SEDIMENTATION AND POLLUTION PROBLEMS IN BOSSO RESERVOIR:

AN INTEGRATED STUDY INVOLVING SPOT XS, GROUND AND LABORATORY DATA

BY

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DECLARATION.

I hereby declare that this project is my original work, supervised by **Dr. A. S. Abubakar** and to the best of my knowledge has never been presented by any student in any form for the award of Master of Technology degree, but work of others are acknowledge and referenced.

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CERTIFICATION

This is to certify that this Thesis (project) was originally carried out by Ibrahim Bello Uthman and approved as meeting the requirement for the award of a Master of Technology Degree (M. Tech Remote Sensing Application) in the department of Geography, Federal University of Technology Minna, Niger State, Nigeria.

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DEDICATION

I dedicate this work to my mother Hajiya Fadimatu Addapullo, my late father Alhaji Usman Bello Jimeta and to my late sister Zainabu (Kande) Usman Bello.

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ABSTRACT

Remote Sensing techniques offer an authentic source of information for surveying, identifying, classifying and mapping.

This study demonstrates the applicability of remote sensing technique in the study of water quality in Bosso reservoir, Niger State.

The multi-band Spot imagery with 20 meters resolution has been applied in this regard. The specific issues examined include how runoff generates sediments, transport and deposits them in Bosso dam, the effects of which collectively threatens the theoretical estimate of design life span of 70 years when the dam was constructed.

SPOT 1994, image was used along with Arc view GIS, Erdas imagine 8.6 and Idrisi 32 processing softwares to divide the area into six (6) distinct classes in a bid to facilitate analysis of sources of sediments and effects of pollution in Bosso dam. The image was georeferenced with the importation of 5 ground control points (GCP's) from the topographical map of Minna sheet 164 SW of scale 1:50,000 and UTM 32n, the DEM was acquired. The classes include the cultivated slope, scattered cultivation, reservoir, densely vegetated areas, settlement and built-up areas and rock out crops.

Both the digital and manual interpretation approaches were employed in such classification. The classes based on their topographical data were used to determine surface runoff in the study area. The classes facilitated the understanding of areas of sediments generation, transportation and deposition into Bosso dam.

Consequently, laboratory analysis of water samples was conducted to determine the effects of pollution in Bosso dam in order to ascertain its fitness for public supplies. Detail analysis of the water samples reveals/indicates that there is some appreciable level of pollution in Bosso dam due to presence of high quantities of some chemical elements, which include iron, lead, copper and manganese.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND

Remote sensing has been used extensively for the delineation of surface water bodies and for the inventory of surface water supplies. Historically, Photo-interpretation has been used, but recently digital multi-spectral data have also been used. The photo-interpretation approach is time consuming and labour intensive if many water bodies are involved or repetitive inventories are needed. Multi-spectral data can be used with an automated analysis procedure to achieve rapid results that in many cases also meets the accuracy requirements. The principal advantage of high altitude or space sensors is the ability to monitor and inventory water bodies synoptically in areas or situations that are difficult to monitor using conventional methods (Welch, 1948) and (Hutchinson, 1957).

The ability of a reservoir to store enough water to meet the requirement of a catchment area is a judicious estimation of its design capacity. The design capacity of a reservoir is usually based on the area to be served. Whether, it is for domestic, industrial, irrigation or recreational purposes. Occasionally, either through changes in cropping pattern, or due to expansion of the town or cities to be served, a dam may be over-designed as a result of uses that were anticipated but that which never materialized. Putting the stated factors into consideration during the design stage can easily eliminate the size problem but due to the difficulty in estimating the rate of sedimentation to be expected in a reservoir, it becomes a problem to say precisely during the design stage the estimated life span of a reservoir. (Sagna et al, 1987).

Erosion and sedimentation refers to two phases in the process of detaching material to its deposition. Particulate material is called sediment once transport has begun. Erosion can also include dissolution and transport of dissolved substances in some of heavy precipitation. Dissolved loads are generally low, although concentrations may be high in dry climate, (Clayton, 1981 and Swanson et al 1982).

In many locations, effective dam management must open controls of erosion and sedimentation. To be sure, other important factors such as pollution by pesticides, nutrients, changes in stream temperature and so on may be considered. Though the later are not to be minimized, their importance in the Dam management often is dwarfed by comparison with effects of erosion and sediment, Adam and Paul as expressed in (Lawal, 2001)

The effects of rainfall on the landscape combined with the action of biological agents, break down rock by weathering forming soil and rock debris. Precipitation also dissolves some of the soil and rock debris formed and subsequently moved through various actions of both Un-concentrated water and water gathered into rills and channels. Gradually, the rock debris moved and deposited are numerous, most notable of these are damages causes to transportation, reduction in water quality and dam storage capacity and an increase in the cost of managing the dam and treating the water.

1.2 RESEARCH PROBLEMS

Considering the impact of soil erosion from the contributing watershed and on the dam, the design capacity of a reservoir will be reduced in time and space as sediments settle in the reservoir. Our inability to estimate during the design stage of a reservoir the amount of sediment to be deposited as a result of erosion has contributed to a great extent to the shortening of lifespan of most reservoirs.

The damage attributable to the soil erosion processes involves both the direct loss of soil nutrients from eroded areas as well as the damage associated with the deposition of eroded materials or sediments at down streams. Their process can lead to reduced crop production potentials, inefficient farming operations, the undermining of structures and the loss of roadways. The damage attributable to sediments on the other hand includes the clogging of stream channels, the silting of ponds and reservoir and contamination of down stream water by sediment borne pollutants.

To conserve the utility and lifespan of reservoirs, information is required on the key factors that constitute some major threats to the reservoir, especially sedimentation and pollution problem.

In Bosso Local Government, Minna, the Bosso reservoir is the main source of water supply to the millions of its inhabitants. The reservoir is facing some major threats of sedimentation and pollution but little comprehensive research information is available on the factors responsible for the occurrence of these two problems. For development purposes, information is no doubt required on these factors. The need for such information constitutes the problem of research interest to this study.

1.3 AIM AND OBJECTIVES.

The aim of this study is to determine the sources of sedimentation and pollution problems on Bosso dam. To achieve this aim the following specific objectives will be considered.

a) To identify and delineate (map out) the landuse classes in order to determine the potential areas of sediment generation, transport and deposition into the dam.

b) To analyse water samples from the dam (Bosso dam) in order to assess the extent of pollution from resulting sedimentation.

c) To suggest/recommend possible measures of water resource management for such a municipal dam.

1.4 JUSTIFICATION.

The study seeks to develop some conservation strategies that could help to develop the ways by which the various uses of the Bosso dam to its immediate environment are sustainably ensured and the objectives of the dam strengthened.

The study will consider steps to be taken to alleviate impending water crisis and contribute to a more stable water supply.

This becomes relevant because water is essential to human life and for sustainable economic development. Therefore special efforts are required to protect water resources from degradation and depletion, whether on the short or long term.

Bosso dam had, initially a storage capacity of 0.681 billion litres which had dropped to below 500 million litres. Consequently daily water supply to Minna municipality has dropped from 1.61 million litres to below 0.5million litres water per day. (Lawal O. H., 2000).

The factors responsible for these problem as well as the effects of pollutants on the quality of water certainly needs to be verified. Thus, this study stands to make some contributions towards water resources development in the area.

1.5 SCOPE AND LIMITATIONS.

Remote sensing technique can be used for studies of water resources management in a reservoir and even other related studies such as the monitoring of crops and vegetation. However, identification of most of the themes that could be studied are usually hampered by a number of factors that limit the increased use of remote sensing technique in the developing world (countries, like Nigeria). Most of the use is either directly or indirectly attributed to the recently, increased use (application) of remotes sensing technique.

The scope of the study is limited to 1994 mappable date only. This is because the satellite data available for use of the study is for that date only. However, field checking shall be used to obtain additional information to complement that derived from the satellite data.

1.6 GEOGRAPHICAL BACKGROUND OF THE STUDY AREA

The study area is Bosso municipal dam northeast of Bosso town. Bosso dam is a reservoir constructed in Bosso Local Government area of Niger State. Niger state is located between latitudes $8^{\circ}15^{1}$ – $11^{\circ}30^{1}$ and longitudes $3^{\circ}20^{1}$ – 7° 10^{1}. It is situated within the middle belt of Nigeria. Minna is located between latitudes $9^{'}40^{1}$ – $9^{'}45^{1}$ and longitudes 6° 28^{1} – 6°36', while Bosso dam is located on latitude $6^{'}28^{1}$ and longitude $9^{'}40^{1}$. The aim of the dam as undertaking by PWD in 1945 was for the purpose of domestic water supply to Minna and surrounding area. Bosso dam was designed by NE EXE, approved by H.E workers and construction work begun in October 1945. The dam was completed by November 1947. Its deepest level of core trench is 299.2m (981.88ft) with a minimum depth of core trench of 6.1m (20.2ft). It has minimum original ground level of 304.47m (999.00ft) with a crest elevation of 324.0m (1063ft) and a maximum height of 17.5m(64ft), Maximum conversion and maximum storage capacity of 0.681 billion litres (400,000 gallons). Figure 1.1 shows the location of the study area.

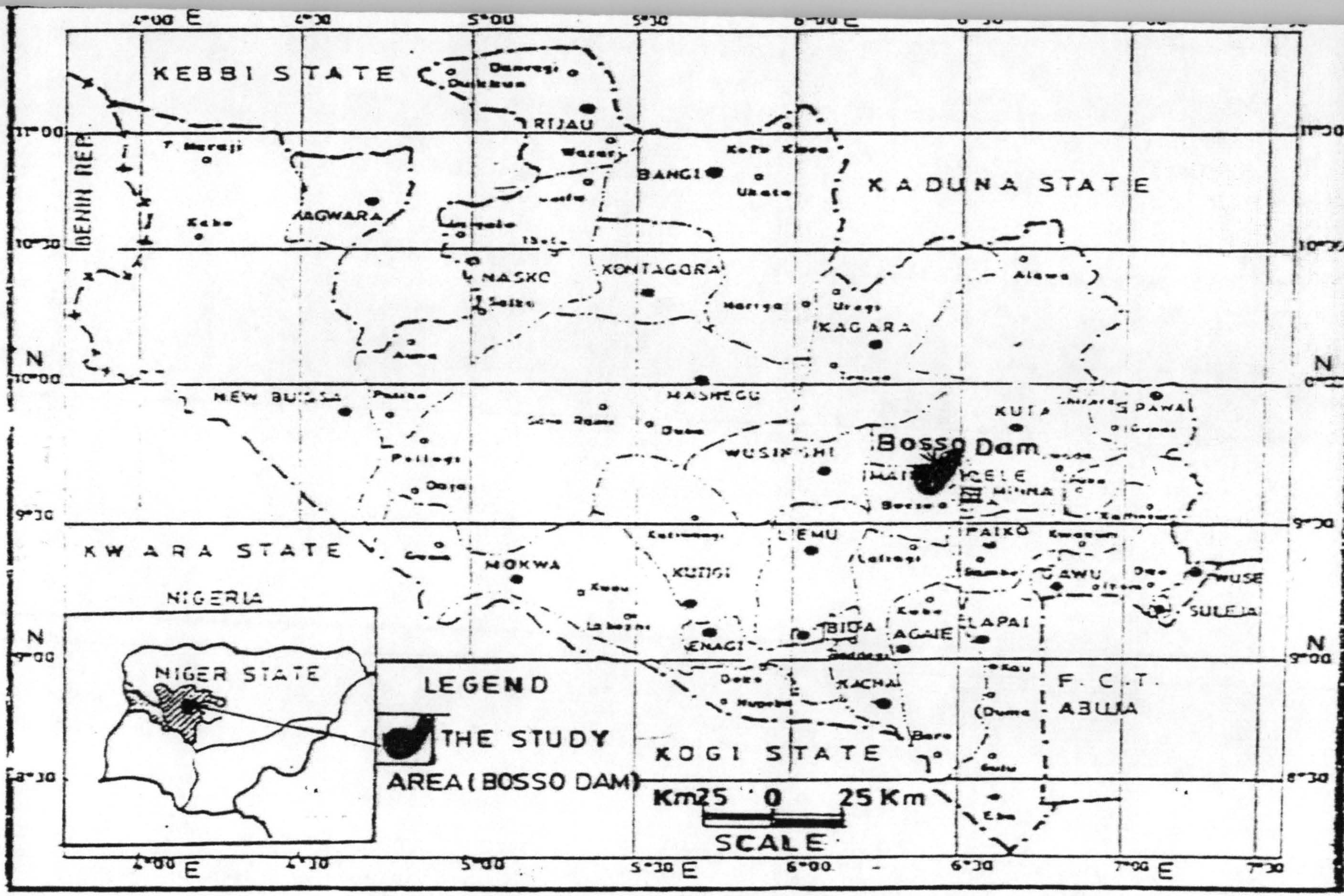

FIG. 1.1 NIGER STATE SHOWING THE LOCATION OF THE STUDY AREA
Source: Geography Depart F.U.T Minna, 2000.

