 meters to the minimum low level in August / September; and
b) The division of the lake into three natural basins namely: the upstream section being strongly under the influence of inflowing main stream water, the middle section consisting of shallow water that covers the largest central part of the lake and the downstream end being the narrowest and the deepest of all (Fig.1.2).

In addition, two different types of flood are experienced in the catchment area of the lake as a result of run offs from local water rainstorms and delayed flow in the main stream. It has been observed that the local water carries larger quantities of colloidal materials giving the flood its milky-white colour. The second (black flood), which originate from the upstream catchment areas of Jos Plateau loses most of its alluvium content in its journey before reaching Kiri through the river Gongola. The water of Gongola River during the mid season is typically turbid owing to suspended silt and clay materials. This turbidity is most pronounced during the white flood.

CHAPTER TWO
LITERATURE REVIEW

2.1 Introduction

This chapter reviews available literature on the rationale of using remote sensing as a tool for Earth's resources investigation. It also attempted reviews on remote sensing applications in land use/land cover studies. The chapter also reviews studies on environmental impacts of reservoirs.

2.2 Rationale for Using Remote Sensing as a Tool for Earth's Resources Investigation

Lintz and Simonett (1976) defined remote sensing as "the acquisition of physical data of an object without touch or contact". Howard (1982) defines remote sensing as "the acquisition of data and derivative information about objects or materials (targets) located on the earth's surface or in its atmosphere by using sensors mounted on platforms located at a distance from the targets and electromagnetic radiation." Whichever definition one chooses to apply for understanding remote sensing, the essential point to note for the purpose of this study is that remote sensing is considered an investigative tool for earth resources impact assessment. It is a technology that has afforded making much diverse application. Its usage has gone through a number of phases, which include invention and utility of aerial photography.

Ojaleye (1996) while commenting on the rationale for using visual interpretation of remote sensing data observed that there has been a tendency for "overselling" the use of computer technology in the third world countries like Nigeria. She recommended a gradual progressive approach from the traditional method of visual data interpretation techniques to advanced sophisticated systems involving the use of computers. In her opinion, visual interpretation of satellite imagery technique is a realistic alternative to numerical analysis of data especially when it comes to the question of assessing natural resources for development and when costs are the deciding factors.

According to Erickson (1994), remote sensing is a powerful tool for EIA in the future. Remote sensing data from aerial photograph, radar and satellite imagery can be used either singly or in combination, to study changes in the physical aspect of the negative impacts of dam construction. Soil moisture content, which is an indication of water logging, pounding and fluctuation of the ground water, can be delineated using remote sensing data. This is because of the change in absorption or reflectance spectrum in the visible region that occurs in the soil when it absorbs water. Soil temperature changes caused by surface moisture difference can also be detected using thermal infrared. Imageries acquired prior to the development of water projects will persist in identification of areas where soils have been distorted, where organic matter had been dislodged and transported into water ways, and where natural vegetation and soil humus which normally retard rapid run-off have been removed, thus increasing the material load being carried by the water.

Erickson (1994) observed that changes in water quality especially turbidious suspended load, temperature increase, pollutants can also be revealed by remote sensing data. These changes are usually caused by presence of life forms or contaminants in water. Shallow water areas could be decided because the natural colour of the bottom can be seen. Surface water temperature can be mapped using thermal infrared scanners and radiometers. Colour infrared photographs and imageries can be used to monitor the sudden changes in vegetation resulting from environmental damage due to pollution arising from the application of pesticides, fertilizer, herbicides and minerals to soils. Remote sensing is also useful for monitoring and mapping land use/land cover. While land use usually refers to the use of land by the people with emphasis on functional role of land in economic activities, land cover refers to what is presently visible on the earth's surface. These include vegetation (natural and man made), trees and buildings. Accurate monitoring and mapping of land cover information can be made possible by interpreting more or less directly from evidence visible on the remote sensing imagery.

Most investigators who have attempted to use landsat data for wetland inventory or classification have used computerized digital processing techniques (Anderson and Brown 1973, Carter and Richardson 1981, Neraassen and Macaulay 1981). The rationale behind digital processing for wetland inventory and classification is the elimination of interpretation subjectivity while improving detail and increasing accuracy. Infrared imagery has been used to identify the distribution of surface water, including occurrences and basin morphology. Incident Electromagnetic Radiation is usually absorbed or reflected by substances suspend in the water column in natural water bodies. Remotely sensed data collected in the sharper visible wave length is best suited for detecting water quality differences because of the increased penetration. Tonal variation on the imagery usually results from suspended solids that may be indicative of water quality.

2.3 **Review of Studies on Environmental Impacts of Reservoirs.**

Abubakar (1997) has enumerated the negative effects of Shiroro dam on the environment and the people to include: reservoir flooding of large areas, population displacement, creation of aquatic environment favourable for the multiplication of harmful organisms, elimination of sediment supply to flood plains, decreased fishing in down stream areas, salinity and water – logging problems, weed problems, dam failure with loss of lives and property, sedimentation and local micro climate change at the dam site.

Hafez and Shenouda (1977) in a study of the impacts of the Aswan Dam on the surrounding environment attributed river bed erosion to sediment trapping. The study concluded that clean water flowing through the river causes erosion to the riverbed and banks and to some extent, to installations along the Nile. In another study of the impacts of the Aswan Dam in Egypt, it was concluded that the flow of water that used to vary from 220 to 14,000m^3/sec has been regulated to between 9300 to 2,600m^3/sec to meet the irrigation parameters. This implies that huge quantities of water, which amounted in a year to 100,000m^3 that used to be released to the Mediterranean Sea, has been stopped.

They also indicated that the inundation of land as a result of HEP dam is in the form of terrestrial system changing into aquatic system. For instance, they identified historical monuments such as Abu Sumbel Temple that has been moved to higher locations. Riverine systems usually change into lacustrine, that is, the River Nile changing into a huge water reservoir extending across the boarder of Egypt and Sudan. The authors also identified sedimentation as one of the major impacts of the dam. The authors also observed those large amounts of sediment and suspended matter that the Nile used to either deposit on the soil in the valley or to carry all the way to the sea is now deposited in the reservoir. Depositions of this sediment naturally will determine the capacity of the reservoir itself and also the pattern and nature of the river delta created in the Sudan. Before the dam construction the suspended matter passing Aswan ranged between 100 – 150 million tons per year. During the few years of storage (1964 – 1967), the sediments, were deposited along the whole length of the reservoir and the turbid water reached the High dam. By 1969 it reached only a point within 100km upstream of the dam. It has also been observed that since the complete damming of the river, sedimentation in the reservoir resulted in loss of about $6 \times 10^6 m^3$ of its capacity every year. Thus the storage capacity of $3 \times 10^4 m^3$ will be filled in about 500 years.

They also observed that the coming into existence of Aswan Dam has impacted on the local weather condition mainly because of the evaporation of water from the surface. Since amount of evaporation is directly proportional to water surface area, it is an important factor, as the lake is filling to its capacity. The raising of the water level by 20m (from 160 to 180m) resulted in doubling the lake surface area (from 2950sq.km to 6118sq.km) which is accompanied by an increase in evaporation rate from $6{,}000m^3$ to $10{,}000m^3$ of water annually.

In a study of the impact of dam construction on fadama cultivation in downstream parts of Jakara Dam in Kano State, Nichols (1989; reported in Abdulkadir, 1993) applied the use of SPOT and aerial photographs to assess changes in the soil moisture status at pre-dam and periods. The study concluded that there is a serious fall in the soil moisture during the post-dam period resulting to a change in land use (from fadama to pre-dominantly rain fed).

Olofin (1980) in his study of Tiga Dam had concluded that reservoirs generally experience lower peak discharges in downstream areas but that the impacts of reservoirs on river regime are variable since such impacts will depend on the operation schedules of such reservoirs. He also observed that dams and reservoirs lower the peak discharges and lengthen the duration curves of flow in downstream location. This conformed to the findings of Leopold et al (1964) that the effect of several reservoirs within a single drainage basin might be extremely complex in a downstream location.

The study has also shown that the alteration of the channel cascade system has triggered off a sequence of interrelated morphological and ecological changes in the channel. He concluded that gully erosion occurred on the low terrace increasing the mean depth of gully mouth from a pre-dam 1.4m to a post-dam 2.02m. He also noted that flood flow downstream of the dam has decreased by more than four meters and the mean annual discharge decreased from a pre-dam $37m^3$ sec^{-2} to a post dam $9.6m^3sec^{-2}$ a decrease occurs entirely in the rainy season while the dry season near discharge increased from a pre-dam $0.5m^3sec^{-2}$ to a post-dam $7m^3sec^{-2}$.

He has also found that the establishment of the increase channel and the alteration of the channel have led to the formation of a flood plain on which suspended load at Post-dam peak discharges has been deposited to form silt and clay layer which is approximately 12cm thick. The median grain size of the post-dam deposit is 0.15mm in diameter (Pre-dam is 0.49mm) while the modal grain size of post-dam deposit is 0.06mm (pre-dam is 0.47mm). The organic matter content in the channel increased from an estimated pre-dam of 0.12 percent to a post-dam of 1.42 percent while the silt and clay portion increased from about 5.5 percent to 63.69 percent.

Some studies have attempted to utilize remote sensing data to evaluate changing land use and impacts of different development projects on the environment. Such studies in Nigeria have not attained the high level of sophistication as are obtainable in America and Western Europe. In a study on the impact of dam construction on fadama cultivation in the downstream parts of Jankara Dam in Kano State, Nichol (1989) used SPOT images and aerial photographs to assess changes in the soil moisture status of pre-dam and post-dam periods. He concluded that there has been a serious reduction in soil moisture during post-dam period, which has resulted in a change in land use from fadama to mainly rain fed agriculture.

Toro (1994) studied the environmental impacts of the Cameroonian Lagdo Dam and identified the negative effects downstream to include siltation of riverbed and loss of fadama and constraints to navigation. He also identified other effects upstream to include flood and land reclamation and increase in dry weather flows.

Moore and Welide (1974) observed in their study that reasonable accurate results could be achieved with a minimum expenses and appropriate measurement equipments. For areas of open surface water, enlargements were printed from the MSS – 7 band negative firms; and to achieve accurate surface area measurements, a properly scaled and professionally processed print requiring compensation Polar Planimeter was used. Large lakes (.e.g. Kainji Lake) were planimetered from 1:25,000 scale prints, while smaller lakes (e.g. Lake Ndakoluwo) were planimetered at a scale of 1:62,500.

The above studies clearly demonstrate that construction of dams have both negative and positive environmental impacts. The present study however poses an additional question of whether we can effectively utilize the positive attributes of remote sensing Technology particularly, the Landsat Thematic Mapper(TM) to more rapidly and more consistently monitor and assess environmental impacts of a developing Nation such as Nigeria.

2.4 **Remote Sensing Applications in Land use/Land cover Studies**

Adefolalu (1986) used a combination of SLAR and Landsat data combined with ground truthing to study the West African and Nigerian vegetation situation. The study recognized five major vegetal covers, woodlands, grasslands, shrublands, farmlands and forests. He showed that as of 1986, Borno and Sokoto States experienced hard effects of desertification of arable lands which had been reduced to 19.29% and 41.89% respectively; while grassland/shrubs were 59.93% and 38.36% respectively. He also showed that for Kano and Kaduna States, human activities had contributed to increasing the total land under intensive agriculture to between 68% and 82% respectively, a factor which may turn arable lands in the two states into complete shrubland vegetation and the Sahel proper by the turn of the century.

Adeniyi (1988) assessed the capabilities of digital and visual interpretation of landsat MSS for identifying, classifying and monitoring the impact of dam construction in the Sokoto Rima Basin. Lan duse and Land cover types were classified using maximum likelihood procedure and the standard visual interpretation techniques to investigate the changes in the dam site areas. He has found that landsat; MSS is suitable for rapid classification and monitoring of the agricultural resources of the area at a regional scale. Significant changes in land use and land cover were identified particularly in the floodplain and the downstream areas of the dam. He suggested that land use planning, rural and urban growth studies, rural transportation planning and desertification studies can be based on the regional thematic map produced from the study and moreover, that the combined use of digital and visual analyses of a higher resolution data such as SPOT image would provide a baseline data for detailed agricultural resource planning and management.

Gordon and Warren (1985) measured land use changes using landsat TM, MSS and aerial photography as he was studying remote sensing of shifting cultivation and grazing pattern in Kenya's semi-arid region between 1963 and 1980. Edward and Wim (1985) mapped vegetation as one of his variables in his studies of environmental impact assessment in a Netherlands' dune areas. Using combination of aerial photographs and landsat, EPP and Nichols (1983) was able to produce land capability map, forest cover map, wood assessment maps and habitat map for Kenya.

The contemporary study (Wang et al, 2003) used satellite remote sensing to investigate the land use/land cover changes along the coast of Tanzania, including Rufiji District (Lower

Rufiji catchment). The associated land use/land cover changes for Rufiji are summarized in Table 2.1. The results show net losses of all the major land use/land cover classes during the two time limits (1990 and 2000). Exception to this general trend is the urban class, which expanded during the two time limits. Here again, the observed negative changes in the land covers for the bushland, mangrove forest and woodland may be associated with the human activities (Farming and urbanization). It should be noted that, the table gives the quantitative changes for the primary classes, and the detailed quantitative changes at the subclass levels (e.g. Woodland - closed woodland, open woodland, dense woodland; Bushland – open bushland, dense bushland etc.) have generally been masked. It is therefore not easy to see the details of the dynamics of land use/land cover changes.

However, their study also noted replacements of some land use/land cover types (Fig.2.1) with other types, namely conversion of open woodland to grassland, conversion from closed or dense woodland into open woodland and woodland with scattered agriculture etc. Below are some of the Land use/land cover changes (expressed in ha) recorded for the Lower Rufiji catchments between 1990 and 2000. In Table 2.1 the fourth and fifth rows of the table give the net change (negative sign indicating net loss, and positive sign indicating net gain) and the average annual change (rate of change), respectively.

Table 2.1: Land use change for lower Rufiji catchment

Agriculture		Bushland		Forest Woodland		Mangrove		Urban	
1990	2000	1990	2000	1990	2000	1990	2000	1990	2000
45.863	45.579	209.488	198.102	673.224	630.957	51.121	49.032	2.054	5.292
-284		-11.386		-42.267		-2.089		+3238	
-28		-1.139		-4.227		-209		−324	

(

(Source: Bantje 1981)

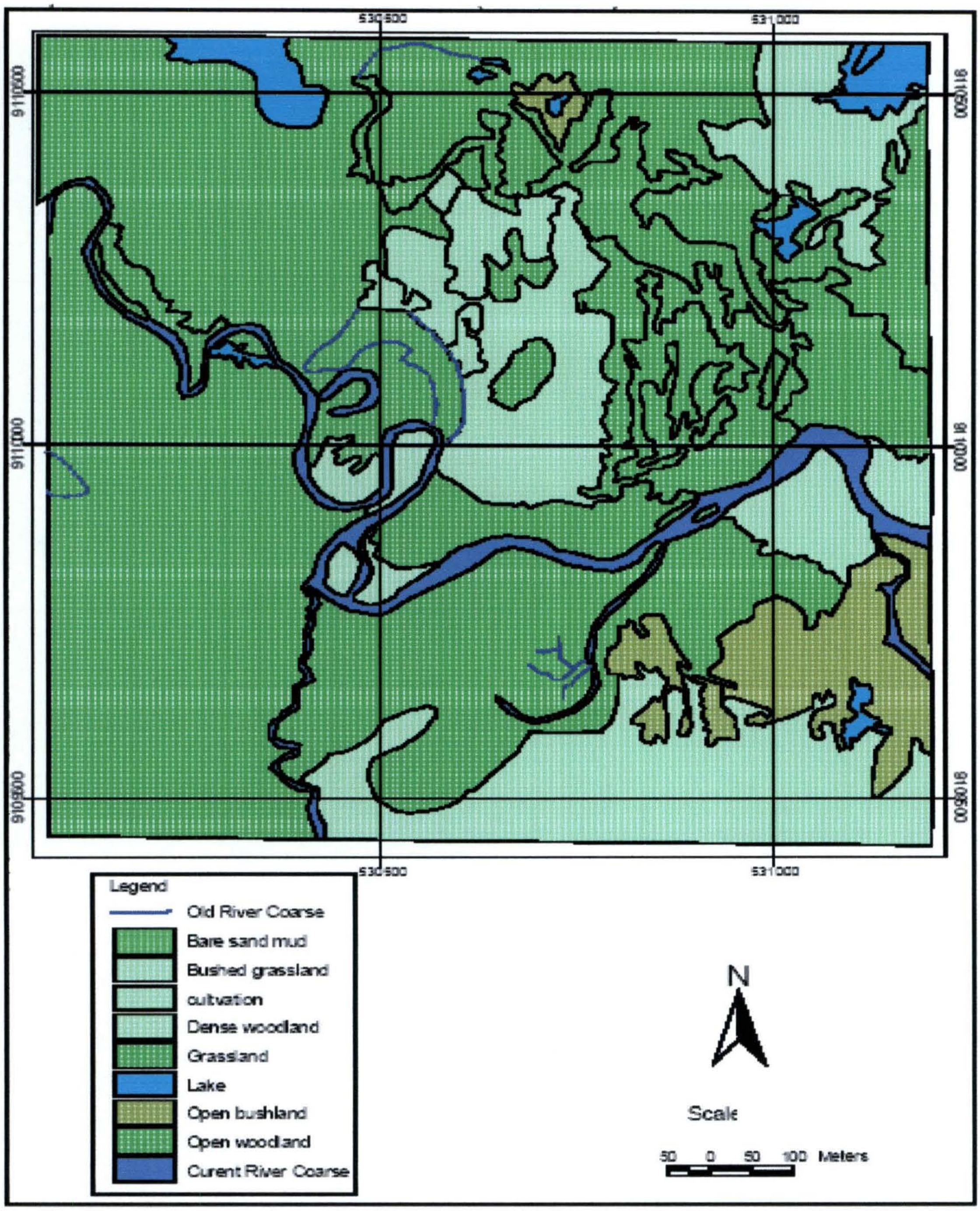


Fig.2.1: Land use/land cover of Rufiji catchment generated from Remote Sensing Data (Source: Bantje 1981)

Adeniyi (1980, reported in Lo, 1991) attempted a land use change detection using sequential aerial photography in the Lagos area. A major problem he encountered was the great difference in scale of the aerial photography. The land use change revealed the rapid increase of the residential land use and strong lateral expansion of the urban area of Lagos. The use of infra red photos to assess changes in soil moisture status in Sweden was carried out by Axelsson et al (1986, reported in Abdulkadir 1993). They found a significant correlation between image data and field measurements.

