DELINEATION OF FLOOD PRONE AREAS FOR FLOOD HAZARD MAPPING IN KADUNA METROPOLIS, NORTHERN NIGERIA

BY

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DECLARATION

This is to certify that I ALHAJI SALIU DAUDA (Reg. No M.TECH/SSCE/926/2003/2004) carried out this project titled "Delineation of Flood Prone Areas for Flood Hazard Mapping in Kaduna Metropolis, Northern Nigeria". It is part of the requirement for the award of the degree of Master of Technology (M.Tech) in Remote Sensing Applications Programme of the Department of Geography, School of Science and Science Education, Federal University of Technology, Minna - Nigeria.

ALHAJI SALIU DAUDA	30/3/2006
(STUDENT)	DATE

CERTIFICATION

I certify that this project titled "Delineation of Flood Prone Areas for Flood Hazard Mapping in Kaduna Metropolis, Northern Nigeria" was duly carned out by **ALHAJI SALIU DAUDA** (Reg. No M.TECH/SSCE/926/2003/2004) under my supervision. It satisfies the condition for the award of the degree of Master of Technology (M.Tech) in Remote Sensing Applications Programme of the Department of Geography, School of Science and Science Education, Federal University of Technology, Minna - Nigeria.

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DEDICATION

This project is dedicated to my late Father Alhaji Dauda Madadi, my Mother Hajiya Salamatu Dauda, my late sister Miss Aishatu Dauda, my wives Hajiya Fatima, Habiba and Halima, the children AbdulRasheed, Hauwa, Hausatu, Rakiya, Ibrahim, Medina, Rahila, Dauda (Daddy), AbdulRahaman and to my sisters and brothers.

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By the pen and what it inscribes, success will always come our way through hardwork and the grace of the Almighty Allah, Amen.

ALHAJI SALIU DAUDA

ABSTRACT

Natural Hazards have become an issue of growing concern throughout the world. The frequency of their occurrence as well as the magnitude of the related disasters is threatening the large population of people living in diverse environments. There is evidence of its dramatic rise everywhere in recent years/decades. This work, titled "Delineation of Flood Prone Areas for Flood Hazard Mapping in Kaduna Metropolis, Northern Nigeria" was aimed at determining those areas in the banks of River Kaduna that are susceptible to flood and zone them according to their degree of vulnerability. A SPOT's Multispectral data of the study area was used. This image was enhanced to highlight contrast between vegetated areas adjacent to the bank of River Kaduna and areas away from the banks having seasonal vegetation cover. An NDVI image of the study area was done for the purpose of highlighting areas having thick vegetation being influenced by moisture and so liable to flooding and differentiating them from dry bare soil that are not flood plains. A digital topographical database was created and analysis operations were done to show how remote sensing and GIS can be used to map flood prone areas bordering River Kaduna. Flood risk map was created to indicate the areas likely to be covered by water during floods of given magnitude. The aim was to achieve vulnerability reduction by identifying those communities that are particularly susceptible to damage or destruction by relating risk to human settlement and their structures The results of the study show the great potential of using satellite imagery for acquisition and analysis of data for a large area which can either be hostile or inaccessible terrain.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

It is a well known fact that natural disasters strike Countries, both developed and developing, causing enormous destruction and creating human suffering, and producing negative impact on national economies.

Though it is not possible to completely avoid the natural disasters but the suffering can be minimized. This is achieved by creating proper awareness of the likely disasters and their impacts by developing a suitable warning system, disaster preparedness and management through application of information technology tools.

Geographic Information System (GIS) and remote sensing provide tools for effective and efficient storage and manipulation of remotely sensed data and other spatial and non-spatial data types for scientific management and policy-oriented information. These tools can be used to facilitate measurements, mapping, monitoring and modeling of variety of data types related to natural phenomenon such as flood.

Flood is one of the most serious threats to mankind. Evidence from previous studies shows that unpredictable distribution of rainfall both spatially and temporally makes flooding a continuous threat (Wang and Chengjie, 1999).

In the field of risk assessment, Hazard mapping to show flood prone areas could be created for cities, districts or even entire country. Flood risk mapping for example would indicate the areas likely to be covered by water during floods of given magnitude. To achieve vulnerability reduction is to identify those communities that are particularly susceptible to damage or destruction by relating risk to human settlements and their structures.

People have long been attracted to the floodplains. Here rivers deposit the topsoil picked up elsewhere, so the land is fertile. Floodplains are both flat and usually located adjacent rivers, so irrigation, ploughing and transport (usually aided by rivers) are all made easier. The heavy settlement along the lower reaches of Egypt' Nile, Indian's Ganges, Bangladesh's Brahmaputra- Padman, the Yellow River and Yangtze of China, and the Tigris and Euphrates of Iraq are all examples of floodplain civilizations.

Floodplains are desirable places to live, not only in agricultural societies, but also in industrial countries where the floodplains often host large capitals that use the river water for industry and its mouth as harbour for shipping.

Floodplains can be looked at from several different perspectives. To define a floodplain depends somewhat on the goals in mind. As a topographic category, it is quite flat and lies adjacent to a stream. A floodplain is built up of layers of sediment deposited by the river when it periodically overflows its normal banks. It is the almost flat area that borders the river. Steep narrow valleys in mountain regions have no floodplains at all, but a large complex system of converging rivers in a lowland region may have a floodplain over a hundred kilometers wide. There is a natural tendency for a river to deposit sediment in its channel during times of low flow, so that equilibrium is arrived at where the river comfortably fills its main channel under normal conditions. Therefore the river will spread out automatically into its floodplain during periods of high flow; after all, floodplains are for floods.