1.6.1 GEOLOGY

The Basement complex rocks of the study area are believed to be Precambrian with over 50% older granite and about 50% of undifferentiated basement complex and undifferentiated meta-sediments all together. The basement complex is categorized basically into:

i. Magmatite and gneiss

ii. Quartzite and Schist and

iii. The granite rocks

The groups can further be subdivided according to composition, with the Magmatite, gneiss and granitic outcrops in many places, as isolated hills around 2km south of the study area. They appear as rugged topography or more or less continuous exposure with trees and shrubs in between. A large area of land with underlying soil that makes it possible for settlements to be built and Conducive environment for plants to grow exists between the exposures of rock. The quartzite and schist occur in belts of ridges with rocks generally poorly exposed, as loose fragments.

The occurrence of lowland within the older granites depicts the gentle slopes that provide the depression for Bosso reservoir.

The occurrence of undifferentiated meta-sediments in some lowlands depicts the gentle slopes of a generally flat area with occasional flat-topped hills (mesas), which are relatively easily weathered as they loosened, form soil and sand. Therefore these areas of undifferentiated meta-sediments form large expanse of land with agricultural cultivation potentials. In general, the topography of the area varies from high grounds of the older granites and undifferentiated basement complex into gentle slopes of the undifferentiated meta-sediments. Figure 1.2 shows the Geology of the study area.

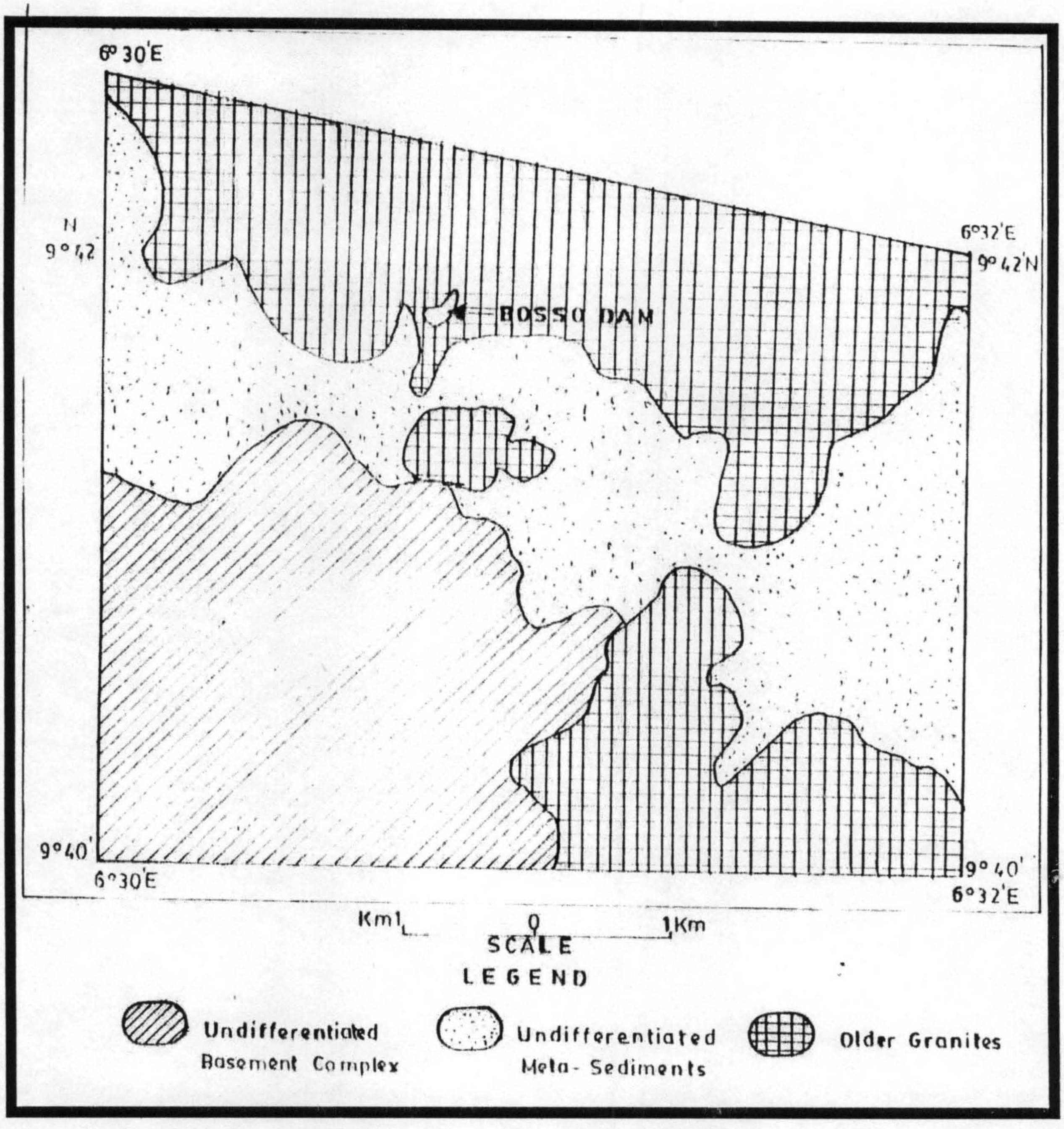

FIG. 1.2 GEOLOGY OF THE STUDY AREA
Source: ABUBAKAR (Geography Department F.U.T. Minna)

1.6.2 HYDROLOGY

The topography of the area is down slopping with the highest altitude of about 1200m above sea level and the lowest 950m above sea level. Bosso dam is located within a valley of hills with outcrops on each side serving as boundary. Bosso dam lies in an area of depression, where water collects and sediments are generated from the slopes of the hills around the dam. These sediments may be carried in transit by water and deposited at the bottom of the dam.

However, the dam is not located along any major river valley rather it depends on surface runoff from rainfall through the collection drainage channels that feed the reservoir, which are about 4 in number. Only Kolako, (a minor seasonal river with its tributaries) drain into the Bosso dam. Chapter 4.5, plate 15 shows the valley of river koloko exposing silt deposits transported from upstream. The plate is obtained at the onset of rainny season (April, 2004). River Kolako flows down towards Federal University of Technology, Minna, and Bosso Campus and represents the major river valley in the area. The water collects and is seen running via the campus to Suleja. It runs from north to south. The channels that mostly drain into the river define a dendrite pattern of drainage. River Kolako and its tributaries are especially seasonal, thus, dry out during the dry season and it is dammed where lower contours near the hill indicate water flow direction. Figure 1.3 shows the drainage pattern of the study area.

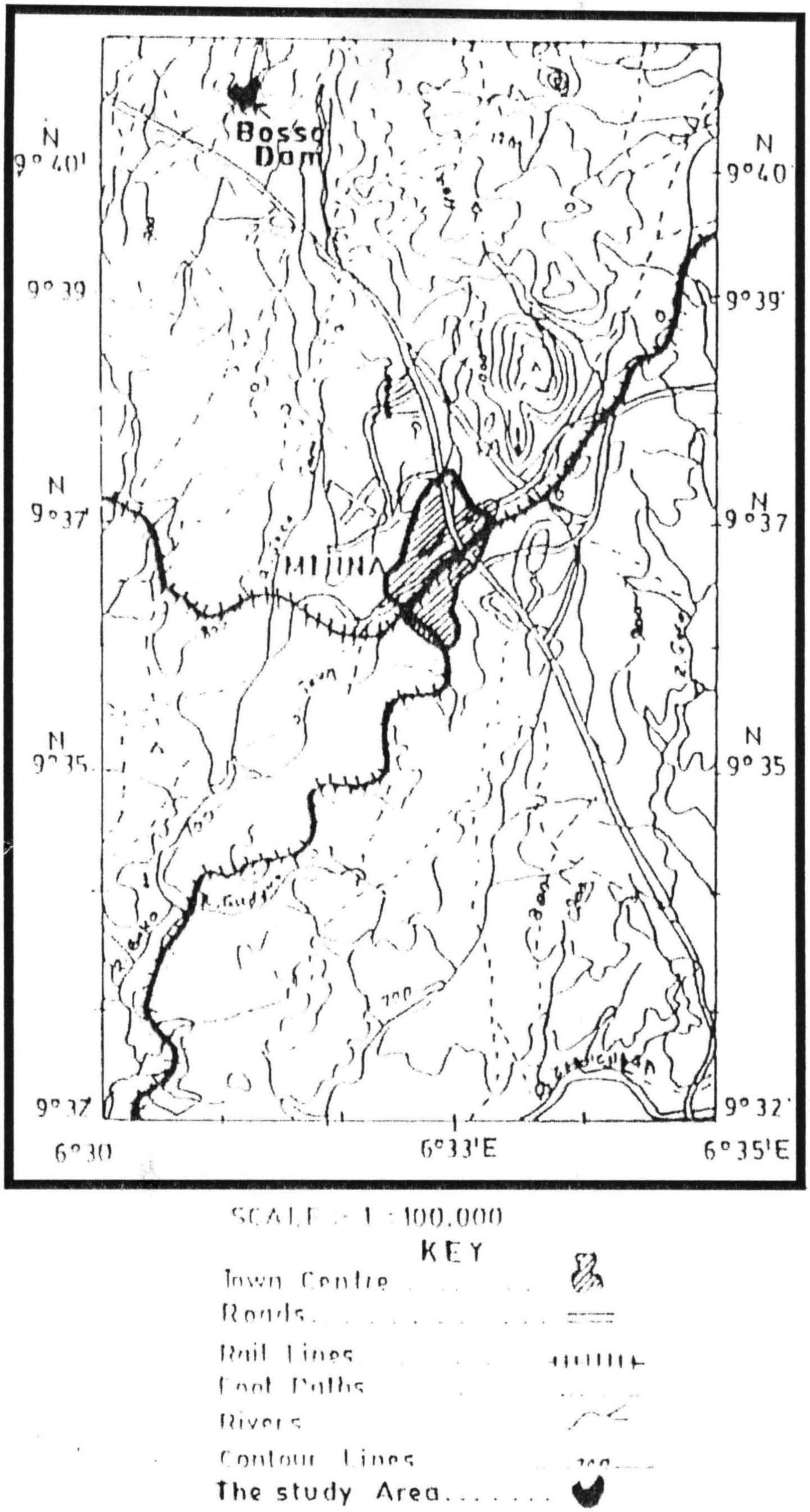

Fig. 1.3 THE STUDY AREA SHOWING DRAINAGE PATTERN

Source: - Minna Topo Sheet 164 (1985)

1.6.3 VEGETAL COVER CLASSIFICATION

The vegetal land cover of the area could be broadly categorized into four classes:

i) Mountainous vegetation

ii) Woodland/forest

iii) Shrub/grasses

iv) Bare ground

The mountainous areas of Minna seen on georenference image on fig 3.2 provide a vast land for the mountainous vegetation type. This class is sometimes seen to be associated with or coexisting with the woodland/forest and are often, riparian vegetation type.

The generally lower areas represent a variety of shrubs/grasses and the bare ground, which are especially associated with farmlands and settlements. Fig. 1.4 shows the Physiographic (vegetation) map of the study area.