Henderson (1975) attempted to evaluate the usefulness of Side Looking Airborne Radar (SLAR) for general land use mapping at a small scale. By using the K-band SLAR imaging over West and Midwest of US (from Minnessota to North Utah), he was able to delineate 14 land use regions. It was found that eight of the ten land use divisions (80%) compiled by Anderson (1970) were similar to the land use divisions or combination of divisions created from radar. It was further noted that more detailed regions were created using radar imaging than using traditional approach.

Parry and Travett (1979) reported the large-scale project of radar mapping of vegetation in Nigeria, which was successfully undertaken by Hunting Technical Services Ltd in Britain. By consulting all the available ancillary information, a team of experienced interpreters tried to relate the various radar signatures to different vegetation types. The project, known as the NIRAD project, was quite successful as it generated vegetation and land use maps and other inserts: forest reserve, geomorphological units and eco-climatic zone maps covering the entire country. Onyebuchi (1993) noted that positive paper prints of mosaics and vegetation/land use maps are utilized by professionals of various user agencies and tertiary institutions for execution of projects, research and teaching purposes. For, instance, the Nigerian National Petroleum Company (NNPC) carried out geological interpretation of SLAR imagery of Okigwe-Umuahia Area for mineral exploration purposes. Comparative studies on interpretation of geologic features on SLAR and landsat of Kaduna area for mineral exploration was carried out in 1985 by the Geology Department of University of Ibadan. Interpretation is however, still limited to visual analysis with illuminated magnifiers.

Panigrahy et al (1999) used RADARSAT S7 data covering a nominal area of 100 x 100 km^2 to assess suitability of RADARSAT for rice and potato identification in India. Five sites of 10km x 10km each were selected within the RADARSAT scene for analysis. Detailed ground truth data were collected within these sites. Results indicated a classification accuracy of more than 90% for rice. Classification accuracy of more than 95% was observed for water, while that potato was inadequate.

Dinku (1999) explained how half hourly METEOSAT datum is used for rainfall estimation in Ethiopia, while NOAA Advanced Very High Resolution Radiometer (AVHRR) is being used for vegetation monitoring. The two outputs are usually combined into daily bulletin whose contents are rainfall and vegetation assessment for the entire country based on the satellite data. Rainfall estimation entails the use of cold cloud duration (CCD) as an input. A linear relationship between CCD and rainfall is assumed. Vegetation monitoring, on the other hand, is achieved through the combination of visible and near infra red bands of NOAA AVHRR, to form the Normalized Difference Vegetation Index map.

Dinku (1999) concluded that rainfall and vegetation information obtained from satellite data have been found to be a good supplement to the conventional data sources for drought monitoring over Ethiopia. However, the data are still far from being the best. Further effort is required to improve the accuracy of the rainfall estimate and make the best use of the NDVI data.

The Lake Chad area was monitored using 11-year MSS data and the results indicate that the vegetation change in the area was a result of recent climatic changes (NOAA, 1984). Dwivedi (1985) used a combination of data derived from LANDSAT and false colour photos to study some areas in India. It was revealed that manipulation of these data sets reveals useful information for assessing land condition including erosion and flood hazards.

Tucker et al (1985) using data from advanced very high resolution radiometer (AVHRR) sensor of NOAA (USA) series of meteorological satellites, classified land cover and monitored vegetation dynamics for Africa over a 19-month period. They found a correspondence between seasonal variation in the density and texture of green leaf vegetation and the patterns of rainfall associated with the inter-tropical discontinuity zone over West Africa.

Tukur (1998) used SPOT XS data to produce a land cover inventory of a 10km x 10km area around Gembu, Mambilla Plateau (Taraba State). Ground truthing was undertaken to facilitate supervised classification of the imagery. The classification revealed that majority of the land around Gembu is either overgrazed (31.73%) or tufted (37.46%). Farmlands and woodlands made 5.6% and 4.17% of the area respectively while settlements, bare/burnt areas made up the rest of the land.

In a study carried out in the Sokoto-Rima basin of North West Nigeria, Adeniyi and Omojola (1999) attempted mapping and evaluating the land use and land cover changes within the study area. Aerial photos taken in 1962 were used in conjunction with SPOT (P & XS) of 1977 and Landsat MSS of 1986. The GIS was applied for the generation of land use and cover statistics for each time period for change assessment. Results indicated that between 1962 and 1977, only settlements and water bodies had positive changes in the study area. Agric land and bare surfaces increased in the Goronyo area while natural/semi natural vegetation had slight increase in the Sokoto area. All other land use/land cover (LU/LC) categories had negative changes. By 1986, the study areas had positive changes in settlements. All other LU/LC categories had varying negative changes.

Dung and Tukur (2000) used a combination of multi spectral SPOT data and the GIS in carrying out a land cover mapping of the tin mining region of Jos Plateau. Results revealed 6.3% accuracy in classification. The few problems encountered included an intermixture between bare surfaces and several other cover types such as farmlands and roads. There was also the overestimation of the mine dumps, in which cultivated areas were classified as mine dumps.

A team from the Catholic University of Louvain, Belguim studied woodland in Ougadougou, Burkinafaso (Defourny 1989 reported in Prince et al, 1990). Landsat MSS data for November 1972 and November 1985 were analyzed visually as false colour composites. The results showed a marked reduction in the extent of woodlands sahelian zone, the woodlands have been lost and the northern boundary of wooded savannah as moved south. In the central and southern zones the deforestation occurs in patches centred and southern zones the deforestation occurs in patches centred on villages and in some cases, these have joined up to create continuous deforested areas.

Adeniyi (1980) applied a modern approach to land use change detection and it involves the use if computer. Two sets of aerial photographs of 1962 and 1974 with scale of 1:400,000 and 1:20,000 respectively covering urban built areas, urban open spaces and non-urban in Lagos were used. A land use classification scheme of nine major land use categories was residential, commercial, industrial and institutional, utilities and recreational open space, non-urban land and water body. A minimum mapping unity of one hectare was used as a basis for interpretation and for subsequent storage into computer. On each model, the built up areas were identified and delineated first and followed by non-urban and open space land use. The interpretation was done using mirror stereoscope. The interpretation and the field check data were transferred into a base map with the aid of a 200m transfer-scope. A dear acetate sheet with 100m by 100m width was placed on the map and the data manually encoded and keypunch into a digit before they were transferred to computer tape for processing. A special computer program was written to:

a) Compare two major land use categories for the two periods on a cell by cell basis.
b) Produce a land use change map with the drawn plotter. A data bank could be easily updated and integrated with other types of data.
c) Provide information about the location, types and amount of changes.

He came up with the following findings:

a) That the computer approach was adjudged to be more flexible and desirable for land use change detection.
b) The land use change reveals a rapid increase in the residential land use and a strong lateral expansion of the urban area of Lagos.

Ademola and Soneye, (1993) used Remote sensing and Geographic information system (GIS) techniques to map the land use and land cover around the basin of Sokoto river, Northwestern Nigeria. A LANDSAT MSS imagery acquired in 1985 with a scale of 1:125,000 were used. The LANDSAT MSS positive image transparency was interpreted using the PRO-COM 2 optical image transparency analysis equipment. 13 land use and Land cover classification categories were delineated. The study reveals that grass occupied about 37.7% or 13,230.6 hectares of land which was the largest, while forest wetland accounted for about 0.01% or 2.7 hectares of the land and which was the smallest. The study concludes that the visual interpretation of the enhanced LANDSAT MSS data can provide adequate spectral information required for the mapping of land use/land cover, while the A/X sub-system can prove easy analysis and presentation of the maps generated through remote sensing techniques.

Adegbola, (1997) used aerial photograph to detect land use change detection of Kaduna south. He used black and white panchromatic aerial photographs of 1962 and 1972 of scales 1:40,000 and 1:25,000 respectively to detect the changes within the study areas over a period of ten years of (1962-1972). The land use classification scheme used was the modified USGS land use classification scheme image interpretation elements such as size, association pattern etc were employed in the manual interpretation and classification of the two aerial photographs using mirrors stereoscope. However, the change dynamics for the periods were calculated from the statistical data generated from the techniques for the 10years period. A land use change map was also produced on which eight categories of land use were delineated. Shrub land category has increased by 14.8%. Built-up area, transportation, wetland and open space also increased by 11.69%, 13.8% and 3.8% respectively.

Henderson (1982) used SEASAT SAR imagery to map the land use in an arid environment of Denver, Colorado area of United States. A general electric imagery of 100% interactive processing system was used to contrast, stretch and enlarge the original image data to three scales: small (1:500,000), medium (1:131,000), and large (1:40,000). Black and white images at all scales were interpreted. An automated machine (Visual interpretation) was also carried out for the image at largest scale. It was found that level I land use classes of the USGS classification system could be delineated from 1:500,000 images for the urban built-up area. The research therefore reveals that SAR imagery could be processed and used for land use change detection effectively.

Hong and Lisaka (1982) used a post a post-classification comparison change detection to study the coastal changes in Tokyo Bay of Japan. They used different LANDSAT imagery of 1972, 1976 and 1980. What they did was to register the three sets of the imageries using ground-controlled points read from 1:500,000 scale of a topographical map. The approach was to classify independent each LANDSAT scene by applying standard procedures of classification. The results were overlaid and compared so that areas types of change could be identified. The LARSY software package was employed for the land use classification. The resultant land use maps were later superimposed two by two, to detect changes, which were indicated by a distinctive colour. The study reveals the percentage change in the area between the three years of study, besides it shows what the changes have been for a specific class from one year to the next. From the finding of the research, it could be deduced that no observation has been made in regard to the factors that gave rise to the changes noted. However, the study is explicit and easy to adopt.

Roger and Brown (1985) conducted a study to assess quantitative change in the land surface occurring as a result of man's activities. Time series analysis of LANDSAT MSS of 1970, 1976 and 1979 covering St. Lawrence valley in Quebec, Canada were used to monitor seasonal and long-tern variation in the land use and vegetation cover. Global Albedo was the land surface parameter studied. Three types of land cover were distinguished: Forest, agricultural and allotropic areas. The result shows that deforestation has occurred and there is a significance decrease in farmland and a marked process of urbanization. From the research, it could be deduced that the researchers did not indicate the method used in their classifications. Besides comprehensive analysis on land use and vegetation cover as seen on LANDSAT imagery has not been made.

Byrne and Kevin (1980) used the transportation enhancement of multi-temporal data to study land use change detection of Atlanta, United States. What they did was to superimpose two LANDSAT data of different dates and treat them as a single-eight-dimension data array. A principal component analysis was carried out. By this method, a new set of co-ordinate axis was fitted to the imagery, choosing the first new axis as an orientation, which would minimise the variance accounted for, by that axis. Subsequent ones would account for successive smaller portions of the remaining variance. In this study, the principal component analysis decomposed the four plus channels of correlated MSS data into eight orthogonal axes. The first and second order component images resulted, which were believed to present on change land use, while the third and later components axis exhibit changes. Changes to be anticipated were of two types:

(a) Those that would extent over a substantial part of the scene such as changes in atmosphere transmission and soil water states.

(b) Those those were restricted to part of the scene such as clearing forest, construction of roads and erection of buildings.

It should therefore be noted that their method of studying land use change detection has been so tedious and requires many techniques that are not popular.

Lo (1981) mapped the land use of Hong Kong using LANDSAT digital computer assisted approach. What he did was to first examine the LANDSAT MSS imagery of the study area separately for each band analogue form. The study area was delineated on band 5 of the image with reference to the scanning number. The LANDSAT computer compatible tape (CCT) digital data acquired from EROS data centre in United States was radiometrically corrected. The delimited study area was extracted from the original data tape and stored in a disc file. To check that, the study area is properly delimited, program called NMAP is run to show the overall pattern of the data at the desired number of bands. This provides the basis for the training data selected for a supervised classification. Land use classification scheme of Hong Kong is determined with reference to existing land use, classes were found appropriate, and they are: cropland, grassland and shrub, water features, residential, mangrove, reclaimed land, residential/commercial and woodland.

Next, a STAT program computes the mean and standard deviations of the pixel values for each band in each training data set. Finally, "D" class program was run to classify the image of the study area, with this a land printer map of the classification is produced by the computer. This was then transferred to the base map by direct tracing. The study concludes that digital approach to land use change detection using LANDSAT can surely produce reasonable accurate result. It should however be noted that the study does not specify the aerial extent covered by each of the land use types even though the approach has been able to effectively delineate the land use categories of the study area. From the study, out of 675 hectares of land, 332 hectares was recovered as having undergone some changes representing about 49% of the total area. Magnitude of about 95.6 hectares of the land was recorded as a decrease in agricultural land, while shrub land category has increased by 14.8%. Built-up area, transportation, wetland and open space also increased by 11.69%, 13.8%, 7.3% and 3.8% respectively.

Adefolalu (1985) studied degradation and trends in drought prone states in the northern parts of Nigeria, covering Adamawa State which was then part of the larger Gongola State. He relied heavily on the atlas of Espendale (Jr.) and McNally (1960) to reconstruct the past vegetation characteristics. The study utilized remotely sensed data by Side Looking Air-borne Radar (SLAR) and LANDSAT. The SLAR imagery for Nigeria acquired by direct contract awarded to the Motorola Aerial Remote Sensing Incorporated (MARSI). The interpretation of the imagery was carried out by Hunting Technical Services Limited of Great Britain. Transects from LANDSAT imageries were made to cross check the vegetation type. Lastly, ground truth observations (GTO) were made. From interpreted works, calculations of area of different vegetation types were made.

The data sets used by Adefolalu (1985) were mainly classified into 1-Forest, 2-Woodlands, 3-Grasslands, 4-Shrublands and 5-Farmlands. From the data set the percentage areas covered by each category in the states which fall within the belt between lat. 7°N and further north were tabulated. These are shown in Tables 2.2 and 2.3

Table 2.2: Types of Vegetation in northern Nigeria

STATES	SHRUBLAND				GRASSLAND		
	Non-Thorny	Thorny	Shrub and Thickets	Grass only	Shrub	Wooded Shrub	Transition to pure shrub
Bauchi	0.34	0.64	-	0.24	0.65	8.27	2.29
Benue	-	-	-	1.34	0.50	1.13	-
Borno	0.01	0.07	5.21	5.0	13.30	23.12	13.26
Gonola	-	-	-	6.52	0.40	7.87	6.00
Kaduna	-	-	0.66	0.59	2.54	11.25	0.24
Kano	0.22	0.30	-	0.86	3.36	5.28	-
Kwara	0.01	-	1.02	-	3.54	3.54	-
Niger	-	-	-	1.41	6.26	0.02	-
Plateau	0.11	0.11	-	0.87	0.64	13.24	-
Sokoto	13.90	-	2.52	1.67	4.00	16.27	-

(Source: Adefolalu 1985)

Based on his study, Adefolalu (1985) opined that woodland/Grassland mixture is dominant in Gongola State (about 48%). This makes the state more stable than states like Borno and Sokoto (which were experiencing the harsh effects of desertification) and states like Kano and Kaduna (which were also experiencing land degradation, due to human activities).