Floodplain analysis has been greatly improved with the aid of computers. Computer models play a critical role in floodplain analyses by aiding in the determination of water surface profiles associated with different flow conditions. Computed water surface elevations are often manually plotted on paper maps to delineate floodplains. Automation of this process can result in efficient savings of both time and resources. However, most computer models used for floodplain analysis have a significant deficiency because the locations of structures impacted by floodwaters (bridges, roads and buildings) cannot be accurately compared to the floodplain location.

Natural hazards have become an issue of growing concern throughout the world. The frequency as well as the magnitude of the related disasters, threatening large populations living in diverse environments show dramatic rise everywhere in recent years/decades. Where hazards of exogenous origin are concerned, such as floods, natural factors such as climate change or fluctuation may, at least in part, account for this increase. The consequences of human interactions on the environment also play an important role. Some of these consequences include:-

i. Land degradation resulting from unsustainable landuse practices increase the disaster susceptibility of the land. Deforestation and other landcover changes in the upper catchments of rivers alter the hydrological regime, resulting in flash floods causing inundations in the lowlands downstream.

ii. Population growth has greatly increased the number of people living in disaster prone areas. Not only has population density increased in existing problem areas, but large groups have also settled in formerly unoccupied dangerous zones, such as along rivers in flood plains.

1.2 Types of Flood

There is no universally accepted definition of flood because different people view it differently. It has been described as a situation when a place is filled or covered with water, an overflow, the covering with water of a place that is usually dry. All these positions reveal the inadequacy, in the accommodation of excess water discharge.

A flood is a body of water, which rises to overflow land, which is not normally, submerged (Adeniran, 2001). While many floods may cause little or no damage, some may result in major disasters. These disasters results in structural and erosional damages, disruption of socio-economic activities, loss of life and property, displacement of people, destruction of agricultural land and contamination of food, water and environment in general.

A flood is too much water in the wrong place, whether it is an inundated city or a single street or a field flooded due to a blocked drain. The major areas which suffer from flood hazard in Nigeria according to (Adeniran, 2001) are:-

a. Low-lying coastal areas in southern parts of the country where annual rainfall is very high.

b. The Niger Delta area.

c. The flood plains of larger rivers namely, the Niger, Benue, Gongola, Sokoto, Kaduna, Katsina-Ala, Osun etc.

d. Flat low-lying areas around and to the south of Lake Chad.

e. Flood hazards are also common in flood plain of urban rivers where human activities have great impact on the environment.

The classification of flood by Oriola (2000) further provides a better meaning of the phenomenon. He described six different types of floods which can be identified as follows:-

i. ***Flash floods***:- These are results of high intensity rain associated with convectional rainfall. They are short in duration, lasting for some minutes and covering small areas. Thus, the appearance and disappearance are sudden e.g. most streets in Nigerian cities are flooded after such intensive rain.

ii. ***A single event floods***:- These are floods with a single high flow. Unlike flash floods, the rains have longer duration. The Ibadan flood of 1980 was as a result of more than ten hours down pour. In some cases, the rain may be for days.

iii. ***Multiple Event Floods***:- They are associated with cyclonic rainfall covering a larger geographical area. They produce a large volume of stream flow and extend over a period of several weeks or months.

iv. ***Seasonal floods***:- These are re-occurrence of multiple event flooding with periods of high water often extending over several months. The flooded area always extends more than thousands of kilometres. Seasonal floods are often the combined effects of inflow of water from many tributaries.

v. ***Coastal floods***:- Coastal floods are associated with meteorological conditions which produce abnormal high sea level. They are known as storm surges, which occur at spring tides. When the wind speed is high, the sea pile up against the coastline and large scale turbulence is generated. This results in moving the wave up the shore above the height of the embankment wall. This type of flood has been reported at the Lagos bar beach.

vi. ***Estuarine Floods***:- These type of floods occurs at the mouth of a river. It is a situation when the high spring tides impede the seaward fresh water flows, which consequently exceed the channel storage capacity of the river. In delta areas, where there is conflict between river and seawater, such type of floods occurs.

1.3 Flood Characteristics

The dangers of flood waters are associated with a number of parameters not necessarily independent of each other but creating different types of clearly recognizable hazards. A summary of the parameters and related hazards is given below.

Depth of water- Building stability against flotation and foundation failures, flood proofing, and vegetation survival have different degrees of tolerance to inundation. In each case these can usually be identified and the depth hazard established.

Duration- Time of inundation is of utmost importance since damage or degree of damage is often related to it. This applies to structural safety, the effect of interruption in communications, industrial activity and public services, and the life of plants.

Velocity- High velocities of flow create high erosive forces and hydrodynamic pressures. These features often result in complete or partial failure of structures by creating instability or destroying foundation support. Dangerously high velocities can occur on the floodplains as well as in the main river channel.

Rate of rise- The rate of rise of river level and discharge is important in its relation to the time available for giving flood warning or making arrangements for evacuation and flood fighting arrangements. Rate of rise can therefore influence planning permission for floodplain occupation and its zoning.