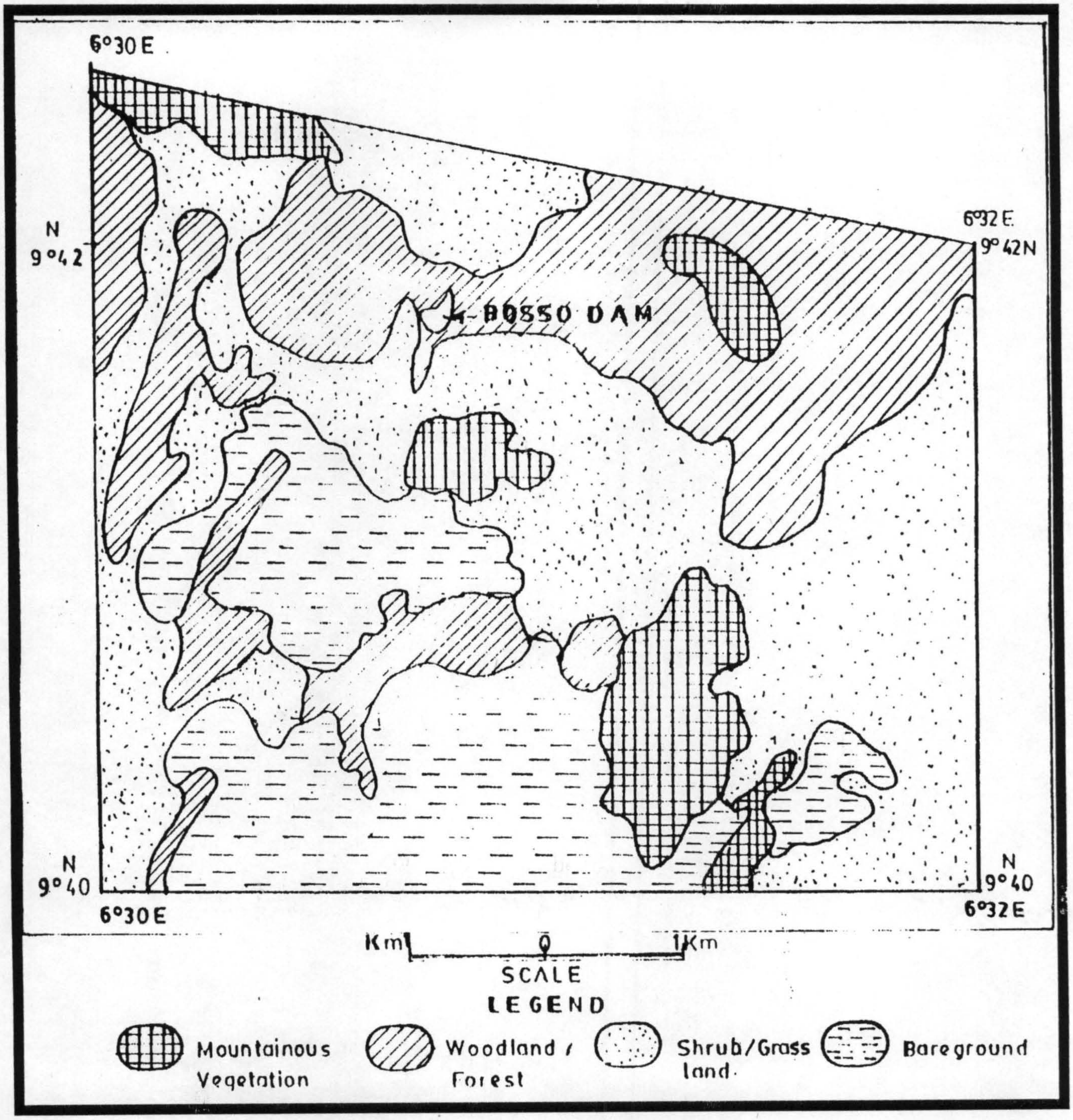

FIG. 1.4 VEGETATION (PHYSIOGRAPHIC) MAP OF THE STUDY AREA
Source: Author's Field Survey, 2003

CHAPTER TWO

2.0 LITERATURE REVIEW

A number of studies have been made using Landsat multi-spectral Scanners (MSS) data to relate suspended sediment concentrations to reflectance measurements (Yarger et al, 1974; Ritchie et al, 1976; Munday and Alfoldi, 1979; Aranuvachapum and Leblond, 1987: Whitlock et al 1981).

A specific remote sensing application of turbidity measurements is in the detection and monitoring of sediment in water bodies. This is made possible because the presence of suspended sediments or organic materials increases the reflectance in the visible regions of the electromagnetic spectrum. However, the reflectance of the sediment and water remains low in the near-infrared portion of the spectrum unless there are significant amounts of algae present. The failure of a sensor to detect turbidity deeper than 1m, at the most, limits this approach to the detection of shallow suspended sediments.

Globally, remote sensing technique has been applied variously in the studies of lakes and reservoirs.

Sediment generation are caused by external agents such as water, wind, gravity, ice and natural processes that have been taking place and will continue to take place even in the absence of man (Vanoni, 1975). Man is only a major factor in triggering and aggravating erosion problems and thus, affecting the natural assembling of processes of denudation. The perception of erosion as both natural and man made processes led to connotations such as geologic erosion and accelerated erosion that implies natural processes and man made processes respectively. Though factors of sedimentation are studied in part, the complexity and insufficient understanding of erosion as an element in sedimentation processes made precise prediction and modeling difficult, aside from vegetation and anthropology of an area.

Erosion has been linked with such factors as human activities, precipitation, run-off, vegetation cover, biological processes on the soil and inherent inability of the soil to resists erosion (Tee, 1988). It has also been linked with factors such as Geologic and geomorphic characteristics of an area (Engman and Gurney, 1991).

There are a number of morphometric parameters that can be derived from remotely sense data to describe lakes and reservoir quantitatively and qualitatively. For extremely accurate work, aerial photography provides best sources of data. Satellite data also provide good source for determining morphometric parameters if the resolution is suitable for specific use. Some of the parameters obtainable from remote sensing products are; maximum length and maximum effective length, maximum width and maximum effective width, direction of major axis, area of water surface for different elevations, and shoreline length and development of shoreline (welch 1948 and Hutchinson 1957).

Remote sensing techniques have been applied to various management issues and soil degradation studies, (Rapp and Helden, 1979, Rodrigues Raja Ram and Okoye, 1978, Hunting Technical Services limited, 1979).

Remote sensing can provide classifications of landscape that identify areas susceptible to erosion.

This chapter reviews literatures of related studies in order of identification of topographical characteristics, soil moisture and geology identification and monitoring of geological features, vegetation degradation monitoring, drainage basin monitoring, monitoring of suspended sediments, and landuse identification.

2.1 IDENTIFICATION OF TOPOGRAPHICAL CHARACTERISTICS

Aerial photographs have been used in the study of the effects of the nature of slopes in relation to runoff to determine erosion in an area in eastern Nigeria (Carter, 1958)

Conventional photos have also been used to interpret relief, landforms and drainage patterns as well as for the mapping of both high level and low level (foot slope) laterites in north eastern Nigeria, Dowling, as expressed in (Lawal, 2001).

Fagbami, (1986) asserts that the slope, vegetation and land use maps of the Benue flood at Makurdi were from the interpretation of aerial photographs by a British firm. Also that a combination of aerial photograph and spot image of Mambila Plateau in north- eastern Nigeria was used to study slope factors and it was discovered that the land is experiencing frightful landslides and erosion along the rivers and back-wearing in headwater region that opens deep gullies.

2.2 SOIL MOISTURE AND IDENTIFICATION AND MONITORING OF GEOLOGICAL FEATURES.

A number of studies have been conducted for soil moisture, erosion and deposition of sediments using various Remote Sensing platforms, from aerial photographs to advance radar using various wavelengths (bands). The use of remote sensing in soil moisture studies relates to precipitation, vegetation runoff and erosion directly (Engman and Gurney, 1991). In another study microwave emission from both active and passive radar has been described as having great potential for the study of soil moisture content and degradation as expressed by Abubakar in (Lawal, 2001).

Jackson et al (1995b) asserts that the ability to monitor soil moisture over extended time periods and areas could provide valuable new information for applications in hydrology and further, stated that depending on the platform and sensor, the scale of application could range from a few meters to the globe. Also that the optimal sensor system would include both an active and passive instrument that would allow range of applications and the synergism of the two types of measurements to provide new information

Radar imagery has its general use in hydrogeology for the interpretation of geological structures Koopmans, 1983; Drury, 1993). In the physical applications of imaging sensors, long wave radar can sometimes detect ground water levels at depths of a few meters and other subsurface features such buried channels (Mc Cauley et al, 1982).

In a study of Bobi, Niger State Halilu, (1993) used spot image to identify fractures and lineaments: A geological database comprising of co-registered landsat TM, regional multi-elements stream sediment geochemistry and regional geophysics.

2.3 VEGETATION DEGRADATION MONITORING

A number of studies have shown the effect of vegetation cover on runoff and sediment (Rapp et al, 1972; Fugel et al, 2004).

Remotely sensed changes in vegetation indices will play an increasing role in water recharge studies considering developments in the research concerning spatial evapotranspiration using weather satellite data (Bastiaanssen,1995; Choudhury,1994 ; Kustas et al,1994).

Bohn et al, 1995 in a bid to determine change detection in vegetation used a change detection map and fire monitoring system from multitemporal landsat-1 image series, which allow to analyse the loss of forest due to shifting cultivation and uncontrolled forest fires and concluded that this knowledge will lead to improved landuse planning measures and fire prevention.

Fugel et al (2004) assert that environmental problems related to floods, non point source pollution and erosion are related to spatially and temporally physiograhic catchment properties characterized by the actual condition of their vegetation – soil – topography, interface (VSTI).

Goetz et al (2000) wrote on improving land cover mapping and ecological modeling capabilities of Chesapeake Bay watershed using satellite remote sensing for studies that included landcover change, landuse planning, carbon exchange modeling and integrated environmental monitoring issues being addressed include nutrient runoff to the Chesapeake Bay, farm and forest productivity, landscape and fragmentation effects on biodiversity. Results of the field activities undertaken during the 1999 growing season are used with a fusion of multiertemporal Landsat -7 enhanced thematic mapper and SPOT panchromatic imagery to classify vegetation types and to characterize development of the severe drought that look place in the region.

2.4 DRAINAGE BASIN MONITORING

Drainage basins are dynamic features. They are also influenced by sedimentation and pollution for obvious reasons like, precipitation, floods and erosion.

Drainage basins are easily discernible on remotely sensed data due to some important characteristics.

Schmugge, (1990) and Hughes, (1982) wrote about the capabilities of aerial photographs and application of remote sensing in mapping drainage basins and also indicated that water bodies are normally evident on imageries as they have close to zero reflectance at 0.7μm wavelength and high reflectance at wavelengths shorter than 0.6μm.

Olofin, (1980) used aerial photographs in his study of down stream morphology of Tiga dam in Kano.

Papadakis et al (1993) carried out a thorough Sensitivity analysis for drainage basins in tropical West Africa in order to obtain information on the resolution required for the modeling effort in time, space and spectral channels. It was discovered that for the 3 available channels of meteosat (Infra-red, visible and Water vapour) only IR information was relevant.

2.5 MONITORING OF SUSPENDED SEDIMENT

Satellite remote sensing provides synoptic view of water bodies while the conventional methods of measuring turbidity optically or grammatically determines the concentration of sediment.

Measurements of reflected lights from satellites such as the landsat provide data on characteristic reflectance of the water bodies (Calson and Mc Callock, 1974) Particularly, band 7 digital multispectral scanners (MSS) data (Hughes, 1982), as the recreational potential of many stream waters well provide the information that erosion is occurring upstream and sediments being transported downstream (Vanoni, 1975).

In studies conducted using landsat MSS and TM (bands 1-4), the data show that suspended sediment samples taken from lake Chicot, Arkansas, all contained information related to near surface sediment with band 3 having the highest linear correlation between reflectance and sediment concentration Ritchie et al, (1984).

In general the reflectance of water increases with increased suspended concentrations (positive correlation) and decreases with increasing salinity (Negative correlation). Mapping suspended sediment concentrations, chlorophyll and salinity using satellite image has been described in previous studies (Gordon et al, Johnson and Harris, Khoran, Smith and Baker, Lathrop and lillesand, Toplis et al, Bhargava and Mariam, Froidefond et al, and Tarsan) in pat et al, (1997). However, much of the previous studies have not attempted to tackle the 'temporal' comparison and change detection of the water parameters, mainly because of the difficulty associated with absolute radiometric calibration of the satellite images. From a monitoring point of view of change detection, therefore, calibration is a critical aspect of ecosystem evaluation and management.

In turbidity measurements for the detection and monitoring of sediment in water bodies using remote sensing approach the presence of organic materials or suspended sediments increases the reflectance in the visible region of the electromagnetic portion of the spectrum, while in the near infrared portion of the spectrum except there are significant amounts of algae present, the reflectance of sediments and water remains low. The failure of sensors to detect turbidity deeper than 1metre at most, limits the approach to the detection of shallow suspended sediment. (Engman and Gurney, 1991).