He warned however, that there is imminent danger of the shrub land of the steppe-type spreading southwards into the dry savannah belt as far as latitude 10^0N. The mixed woodlands-grassland, found between latitude 8-10^oN will shift with aggressive agricultural adventures in these belts. He finally concluded that the belt of thorny or non-thorny shrub-type of vegetation known as the SAHEL-PROPER extends to about lat.12°N in the extreme west to longitude 8°E and slides rather sharply down to about latitude 8°N at the eastern border of the country. Thus the change to complete desert conditions is imminent once the dry grassland savannah gives way to the pure steppe type of vegetation cover.

Geomatics (1996) carried out a similar study on behalf of the Forestry Management and Co-ordination Unit (FORMECU). The study aimed at:

(i) Establishing a historic statistical record on the status of vegetation and land use in 1976/78 to be used as baseline information from which the assessment of change begins.

(ii) The establishment of current information on vegetation and land use for 1993/95, based on the same classification scheme and the general format of the 1977/78 baseline information and

(iii) The analysis of trends identifying extent and intensity of the changes in vegetation and land use over 18-year period.

A total of 69 LANDSAT MSS scenes were used to recreate the vegetation /land use characteristics of 1978, out of which seven were used for Adamawa State. The interpretation of the 1976/78 vegetation and land use was done visually using the 1:150,000 scale hard copy maps. Before interpretation could begin a familiarization process with the imagery and known ground truth was conducted. For example, all photo and station locations from the October 1994 reconnaissance survey had GPS co-ordinates and hence could be marked on the appropriate map. This allowed for the interpreters to become familiar with the appearance of each class on the imagery and identify differences, similarities and relationships between classes. The SLAR derived vegetation and land use maps, the same data set used by Adefolalu (1985) were used as a source of ground truth during the MSS interpretation.

For the 1995 data set, a total of 285 SPOT XS, 3 LANDSAT TM and 21 ERS1 data were used. Out of this, 2 LANDSAT TM, 1 ERS-1 and 13 SPOT XS were used for interpretation in Adamawa State. The interpretation of the 1993/95 vegetation and land use was done visually using 1:150,000 scale hard copies. During the interpretation of the 1993/95-satellite imagery, a field survey was conducted to provide ground truth of vegetation and land use, which could be used as a reference tool to ensure and verify the accuracy of the satellite image interpretation. The main field survey was undertaken in May 1995.

An area summary of dominant vegetation and land use classes in Adamawa State for 1976/78 and 1993/95, based on the study carried out by Geomatics (1996) is shown in Table 2.3

Table 2.3: Land use classes in Adamawa State for 1976/78 and 1993/95

Land use Category	1976/78		1993/95	
	% of state	Sq km.	% of state	Sq. km.
Extensive (Grazing) agric	25.0	9291	29.8	10928
Sudan Savannah	32.0	11723	27.5	10062
Intensive (Crop) Agriculture	23.0	8487	22.1	8082
Guinea Savannah	11. 9	4361	6.3	2319
Flood plain agric	1.0	348	3.1	1120
Montane Forest	0.8	281	1.6	573
Shrub Swamp	1.9	679	0.4	129
Undisturbed Forest	2.8	1022	0.3	119

(Source: Geomatics 1996)

According to Geomatics (1996), in 1976/78 the Benue floodplain in Adamawa State was predominantly a shrub dominant swamp with an area of 679sq.km. There was floodplain Agriculture at the confluence of Rivers Gongola and Benue surrounding the town of Numan and eastward to Yola. The floodplain has expanded in many places and the area of floodplain agriculture has tripled from approximately 348sq km. in 1976/78 to 1120 sq. km. in 1993/95. Currently most of the flood plain is used for agriculture.

The highland areas south of the Benue River include the Shebshi Mountains and the edge of the Mambilla plateau. In 1976/78 this large area was all Guinea savannahs with undisturbed forest in the Shebshi Mountains and some undisturbed forest on the Mambilla plateau with montane forest in the highlands. There has now been a deterioration of the

Guinea and forest areas. Lastly, in 1976/78, 11.9% of the state or 4361sq. km. (Table 2.3) was Guinea savannah, by 1993/95 only 6.3% of the state or 2319 sq. km. remained as Guinea savannah. This loss by 2042 sq. km. of Guinea savannah is being attributed to the collection of fuel wood and the growing need of grazing land. The drastic reduction in Guinea savannah from 11.9% of the state to 6.3%, almost half, seems to tally with Adefolalu (1985)'s prediction. Land degradation, as it affects the state, therefore can not be assumed to have stopped. In fact rate of degradation seem to be higher than in the past.

While Adefolalu (1985) and Geomatics (1996) successfully identified and quantified degraded areas in the state, it was done taking the whole state as one entity (hence the reason for giving figures as percentages of the entire state). This kind of study could give the general trend of degradation in the state, but stands the risk of leaving out fine details. Some areas within Adamawa State, for instance, are degraded faster than other areas. Yet other areas have managed to remain stable. Identification of the high-risk areas coupled with knowledge of the physical/anthropogenic characteristics of such areas will go along way in identifying the causes of degradation in such areas. To do this, a more detail analysis needs to be carried out.

Byers (1987) used repeat photography combined with ground-truth verification to study landscape changes in the Sagarmatha (Mountain Everest) National park, Nepal. Results suggested that since the 1950s, forest removal and geomorphic damage has occurred in the National park than has hitherto assumed. Most shrub/grassland and forested slopes below 400m are significantly stable, but high soil loss occurs in certain degraded alpine summer settlement areas because of continued shrub harvesting for fuel wood, grazing pressure and natural freeze-thaw processes.

In yet another study in New South Wales, Australia, Graham (1992) used aerial photos to undertake a survey of land degradation. His study revealed that sheet and rill erosion and soil structure decline were confined mostly to lands used for cropping. Gully erosion was commonly found across the state while mass movement was confined to steeper lands.

That aerial photographs have gained acceptance among environmental scientists in Nigeria is now an accepted fact. However the use of aerial photos in studying land areas that run into thousands of hectares (like the one being proposed in this study) can become very tasking, expensive, and time consuming. For instance it has been noted that while the whole of Nigeria can be viewed in 50 scenes of landsat data, it requires up to 150,000 aerial photos will require more man hours to extract information that could easily and cheaply be gathered from lower resolution landsat data (Adeniyi, 1980; Fagbemi, 1986; reported in Tukur, 1996).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

This chapter is devoted to research methodology. It explains the methods used in collecting and analysing field survey data and the procedures followed. The chapter is also devoted to explaining the techniques used in processing and analysing satellite image data and the procedures adopted.

3.2 Methods of Data Collection and sample Size

Two basic research methods are used to carry out this study: quantitative and qualitative.

a) **Quantitative Method**: Is aspect of the research that consists of a field questionnaire administration and oral interviews with the people. The research utilized a self-administered survey method where survey questions were developed based on measurement scale and administered to selected farmers, and village heads in the study area. However, prior to collecting the main data for the study, a pilot study was conducted to test the measurement scale and survey questions in order to improve clarity and readability (see detail of pre-test survey in section (3.2.3).

b) **Qualitative Method:** This involves processing of LANDSAT imagery of the study area (ETM, TM and MSS) obtained for different periods (2007, 1999, 1986 and

1975) using ARCVIEW GIS 3.2 and IDRISI 32 soft wares to produce land use/ land cover maps.

3.2.1 Study Population

Population can be defined as the entire group under study as specified by the objective of the research (Pedhazur and Schmelkin, 1991). Since the aim of this study is to assess the impact of Kiri Dam on the land use/land cover at the lower course where agriculture is the predominant activity, the target population consists of the farmers in the study area.

3.2.2 Sample Size

This study employed the use of Chi-square statistical Analysis to test the impact of the dam on the land use/land cover in the study area. In general, there is no correct sample size in the absolute sense, and lager samples are always preferable. Based on the total population of the study area (382,336), ten villages were selected randomly among the 28 villages in existence and 50 copies of the research questionnaire were administered in each of the selected villages. In all, a total of 500 copies of the questionnaire were administered. These therefore, represent 0.1% of the total targeted population.

3.2.3 Pre-test and Procedures for Survey Instrument

Measurement scale and survey questionnaire were developed based on the objectives of the study. The initial pre-test survey questionnaire was then administered to some members of academic staff and post graduate students in the department of Geography, Federal University of Technology Minna. The purpose of this procedure was to determine if there was a need to revise the survey design, layout, wording, and also if it was necessary to clarify any ambiguous measurement items. Respondents were urged to make necessary comments on the initial survey questions for corrections and improvement. With the improved measurement scale and questions, a focus group interview was conducted on 10 Local Government senior staffers selected from the department of agriculture and natural resources within the study area. Relevant comments and suggestions made during the interview were used to clarify the layout, wording and design of the survey questions administered to major farmers and village heads of the selected villages in the study area.

3.3 Measurement of the Kiri Dam Development Impact

A measurement scale for assessing the impact of the dam on the lower reaches was developed. As a result, ten statements about the impacts of Kiri Dam development were established for the measurement scale. The items were chosen based on the significant relationships with their corresponding variables as shown in Table 3.1.A five-point Liker scale was used as the response format with assigned values ranging from 1 = strongly disagree to 5 = strongly agree. The reliability of this measurement scale is reported in the discussion section.

Table 3.1: Measurement scale for assessing the impact of Kiri Dam

Measurement of Kiri dam Development Impacts
1. Kiri irrigation dam has created jobs for your community.
2. Irrigation farming has attracted more investment to your community.
3. The standard of living has increased considerably because of all season farming.
4. The construction of the dam on the river has negatively affected your way of life.
5. The damming of the river has changed your precious traditional culture (fishing or farming).
6. Local residents have suffered from negative effect of the dam (flood).
7. The construction of the dam has boosted the activities of the residents.
8. The damming has resulted in positive impacts on the cultural identity of your community.
9. Damming of Kiri has resulted in land use /land cover change, and flood.
10. The Construction of dam and other irrigation facilities have destroyed the natural environment.

Note, as appropriate: 1 = strongly disagree, 2 = Disagree, 3 = neither disagree nor agree, 4 = Agree, and 5 = strongly agree

3.4 Field Survey Response Rate

Since the main focus of this study is to assess environmental impact of Kiri Dam, the study samples are the farmers, fishermen among others involved in socio-economic activities in the study are. The self administered survey questionnaire in Appendix A and B were administered to 500 respondents. As presented in Table 4.2 a total of 481 questionnaires were returned, however 477 respondents were coded and used for the analysis after eliminating the unusable responses. Since some of the survey questionnaires were not returned due to unavailability of the respondents at the time of visitation, the initial responded rate included in the data analysis resulted to 96.2%. However, after eliminating the total of 14 (2.8%) respondents with unusable responses a total of 477 responses were finally coded and used in the field data analyses for this study. As a result, 95.4% response rate was obtained.

3.5 **Data Collection Procedures**

The research procedure is detailed within three steps:

A). Pre-fieldwork. (B). Fieldwork. (C). Post fieldwork.

3.5.1 **Pre-fieldwork**

This involves the collection of relevant information about the study area from previous works, journals and organizations such as Adamawa State Ministries of Lands and Survey, Agriculture and Natural Resource, review of related literatures on land use/land cover changes and environmental impact assessment studies on reservoirs. The step also includes geocorrection of satellite imagery, classification of images, determination of Normalized differential vegetation index (NDVI) and generation of false colour composite using edge enhancing filter.

3.5.2 **Fieldwork**

This aspect involves conducting reconnaissance survey of the study area to compare the tentative land use map generated on the basis of unsupervised classification (broad classification), False Colour Composite (FCC), and Normalized Differential Vegetation Index (NDVI) to identify and sample the spectrally reflected features. The fieldwork also includes interviewing residents of the area in order to obtain relevant information about the dam, its effect on farming activity, and other necessary data.

3.5.3 **Post-fieldwork**

This involves data processing, analysis and presentation. It includes creating data on land use types, supervised classification of LANDSAT ETM (2007), LANDSAT ETM (1999), LANDSAT TM (1986) and LANDSAT MSS (1975), including transformation of their bands to produce past and present land use/land cover maps. The step also involves determining percentage change in land use/land cover for the given period using different techniques and methods of image classification and assessment such as: (a) Normalize Density Vegetation Index (NDVI) (b) False Colour Composite (FCC) (c) Maximum Likelihood Classification. (d) Accuracy assessment for land use/ land cover map.

3.6 **Processing and Visual Interpretation of Satellite Image**

Procedures adapted in this research can be seen in Fig 3.1 and explained below.

3.6.1 **Creation of Digital Change Database**

The hardcopy of the topographical map covering the study area was first converted into digital database, using Geographic Information System (GIS) software and ARCVIEW GIS 3.2. The process involves scanning of the map, followed by georeferencing and digitization using the onscreen digitization technique. The final output was a vector land use/land cover.

3.6.2 **Rasterization and Cross Operations**

The output from step 2 was rasterized to obtain the raster database for the computation of the areas with ARCVIEW GIS 3.2 software. Cross operations were performed on the land use/land cover maps for the periods (1975, 1986, 1999 and 2007) to obtain a quantified overview of the type of changes.

3.6.3 **Area Calculation of the Land use/Land cover**

Using the raster database generated, the area coverage of each land use/land cover class for the periods (1975, 1986, 1999 and 2007) was computed and expressed in square kilometers. From the raster maps of each year the attribute table showing the number of pixels for each Land use/land cover class and the area for each class in square metre was produced. Using the column operation function, the area coverage in the respective Land use/land cover classes was calculated.

3.7 Geometric Correction and Image Enhancement

Geometric correction includes correction for geometric distortions due to sensor, earth geometry variations and conversion of the data to real world coordinates (e.g. Latitude and Longitude) on the Earth's surface. The satellite imagery was geometrically rectified with reference to the geo-referenced topographic sheets and vector data. Image enhancement is one of the important image processing functions primarily done to improve the appearance of the imagery to assist in visual interpretation and analysis. Various options of image enhancement techniques were carried out to get the best image for visual interpretation. Histogram equalized stretch enhancement techniques was applied to the imagery for better interpretation of different features. A number of methods can be applied to perform image enhancement. The most suitable methods must be selected to achieve the best colour of images for visual interpretation. In this study, the following spatial enhancements have been applied: False colour compositing (FCC) and Principle component analysis (PCA).

3.7.1 Assessment of False Colour Compositing (FCC)

A colour composite that is usually composed of three bands is assigned to one of the basic colures: Red, Green, and Blue. Two types of colour composites i.e. a False Colour Composite (FCC) and a Natural Colour Composite (NCC) are distinguished here. In order to create a clear feature on the LANDSAT TM images, it is necessary to know the reflection characteristics of the basic cover types of the earth surface.

The best FCC depends on the purpose of the study. From several FCC produced for visual interpretation the best combination was 7, 4 and 2 (Fig. 4.4). In this band combination, 4 different types of features can be distinguished as shown in Table 4.1

3.7.2 **Multi-temporal Principal Component Analysis (PCA) for Derivation of Change in Land use and Land cover**

Principal component analysis is a statistical method used for compressing the original data set without losing too much information. PCA is collecting the information of the spectral bands used in a cloud of points in a multidimensional space and calculates a new optimum set of axis through this cloud of data points. The number of principal components is equal to the number of bands. The first PC is defined by maximum variance of the original data set; the last PC defines the leftover variance (Meijerink et.al, 1994). In this research several PCA are produced for visual interpretation, the best combination was 1.2.3 that showed clearly the difference between bare soil, water bodies and vegetated areas (Fig.4.1a, 4.1b and 4.1c).