Frequency of occurrence- Total potential damage in a floodplain relates to the cumulative effect of depth, duration and velocity hazards measured over a long period of time. This will very often, but not exclusively, influence decisions on planning permission, especially if the hazards can be measured in quantitative terms. Cumulative frequency of occurrence of the various hazards is a consideration that farming communities throughout the world have always taken into account, usually on the basis of experience and intuitive reasoning, as they decide the type and intensity of agricultural or livestock farming to employ in regions susceptible to floods.

Seasonality- Inundation of land during a growing season can have a completely destructive effect on agricultural production, as severe in fact as a prolong drought. If flood waters occur during cold weather and if they derive predominantly from snow-melt with possible ice flows, general discomfort and subsistency levels of affected communities are also considerably influenced. Seasonality in large floods is therefore an important influence on severity of flood hazard.

1.4 Causes of Flood

Flood results from three basic causes. Umoh (2000) refers to them as follows:.

Climatological

Induced floods are the most common types of floods, usually resulting from either short duration intense rainstorms or excessively long periods of rainfall. Floods in this category can also result from seasonal or spisodic melting of ice or snow.

Part - Climatological

Flooding may also result from causes that are not directly related to a particular climatic event (e.g. a severe rainstorm) but are indirectly related to climate. For example, floods caused by tides and storm surges belong to this category.

Structural Disturbances or Failures.

This provides another opportunity for water to inundate adjacent land. Included in this category are floods caused by terrestrial and submarines, earthquakes, landslides, the failure of dams and other structural works designed to confine water.

1.5 Measures for Flood Control

Flood is a weather event, which cuts across the entire globe. Flood control is the regulation of excessive runoff of water in order to prevent inundation of land. It is an attempt to reduce flood damage to lives and properties as much as possible. There are two classes of flood control measures; namely structural and non-structural measures (Nsofor, 2003).

1.5.1 Structural Control Measures.

This is a collective term used for those efforts that reduce flood damage, by restricting movement of water into the flood plain. They include.

i. *Flood confinement*:- It is one of the direct and most effective means of reducing flood damage. It involves the construction of earthen level, emergency walls made of sand bags and dykes to confine river water.

ii. *Flood water storage*:- This is the storage of flood water in reservoirs formed by dams and releasing it at rates within the capacity of the downstream channels. These reservoirs also use this water for municipal water supply, Hydro Electric Power (HEP) generation, recreation etc.

Perhaps the greatest disadvantages of detention facilities, assuming a structurally found facility, is the false sense of security that such structures create among the general public. These facilities are almost never designed to contain the probable maximum flood. Thus they require a spillway to pass discharge in excess of the design flood.

iii. *Channel improvements*:- This involves the enlarging of rivers channels, which can be accomplished by dredging or excavation. It is done by removing snags and obstructions to provide a more uniform cross sections of flow and eliminating meanders.

iv. *Urban storm drainage and highway culverts*:- These involve channel improvement, improved ditches and buried storm drains.

1.5.2 Non-Structural Control Measure.

Non-Structural measures include the following.

i. *Land treatment*:- This includes measures to decrease runoff and increase infiltration. Typical measures include contour plowing, land leveling, bush control, fire control on forest lands etc. This control method in addition to reducing flood peaks also reduces flood damage by reducing the sediment content of the water.

ii. *Land use adjustment*:- Land use adjustment involves the design of zoning laws to regulate flood plain land use. Many conflicting goals may have to be compromised in determining the best land-use plan. There are three major methods of land use regulations.

   a. Public purchase, which involves a large financial obligation.

   b. Purchasing the right to develop the land

   c. To restrict the development of private property by zoning

iii. *Flood proofing*:- This includes all actions within the flood plain to reduce flood damage to their property by individuals or small groups. It includes emergency measures evacuation, sand bagging etc and the use of building materials or methods, which are less susceptible to flood damages.

Retrofit floodproofing of existing building is sometimes a viable solution, depending upon the location of the structure within the flood plain and its structural integrity. There are two basic types of floodproofing: active and passive. Active floodproofing is temporary, requiring some positive action on the part of the building owners and/ or occupants immediately before a flood event. It will not be effective if personnel are not available to perform the necessary functions where the flood occurs. Passive floodproofing is permanent and does not require any action at the time of the flood.

Active floodproofing requires some type of flood detection and warning system to give time for the personnel to install the floodproofing devices. In flash flood situations the personnel may not be available to respond in time. Therefore active floodproofing is most effective in areas with long warning lead times; it should not be relied upon, if possible, in flash flood areas.

1.6 Statement of Research Problem

Flood causes havoc and serious damages to the environment and people. The damages range from destruction of properties, roads and farmlands to displacement of persons and loss of human life.

Irin (2003) reported that at least 80,000 people living in Kaduna have been displaced by flooding, with Barnawa, Kabala, Nassarawa and Trikania districts mostly affected. The flood was the result of torrential rains that forced the Kaduna River to burst its banks.

Gathering hydrologic data directly from rivers and streams is a valuable but time consuming effort. If such dynamic data have been collected for many years through stream gauging, models can be used to determine the statistical frequency of given flood events, thus determining their probability. However, without a record of at least twenty years, such assessments are difficult.

In many countries, stream-gauging records are insufficient or absent. As a result, flood hazard assessments based on direct measurements may not be possible, because there is no basis to determine the specific flood levels and recurrence intervals for given events.