In Aswan high dam (AHD) reservoir records of each sounding of accumulated depth of sediments deposited during the period of flood highly correlated with measurements of instantaneous surface turbidity of the southern portion of the reservoir from reflectance data in bands 4(0.5 to 0.6) μm and 5(0.6 to 0.7) μm of landsat over pass Scot et al, as expressed by Lawal, O.H. 2001).

2.6 LAND USE IDENTIFICATION

Patrick, (1983) argue in favour of aerial photographs in monitoring landuse changes of Taraba state.

Adeniyi, (1985) asserts that Man's escalation of natural denudation is highly dependent on the use he puts the land. That various land use affects sedimentation differently, depending on the conservation measures taken. He added that one of the most common uses of remote sensing technique is in landuse identification, classification and land use changes.

Adeniyi et al as expressed in Lawal, (2001) used enhance classification approach from landsat MSS data sets (1975 – 1984) in assessing natural and man induced changes in land use in semi arid environment of Northern Nigeria after the construction of Bakalori Dam.

Verstoppen, (1997) asserts that land system mapping from images such as landsat and Spot may prove more useful than contour maps for general planning, particularly in a very large region at a time.

CHAPTER THREE

3.0 DATA AND METHODOLOGY

3.1 METHODOLOGY

The methodology adopted for this research is a remote sensing approach in conjunction with conventional methods; Ground truth and laboratory analysis of water samples results in order to determine sources of sedimentation and the effects of pollution on Bosso dam.

The topographical map of Minna Sheet 164 S.W of scale 1:50,000 was scanned and digitized. The digitizing of the contours was done using Arc View GIS which were then imported into ERDAS imagine 8.6 and used to create DEM with the spot image of the study area.

3.2 DATA COLLECTION

The materials collected for this study are from various sources. These data include materials from libraries such as textbooks and journals, internet facilities, literatures on past work, topographical map of Minna sheet 164 S.W, Land use map of Minna, Soil and Geologic Map of Niger State, Water quality laboratory test (analysis of water samples) and Spot 1994 satellite image.

3.3 SPOT IMAGERY

The SPOT Satellite has an instrument with twin HRV (High Resolution Visible) systems, which can be operated independently or simultaneously, in the panchromatic or multispectral channel(s). The satellite is sun synchronous and near polar orbiting at an altitude around 830km above the earth which results in an orbit repetition every 26 days with an equator crossing time of 10.30am local time (temporal resolution).

The SPOT XS (multispectral) image from its HRV camera covering 60km section at 20m, spatial resolution is used in this study. The SPOT XS (multispectral) has 3 bands in the red, green and near infrared channels of the electromagnetic spectrum described below:

Red	0.50 – 0.59μm
Green	0.61 – 0.68μm
Near infrared	0.79 – 0.89μm

Multispectral sensors record energy over several separate wavelength ranges at various spectral resolutions. The spectral resolution is determine by spectral responses and spectral emessivity curves (for targets). It characterizes the reflectance or emittance of feature or target over the variety of wavelength. Spectral resolution describes the ability of a sensor to define fine wavelength intervals (i.e. the finer the spectral resolution the narrower the wavelength range for a particular channel or band).

SPOT allows application requiring fine detail such as urban mapping to be addressed while retaining cost effectiveness and timeliness advantage of satellite data. It serves well for applications requiring frequent monitoring such as those for water bodies, vegetation, agriculture and forestry.

The acquisition of stereoscopic imagery from SPOT has played an important role in mapping and in the derivation of (DEM) topographic information from satellite data. Thus, this explains the choice of SPOT multispectral image for this research. Figure 3.1 shows the raw spot image of Minna and environs.

SPOT IMAGE

FIGURE: 3.1 RAW SPOT IMAGE OF MINNA, 1994

3.4 IMAGE PROCESSING

The image underwent some preprocessing in preparedness for image processing, interpretation and the creation of 3-dimensional perspective of the study area. The image processing interpretation operations applied are Georeferencing, Spectral enhancement and Image Sub-setting.

The Procedure for Georefrencing is presented immediately below while Spectral enhancement and Image Subsetting are addressed later in this chapter.

3.4.1 IMAGE GEOREFERENCING

The image, SPOT image was acquired with raw pixel coordinates and had to be Georeferenced. The image was imported into Erdas Imagine 8.6 using the Import option. Image Georeferencing was performed using Erdas Imagine Geocorrection tool. The ground control points (GCP's) were obtained from a digitized Federal Surveys Topographic map of Minna, Sheet 164 S.W. The map was digitized using ArcView GIS 3.2 and using plain table coordinates.

The digitized mapsheet was edited and imported into Erdas and the file coordinates transformed using Lat/Long real world coordinates. The coverage was then projected into the Universal Transverse Mercator (UTM) coordinate system with the following parameters:

Projection:	UTM
Units:	Meters
Spheroid Clarke:	1880
Zone:	32

This coverage provided the GCP's used in the image Georeferencing process.

A total of five (5) GCP's were collected from road and rail intersections, stream/river intersections. Using Erdas Imagine geometric tools and the chipset window, the corresponding points were identified on the image and as precise as possible marked with the GCP Tool.

On completion of the GCP collection from the referenced digitized vector sheet, the image was then transformed to the new coordinate space using the specified parameters and with the bilinear interpolation method with a pixel size of 20 meters. The resulting image had this extent:

ULX: 225721.7031250	ULY: 1076108.50
LRX: 235921.7031250	LRY: 1066008.50

The Georefenced image is seen as fig. 3.2

GEOREFERENCED IMAGE

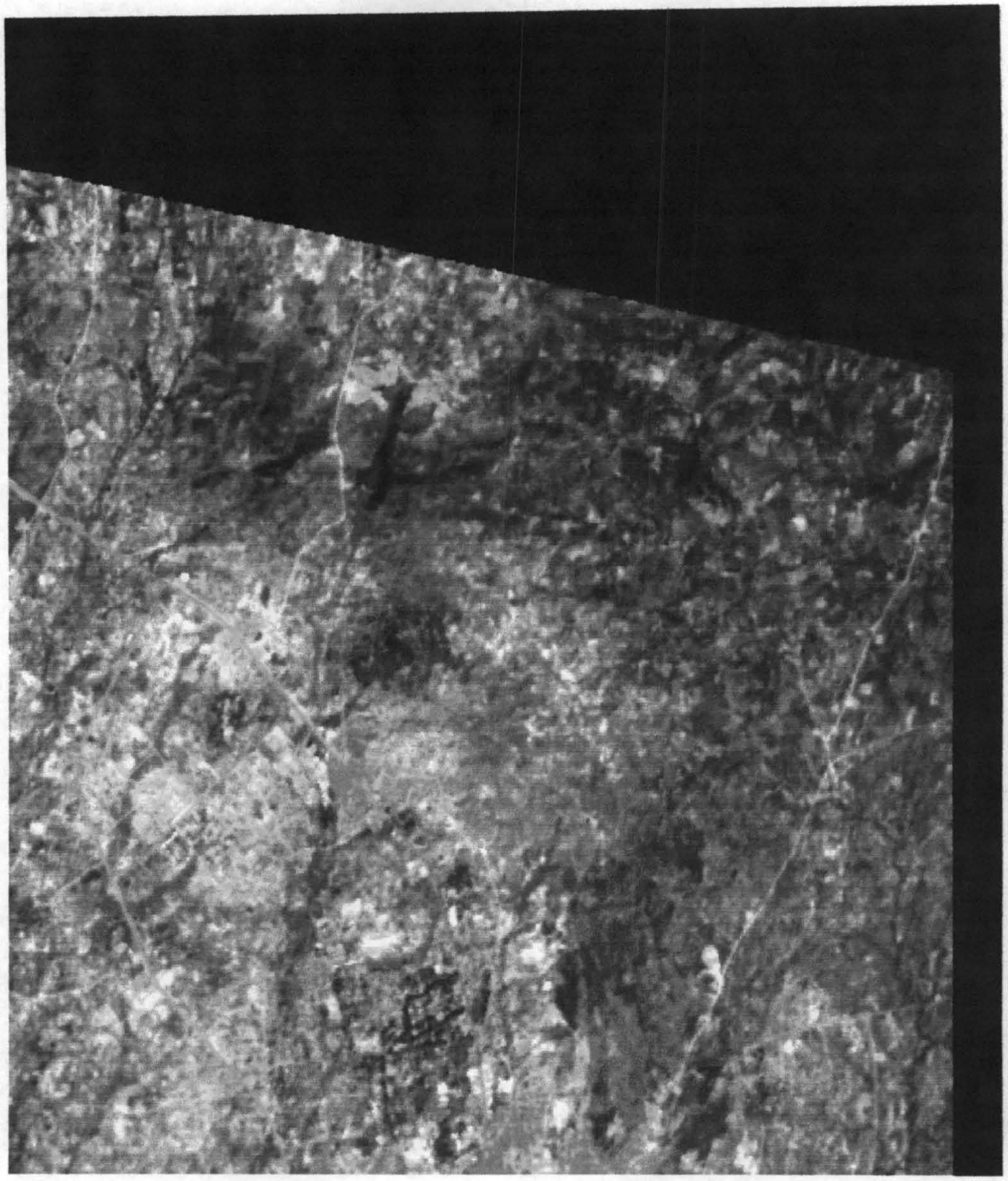

FIGURE: 3.2 GEO-REFERENCE IMAGE OF MINNA, 1994

3.4.2 PRODUCTION OF DIGITAL ELEVATION MODEL (DEM)

The Production of a DEM for the Orthographic 3D view in Idrisi was accomplished through the following process.

Elevation information required for the production of the DEM was extracted from digitized contours of the Topographic Map of Minna Sheet 164 S.W., the contours were digitized and coded using ArcView GIS. The contours were then imported into Erdas Imagine. Using Erdas Imagine Data Preparation/Create Surface menu, the elevation information, were read in as line contours for the Z value and the contour values were used. The surface was created using the bilinear method with a pixel size of x-20, y-20. The resulting DEM was then subset to produce an image of Rows-506 and Columns-511.Figure 3.3 shows the digital elevation model (DEM) of the study area.

DEM

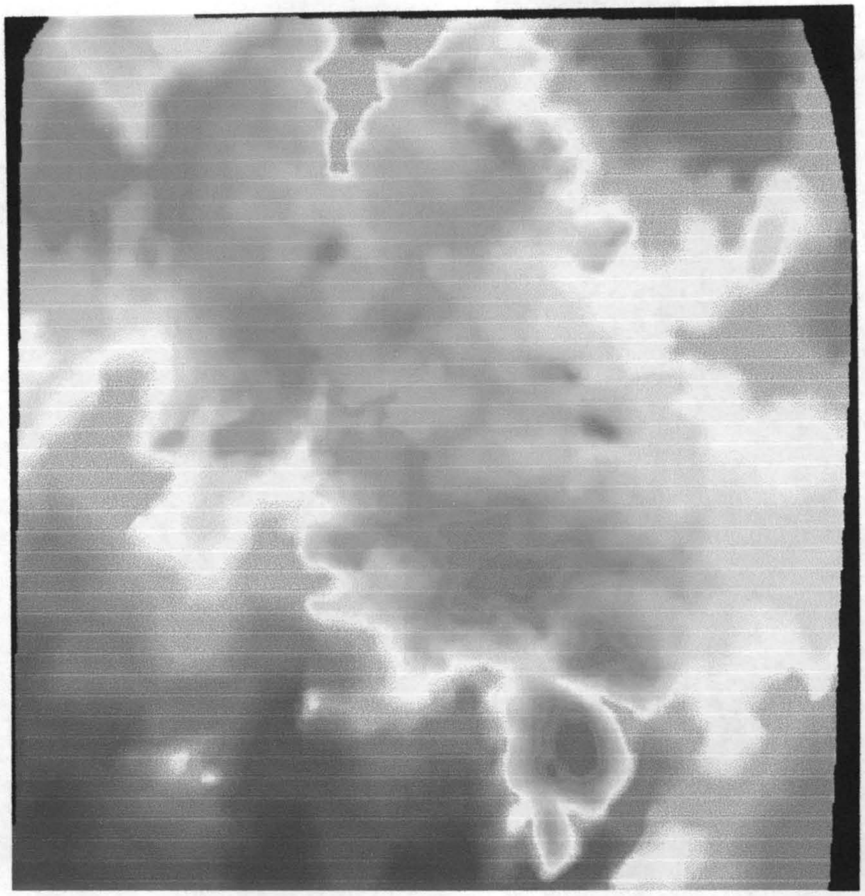

FIGURE: 3.3 DIGITAL ELEVATION MODEL (DEM)

OF MINNA, 1994

3.4.3 DELINEATION OF THE STUDY AREA

The study area was delineated using Erdas imagine 8.6 through (i) image subsetting using the utility menu and enquiry box, and (ii) creation of DEM by interpolation of contour lines.