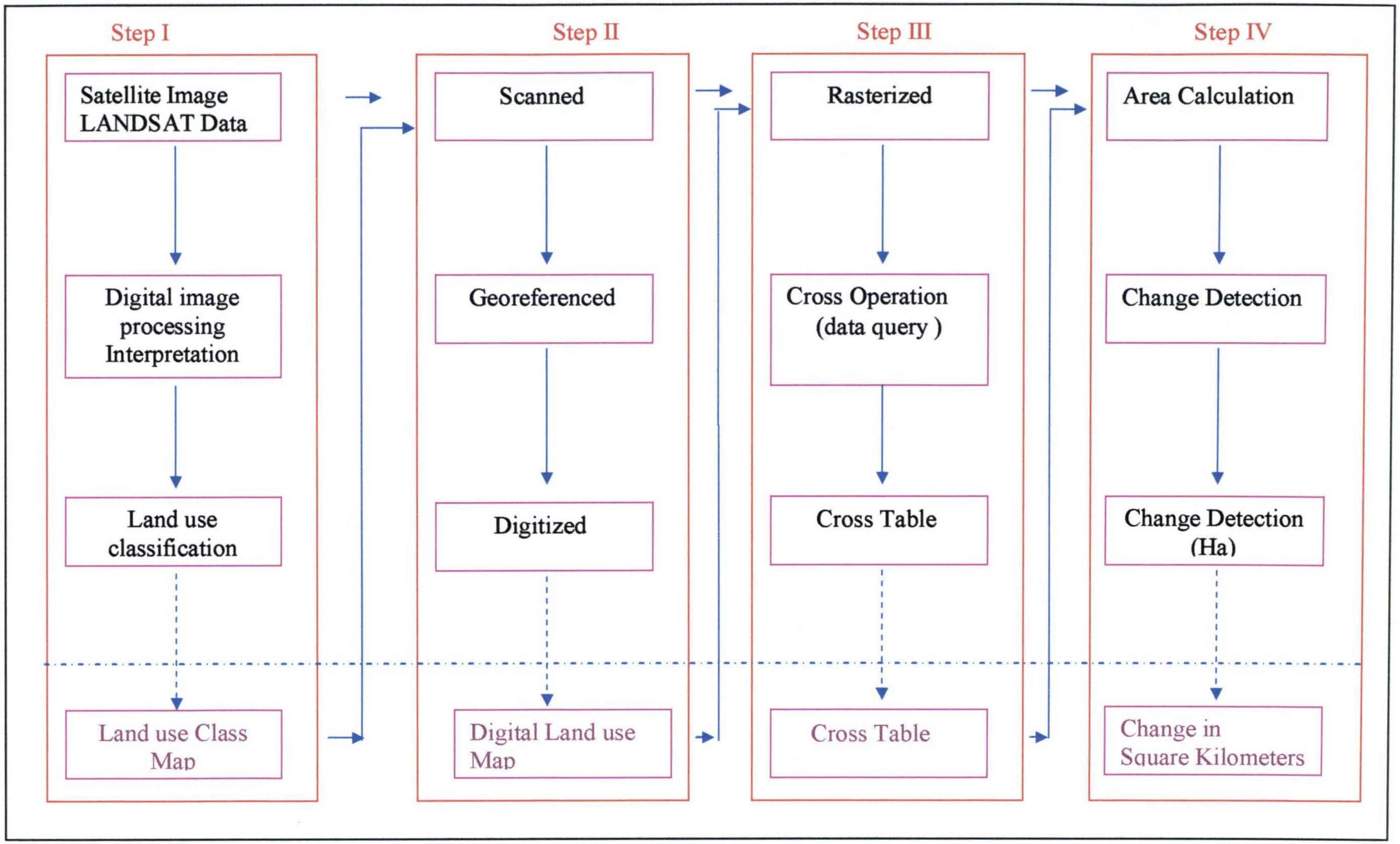


Fig.3.1: Procedure adopted for image analysis

3.8 **Methods of Land Use Classification**

Different methods and techniques have been used in the process of image restoration, enhancement and classification in this study. The procedures followed are illustrated in Fig. 3.2 and described below.

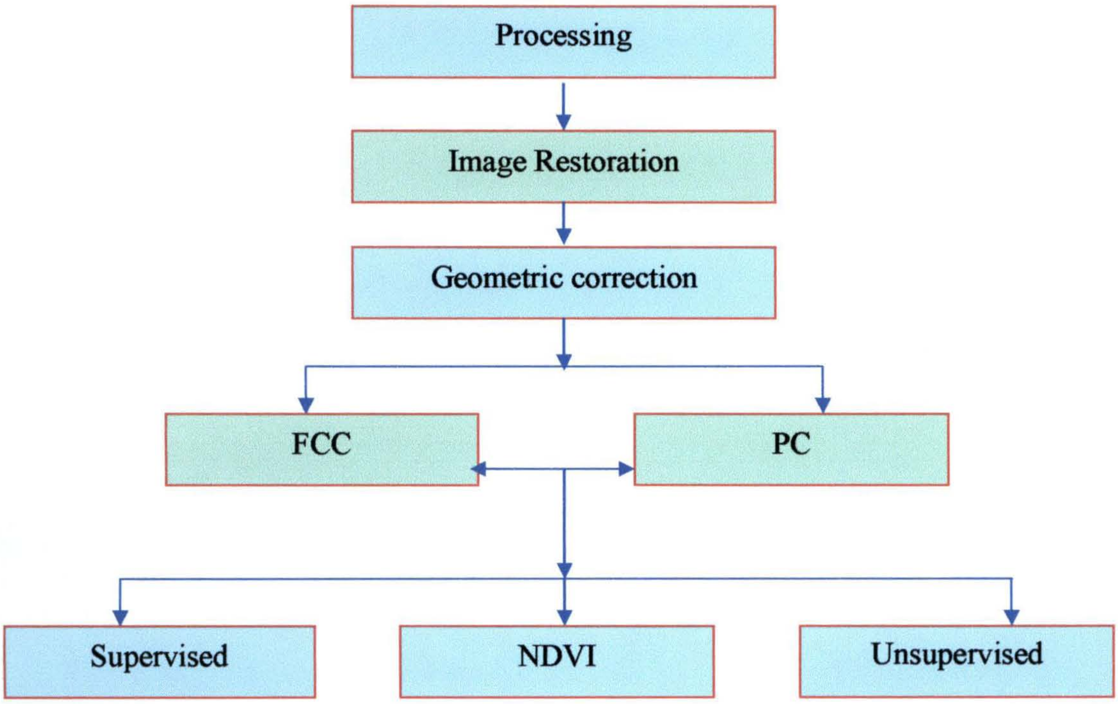


Fig.3.2: Image classification procedure

3.8.1 **Supervised Classification**

After extraction of the study area, stratified approach was applied to generate land use / land cover map from digital classification of LANDSAT ETM data acquired in 2007 and 1999, LANDSAT TM acquired in 1986 and LANDSAT MSS acquired in 1975.The first step performed was *linear contrast stretch* for all the bands, then the ETM bands with 30m pixel size were combined in order to select the most suitable band combination. The enhanced false colour composite of bands depicting the vegetation was chosen and classified by supervised mode with maximum likelihood (MXL) algorithm, using ground truth information. Data obtained during the site visits pertaining to land use/land cover substantiated the training sites during image classification by MXL classifier. This analysis offers the changing trends in land use/land cover patterns of the study area. The procedures adopted for supervised classification are as follows:

(a) **Training Site Selection**

This involves the creation of a vector file and the display of the image in question. The false colour image composite was displayed using the DISPLAY Module (the fourth icon) in composite palette and the DIGITIZ button activated. This Module was used to create a vector file and the file name was entered, including polygon option and identifier number for the first object. The selected features were digitized using the same number following IDRISI rule of ten for each training site except where the feature to be digitized is very small. The next feature was chosen with different identifier up to the last feature. The same features were given the same "ID" number while different features were given different "ID" number. SAVE DIGITZED data button (icon 16) was used to enter and save the polygons created as a vector map.

(b) **Signature File Development (MAKESIG)**

Training site signature was created for the classification. MAKESIG creates signatures from information contained in remotely-sensed images using training site polygons. MAKESIG first requires that the file containing the training sites be indicated as a vector or an image file. Then the name of the file entered. When vector file is chosen the module "rasterizes" the training sites to match image dimensions and stores the resulting image using the same name as the vector file. Next, the signature file names created for each of the training sites as defined in the input file was entered. Each signature name made to correspond with the IDs in the input file defining the training sites. From the dialog, the default setting was used to create a group file with the same name as the training site file. Then the group file was later edited with the Collection Editor, under the File menu.

3.8.2 **Maximum Likelihood Classification**

In this procedure, training site sets were developed. The sets are polygons which correspond with each of the finally defined land use/land cover classes. A ground truthing was conducted to identify the existing land use/land cover of the study area. The training sets developed were radio metrically examined, i.e. observation of the differences in reflectance between each defined set of land use/land cover for the channels of the LANDSAT images and then transformed into final groups containing land use/land cover types.

3.8.3 **Unsupervised Classification**

False colour image was developed and used for the unsupervised classification. The clusters were produced using IDRISI IMAGE PROCESSING Module and Sub-Module CLUSTER. This procedure was used to process the image in a fine generalization level to a maximum number of six clusters. The same process was also used to produce unsupervised classification that was taken to the field. The two were regressed to see if they have any significant difference. The unsupervised classification with fine generalization looks better and closer to the expected general classification of the image in qualitative 16- palette option display and thus was chosen. In this type of classification, the computer produces spectral classes based on the digital numbers (DN) without any direction from the user. It gives preliminary information on the potential spectral clusters to be assigned to thematic classes. Therefore, subsets of the satellite data were first classified into six (6) classes using unsupervised classification in order to have idea of possible cluster which represent the landuse types. This classification technique as presented in Fig. 4.3 helps as a guide in the selection of training sites for input into the supervised classification.

3.8.4 **Normalized Differential Vegetation Index (NDVI)**

The Normalized Differential Vegetation Index (NDVI) is calculated from a TM-scene by taking the ratio of the difference of the near infrared and red reflection and the sum between these two bands using the following formula.

$$NDVI = (TM4 - TM3)/(TM4 + TM3)$$

Where:

NDVI: Normalized Differential Vegetation Index

TM4: TM spectral band 4

TM3: TM spectral band 3

On a NDVI image, vegetated areas will generally yield high values because of their relatively high near –infrared reflectance and low visible reflectance. In contrast, water, have larger visible reflectance than near-infrared reflectance. Thus, these features yield negative index values. Rock and bare soil areas have similar reflectance in the two bands and result in vegetation indices near zero.

In this study, the NDVI map has been produced (Fig.4.2a, 4.2b and 4.2c) and then classified in a map with three-land use/land cover classes, i.e. Poor grass/vegetation range (Water Surface areas); moderate grass/vegetation range (bare soil/degraded/ agriculture area) and highly vegetated areas.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents results arising from the procedures followed in processing and analysing the data obtained from the field survey and satellite imagery. The results obtained are presented in tables, figures and plates.

4.2 Result from Satellite Image Processing

4.2.1 Multi-temporal Principal Component Analysis (PCA)

Several PCA are produced for the Visual interpretation, the best combination obtained are 1, 2 and 3 (Fig. 4.1a, 4.1b and 4.1c). The figures show clearly the reflection of water bodies, bare soil wetland and vegetation.

4.2.2 Assessment of False Colour Composite (FCC)

False Colour Composite (FCC) within bands combination of 7, 4 and 2 produced the best FCC (Fig. 4.4). The presentation shows that four different types of surface features shown in Table 4.1 can be clearly seen and identified.

4.2.3 Normalized Differential Vegetation Index (NDVI)

NDVI Maps of the study area for post dam period (1986 to 2007) are produced as shown in fig. 4.2a, 4.2b and 4.2c. The maps show the condition of the vegetation for the period.

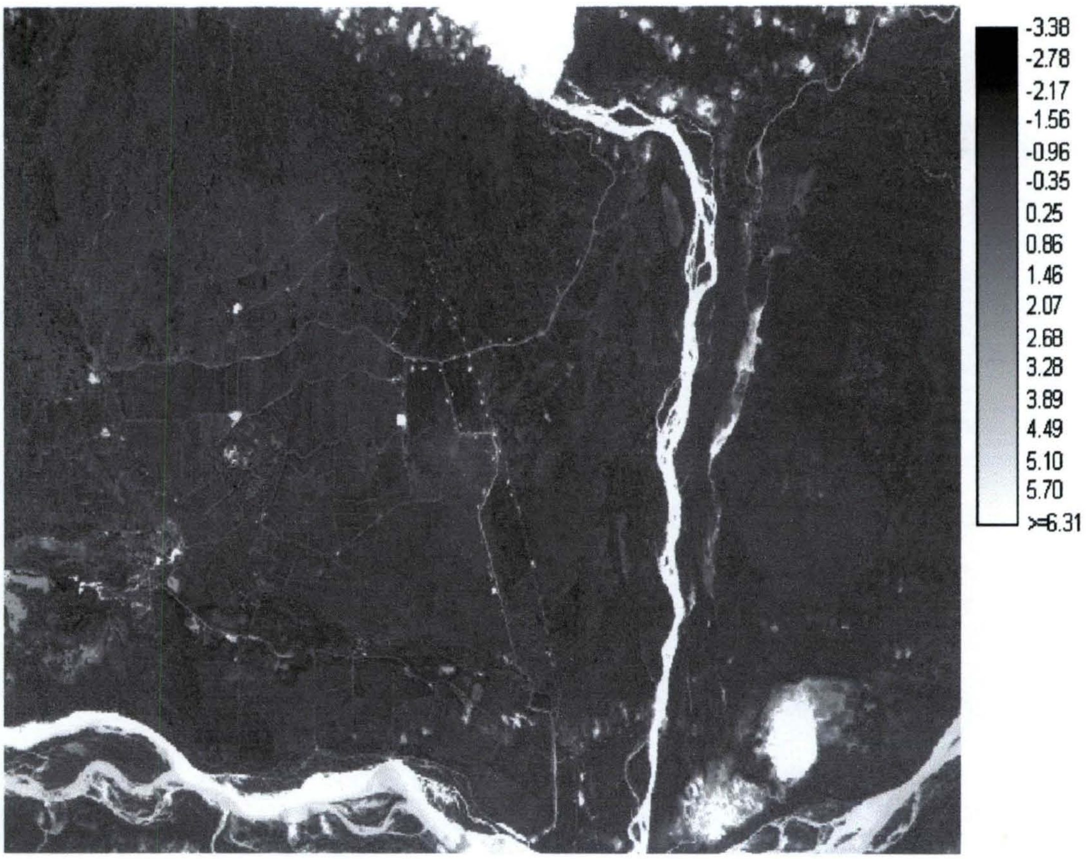


Fig.4.1a: Principal component 1: shows clearly reflection of the water body in White colour

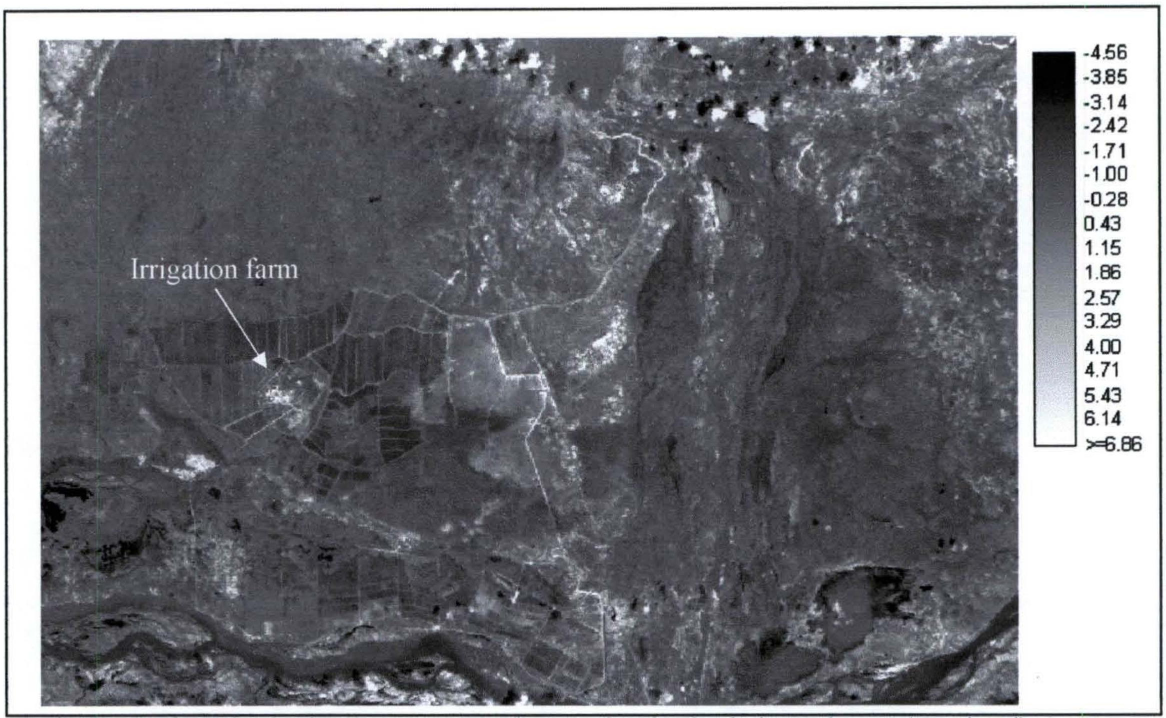


Fig.4.1b: Principal component 2: shows clearly the irrigated area (Wetland).