For formulating any flood management strategy, the first step is to identify the area most vulnerable to flooding (Sanyal and Lu, 2003). This step is even more critical for Nigeria as a developing country, as the funding available for developmental activities is very limited. In addition, the density of gauging stations is very low and thus any flood prediction or risk assessment model tested in the developed countries faces acute shortage of ground data when applied.

Another primary issue for flood management is to identify the area having higher hazard potential. Hazard can be defined as some threats, natural, technological or civil to people, property and environment and risk is viewed as the probability that a hazard will occur during a particular time period.

Conventional dynamic flood frequency analysis techniques have been developed to quantitatively assess flood hazards over the past half century. These traditional techniques yield dynamic historical flood data which, when available, is used to accurately map floodplains. In addition to a record of peak flows over a period of years (frequency analysis), a detailed survey (cross sections, slopes and contour maps) along with hydraulic roughness estimates is required before the extent of flooding for an expected recurrence interval can be determined. In traditional floodplain mapping, the requisite data and maps include the following:

1. The selected base (topographic) map with the surface water system
2. Hydrologic data
    (a) Frequency analysis (including river discharge and historical flood data).
    (b) Flood inundation maps
    (c) Flood frequency and damage reports, etc
    (d) Stage-area curves
    (e) Slope map
    (f) Cross sections
    (g) Hydraulic roughness
3. Related maps such as soils, physiography, geology, Hydrology, Landuse, Vegetation, Population density, infrastructure and settlements.

This dynamic approach requires extensive long-term field surveys, with a network of gauging stations that can develop the data needed for precise risk assessments. Such extensive long-term information is seldom available for river system in less developed countries. Remote sensing technology is widely used for global monitoring of the environment. The rapid advance of this technology through earth observation satellites from outer space has enable data acquisition over large areas and short repetitive cycles without actual ground surveys or aerial photography

The issue of preparing a reliable hazard map is one of the latest concerns, within the subject of flood management. The problem to be investigated here is to see whether remote-sensing techniques can be used for delineation of flood zones and preparation of flood hazard maps for the study area.

1.7 Environmental Background of the Study Area

Geographic Location

The project area is Kaduna and its Environs. It is located between latitudes 10^0 25'N and 10^0 39'N; and longitudes 7^0 21'E and 7^0 31'E;. Having an areal extent of about 160,000 ha [$1600KM^2$], the project area covers Kaduna South Local Government Areas as well as parts of Chikun local government area. Figure 1.1 shows the project area and its drainage and settlement pattern.

Kaduna is the capital city of Kaduna State. It is bounded by Kachia, Kajuru, Kaura, Soba, Zaria, Giwa and Birnin Gwari Local Government Areas of the State and at the South Eastern part by Niger State. The 1991 census provisional results put the population of the people within this area at about 396,055.

Climate

Kaduna State experiences a tropical continental climate with distinct seasonal regimes oscillating between cool to hot dry and humid to wet. This seasonality is pronounced with cool to hot dry season being longer than the rainy season. The raining season last for six months from May to October while the dry season has a duration of three months from January to March.

Topography

The general land structure consists of an undulating terrain. Rocks and hills could be seen everywhere especially in places like Kajuru, Kujama, Zaria and Jama'a. Almost all the hills lie between 305m and 1,310m above sea level. Landforms in the state are associated with rocks in which they are derived. And rock types are related to the type of soils found in the State.

Drainage Pattern

River Kaduna is the main river in the State. The State has good drainage systems through which water are channeled to the rivers especially during the rainy season. The rivers serve as sources of domestic and industrial water supply to the state. They also serve as sources of irrigation. During the dry season, farmers draw water from the rivers and stream to water their farm crops. The rivers vary in water level a great deal according to the season.

The Kaduna River runs through the project area. The river takes its source from the Jos Plateau. It rises from the Jos plateau 29 km southeast of Jos town near Vom and flows in a northwesterly direction for 210 km before reaching Kaduna town. It crosses the city, dividing it into North and South areas. Beyond Kaduna, the river flows for about 100 km into the Shiroro dam project areas. After Shiroro, it continues to flow for 200 km and finally discharges into the River Niger on the Northern shores of Pategi. Figure 1.2 shows Kaduna River watercourse from source to sink.