The carved area shows Bosso dam to the north of the SPOT Georeferenced image on Fig. 3.2 The mountain ranges to the east, center and at the fringes of Minna township. Other features will be classified for the purpose of this research later. The orthographic view of the image is shown on figure 3.4

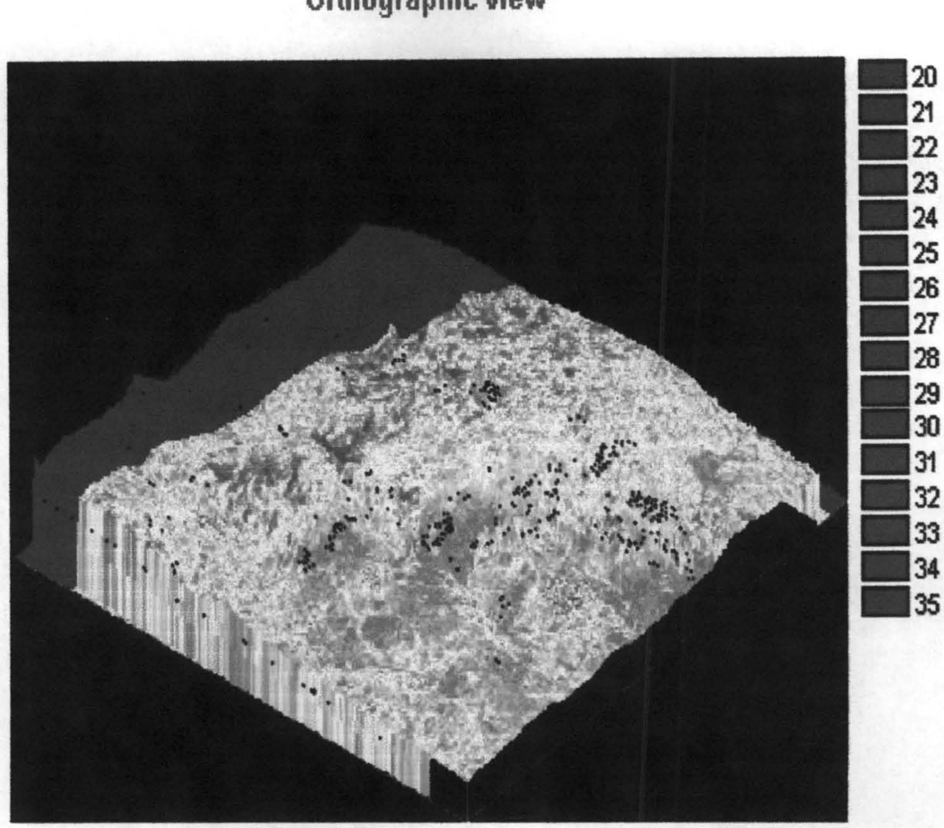

FIGURE: 3.4 SHOWING THE ORTHOGRAPHIC VIEW

OF THE IMAGE OF MINNA, 1994

3.5 IMAGE INTERPRETATION TECHNIQUE

Using ArcView GIS the image interpretation technique carried-out is largely the visual method of image interpretation.

The SPOT multispectral having 3 bands (channels) allows the performance of visual interpretation of image (Digital data), unlike manual interpretation method (where imagery is displayed in a pictorial or photographic format independent of the data source) limited to analyzing a single channel of data or a single image at a time.

The visual interpretation technique,was performed by examining digital imagery, displayed on the computer and processing on screen.

However, with the local knowledge of the area the manual technique has also guaranteed the accuracy of result in performing classification of the image, seen in figure 4.1

3.5.1 SPECTRAL ENHANCEMENT

Prior to image interpretation/classification for the landuse classes, the georefereced image had to be spectrally enhanced to facilitate the identification and separation of the various colours in the multispectral image. Image enhancement/processing applied included contrast stretching and band rearrangement of 2:1:3 (GRB) to natural colours.

3.5.2 DELINEATING LANDUSE BOUNDARIES

Using the spectral signatures of the features, boundaries were carefully delineated by digitizing on-screen using Erdas imagine 8.6. Vector module. Using the Vector module Polygon Tool, the various landuse features were digitized as vector polygons and used to create a thematic land use map of the area. This was used for the analysis of Bosso Dam landuse in Chapter 4 shown as figure 4.1

3.5.3 CLASSIFICATION OF FEATURES

Six classes were identified from the image namely

1. Cultivation on steep slope
2. Scattered cultivation
3. Reservoir
4. Densely vegetated areas
5. Settlements and built-up areas
6. Rock outcrops

An interpretation key was drawn alongside the 3D view of the image to guide the interpretation process in feature recognition. Features were assigned to the classes above using these decision rules.

Cultivation on steep slope: A cleared portion of the image with pink to bright tones depicting agricultural activities located on high slopes.

Scattered Cultivation: Scattered bright to pink tones, interspersed with settlements.

Reservoir: Water body recognized by local dark tone.

Densely Vegetated areas: Bright to dark red tone signifying dense vegetation in the red band and located on high slopes or along water courses.

Settlement and Built-up areas: Bluish mixed with bright tones clustered with road networks characteristic of urban areas in an RGB band arrangement.

Rock Outcrops: Dark, black and shinny bluish tone corresponding to areas devoid of vegetation in 3D view.

3.6 CREATION OF DATABASE

Based on the classes above and considering the decision rules for their identification a database is developed to provide the following information on the land use classes; for each of the features, the area assigned to a landuse, perimeter, class, acres and hectares of land have been provided alongside their corresponding land use identification numbers (ID's) respectively. Table 3.1 provides the land use database.

AREA	PERIMETER	LNDUSE_	LNDUSE_ID	CLASS	ACRES	HECTARES
1544064.574	6906.727	1	6	Rock Outcrop	381.545	154.406
1599646.259	7007.263	2	4	Densely Vegetatn	395.280	159.965
3274589.100	8668.720	3	1	Cultivated Slope	809.165	327.459
29264506.739	87186.599	4	2	Scattered Cultiv	7231.388	2926.451
14772832.087	29739.959	5	4	Densely Vegetatn	3650.432	1477.283
901819.610	10565.358	6	4	Densely Vegetatn	222.844	90.182
695704.747	3986.941	7	6	Rock Outcrop	171.912	69.570
57735.613	1242.888	8	3	Reservoir	14.267	5.774
78739.264	1622.228	9	4	Densely Vegetatn	19.457	7.874
118609.445	2745.457	10	4	Densely Vegetatn	29.309	11.861
6153567.402	18078.771	11	5	Builtup/Settlmnt	1520.574	615.357
993144.979	4473.052	12	6	Rock Outcrop	245.410	99.314
1053918.075	7812.573	13	4	Densely Vegetatn	260.428	105.392
3402020.780	8659.141	14	6	Rock Outcrop	840.654	340.202
800011.798	7568.225	15	4	Densely Vegetatn	197.686	80.001
269983.494	2643.011	16	4	Densely Vegetatn	66.714	26.998
10346165.032	22112.752	17	5	Builtup/Settlmnt	2556.583	1034.617
126440.316	1694.983	18	2	Scattered Cultiv	31.244	12.644
1090421.826	5751.855	19	5	Builtup/Settlmnt	269.448	109.042
438741.397	4664.401	20	6	Rock Outcrop	108.415	43.874
153655.212	3087.927	21	4	Densely Vegetatn	37.969	15.366

TABLE 3.1 SHOWING THE LAND USE DATABASE

3.7 WATER QUALITY SAMPLES

Water samples were taken from two points (A and B) at the dam. Point A is outside the dam, right at the point of exit below the spillway of the reservoir. Point B is inside the dam, right inside the reservoir.

Elements to be tested, for in the samples are meant to determine the quality of water for public uses. This is to be achieved by comparison with the World Health Organization (WHO) Standards.

3.7.1 DETAIL PROCEDURE FOR WATER QUALITY ANALYSIS.

The method of analysis used is based on one developed using the Unicam SP500 Spectrometer (Hoather and Rackham, 1965).

3.7.2 DETERMINATION OF METALIC ELEMENTS

Atomic Absorption Spectrometer (AAS) method of Analysis is used for determination of all metallic ions in the sample extracts and for all the metallic elements Iron (Fe), Lead (Pb), Cupper (Cu), Manganese (mn), Calcium (Ca) and Magnesium (Mg), the procedure is as follows:

Hollow cathode lamps of metallic ions to be investigated must be inserted or fixed into the instrument at their standard wavelength and current at which the lamp glows.

Oxyacetylene gas must be provided for ignition of flame at the burner while air pumps must also be supplied to provide complete combustion.

Before each element or metallic ion is analysed, standard solutions or working standard of each element is prepared to calibrate or standardize the instrument.

Distilled ionized water is used to set the machine to zero and flush ion residue that may be present in the burning flame. This is done each time reading is taken to avoid contamination of ions; resulting to wrong readings.

Adjust the instrument to read absorbance or concentration of the aspirated sample solutions.

Result obtained, from these standards are used to plot a standard graph where the concentrations of samples analysed are traced out by interpolations.

3.7.3 DETERMINATION OF CHLORINE

To 100ml of filtered samples add 2 drops of methyl orange indicator. Titrate with H_2SO_4 0.02N until the indicator just changes to orange. Add 10 drops of potassium chromate indicator and titrate with $AgNo_3$ solution 0.02N, Mixing gently until yellow colour of the indicator changes to redish brown.

Carry out a blank on the regents by repeating the test with 100ml of distilled H_2O in place of the sample.

3.7.4 DETERMINATION OF SULPHATE

Take $50cm^3$ of filtered samples. Add Nacl/Hcl solution and glycerol/Alcohol solution, Make-up to $100cm^3$. Use water as blank. Measure the absorbance at 400nm (turbidly measurement).

Use H_2SO_4 as Standard with 2,4,6,8 and 10mg/l SO_4^2 as working standard.

To the same sample add 0.15gm Bacl and Shake for 5 minutes constantly. Leave for 30 minutes and later measure the absorbance for determination of Sulphate.

3.7.5 DETERMINATION OF NITRATE

Filtered sufficient sample through a suitable membrane. Read the absorbance of standards and samples at 210nm and 275nm using 4 cm cells with twice distilled water in the reference cell. Drew a calibration graph relating absorbance at 210nm with concentration of nitrogen in PPM in the standards. Corrected sample readings for organic content by subtracting four times the 275nm value from the 210nm absorbance value.

$$A = A_{210} - 4A_{275}$$

This correction for organic matter is satisfactory if it corresponds to less than 10% of nitrate.

3.7.6 DETERMINATION OF BIOCHEMICAL OXYGEN DEMAND (BOD) /EXAMINATION OF OXYGEN IN BOSSO RESERVOIR WATER SAMPLES

Care is taken in collecting water samples. The sample bottles are filled slowly and by gently immersing under the surface of the water until completely full and over flowing. The stoppers then inserted and pushed in tightly so that there are no air bubbles inside the bottles. The samples are stored in the dark to prevent the generation of oxygen in the presence of sunlight by any algae present.

3.7.7 PROCEDURE FOR BIOCHEMICAL OXYGEN DEMAND (BOD)

Water sample is provided in sample bottles of 300ml capacity. Added 2ml manganous chloride solution to the sample, followed by 4ml of alkaline iodide solution. Stopper immediately, mixed and allowed the precipitate does resettle, taking care not to remove any of the precipitate at this point. The $Mn0_2$ has quantitatively bound the oxygen in the water.

3.7.8 DETERMINATION OF CHEMICAL OXYGEN DEMAND (COD)

Take 50mls of the sample in to conical flask and heat on a water bath for 1 hour after addition of 5ml $KMn\,0_4$ to the samples. Cool for 10 minutes and add 5ml KI and 10ml of 2M H_2SO_4. Then titrate with thiosulphate until colour turns pale yellow; add 1ml of starch solution. Continue the titration until blue colour disappears.

$$\text{COD} = \frac{8C_t(v_b - v_{as})}{V_s}$$

3.8 GROUND TRUTHING.

This constitutes reference or ancillary data that is fundamental to effective interpretation and classification of the satellite imagery used. The various categories involved in this research include maps and database. Test sites and laboratory measurements for water quality samples and most importantly the actual onsite visit of the area of study.