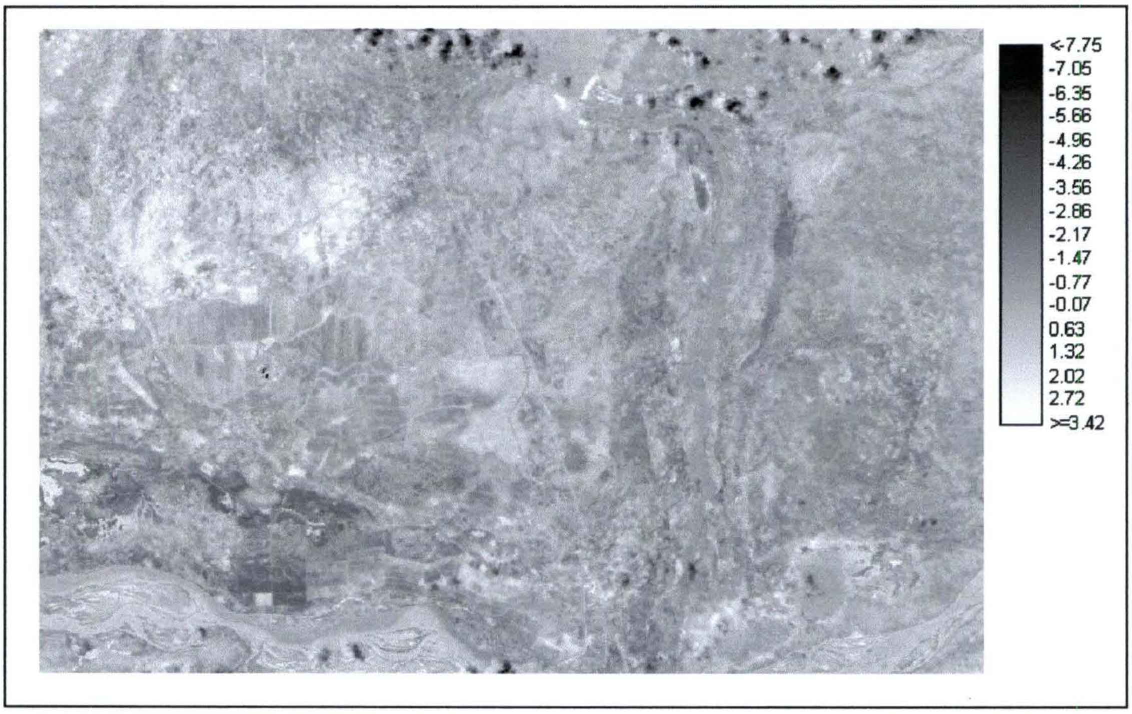
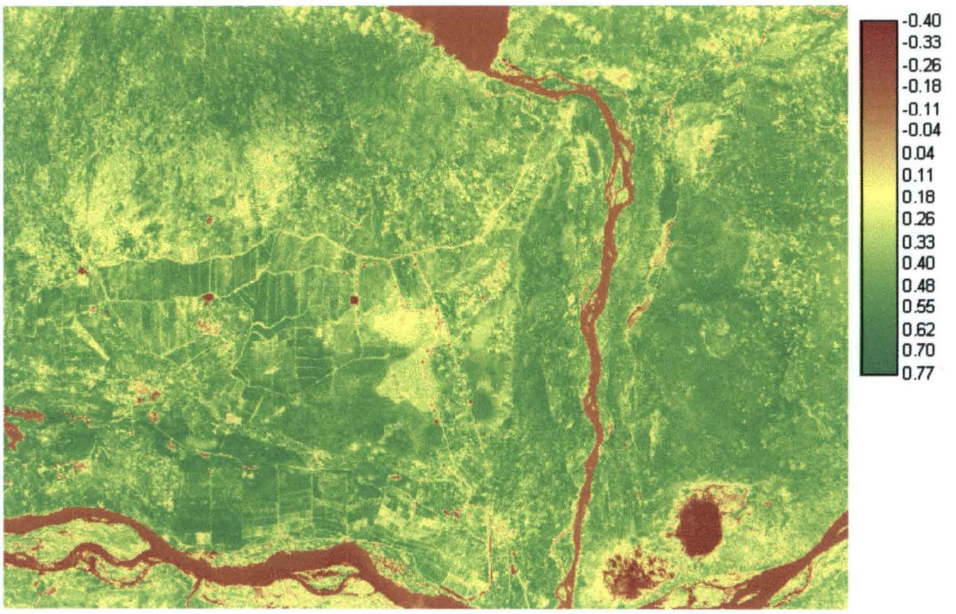
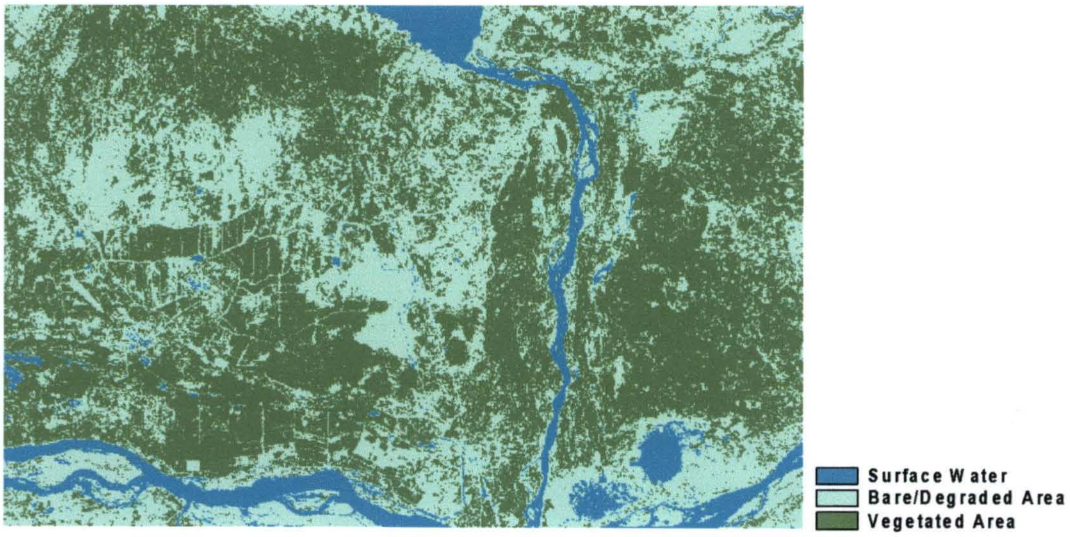


Fig.4.1c: Principal component 3: shows clearly the reflection of bare soil and Vegetation

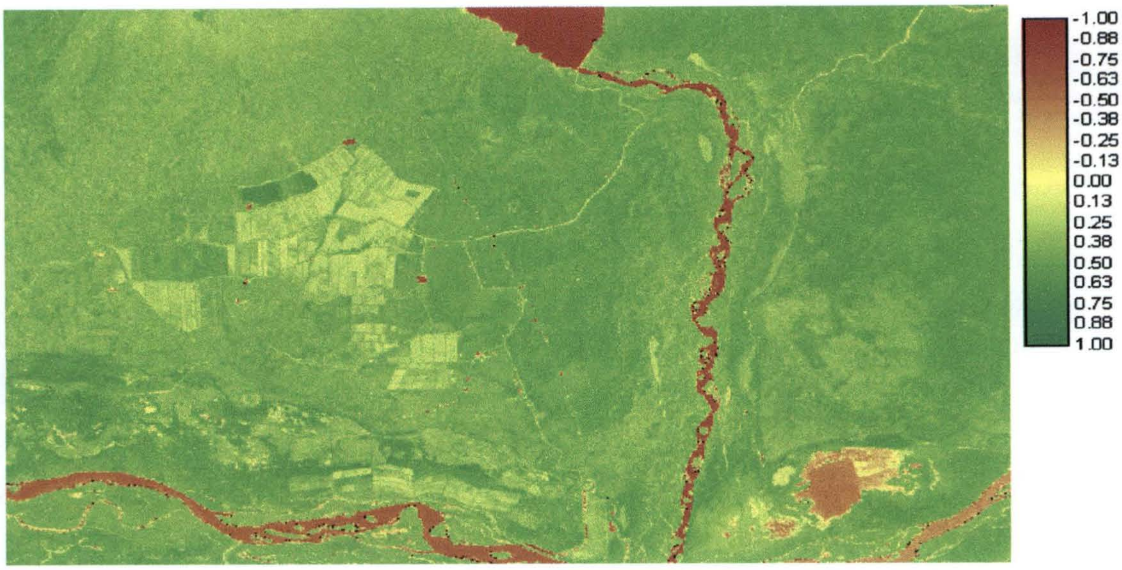


i).NDVI Map of Greenness condition May, 1986.

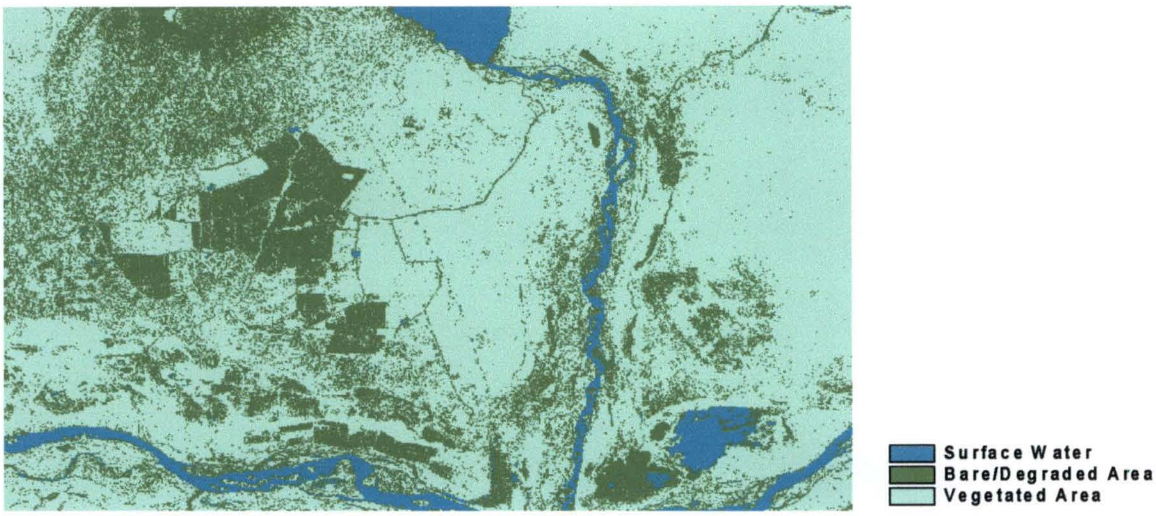


ii). Reclassified Map Greenness condition, May, 1986.

Fig.4.2a: Post-Dam condition of vegetation greenness from LANDSAT TM, 1986

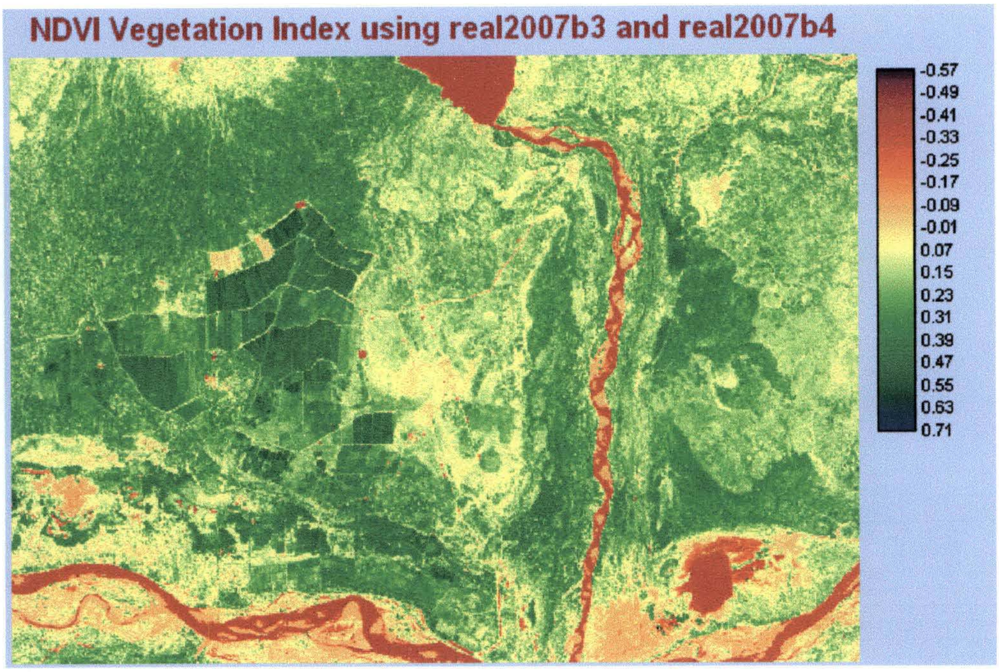


i). NDVI showing the Vegetation Greenness Condition May,1999.

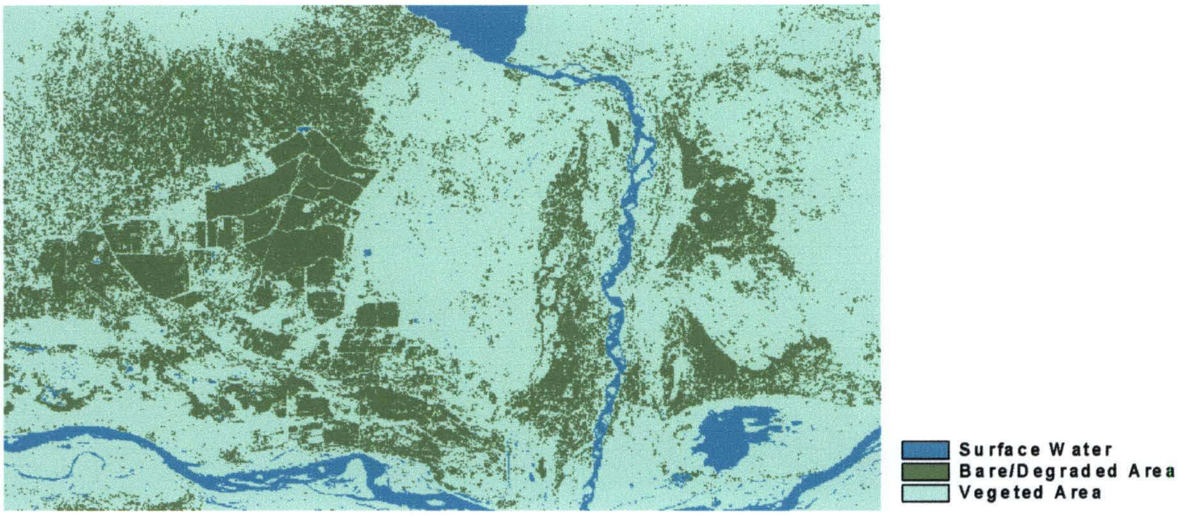


ii): Reclassified NDVI May, 1999 showing the vegetation Extent.

Fig.4.2b: Post-dam condition of vegetation greenness. LandSat ETM, 1999



i). NDVI showing the Vegetation Greenness Condition May,2007



ii). Reclassified NDVI May, 2007 Showing the Vegetation Extent.

Fig. 4.2c: Post-dam condition of vegetation greenness. LandSat ETM, 2007

4.2.4 **Unsupervised Classification**

A land use/land cover map of the study area is produced based on unsupervised classification (Fig. 4.3). The presentation shows six clusters used in selection of training sites for input into supervised classification. With unsupervised classification, however, clustering software is used to uncover the commonly occurring landcover types with the analyst providing interpretations of these cover types at later stage.