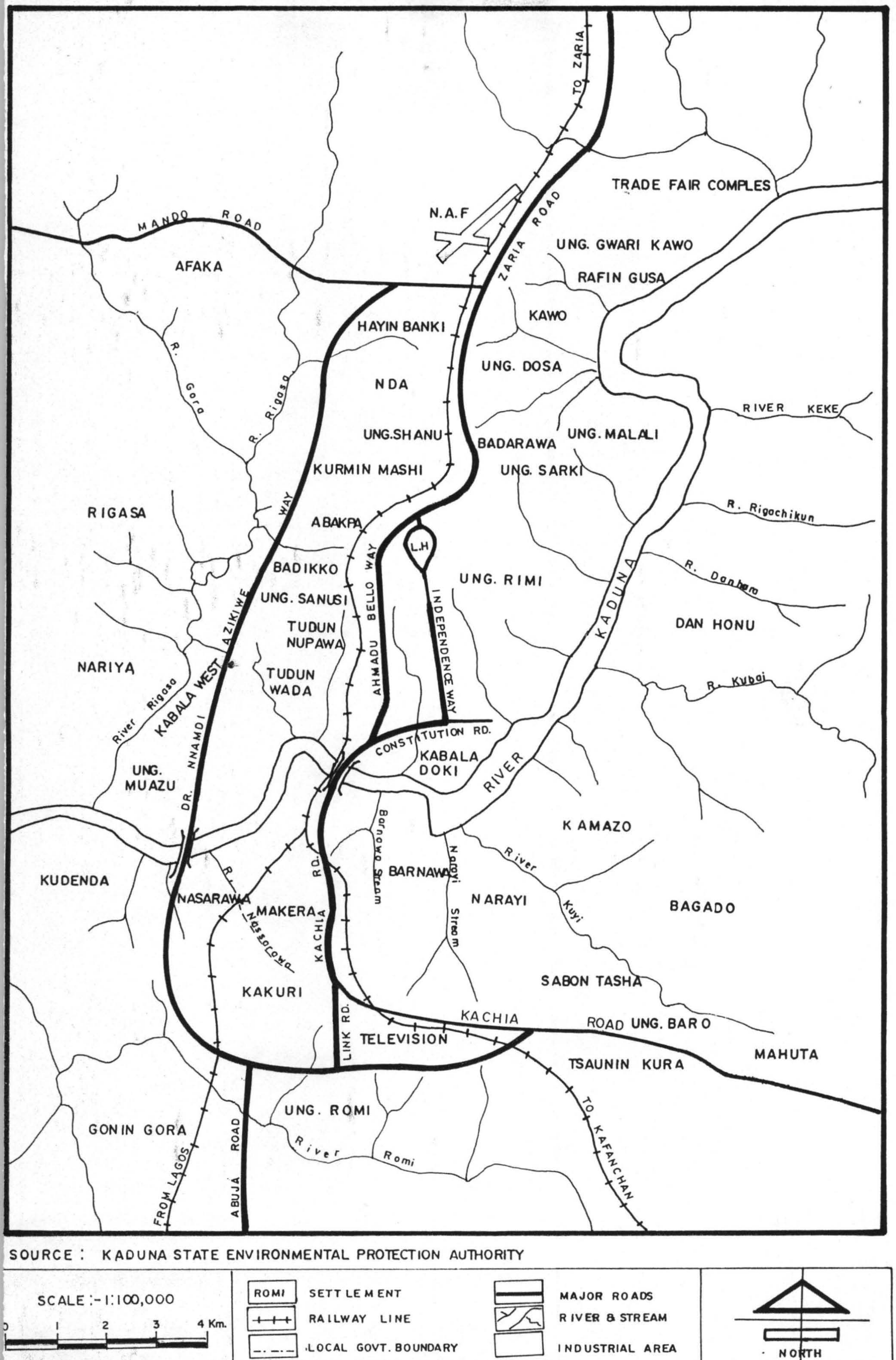
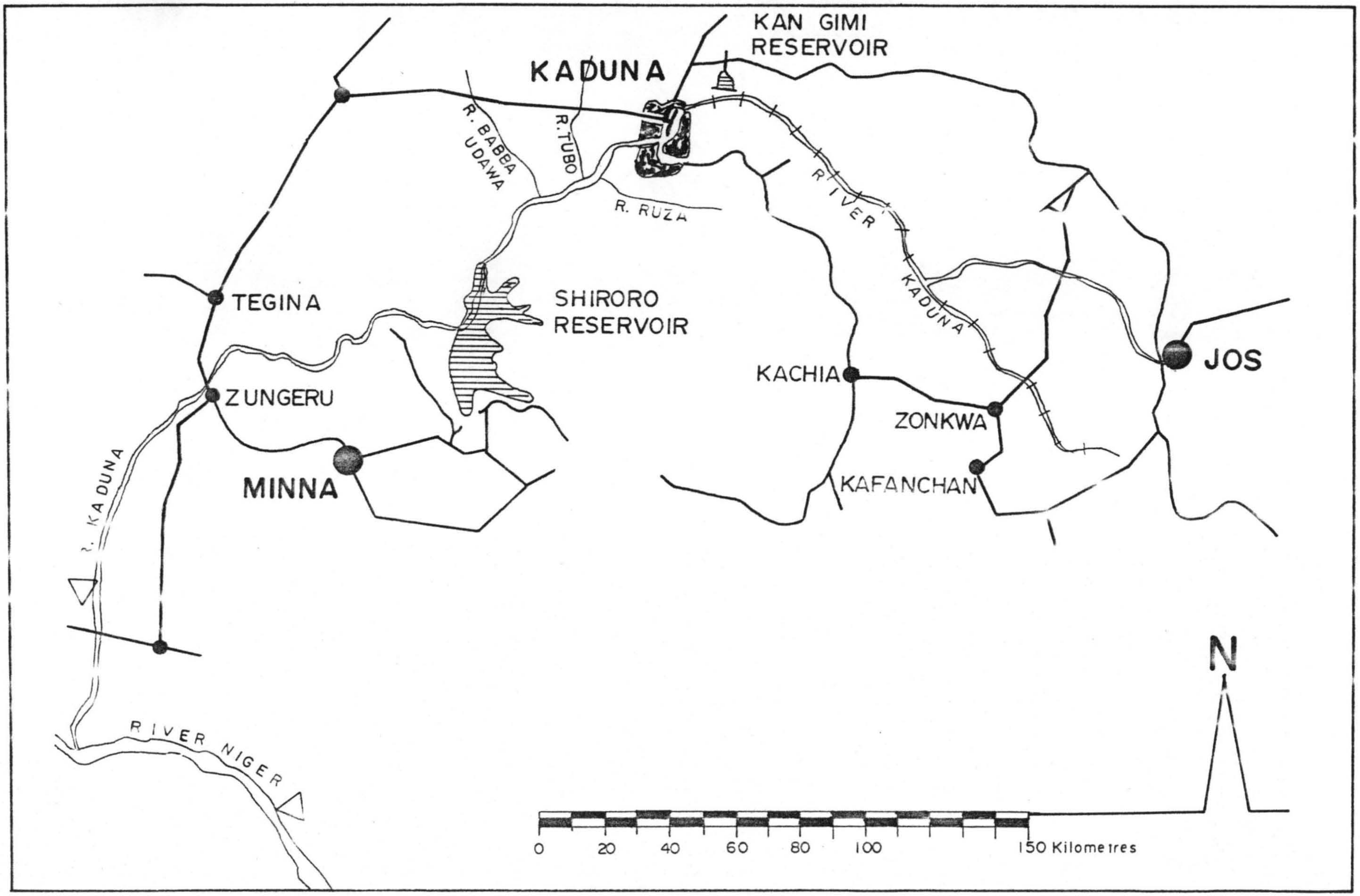