As fieldwork of about ten days in two months helped to identify features in terms of classes or materials that facilitated classification into map themes. Revisiting parts of the classified image area and other places not visited earlier as well as taking photographs of features, shown at the end of chapter four helped to verify the accuracy of identification.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents the analysis of the images and the detail analysis of water samples results. The landuse classes of the thematic map serves as a primary source of surface information used to explain the source sedimentation and effects of pollution resulting from runoff and erosion into Bosso dam.

The thematic map (fig. 4.1 provided is the end result of image processing exercise and facilitated the interpretation of the processes involved in the area.

The landuse classification (Table 4.1) is a summary of the landuse database acquired from the thematic landuse map of Minna.

The analysis of water samples results (Table 4.2) represent the value of chemical contents and other properties of the water samples from Bosso reservoir.

4.1 GENERAL CLASSIFICATION

The SPOT image was classified into (six) 6 distinct classes as shown in figure 4.1. These classes are fundamental for the understanding of landuse in the study area as they represent the information contained in the themes presented in the map of area of study. It is also accompanied with a summarized general classification table to explain the landuse of the area.

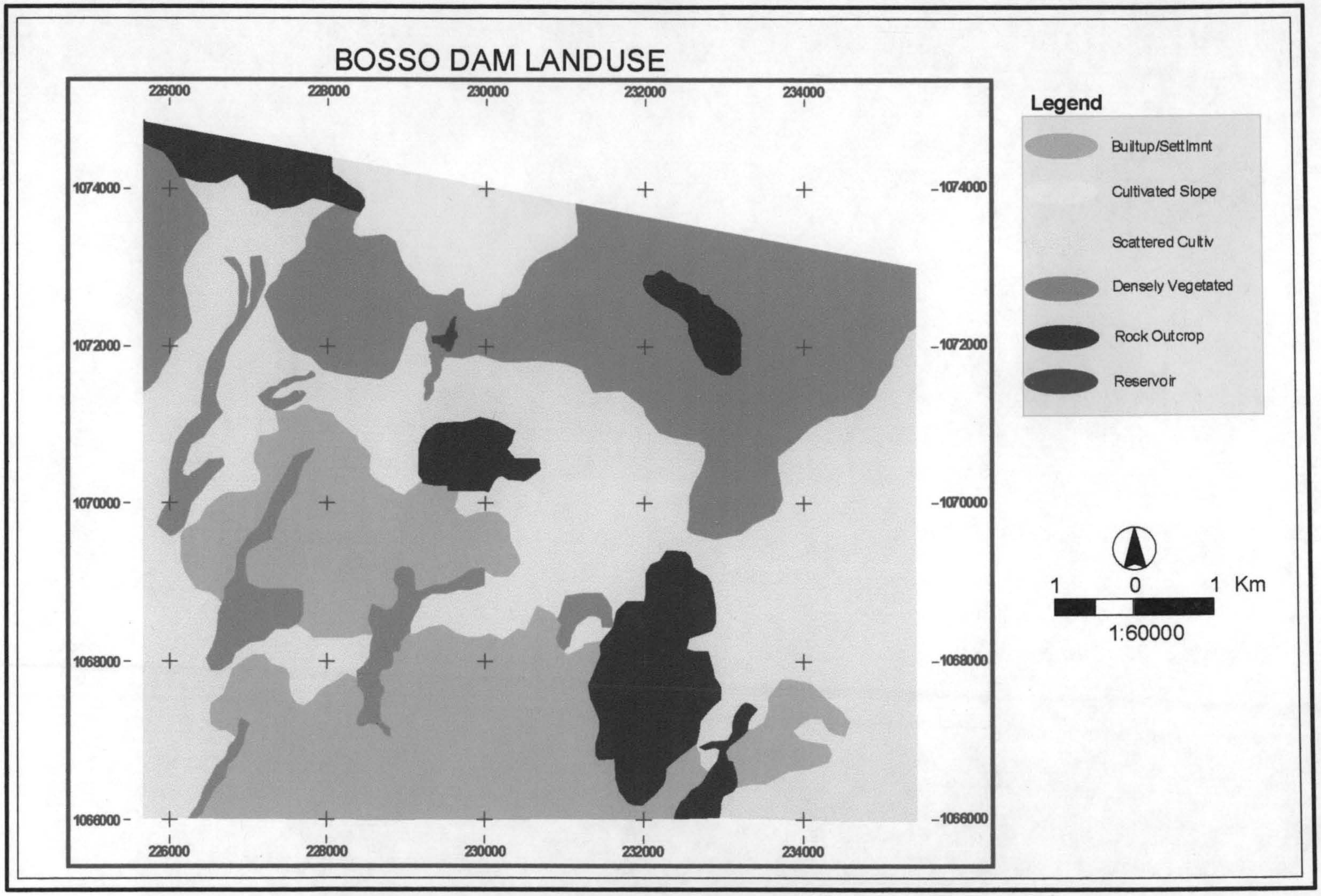

FIG. 4.1 THEMATIC LAND USE MAP OF MINNA, 1994

AREA	PERIMETER	RANKING	LNDUSE_ID	CLASS	ACRES	HECTARES
3274589.100	8668.720	5	1	Cultivated Slope	809.165	327.459
29390947.055	88881.582	1	2	Scattered Cultiv	7262.632	2939.095
57735.613	1242.888	6	3	Reservoir	14.267	5.774
19749215.244	72792.001	2	4	Densely Veget	4880.119	1974.922
17590154.260	45943.378	3	5	Builtup/Settlmnt	4346.605	1759.016
7073676.477	28690.262	4	6	Rock Outcrop	1747.936	707.366

TABLE 4.1: SHOWING LANDUSE CLASSICATION.

Scattered cultivation covering about 2,939.095 hectares of land is the largest class. The area is identified by scattered bright to pink tones interspersed with settlements in the image. This is the largest landuse class, well distributed and is seen depicting a broad coverage in the thematic map. The scattered cultivation class is characterized largely by the subsistence agricultural practice around Minna town. Cultivated areas are found interspersed with settlements where a kind of subsistence neighbour hood farming or tillage of the land and pastoral activities that are characteristic of subsistence agriculture is observed. Human activities like construction works, earth excavation, felling of trees and rearing of animals are increasing the potentials for soil erosion.

The densely vegetated area covers about 1,974.922 hectares of land and is identified by bright to dark red tones signifying dense vegetation in the Red band and located on high slopes or along watercourses. This class is found located largely to the north, northeast, northwest of the images and along the streams and valleys as riparian vegetation. Chapter 4.5, Plates 5,10and15 show some parts of the densely vegetated area. The area represents large virgin forest where natural systems are not much altered by human (influence) activities. The area is also protected from major erosion activities.

Settlement and Built up areas covers about 1,759.016 hectares of land and is identified by a bluish mixed with bright tones clustered with road networks characteristic of urban areas in an R G B land arrangement. The settlements appear clustered and large in terms of the total coverage with two densely populated spots located to the southwestern part of the two major rock outcrops in the image. Erosion activities have been reduced greatly with the construction of large water channels in this area.

The rock outcrops covers about 707. 366 hectares of land and is identified by Dark, black and shiny bluish tone corresponding to high elevation areas devoid of vegetation in 3D view. The rock outcrops appear conspicuous in the center, southern and eastern part of the image and also within the densely vegetated area of the northeast. The two major rock outcrops appear to influence the direction of runoff and drainage reaching the settlements located to their southwest.

Cultivation slopes covers about 327.459 hectares and is depicted as a cleared portion of the image with pink to bright tones depicting agricultural activities located on high slopes. At the tip of the dam is this verse land, which slopes downwards and westwards into the valleys of the dam. The area has few isolated settlements that could be regarded as hamlets. Predominant human activities in this area include Agriculture, the raising of crops such as maize, guinea crone, tubers such as yams and cassava are raised on various scale but largely on subsistence level. Some nomadic activities by the Fulbe are observed in some parts especially in the open areas with gentle slopes. The cultivated slope seems largely responsible for generation of sediments that are being washed upstream and transported southwards through the valleys into dam. The area is largely influenced by erosion due to lack of proper vegetation cover.

The reservoir, a water body is recognised by a local dark tone. The reservoir is small in terms of size covering about 5.774 hectares of land. Although very small it represents the most important feature in this study. The dam is seen located in northern part of the image or the northeastern part of Minna town. The area is generally a high ground with mountains surrounding the dam, which is situated in a relatively lower terrain relief. Increasing human activities around the dam area include indiscriminate farming and rearing of animals, the excavation of laterite at the northwestern bank of dam (chapter 4.5, plate 7 and 8). These activities are becoming a threat by increasing the potentials for soil erosion, transport and deposition of sediments that may have been causing pollution in Bosso dam. Effects of erosion activities upstream and land degradation are well pronounced in the valleys and downstream through sedimentation by clogging of some of the major valleys that feed the dam, especially at the northern tip of the dam. (See Chapter 4.5, plates; 3, 4, 6,7, 8, 9, 10, 11, 14, and 15)

4.3 DETAIL ANALYSIS OF WATER SAMPLES RESULTS

SAMPLES	Fe	Pb	Cu	Mn	Ca	Mg	Cl	So_4	No_3	BOD	COD	PH	Conductivity
A Outside the dam	1.13	6.67	0.99	0.68	36	27	2.76	23	2..14	6	2	8.49	$1x10^2\mu scm$
B Inside the dam	0.88	0.45	0.64	0.36	29	21	1.87	41	1.95	4	3	8.04	$1x10^2\mu scm$
WHO STANDARDS	0.1-1.0	0.1	0.5-1.5	0.5	200	150	200	400	10	6	10	6.5-9.2	$2x10^2$-$2x10^3\mu scm$

TABLE 4:2 SHOWING ANALYSIS OF WATER SAMPLES RESULTS

Iron (Fe) concentration inside and outside the dam is slightly above the standard limit. This implies that the soil washed into the dam through erosion contains some iron. A reason that could be attributed to this is excavations of laterite that is now becoming a threat to the environment. This activity at the northwestern bank of the dam is yet on the increase. Iron (Fe) could also enter water systems by leaching from natural iron deposits or from acidic mine drainage. The high concentration of iron could be one the reasons for treatment by water board. Iron, in groundwater is normally present in the form of ferrous (Fe^{2+}) state, which is easily oxidized to ferric (Fe^{3+}) iron on exposure to air. Thus, precipitated as ferric hydroxides, which is removed by treatment. Iron in domestic water supplies system stains laundry and porcelain causing more nuisance than a potential health hazard. A bitter and stringent flavour of taste is felt when iron levels of drinking water exceeds 1mg/l.

Analysis of lead (Pb) indicates that it is above the minimum limit for consumption, hence the treatment of the water. Natural waters contain very low levels of lead due to its tendency to be precipitated by a large number of substances amongst which are the intrusions of industrial mine or smelter wastes or the decomposition of lead plumbing fixtures and pipes. Lead could have been carried through erosion activities from distant areas or through washing of the surrounding into the dam. It could be possible that the topography of the area consist of lead, which could have dissolved into the moving water but of concentrations not too much for the vegetation to thrive. The exact amount of lead constituting a lethal dosage is not known, but a value greater than 50 μg /l lead in drinking water is considered as good grounds for rejection. Lead is a serious poison, which tends to accumulate in the borne structure when ingested in levels exceeding the natural elimination rate of 300 μg lead/day. Accumulation of significant amounts of lead in the body may result in severe brain damage, convulsion and death.

Analysis of copper (Cu) indicates that both inside and outside the dam is within standard limit. However the values are slightly on the high side. The element exists as copper in natural waters or as industrial soluble. These might have been carried by erosion, transported through the valleys into the dam. Average concentration in portable water is about 0.03mg/l and ranges up till 0.6mg/l in natural water(s) from some areas. Trace elements of copper are necessary requirement for metabolism and absence is known to cause nutritional anemia in children. Large oral doses of copper can cause emesis and may eventually result in liver damage and large amounts in (water bodies) reservoirs would endanger the aquatic habitat. Copper is generally not considered a health hazard but more than 1mg/l copper can impart a bitter taste to the water.