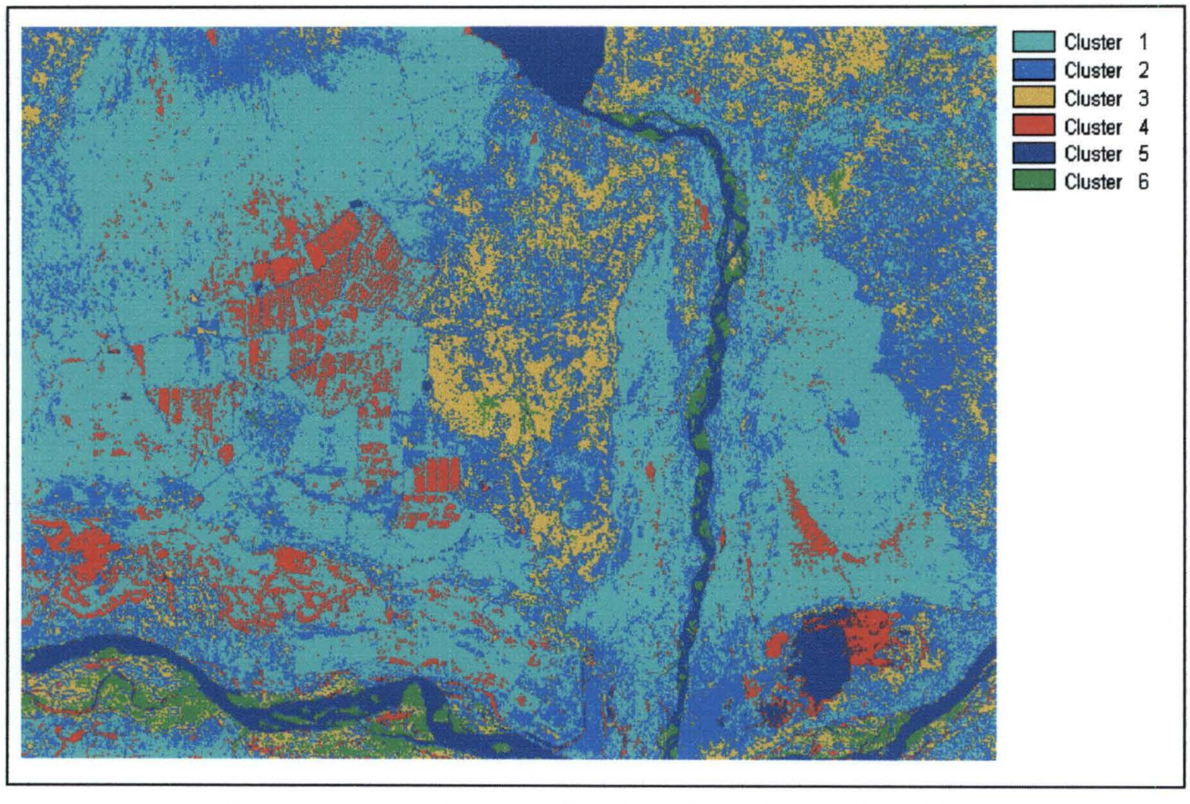


Fig. 4.3: Unsupervised classification of LandSat ETM, 1999

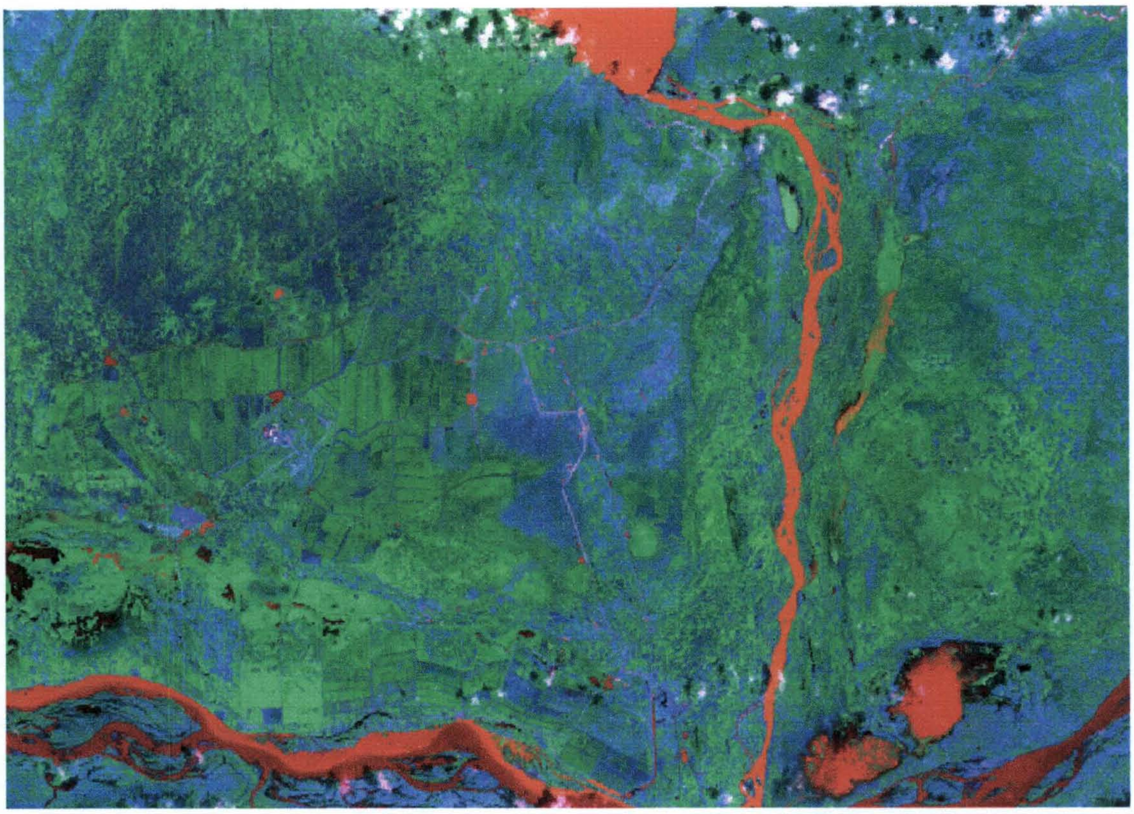


Fig.4.4: False Colour Composite of bands 742

Table 4.1: Colours of surface features in FCC 742

Surface feature	Colour
Irrigated agriculture	Green to yellow
Water	Red
Rangeland	Dark green
Settlement(Residential)	Blue to dark green

4.3 **Result from Field Survey Questionnaire Response Rate**

Result of the response to survey questionnaire from the respondents is shown in Table 4.2. The presentation shows the total number of coded responses used in the analysis, out of the total responses.

Table 4.2: Survey response rate

Target and Response rate	**Number**	**Percentage (%)**
Total target population	500	100
Undelivered survey	-	0
Total survey population	500	100
Total responses	481	96.2
Unusable samples	14	2.80
Total coded samples	477	95.4
Total usable samples	477	95.4

4.4 **Satellite Image Data Analyses Result**

4.4.1 **Classified Land use / Land cover Map for 1975 and 1986.**

Classified land use/ land cover maps of the study area for pre-dam and post dam periods (1975 and 1986) are produced as shown in Fig. 4.5 and Fig. 4.6. The classified maps show the land use/land cover conditions for the period. Table 4.3 shows the aerial extent of each class of land use / land cover expressed in percentage.

4.4.2 **Magnitude of Change in Land use / Land cover Between 1975 and 1986**

Changes in the Land use/land cover condition are identified between 1975 and 1986. Table 4.4 shows the changes in terms of gains and losses in aerial extent and percentage coverage for each class.

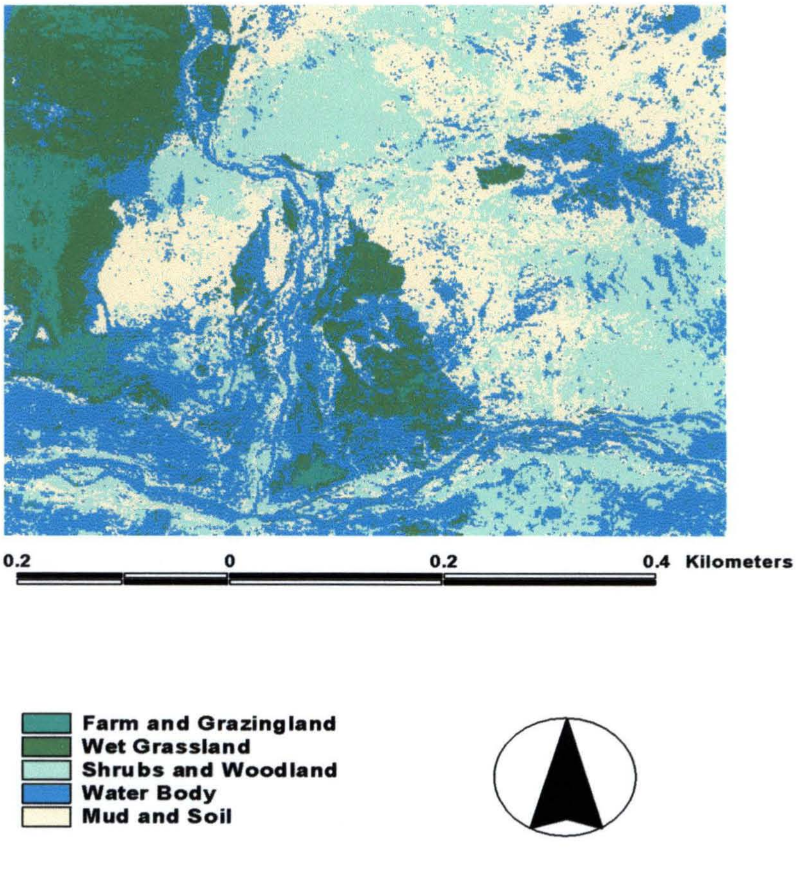


Fig.4.5: The land use/land cover pattern of the pre-dam period obtained from Landsat MSS, 1975.

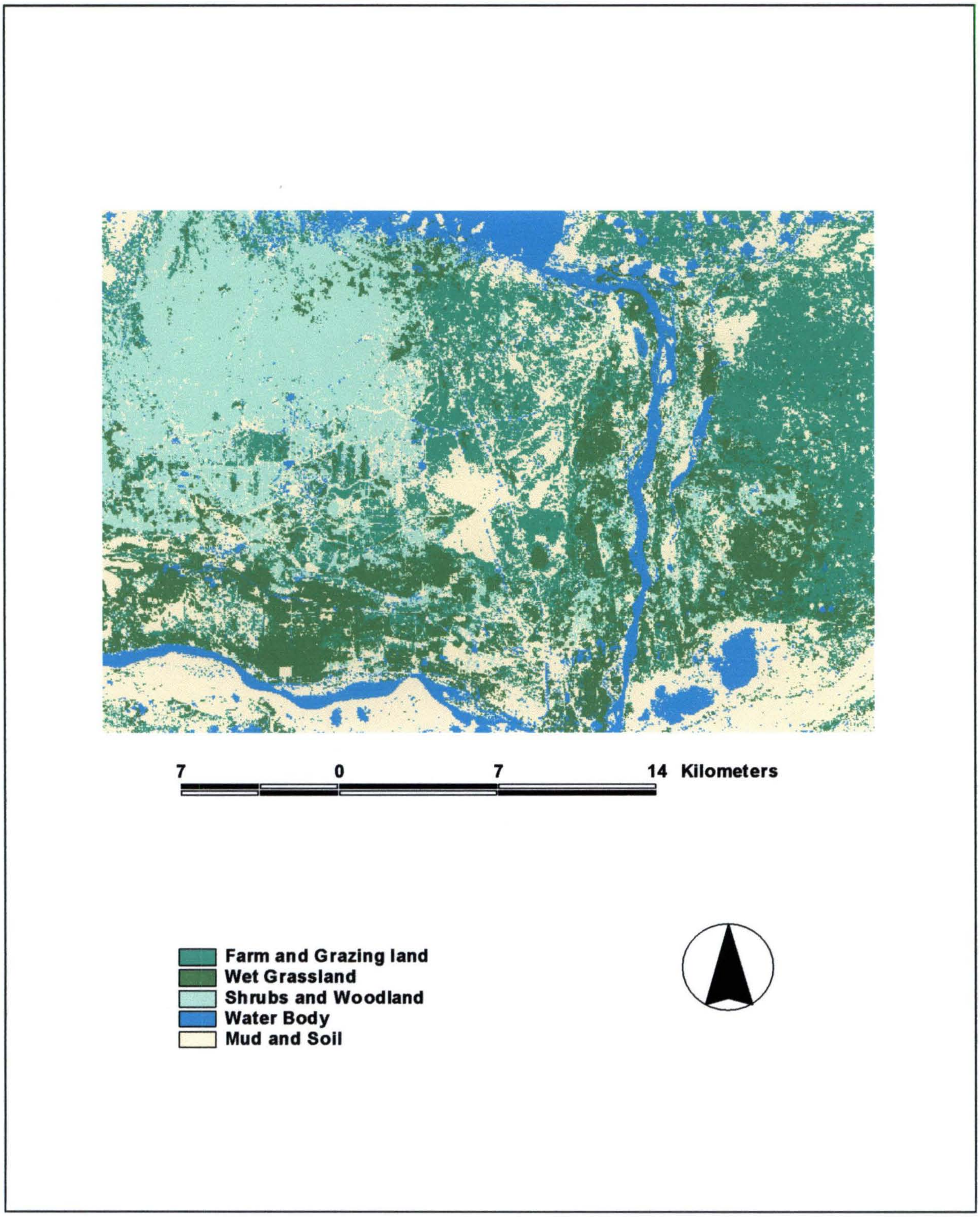


Fig.4.6: The land use/land cover pattern of the post-dam period obtained from Landsat TM, 1986.

Table 4.3: Aerial extent and percentage coverage of land use/land cover in 1975 and 1986.

Land use/land cover Class	**1975. Area in Sq.km**	**Percentage coverage %**	**1986. Area in Sq.km**	**Percentage coverage %**
Farm and grazingland	174.30	21.24	198.30	24.17
Wet Grassland	161.39	19.67	131.39	16.01
Shrub and woodland	165.12	20.12	161.12	19.64
Water body	95.03	11.58	78.02	9.51
Bare soil and mud	224.64	27.38	251.64	30.67
Total	820.47	100	820.47	100

Table 4.4: Magnitudes of change in land use/land cover between 1975 and 1986

Land use/land cover class	**1975 Area In Sq.km (A)**	**%**	**1986 Area in Sq.km(B)**	**%**	**Magnitude of change in Sq.km**	**%**	**Remarks**
Farm and grazingland	174.30	21.24	198.30	24.17	24.00	35.30	Gain
Wet grassland	161.39	19.67	131.39	16.01	-30.00	-44.12	Loss
Shrub and woodland	165.12	20.12	161.12	19.64	-4.00	-5.88	Loss
Water body	95.03	11.58	78.02	9.51	-17.00	-25.01	Loss
Bare soil and mud	224.64	27.38	251.64	30.67	27.00	39.71	Gain
Total	820.47	100	820.47	100	68.00	100	Loss

4.4.3 **Classified Land use/Land cover Map for 1999 and 2007.**

Classified land use/land cover Maps of the study area for post-dam period (1999 and 2007) are produced as shown in Fig. 4.7 and Fig. 4.8. The maps show the land use/land cover condition for the period.

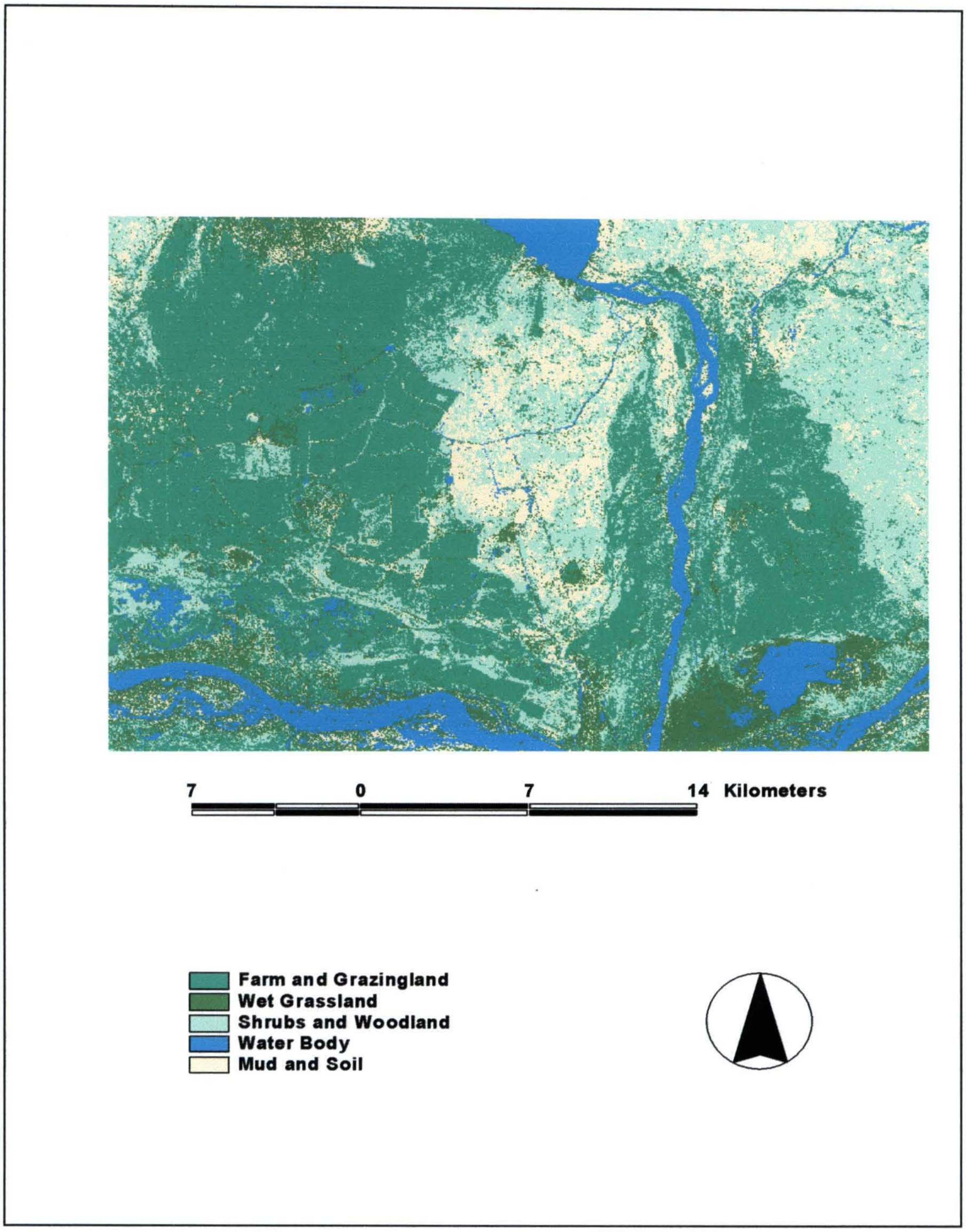


Fig.4.7: The land use/land cover changing pattern obtained from Landsat ETM, 1999.

Table 4.5: Aerial coverage and percentage of land use/land cover for 1999 and 2007.