FIG.1·1 DRAINAGE AND SETTLEMENT DISTRIBUTION IN KADUNA TOWN



SOURCE : KADUNA STATE ENVIRONMENTAL PROTECTION AUTHORITY

FIG. 1-2 KADUNA RIVER WATER COURSE FROM SOURCE TO SINK.

Landuse

By landuse, we mean the uses to which a land is put. Kaduna land use can be classified into agricultural, residential, commercial, recreational, institutional, industrial and religious. The commercial and residential areas are inter-woven. It will be difficult to separate these two. The industrial area is restricted to the southern part of the town, while educational institutions as well as other landuses are scattered all over the town.

Soils And Vegetation

Generally, the soils and vegetation are typical red-brown to red-yellow tropical ferruginous soils and Savannah grassland with scattered trees and woody shrubs. The soils in the upland areas are rich in red clay and sand but poor in organic matter. However, soils within the *Fadama* areas are rich in Kaolinitc clay and organic matter.

Natural Resources

Kaduna State is endowed with wide range of natural resources waiting to be fully utilized. The natural resources potentials are classified into Agriculture/Forestry, livestock and minerals.

Agricultural and forest resources are enormous. On the rolling high plains, the tropical ferruginous soils have been intensively used for cereal cultivation. The not so-rich soils, with good conservation and land management practices are capable of supporting calcium rich grass for livestock feeding. Yam, maize, cereals, cassava and ginger are commonly cultivated in the State. Forest reserves are limited, except in some few riverine areas.

Livestock resources are still in small scale. Some areas of the State possess development potentials for excellent rangeland to support large-scaled livestock production. The National Animal Production Research Institute [NAPRI] at Shika, near Zaria, offers good veterinary technical advice and services.

Graphite, Kyanite and Rutile are reported to be in large quantities in the State. They are good sources of raw materials for pencils, welding electrodes and ceramic industries. Magnetite and Hematite are also locally exploited for making local iron implements. Also, some broad river valleys are rich sources of sand, granite rocks and clay that are usually exploited for building.

1.8 Aim and Objectives

The main aim of this research work is to attempt using remote sensing data to prepare a flood hazard map to show areas that are potentially under the threat of flooding along the bank of river Kaduna. To achieve the stated aim, the specific objectives include.

1. Preprocessing of the dry season SPOT XS image data. Spectral enhancement is to be performed on the image data to highlight contrast between areas which obtain moisture from the drainage continuously throughout the year adjacent to the banks of the main river drainage, and areas away from the channels having seasonal vegetation cover.
2. Preparation of a digital topographical map from the colour composite of the spectrally enhanced bands of the SPOT;s data . This will be used as a database that contains agriculture, socio-economic and infrastructural data.
3. Derivation of Normalised Difference Vegetation Index (NDVI) image to clearly highlight areas along the banks of the major drainage channels of the study area , having dense, healthy vegetation only, being influenced by moisture from the drains and so liable to flooding. This was to distinguish areas that may be dry bare soils (having strong radiances) that are not riverine floodplains.
4. Generation of a digital elevation model (DEM). This will be derived from the contour information on the existing topographic map of the study area. The

contours are digitised and interpolated. The resultant DEM will be used to visualize the satellite imagery in three dimensions so as to appreciate the topography of the land in addition to viewing possible flood able areas along the river bank.

5. Delineation of the floodplain along the main river channel. Using the Kaduna State Urban Planning and Development Authority (KASUPDA) law to scale to buffer zone.

6. Delineating the different flood zone areas at peak and off peak periods of runoff water. Each flood zone represents a risk level of the flood map.

7. Overlaying the various flood zones to present a flood hazard map showing the various degree of vulnerability of the area.

1.9 Research Hypotheses

1. Remotely sensed data and digital image processing techniques can be used effectively in flood hazard mapping over large and/or in accessible areas in Kaduna metropolis.