Analysis of manganese (Mn) indicates that it is within World Health Organisation (WHO) standard inside the dam while it is higher outside the dam. This is because unlike its occurrence in ground waters as divalent iron (mn^{2+}) due to lack of oxygen, surface waters may contain combinations of manganese in various oxidation states as soluble complexes or as suspended particles. Therefore, due to continuous exposure manganese is further oxidized to give higher values outside the dam. The occurrence of manganese in this water meant for public supply is more of an economic problem than a health hazard. Manganese causes dark stains in laundry and plumbing fixtures, tends to deposit in water lines and impart an objectionable taste to beverages industrial users.

The analysis of all other elements and anions, which includes calcium (ca), magnesium (mg), chlorine (cl), Sulphate (So_4) and nitrate (No_3) are within the WHO Standards.

Analysis of Biochemical oxygen demand (BOD), for microorganisms in the water is within the WHO standard for both inside and outside the dam.

Analysis of chemical oxygen demand (COD) which is the oxygen required to oxidize the water is within the WHO standards.

Analysis of pH indicates that it is within WHO standards. This implies that the water is neither Acidic nor Basic, but falls in the normal range of the general scale for measurement of pH, (Acidity or Alkalinity). Also, analysis of conductivity also indicates that measurements of electrical properties of the water are within the WHO standards.

4.3 DISCUSSION

From the foregoing analysis of landuse, detailed analysis of water samples and ground truth data, it is clear that remote sensing technique could be applied to water quality studies through processing and analyzing of satellite imagery such as the SPOT XS used in this study in combination with adequate ground truth data that includes plates of photographs, test sites and laboratory measurements of water quality samples.

The method of mapping of surface areas and water body (figure 4.1) can facilitate the understanding of the area and can also be useful in monitoring change detection of landcover due to sedimentation over time especially bearing in mind the small size of the reservoir.

In is study remote sensing application techniques is used to identify landuse classes around Minna in an effort to explain, the geologic and geomorphic processes of erosion as it relates to sediment generation, transport and deposition in the reservoir.

Based on this study, it was discovered that human activities that affect landcover and influence the quality of water in the reservoir includes cultivation on slopes, indiscriminate farming upstream the reservoir, intrusion into the dam area for grazing and water needs, felling of trees and cutting of shrubs, excavation of laterities and making of bricks at the banks of the reservoir. (See Chapter 4.5, Plates 1 – 15). Sediments are generated from the various human activities mentioned. Sediments could also have been generated from settlements and distant areas and all transported through the valleys into the dam during the rainny seasons.

These sediments carried by the streams cause pollution to the reservoir as they mix up in the process of transportation and finally settle in the stream channels and at the bottom of the reservoir. However, no much impact has been observed yet on the quality of vegetation owing to sedimentation and pollution problems in the area.

Consequently, the effects of sedimentation on the quality of water are determined through, detailed analysis of water samples of Chapter 4.3, table 4.2.

The detailed analysis indicates that there is some appreciable level of pollution in Bosso dam due high to quantities of certain chemical elements like Fe, Pb, Cu and Mn while other elements are yet within the acceptable limits of the world Health organization (W.H.O) standards.

4.4 PLATES SHOWING THE STUDY AREA

Plate 1.

Plate 2.

Plate 1 & 2:- Showing the agricultural activities on Cultivated slope.

Plate 3.

Plate 4.

Plate 3 & 4:- Showing indiscriminate agricultural activities just upstream the reservoir.

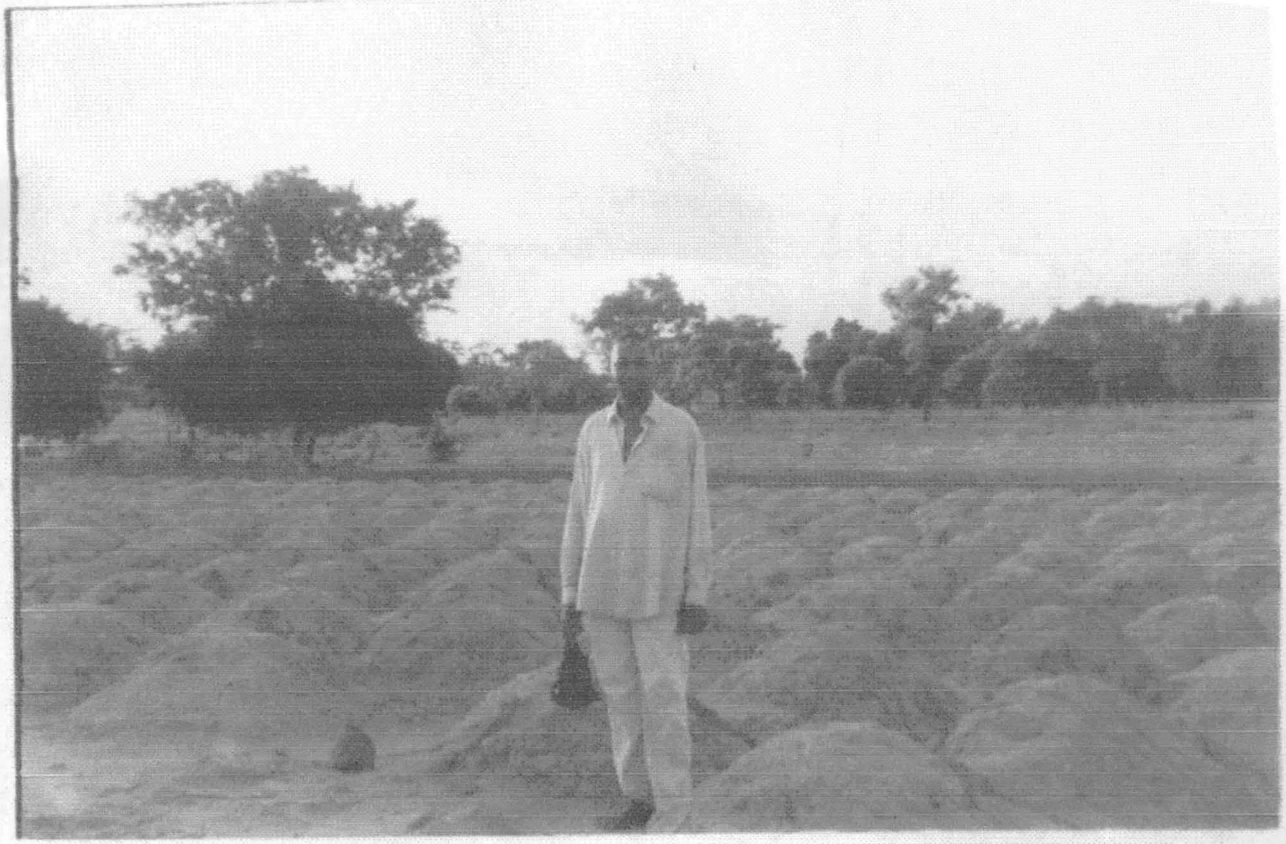

Plate 5:- Showing a boundary between the cultivated area and Densely vegetated area during ground truthing.

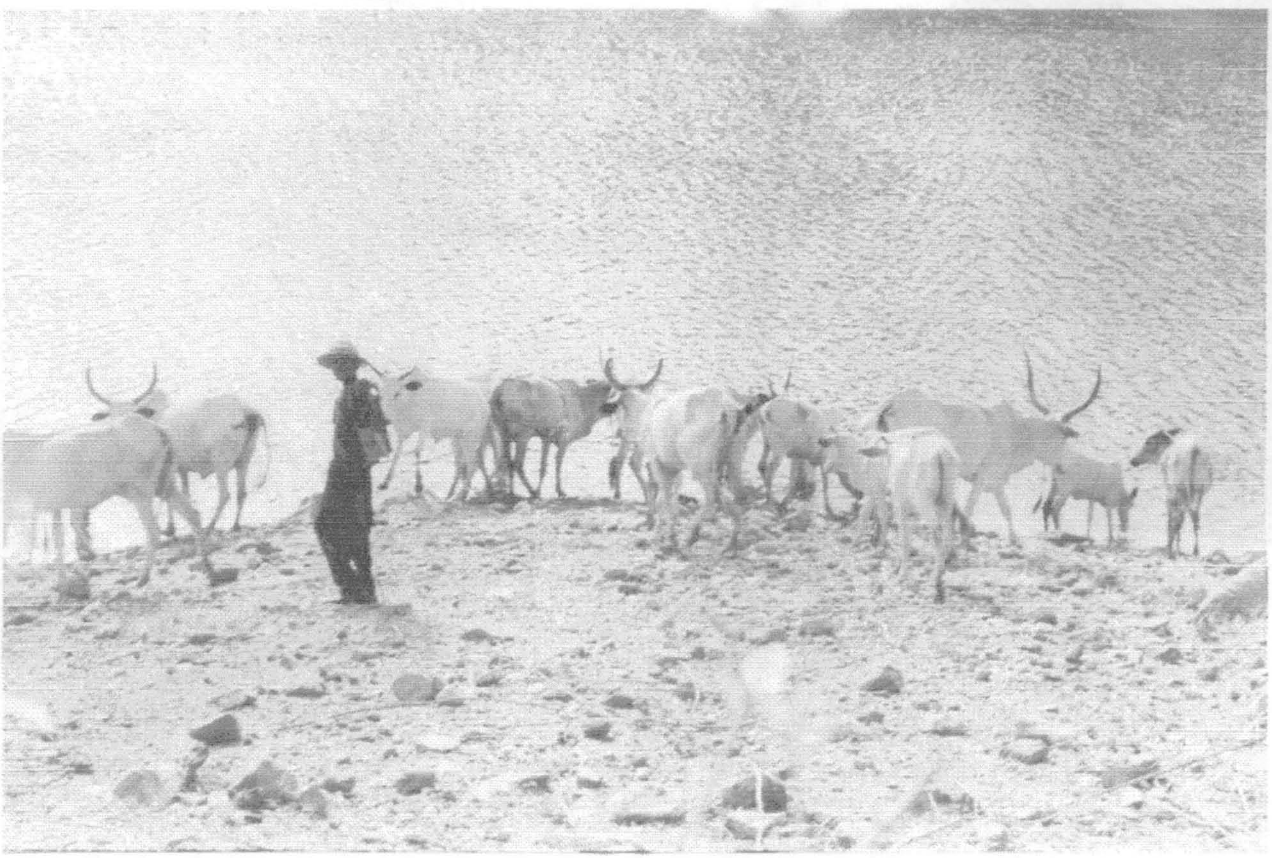

Plate 6:- Showing intrusion into the Dam area by Fulani herdsmen.

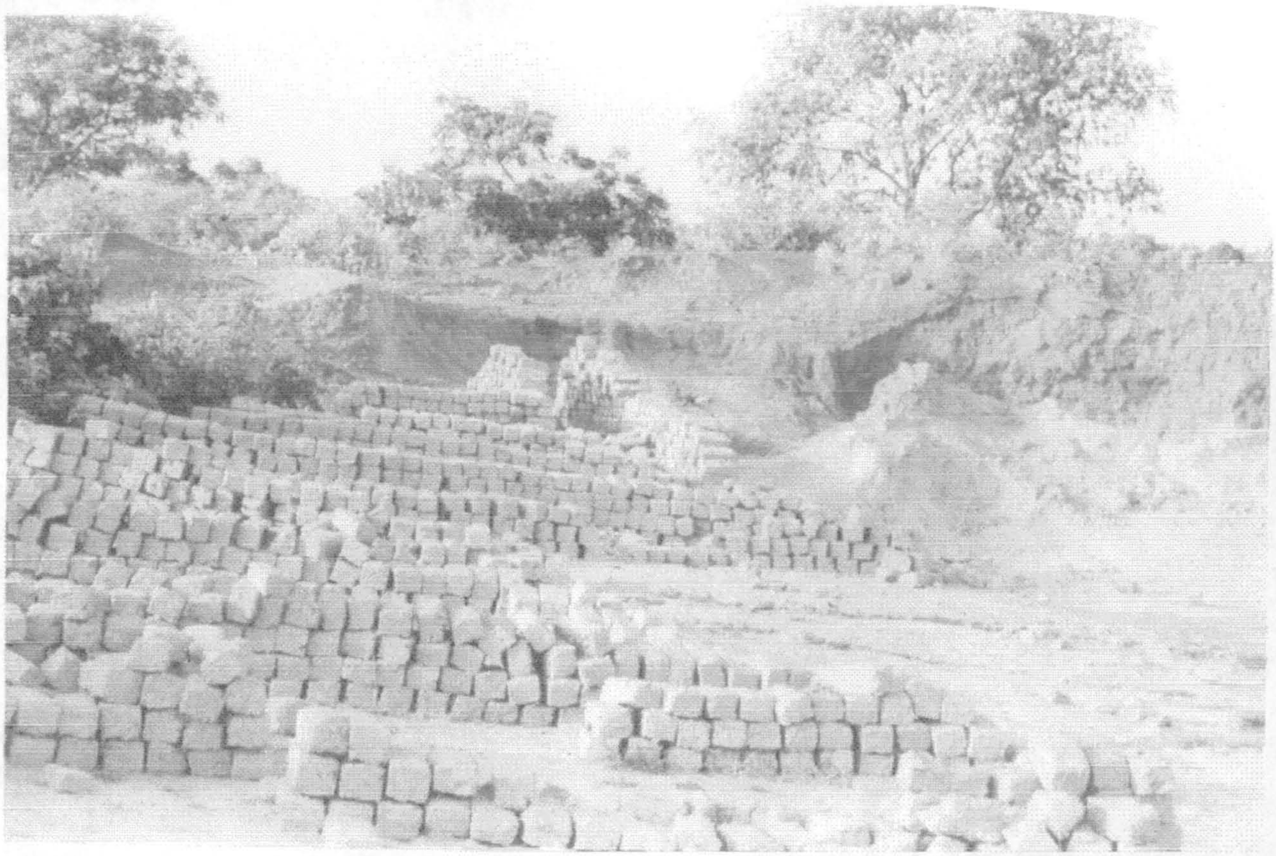

Plate7:- Showing bricks made from laterite at the bank of the reservoir.