Land use/land cover Class	1999. Area in Sq.km	Percentage coverage	2007. Area in Sq.km	Percentage coverage
Farm and grazingland	265.94	32.41	296.94	36.19
Wet Grassland	40.11	4.89	20.11	2.45
Shrub and woodland	141.85	17.29	123.32	15.03
Water body	74.02	9.02	70.01	8.53
Bare soil and mud	298.56	36.39	310.09	37.79
Total	**820.47**	**100**	**820.47**	**100**

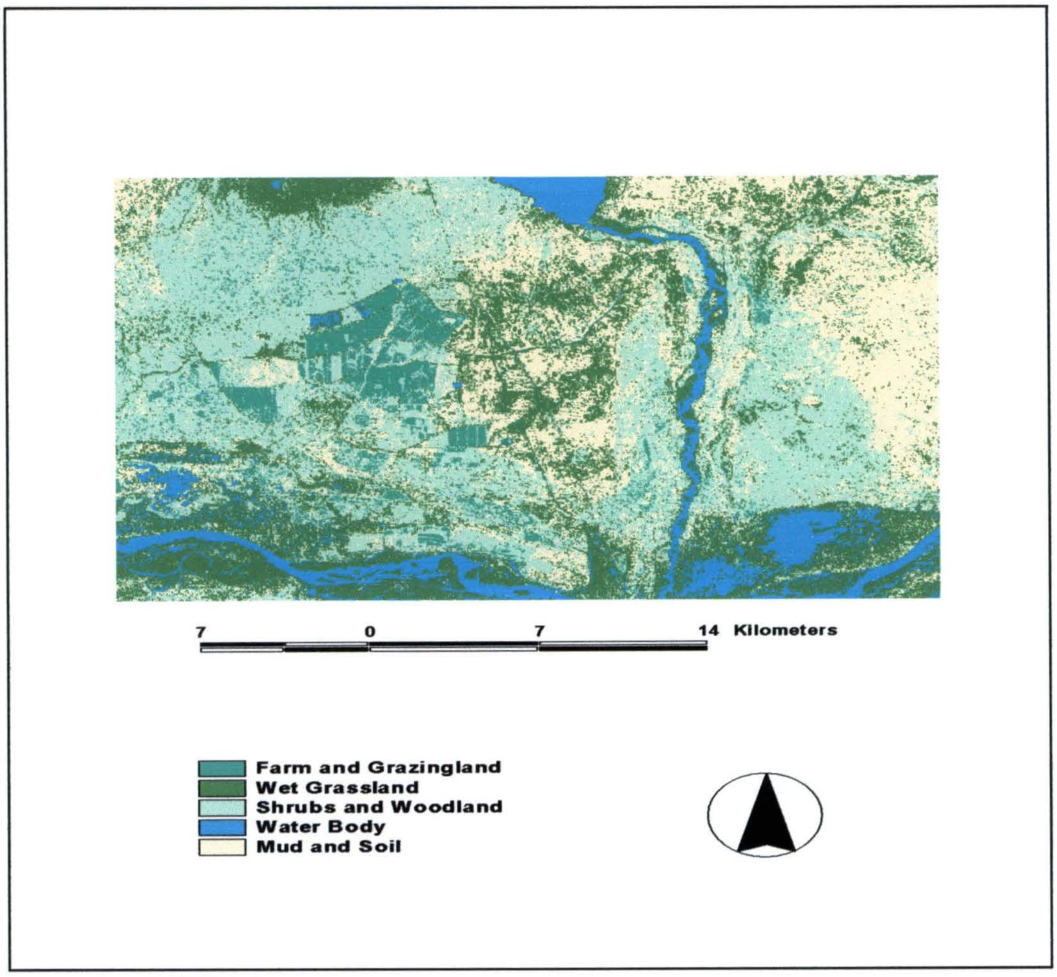


Fig.4.8: The land use/land cover changing pattern obtained from Landsat ETM, 2007

Table 4.6: Magnitude of change in land use/land cover between 1999 and 2007

Land use/land cover Class	**1999. Area in Sq.km**	**Percentage coverage**	**2007. Area in Sq.km**	**Percentage coverage**	**Magnitude of Change in Sq.km**	**Percentage Change**	**Remarks**
Farm and grazingland	265.94	32.41	296.94	36.19	31	40.24	Gain
Wet Grassland	40.11	4.89	20.11	2.45	- 20	- 25.96	Loss
Shrub and woodland	141.85	17.29	123.32	15.03	- 18.52	- 24.04	Loss
Water body	74.02	9.02	70.01	8.53	-4.01	- 5.21	Loss
Bare soil and mud	298.56	36.39	310.09	37.79	11.53	14.97	Gain
Total	**820.47**	**100**	**820.47**	**100**	**77.04**	**100**	**Loss**

Table 4.7: Overall magnitude of change in land use/land cover, between 1975 and 2007.

Land use/Land cover Class	**Magnitude of change in Sq.km**	**Percentage Change**	**Remarks**
Farm and Grazing land	27.50	37.77	Gain
Wet Grassland	-25.00	-35.04	Loss
Shrub and Woodland	-11.26	-14.96	Loss
Water body	-10.51	-15.11	Loss
Bare Soil and mud	19.27	27.34	Gain

4.4.4 **Magnitude of Change in Land use / Land cover Between 1999 and 2007, and Overall Change between 1975 and 2007.**

Changes in the land use/ land cover condition between 1999 and 2007 and the overall change between 1975 and 2007 are identified. Tables 4.6 and 4.7 show the changes in terms of aerial losses and gains expressed in percentages. Photographs are produced and presented in plates I, II, III and IV, showing the situation of the land cover in 2005.

Plate I: Bare surfaces resulting from over- grazing in Shelleng, June, 2005

Plate II: Existing condition of shrub and wood vegetation in Guyuk, May, 2005

Plate III: Intensive cultivation at the flood plain in Kiri. May, 2005

Plate IV: Canalization pattern of River Gongola at Numan, June, 2005.

4.5 Accuracy Assessment of Image Classification

Accuracy in image classification for 1999 landsat ETM and 1975 Landsat MSS is assessed. Table 4.8a and 4.8b show that the result of the accuracy achieved is remarkable.

Table 4.8a: Contingency table for 1999 LANDSAT ETM image classification

Land use /Land cover type	Farm/ Graze land	Wet grassland	Shrub/ Woody	Water Bodies	Mud/ Soil	Total	Accuracy
Farm/Grazing land	23	13	13	1	15	65	35.38%
Wet Grassland	14	113	10	0	0	137	82.48%
Shrub /Woody	1	8	434	1	0	444	35.42%
Water bodies	0	0	0	163	0	163	100.00%
Mud/soil	2	2	5	0	111	120	92.63%
Total	40	136	463	165	126	929	
Accuracy	57.61%	83.09%	93.94%	98.79%	88.10%		

Overall accuracy = 90.75% Khat Statistic = 89.82%

Table 4.8b: Contingency table for 1975 LANDSAT MSS Image Classification

Land use /Land cover type	**Farm/ Grazing land**	**Wet grassland**	**Shrub/ Woody**	**Water Bodies**	**Mud/ Soil**	**Total**	**Accuracy**
Farm/Grazing land	371	14	0	1	12	88	69.32%
Wet Grassland	14	76	14	1	3	107	71.03%
Shrub /Woody	13	0	371	4	0	375	98.92%
Water bodies	0	1	6	58	0	65	89.25%
Mud/soil	6	0	0	0	127	133	55.49%
Total	80	91	391	64	142	768	
Accuracy	76.25%	83.52%	94.88%	90.63%	89.44%		

Overall accuracy = 90.53% Khat Statistic = 85.74%

4.6 **Field Survey Data Analysis Result**

4.6.1 **Demographic Characteristics of Respondents**

Result of the respondents' demographic characteristics is presented in Table 4.9. The presentation shows result of each variable expressed in percentage.

Table 4.9: Demographic characteristics of respondents

Variables	Frequency (N= 477)	Valid Percent (%)
Gender		
Male	328	68.7
Female	149	31.3
Age		
< 31	29	6.1
31-40	110	23.8
41-50	152	31.9
51-60	141	29.6
> 61	45	9.4
Education		
Primary school	45	8.8
Secondary school	271	51.6
Graduate	41	3.4
Qur'anic/primary education	120	25.2
Martial status		
Single	92	19.5
Married	359	75.0
Widowed/Divorced/Separated	26	5.5
Occupation		
Civil servant	14	2.9
Farmer	282	59.1
Fisherman	28	5.9
Farming/Fishing	112	23.5
Trader	41	8.6

Income per month		
Less than ₦30, 000	332	69.6
₦30, 001– ₦60, 000	140	29.4
₦60, 001– ₦90, 000	5	1.0
₦90, 001– ₦120, 000	0	0.0
₦120, 001 or more	0	0.0
Length of residence		
< 5 (years)	34	7.1
6-20	238	49.9
21-35	122	25.6
36-50	67	14.0
51-65	16	3.4
> 66	0	0.0

4.6.2 **Respondents Perception of Kiri Dam Impact**

Result of the respondents' opinion on the impact of Kiri Dam is shown in Table 4.10. The presentation shows the total mean and standard deviation score in each impact statement.

Table.4.10: Descriptive analysis of Kiri Dam impact Items

Kiri Dam Development Impact item	Mean (M)	Standard Deviation
1. Kiri irrigation dam has created jobs for your community.	4.33	.92
2. Irrigation farming has attracted more investment to your community.	4.33	.92
3. Our standard of living has increased considerably because of economic benefits from all season farming.	3.33	.92
4. The construction of the Dam on the river has negatively affected activities.	3.52	1.04
5. The damming of the river has negatively changed your precious traditional culture (fishing to farming).	1.81	1.00
6. Local residents have suffered from negative effect of the dam (flood).	1.94	.94
7. The construction of the dam has boosted the activities of the local residents.	3.65	.94
8. The damming has resulted in positive impacts on the cultural identity of our community.	3.42	.93
9. Damming of Kiri has resulted in land use /land cover change, and flood at the downstream.	4.33	.92
10. Construction of dam and other irrigation facilities have destroyed the natural Environment.	2.21	1.05

Note: Measurement scale, 1= Strongly Disagree and 5 = Strongly Agree

CHAPTER FIVE

DISCUSSION, SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Satellite Image Result

5.1.1 Classified land use/land cover Map for 1975

The interpretation of the classified map of pre-dam period shown in Fig.4.5 reveals farm and grazing lands. As presented in Table 4.3 the land cover occupied 174.30sq.km of the total area (820.47sq.km) representing 21.24%. Farm and grazing lands dominated the western part of the area and sparsely intersperse with other land covers. Wet grassland also existed with a significant aerial coverage of 161.13sq.km representing 19.67%. The land cover is seen mostly around the water bodies especially the drainage channels of River Gongola and part of Benue River. The existence of wet grassland was an indication of dry season farming potentials.

Occurrence of Shrub and woodland (165.12sq.km) is substantial. This class of land cover existed mostly in the extreme north and south eastern parts of the study area with a percentage coverage of 20.12%. Shrub and woodland offered opportunity for expansion of socio-economic activities. Water bodies are seen to exist over an area of 95.02sq.km representing 11.58% of the total coverage. The areas consisted of the drainage channels of river Gongola and a part of River Benue around Numan. The proportion of water bodies in the study area was a great opportunity for socio-economic activities such as irrigation and fishing. The study area had a significant proportion of bare soil and mud, amounting to 224.64sq.km which represents 27.38%.The traces of bare soil and mud existed amid other classes of land cover in many parts of the study area, including the surroundings of water bodies. This finding can be attributed to intensive cultivation and over grazing practices, including decrease in water bodies as a result of the Kiri Dam.

5.1.2 **Classified land use/land cover Map for 1986.**

The classified map (Fig.4.6) shows a wide spread of farm and grazingland in high density, especially around Shelleng and Numan areas. Results in Table 4.3 shows that the land cover occupied 198.30sq.km of the study area representing 24.17%. There was a significant existence of wet grassland measuring 131.39sq.km representing 16.01% of the total area. The wet grassland is seen in the adjoining areas of the water bodies and amid other land covers. This class offered opportunities for both dry and wet seasons farming to the residents. The interpretation has revealed a wide range of shrub and woodland covering 161.12sq.km. This class existed intersperse with other land covers and showed dominance in the extreme northwest of Guyuk. It represented 19.64% of the study area. The land cover offered the inhabitants opportunities for expansion of farm and grazing lands.

The Gongola River basin had water bodies occupying 78.02sq.km representing 9.51% of the total area. Surface water is seen sparsely around the entire study area with the main source been the drainage channels of Gongola river and part of River Benue at Numan, including the portion of Kiri dam. It could therefore, be deduced that the water bodies offered a remarkable opportunity to the inhabitants for irrigation and fishing. It is also observed that 30.67% of the study area was covered by bare soil and mud representing 251.64sq.km. Bare soil and mud were seen amid other land covers notably around the surface water areas. The phenomena indicated a prevalence of intensive cultivation and over grazing practices; it also indicated a considerable decrease in water bodies.

5.1.3. **Magnitude of Change in Land use/Land cover between 1975 and 1986.**

Changes in the condition of land use/land cover between 1975 (pre-dam period) and 1986 (10 years post-dam period) were detected from the classified maps shown in Fig.4.5 and 4.6. Result presented in Table 4.4 shows that farm and grazing land has shown a remarkable change with an aerial gain by 24.00sq.km representing 35.30%.This result can be attributed to a possible occupational change most likely from fishing to farming and grazing practices, brought about by the declined fishing activities resulting from decrease in the water bodies.

Wet grassland has shown a drastic change with a tremendous loss by 30.00sq.km representing 44.12%. This scenario implies a possible economic loss to the inhabitant farmers. Similarly, a remarkable loss in water bodies is noticed by 17.01sq.km representing 25.01%. This phenomenon therefore, resulted to a drastic loss in the moisture content of the wet grassland areas, thereby causing them to dry up. The change has also resulted to a possible decline in socio-economic activities such as fishing.

Shrub and woodland has also indicated a loss by 4.00sq.km. This implies a possible loss of land to farmlands and grazing fields which had an aerial gain by 24.01sq.km. It is also observed that bare soil and mud gained by 27.00sq.km representing 39.71%, constituting the highest gain between 1975 and 1986.

5.1.4. **Classified Land use/Land cover Map for 1999.**

The classified map in Fig.5.7 shows farm and grazing land intersperse with other land covers around the entire study area. As presented in Table 4.5 farm and grazingland significantly occupied an expanse of 265.94sq.km representing 32.41%. The phenomenon therefore, implies that farming and grazing were common socio-economic activities among the inhabitants.

Shrub and woodland covered 141.85sq.km seen in many parts, especially at the extreme northwest of Guyuk where the land cover lay in high density. The class represented 17.29% of the study area. This proportion offered the inhabitants opportunity for farm and grazing land expansion and tree felling for fire wood. The study area had water bodies occupying 74.02sq.km representing 9.02%. It existed sparsely around the entire area with the main body been the drainage channels of Gongola River, part of Benue River in Numan and a portion of Kiri dam. It could therefore be noted that the land cover offered opportunity for irrigation and fishing to the residents.

Wet grassland has shown a substantial coverage with 40.11sq.km representing 4.89%. The land cover was interspersed with other classes notably the water bodies. This condition implies that wet grassland loss as a result of loss in water bodies. In terms of dry season farming it is suitable for all types of irrigation practices. Beside, the rich soil fertility helps in promoting crop yields. Bare soil and mud areas are seen occupying an expanse of land amounting to 298.56sq.km representing 36.39%. Bare soil and mud appeared mostly in the wet grassland and sparsely in the adjoining areas of water bodies.

5.1.5 **Classified land use/land cover Map for 2007.**

From the classified map in Fig.4.8 it is observed that farm and grazing land appeared widely in the entire study area however in great concentration around Numan and northwest Guyuk. Results presented in Table 4.5 shows that this class covered 296.94sq.km representing 36.19%. The result implies that farming and grazing practices were common among the inhabitants as can be seen in Plate III.

There was a considerable appearance of bare surfaces mostly around water bodies, farmlands and grazing areas. This class covered an aerial extent of 310.09sq.km, representing 37.79%. The expanse of bare soil and mud resulted due to loss in water bodies, and practices such as over grazing and intensive cultivation as can be seen in PlateI.

Traces of wet grassland areas are noticed to have existed with an aerial coverage of 20.11sq.km representing 2.45%. This class of land cover is seen mostly around the water bodies notably, the adjoining areas of the drainage channels of River Gongola, and part of Benue River around Numan. Wet grassland areas are desired mostly by farmers for high yielding potentials and ease of dry season farming through irrigation practices. The land cover occupied 20.11sq.km of the study area, representing 2.45%. Shrub and woodland also existed in the extreme northwest of Guyuk and eastern part of Numan towards

Shelleng, where the density was relatively high. It covered 123.32sq.km of land representing 15.03%. The condition of a typical shrub and woodland in the study area can be seen in Plate II. It could be deduced that this land cover is desired for the expansion of socio-economic activities such as farming and grazing when needed.