2. Remotely sensed data is a good optional input for delineating different land cover types.

1.10 Justification of the Study

The landuse database can be used in conjunction with the flooding data to adapt an evacuation strategy, rehabilitation planning and damage assessment in case of a critical flood situation. Improve mapping of flood risk areas will enable properties at risk of flooding to be more accurately defined.

Flood hazard map of vulnerable area will encourage the provision of adequate and cost effective flood warning system by the various government agencies. It will also encourage the provision of technically sound and sustainable flood defense measures. Theoretically, this information could then be used to coordinate flood-warning activities such as road closures and evacuations.

Inadequate and inefficient drainage of low-lying and flat areas to the overflow, results in flooding. It will enable the various government agencies and construction companies to promote sustainable drainage techniques. Using the grid based floodplain delineation, a hydraulic engineer can zoom in on the area of a particular drainage control structure, and both view the floodplain extent and query the flood grid for water depth at various locations of bridges, culverts, storm drains and other drainage control devices where hydraulic analyses are used to determine conveyance capacity.

The presentation of flood prone areas will discourage inappropriate development in the areas at risk from flooding and erosion, continued management of flood risk thereby minimising the threat to human life, reducing distress and damage to property.

Improved visualisation and a digital database of floodplain extent will become very useful in management of the areas existing in the floodplain. Planners, developers and property owners would also benefit from a higher knowledge of floodplain extent.

The States and Federal Emergency management Agencies can use Digital Flood Insurance Rate Maps (DFIRM) which are intended to replace the existing paper maps. Inundation limits for floods can be determined by combining water surface profiles with digital terrain surfaces. These digital maps will be more readily adjustable with new or additional data.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction of Remote Sensing

Ndukwe (1997) defined remote sensing as a method of acquiring information about an object (target) without making physical contract with the object. It is a scientific method that employs electromagnetic energy as means of detecting and measuring target characteristics. Electromagnetic energy is the supreme medium of link between the measuring device (sensor) and the object of study.

In the past, environmental remote sensing was accomplished by the systematic interpretation and analysis of photographic emulsions sensitive only to visible portion of the electromagnetic spectrum. Later, there became available emulsions, which extend the photographic capability beyond the visible portion into the infrared portion. In recent years, additional systems which could detect and record electromagnetic radiation well beyond the range covered by photography become available given remote sensing a great boast and capabilities.

Adeniran (1999) define remote sensing as the science and technology of recording and analysing the characteristics of earthly phenomena by airborne and space borne platforms to assist in inventory mapping and monitoring of earth's resources. The platforms are equipped with electromagnetic energy sensors, which acquire data on the way various earth surface features emit or reflect electromagnetic energy and these data are analysed to provide information about the resources under investigation.

Jones (1997) distinguishes the two classes of remotely sensed data as:

i. A classification by the wavelength of the radiation that is detected. The ranges of electromagnetic wavelengths that are commonly used for remote sensing survey are 0.4 - 0.7um, which is the visible range, 0.7 - 3um called the reflected or near and mid infrared, 3 – 14um, the thermal infrared, and 5 – 500mm referred to as microwave radiation.

ii. Classifying remotely sensed data according to the physical form in which it is acquired, which relates closely to the survey technology employed i.e. photographic surveys, from multispectral scanners and microwave sensor

2.2 Advantages of Remote Sensing

Remote sensing has several advantages over the conventional or ground-base methods of observation and data collection. Kufoniyi et al, (2003) categorised these advantages in four as follows:

i. Synoptic perspective i.e. the ability to revisit and acquire data of the same ground area as many times as may be required. Earth observation satellites are programmed to pass over a target area at given temporal interval which makes satellite remote sensing an efficient tool for monitoring land cover changes within a period of time.

ii. Unique vantage point:- Orbiting at an altitude of above 500 km or flying at 15km gives space or airborne platforms good vantage point to view the earth and record land surface changes especially at a global scale.

iii. Extra:- visual information: Satellite remote sensing capability of providing data across the electromagnetic spectrum i.e. from the visible through to the microwave region in addition to the expansive ground area coverage provide great wealth of information within a scene and in a degree of detail.

iv. Historical and permanent record:- Satellite system collects and archive high quality data for use many years after acquisition for trend study.

2.3 Concepts of Remote Sensing

The practice of remote sensing is based on certain concepts. These concepts addresses ideas central to the practice of remote sensing, regardless of specific disciplinary applications. According to Campell (1996), the concepts include:

(i) Spectral Differentiation

Identification of physical features on remotely sensed data is facilitated by observed spectral differences in radiation reflected or emitted from the features. Images are acquired using various wavelengths and the response of a feature within the range concerned is called spectral response pattern of the features. Images acquired over a number of these wavelengths are referred to as multi spectral images.

(ii) Radiometric Differentiation

Features on remotely sensed data can be differentiated because of the variation in their brightness (tone) as detected by the sensor (instrument used). Within a given spectral region, this contrast in brightness must be sufficient for the instrument to detect, as it influences the information that can be derived. Consequently, pertinent issues in remote sensing investigations include the sensitivity of instrument (sensor) used and existing contrast in the scene between the features and their background.

(iii) Spatial Differentiation

Every sensor has a minimum area that can be recorded as an entity on image. This determines the spatial detail (or resolution) or the fineness of the patterns on the images. For some remote sensing systems, these smallest areas units-picture elements or pixels- are in fact discrete, distinct units, identifiable on the image.