Plate 8:- Showing laterite excavation activities around the Dam

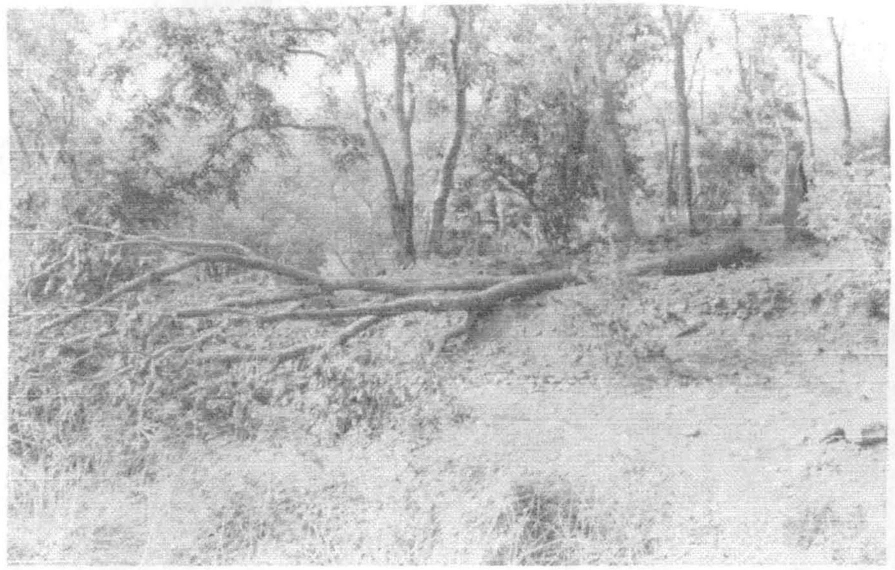

Plate 9.

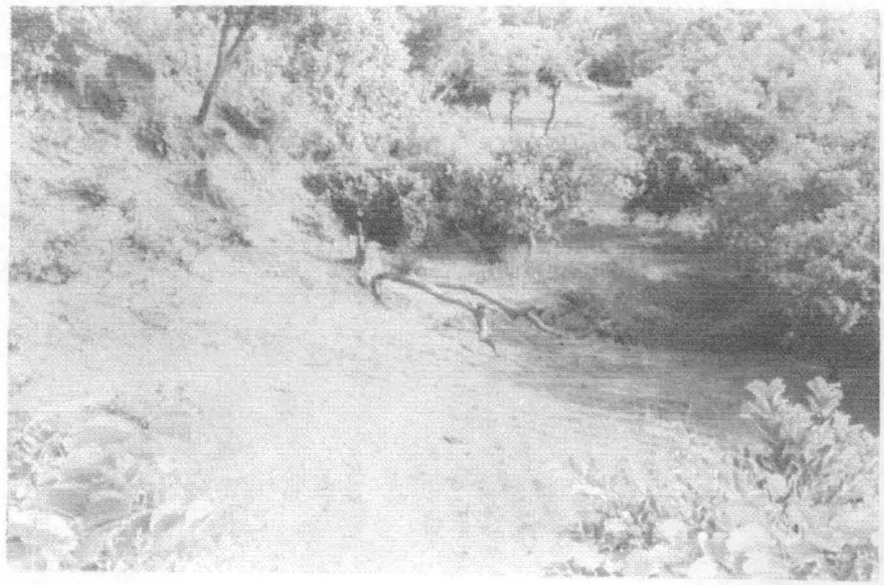

Plate 10.

Plate 11.

Plate 9, 10 & 11:- Showing degradation of the environment by felling of trees and cutting of shrubs at the banks of the reservoir.

Plate 12:- Showing Eroded fringes of the reservoir at the Spillway.

Plate 13:- Showing vandalized equipments (Pipes) at the reservoir.

Plate 14:- Moved rock debris and vegetation growing on sediments.

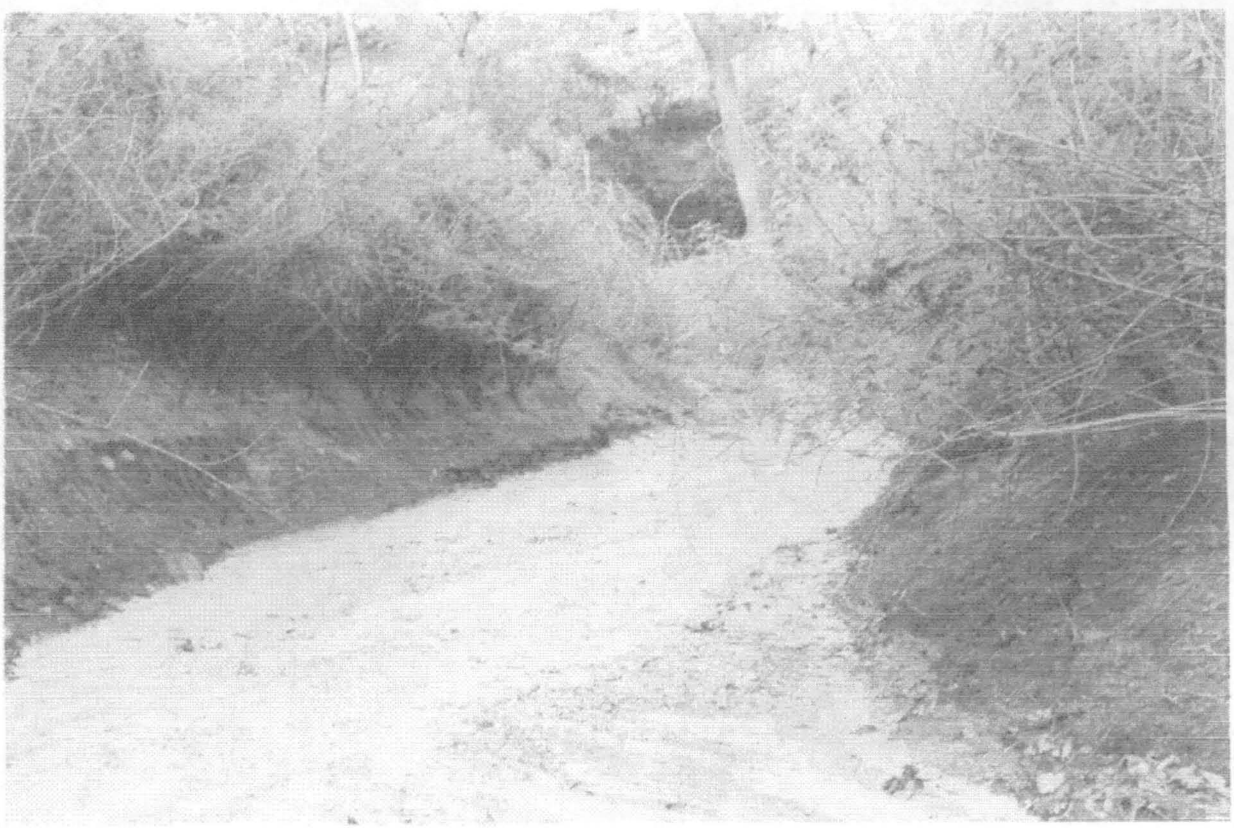

Plate 15:- The main tributory of the seasonal river Koloko exposing silts and sediments transported from upstream.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The results of this study can be summarized as follows:

This study provides useful informational for the conservation and management of Bosso reservoir.

The SPOT XS imagery, ground truth data and water quality samples analysis are used in an integrated study to determine the sedimentation and pollution problems in Bosso reservoir.

In the present study, mapping and estimation of landuse classes were developed and combined with ancillary (ground truth) data that facilitated the understanding of the operating processes over the years 1993-2003.

The division of the area of study into classes definitely helped to define the relationship between the SPOT data and water quality.

The cultivated slope located on higher grounds to the East of the reservoir and the densely vegetated mountains areas and streams banks generally provide the water flow into the reservoir. These two classes located on higher slopes have several valleys running down to the reservoir hence the impact of erosion, transport and deposition of materials is pronounced. Also, the influence of human activities on these lands, which include farming, grazing of animals, laterite excavation and others has much impact on the area. Thus, these activities are largely responsible for the sedimentation and pollution problems in Bosso reservoir.

The water quality analysis of the dam indicates that there are high values of certain chemical elements in the dam, and these includes Fe, Pb, Cu and Mn which could largely be attributed to the laterite excavation activity close to the bank of the reservoir.

However, the analysis did not suggest the occurrence of excessive nutrients or chemicals from agriculture or agricultural fertilizers. This is evident by the low values of Mg, Ca, No_3 and So_4 in the water sample analysis.

It is clear that there is also a very high possibility that some chemical elements could have entered the reservoir through leaching from higher terrain and also through washing of the topography or from distant areas.

5.2 CONCLUSION

Some conclusions were drawn from the results of this study:

The sediments that are generated and transported from the cultivated slope, Densely vegetated areas, settlements and leaching from distant areas into the reservoir constitute pollutants to the water. High values of certain chemical elements constituent (Fe, Pb, Cu and Mn) of the Bosso reservoir indicate that the impact of pollution is pronounced.

The application of remote sensing technique provides a powerful tool for studying landuse and water resources, as it allows the assessment of the inaccessible areas and is cost-effective.

Remotely sensed data allows for the accurate definition and quantification of objects (features) on the ground that led to accurate classification.

The combination of satellite imagery and conventional methods as well as adequate ground truth information/data constitutes one of the best ways to study water resources. This would allow better planning and management of land and water resources in Bosso dam, Minna.

Also, it could be concluded that human activities affect the quality of water in Bosso dam.

Therefore, proper use of water resources and mitigation of the effect of sedimentation and consequent pollution of the water will yield a cost-effective management strategy and will promise a better life for the people

5.3 RECOMMENDATION

Since Bosso dam is the main source of water supply to millions of inhabitants in Bosso, the problems of sedimentation and pollution needs to be monitored. In this regard, the sediment generating areas need to be given prior attention. All human activities in the area that have negative impact on the reservoir should be discouraged.

The state or Bosso Local government council should endeavour to dredge accumulated sediments, as this will prolong the life span of the reservoir.

It is recommended that the result of this study should be used in conservation planning of landuse and water resources around Bosso dam in light of the threat on the environment and water quality.

Proper conservation measures by informing and educating the inhabitants of the area on the dangers of environmental degradation like laterite excavation, indiscriminate farming and grazing of the surrounding area of the dam.

It is recommended that more recent aerial photos be used, as such will provide multiple / multidate information about the landuse and water quality of the reservoir.

It is recommended that other factors such as rainfall patterns (changes) and volume of water be emphasized in further studies.

It is recommended that other remote sensing application techniques for water quality assessments such as for; the determination of the quantity of chlorophyll and suspended sediments, as well as measurement of turbidity and water temperature be adapted in further studies.

It is also recommended that other conventional methods of measurements of effects of sedimentation and pollution be conducted in further studies

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