Water bodies are seen, notable the drainage channels of River Gongola and part of river Benue around Numan, including a portion of Kiri dam that lay within the study area and others, sparsely existed. This land cover occupied 70.01sq.km; representing 8.53 %. It could therefore, be deduced that the water bodies were a source of wide range of opportunities to the inhabitants, for socio-economic activities such as fishing and irrigation. Bare soil and mud areas are also seen mostly around the wet grassland and adjoining areas of water bodies, covering 310.09sq.km representing 37.79%.

5.1.6. **Magnitude of Change in land use/land covers between 1999 and 2007.**

From the presentation in Fig. 4.7 and 4.8 changes were noticed in the land use/land cover pattern between 1999 and 2007. Result on the magnitude of change presented in Table 4.6 shows a substantial gain in farm and grazing areas by 31sq.km; representing 40.24%. Such a gain can be attributed to a possible occupational change especially from fishing to farming and grazing practices. This phenomenon was due to declined fishing activities following a loss in the water bodies by 4.01sq.km. The overall changes between 1975 and 2007 are presented in Table 4.7. Wet grassland areas have also indicated a drastic change with a loss by 20sq.km representing 25.96%. This phenomenon implies a considerable economic loss on farming activities. It is also observed that water bodies have indicated a considerable loss by 40.01sq.km representing 5.21%. Plate IV shows the canalization pattern of River Gongola at Numan in June, 2005.

Shrub and woodland has also indicated a loss by 18.55sq.km representing 24.04%. This development implies a possible loss of land to farm and grazing land which increased by 31sq.km. However, bare soil and mud experienced a noticeable gain by 11.53sq.km representing 14.97%. This phenomenon can be attributed to an intensive cultivation and over grazing activities, coupled with significant loss in water bodies.

5.1.7 Magnitude of Change in Land use/land cover between 1975 and 2007

The pattern of land use/ land cover distribution in the study area between 1975, (pre-dam period) and 2007, (post-dam period) reveals substantial changes in form of decrease and increase in aerial extent and percentage coverage. The overall magnitude of changes presented in Table 4.7 shows that out of the total size of the study area (820.47sq.km) wet grassland, shrub and woodland and water bodies decreased by 35.04%, 14.96% and 15.11% respectively. Whereas farm and grazing land increased by 27.50sq.km representing 37.77%, bare soil and mud by 19.27sq.km to represent 27.34%.

5.2 Accuracy Assessment of Image Classification

As can be seen in Table 4.8a and Table 4.8b, the overall accuracy for the 1999 image was 90.75% while that of the 1975 image was 90.53%. In the 1999 classification the major areas of confusion were in grass/marshy lands (Misclassified as cultivated/grazed areas) and cultivated/marshy areas (Which in fact had the lowest accuracy of 35.42%). The source of confusion was bare soil, this should not be surprising since, for the former, it is the grass/marshy area that are grazed while in the later fields cleared for cultivation are more or less bare surfaces.

On the 1975 image, water was not as accurately classified as was done in the 1999 image because in 1975 water was everywhere, most places having ponds/pools of water often covered with grasses. Grass/marshy areas have also been intermixed with cultivated/grazed areas, as was the case with the 1975 image. The lowest accuracy remained in cultivated/grazed areas with sources of error again being grassland and sand. The accuracy in the classification of wood/shrub land for the two images were almost the same (difference of less than 2%); of course, woodlands are more easily discernible from all other cover types.

On the whole, the accuracy achieved is remarkable, given the tile gap between the acquisition and interpretation of the images and the drastic changes occasioned by the construction of the dam, and reasonably consistent with findings elsewhere.

5.3 Field Survey Questionnaire Result

5.3.1 Demographic Characteristics of Respondents

The demographic characteristics of the samples used in this study were measured by gender, age, education, marital status, income and occupation of the respondents. The summary of the demographic characteristics is shown in Table 4. 9. From the table it is shown that the respondents comprised of male (68.7%) and female (31.3%) and the average of the respondents' age was 48 years old, although 31.9% of them ranged between 41 and 50, followed by 29.6% of them that ranged between 51 and 60 and 23.9% ranged between 31 and 40 years from the result. Thus the majority of the respondents were middle-aged (55.7%), between 31 and 50 years (see Appendix A part III).

The result further shows that 25.2% of the respondents had Qur'anic/primary education, 56.6% had secondary school certificate education while 9.8% had primary school. 8.4% of the respondents had degree certificate. The educational level of the respondents therefore showed that all of them (100%) have acquired formal education. This finding implies that with little orientation, they can easily learn and adapt to new discoveries on how to mitigate the impact of the dam on Land use/Land cover.

In terms of marital status, 75.0% are married while 19.5% are single and others (5.5%) are either divorced or widowed. The high proportion of married population can be attributed to the fact that tradition and culture of the majority of the respondents who are Muslims marry early and can marry up to four wives. The implication of this situation is that high fertility rate which would lead to increase in the total population is anticipated in the future

The result also shows that 59.1% are farmers, while 23.5% are both farmers and fisher men. Only 2.9% are civil servants and 8.6% as traders whereas fisher men are 5.9%. The decrease in water bodies by 30.01% among other factors is responsible for the low percentage of fisher men. Farming is revealed therefore, as the major occupation of the respondents. Income level per month showed that 69.6% earn less than ₦30, 000 while 29.4% earn between ₦30, 100 and ₦60, 100. This finding is an indication that majority (69.6%) of the respondents are low income earning farmers. Decrease in wet grassland areas by 35.04% and increase in bare surfaces by 27.34% as presented in Table 4.7 among other factors, are responsible for the low income earning. The increase in bare surface due to intensive cultivation and decrease in wet grassland due to loss of soil moisture content are not favourable for farming thereby given rise to low productivity among farmers.

5.3.2 Respondents Perception of the Impacts

The results of the people's perception of the impact of the Kiri Dam development are presented in Table 4.10. Based on the mean score of each of the ten items of measurement, respondents tended to strongly agree that the dam has created jobs for their community (M=4.33, SD=.92). This response confirms the fact that the Kiri Dam has offered opportunity for continuous farming through irrigation in the dry season.

Further, respondents tended to also strongly agree that the dam construction has resulted in land degradation and changes in land use (M=4.33, SD=.92). This response confirms the result of the image analysis which shows a significant increase in bare soil and mud areas to the extent of 38.31sq.km as a result of land degradation resulting from over grazing, intensive cultivation and considerable decrease in water body areas. Cases of loss and gain in Land use/Land cover classes were also noticed and presented.

However the respondents strongly disagree that the dam construction has negatively changed their traditional culture, from fishing to farming (M=1.81, SD=1.00). This result also confirms the presentation in Table 4.9 where majority of the respondents were farmers (59.1%) whereas only 5.9% were engaged in fishing as their primary occupations. In terms of increase in standard of living, the respondents agree that the dam has given considerable economic benefits to the people, since all season farming takes place (M=3.52, SD=.94). It can be deduced from this response that the dam construction has made dry season farming possible through irrigation on the arable land. With this opportunity, the inhabitants can realize steady income from the sales of their farm products throughout the season.

With regard to the destruction of the natural environment, the respondents are of the opinion that the dam construction and irrigation activities have not destroyed the natural environment (M=2.21, SD=1.05). In terms of the positive impact of the dam on cultural identity, respondents tended to agree that the dam has positively impacted on the cultural identity of their community (M=3.42, SD=.93). The response has confirmed the presentation in Table 4.9 where farming was the major primary occupation and has been strengthened through irrigation, based on the dam water during the dry season. It has also confirmed the wide spread farmlands in the study area, as revealed from the results.

5.4 Summary of Major Findings

5.4.1 Condition of the land use/land cover between 1975 and 2007

Analysis of the classified map for pre-dam period (1975) shows that 174.30sq.km consisted of farm and grassland, representing 21.24% out of the total area (820.47sq.Km). The land cover lay predominantly in the western side of the study area and sparsely interspersed with other land covers. Wet grassland is seen around the water bodies, occupying 161.39sq.km representing 19.67%. The study has also revealed shrub and woodland, laying densely in the extreme north and south eastern side of the study area, covering 165.12sq.km. Water bodies are also identified, comprising mainly the drainage channels of River Gongola and part of River Benue at Numan, occupying 11.58% of the study area. The result shows that bare soil and mud covered 224.64sq.km mostly seen around wet grassland, farm and grazing land.

Classified map for 1986 shows a wide spread farm and grazing land in the study are occupying 198.30sq.km to represent 24.17%. Wet grassland existed to the extent of 131.39sq.km representing 16.01%, seen mostly around water bodies. The analysis also reveals a wide range of shrub and woodland covering 161.12sq.km representing 19.64%. This class lay interspersed with other classes and dominated the extreme northwest of Guyuk. Water bodies were also identified comprising mainly the drainage channels of the lower reaches of River Gongola and part of River Benue at Numan, occupying 78.02sq.km. The analysis further shows that 30.67% of the study area was covered with bare soil and mud, representing 251.64sq.km.

The analysis of the classified land use/land cover map for 1999 shows farm and grazingland occupying an expanse of 265.94sq.km, representing 32.41% of the total area. The class lay interspersed with other landcovers around the entire study area. The result further shows that 141.85sq.km comprised of shrub and woodland, seen in many parts however, in the extreme northwest of Guyuk, the density was higher. Water bodies comprising mainly the drainage channels of River Gongola and part of River Benue at Numan were also seen. They covered 74.02sq.km representing 9.02% of the study area. Whereas, wet grassland covered 40.11sq.km representing 4.89% of the total area, seen interspersed with other land covers notably the water bodies. While bare soil and mud occupied 298.56sq.km to represent 36.39%.

The classified map for 2007 shows farm and grassing land widely spread, especially around Numan where sugarcane plantation activities dominated, the land cover occupied 295.94sq.km representing 36.191%. Bare soil and mud patches were seen mostly around the wet grassland, covering 310.09sq.km. Traces of wet grassland were also noticed around the water bodies to the extent of 20.11sq.km representing 2.451% of the study area. Beside, shrub and woodland existed in the extreme northwest of Guyuk and east of Numan towards Shelleng in relatively high density, covering 123.32sq.km. Water bodies were seen, covering 70.01sq.km to represent 8.53%, comprising of the drainage channels of River Gongola and Part of River Benue at Numan.

5.4.2. **Magnitude of Changes that have occurred on the Land use/Land cover Condition**

Between 1975 (pre-dam period) and 1986 (eleven years post dam period), the result of the analysis shows that farm and grazing land increase by 24.00sq.km to represent 35.30%. However wet grassland decreases by 30.00sq.km representing 44.12%. The loss was as a result of decrease in the water body bodies by 17.00sq.km which represents 25.01%. Shrub and woodland have also changed, with a decrease by 4.00sq.km representing 5.90%. The period witnesses substantial increase in bare soil and mud to the extent of 27.00sq.km which represents 39.71%.

Further changes were observed between 1999 and 2007 (thirty two years post dam period), which include gain in farm and grazing land by 30sq.km to represent 40.24% and loss in wet grassland by 20sq.km representing 25.96%. It is also observed that the water bodies experienced decrease by 4.01sq.km representing 5.21%. Further decrease is noticed in shrub and woodland by 18.52sq.km to represent 24.04%. However, bare soil and mud areas have indicated an increase within the period, by 11.53sq.km representing 14.97%.

5.4.3 **Respondents Perception of the Impact**

The result of the people's perception of the Kiri Dam development reveals that respondents tended to strongly agree that the dam has created jobs for their community, by offering opportunity for fishing and dry season farming. The agreement was based on a total mean score of 4.33 and a standard deviation of .92. The respondents also strongly agree that the

Kiri Dam has resulted to land degradation and changes in land use/land cover, based on a total mean score of 4.33 and a standard deviation of .92. With regard to the destruction of the natural environment, the respondents are of the opinion that the dam has not destroyed the natural environment (M=2.21, SD=1.05). In terms of increase in standard of living, the respondents strongly agree that the dam has offered considerable economic benefits to the people, since fishing and dry season farming take place.

5.5 **Conclusion**

Regulation of the Gongola River flow by damming has indeed affected the resilience of the downstream environment, resulting to changes in the wetlands scenario of the pre-dam period. Assessed against the background for which the Kiri Dam was constructed the benefits could not be said to have been fully achieved, since the Kiri Dam development reduces fishing and leads to massive alteration in the downstream environmental conditions of land use/land cover. Thus, the project could be adjudged to have impacted negatively, both in economic and environmental terms. Therefore, the current thinking and plans for the construction of several dams in the country need to proceed with great caution, taking into cognisance of what became of most existing dams.

5.6 **Recommendations**

Environmental Impact Assessment (EIA) should be conducted before gigantic projects such as the Kiri Dam are sited, to identify any possible negative impact on the environment and on the socio-economic activities of the people.

In as much as land use planners are involved in the decision making of the state in terms of land use planning, care should be taken to involve the meteorologists and other environmental scientists so that coherent and sound decision could be made to help reduce environmental problems on land use/ land cover.

Satellite remote sensing data with high resolution imagery such as Ikonos is needed to help show a clearer view of the land use/land cover conditions, for a detailed time series analyses. This will help provide a better framework for understanding environmental impacts of projects like the Kiri Dam.

There is the need for routine information on the socio-economic activities in the lower reaches of the Gongola River and the resultant impact on the land use/land cover at an interval of five to ten years.

There is a need for further research to focus on the effects of the Kiri Dam on aquatic ecosystem that could include dense algae growth and aquatic weeds that invade channels and distribution systems, as well as a research that would look into the array of other environmental effects that require urgent attention, including ecological changes and human diseases.

5.7 **Contribution to Knowledge**

(a) The study has made recommendations on how to mitigate the major impacts that resulted from the Kiri Dam development.

(b) It has identified the impacts of the Kiri Dam on the socio-economic activities of the people in the study area.

(c) The study has analysed the land use/land cover condition for the pre-dam period (1975) and post-dam period (between 1975 and 2007) in terms of aerial extent and percentage coverage. It has also identified the magnitude of change that has occurred on the land use/land cover as a result of the Kiri Dam.

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Appendix

(A)

Survey Instrument

<u>Survey of Environmental Impact Assessment of the Kiri Dam on Landuse and Land cover at the Downstream of Gongola Rive Basin</u>

Part I: Measurement of Kiri dam Development Impacts

Please indicate **how much you agree or disagree with** each of the following bases of measure of Kiri dam development impacts statements.

1= Strongly Disagree 2= Disagree 3= Neither Disagree nor Agree 4= Agree 5= Strongly Agree

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Measurement of Kiri dam Development Impacts

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1. Kiri irrigation dam has created more jobs for your community.
2. Irrigation farming has attracted more investment to your community.
3. Our standard of living has increased considerably because of all season farming.
4. The construction of the Dam on the river has negatively affected our way of life.
5. The damming of the river has changed our precious traditional culture (fishing or farming).
6. Local residents have suffered from negative effect of the dam (flood).
7. The construction of the dam has boosted the activities by the local residents.
8. The damming has resulted in positive impacts on the cultural identity of our community.
9. Damming of Kiri has resulted in landuse /land cover change, and flood at the downstream.
10. Construction of dam and other irrigation facilities have destroyed the natural environment.

Part II: Your Demographic Information

Please indicate **how much you agree or disagree with** each of the following demographic information statements.

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1. Gender: (1) Male (2) Female
2. Your Age:___________
3. How long have you been living in Area?_________ year(s):1.) <5(2) 6- 20(3)21-35 (4)36 – 50 (5)51-65 (7) >66
4. Marital Status: (1) Single (2) Married (3) Widowed/Divorced/Separated
5. Education: (1) Primary school (2) Secondary school (3) Graduate (4) Qur'anic school
6. Occupation:1)Farming(2)Fishing(3)Both Farming and Fishing(4)Trader(5)Civil servant
7. Your Income per month:1)Less than ₦30,000 (2) ₦30,001– ₦60,000 (3) ₦60,001- ₦90,000(4) ₦90,001- ₦120,000 (5) ₦120,001 or more.

(B)

Result of Non-Response Tests by Chi-Square

Variables	**Early Respondents**	**Late Respondents**	
Gender			
Male	328	26	Pearson χ_2= 2.208129
Female	149	6	$p < 0.137$
Total	477	32	
Education			
Primary school	42		Pearson χ_2
Secondary school	246		$p <$
Graduate	16		
Qur'anic	120		
Illiterate	53		
Total	477		
Martial status			
Single	92	5	Pearson $\chi 2$ =0.278
Married	359	25	$p <0.87$
Widowed/Divorced/Separated	26	2	
Total	477	32	
Occupation			
Civil servant	18	4	Pearson χ_2
Farmer	298	10	$p <0.8$
Fisherman	67	5	
Farming/Fishing	118	8	
Trader	43	5	
Total	477	32	
Income per month			
Less than ₦30, 000			Pearson χ_2
₦30, 001- ₦60, 000			$p <$
₦60, 001- ₦90, 000			
₦90, 001- ₦120, 000			
₦120, 001 or more			
Total			