Spatial resolution is dependent on the type of sensor and the altitude of image recording system. Terrain features vary in their spatial complexity. They could either be clearly recorded using coarse or fine levels of details depending on the spatial complexity.

(iv) Geometric Transformation.

The specific geometric relationship of landscape is represented by images recorded by sensors. However, sensor design, specific operating conditions, terrain relief and other factors determine this. The ideal remote sensing instrument would be able to create an image with accurate, consistent geometric relationships between points on the ground and their corresponding image representation. Accurate measurements of areas and distances could be obtained from such images.

In reality, images are subjected to geometric (locational) errors as a result of terrain relief the perspective of the sensor optics, motion of scanning optics and earth curvature. These errors must always be accounted for before using the images for measurements. This is because they are inherent characteristics of these images even though sometimes they can be reduced or removed.

(v) Interchangeability of Pictorial and Digital Formats.

The original format of most remotely sensed data is usually digital arrays representing the brightness of features recorded. If these values portray level of brightness, each digit can portray a photographic brightness level. Pictorial images can also be converted to digital format by subdividing the image into small squares of equal size, each assigned discrete values, indicative of its brightness. Depending on the investigation being conducted, remotely sensed images can be presented in any of these formats though some times with some loss in detail. No real difference occurs in the information content. Both formats require different way of display representation.

(vi) Role of the Atmosphere.

The accuracy of interpretation of remotely sensed data is influenced by the quality of the image. The atmosphere through which radiation passes before reaching a sensor usually degrades the quality of the image. It does this by either altering the intensity of wavelength of recorded radiation.

2.4 Context for Using Remotely Sensed Data

Remotely sensed data must be analysed to extract useful information. The principal steps used for this analysis according to Aronoff (1993) are as follows.

(a) Definition of Information Needs

The objective of using remotely sensed data is to generate information. Before any data acquisition or analysis can begin, the information needs have to be defined. Only then can the techniques be identified that might best satisfy the requirements. This assessment should take into account such factors as, the accuracy needed, how quickly it is needed, in what time or period should the information be collected (e.g. within the past year or in particular season), the cost to produce it and the form (e.g. electronic format, paper map, tabulated statistics) in which it is needed.

(b) Collection of Data Using Remote Sensing and Other Techniques

Remotely sensed data are rarely used as sole data source. Field observations and measurements as well as existing information such as maps and reports are used together in the analysis. The data requirement must be defined, the available data assessed and then the new data to be collected must be specified.

Remotely sensed data are collected using a variety of devices that detect energy reflected or emitted from objects. The data specifications should be planned and integrated with other data collection activities. Field collection procedures can be modified so that expensive field sample data can be properly integrated into remote sensing analysis.

(c) Data Analysis

There are three principal types of analysis applied to remotely sensed data they are:

(i) Measurement Analysis

This analysis method use the values measured by the sensor to calculate environmental conditions like surface temperature, soil moisture, quantity of plant material or the condition of crops. Measurement results are usually produced as a large number of individual values, one for every sample point.

(ii) Classification Analysis

In this method, regions that have the same characteristics are defined. These results are commonly provided in the form of a map-like image where regions with the some characteristics are shown coded as the same colour or pattern. The image may be produced as a paper map, a digital image or a set of boundary outlines for each region. The classification may be used to generalize a measurement analysis for presentation. For example, ranges of temperature could be shown as different coloured classes.

(iii) Estimation Analysis

They are commonly applied to classification results. The objective of this type of analysis is to estimate the quantity of a material for each management area. This analysis method is not a mapping application and so precise delineation of boundaries is not usually needed. The type of classification used serves to divide the area into regions, termed strata, which have statistically similar characteristics. The advantage of using remotely sensed data to stratify the region in this way is that estimates with the same or better accuracy can be obtained with fewer field samples and therefore at a lower cost.

(iv) Verification of Analysis Results

To use information effectively, we need to know something about its accuracy. Information need not be 100% correct for it to be useful, so long as the expected level of accuracy is known and taken into account when the information is used.

Result of remote sensing analysis should be accompanied by a report on the quality of the data. The verification step involves analysis step, in order to verify that the results are of sufficient quality to be accepted for use.

(v) Reporting the Results

Once the quality of the information has been assessed and found to be acceptable, the information can be assembled into a suitable reporting format. The format may be a paper map, an annotated image (such as a flood hazard map), a computer data file or a written report with diagrams, maps and tables. The format selected should convey the information and take into account the way the data will be used.

(vi) Taking Action Based On The Information

The objective of producing information is for decision-making if information is being produced and not used, it is generally because there is no user, the information never gets to the intended user or the information is not in a suitable format.

2.5 Remote Sensing As a Tool for Flood Area Delineation

In the early stages of satellite remote sensing, the data available was from Landsat Multi Spectral Scanner (MSS) with 80m resolution. It was used in flood mitigation on the flood prone regions of USA (Smith, 1997). They band 7 of MSS (0.8-1.1um) was found suitable for distinguishing water or moist soil from dry surface due to strong absorption of water in the near infrared range of the spectrum.

From the early 1980's Landsat Thematic Mapper (TM) imageries with 30m resolution was used for monitoring flood and delineating boundary of inundation using band 4 to discriminate water from dry land surface (Sanyal and Lu, 2003). Wang et al (2002) solved the problem of confusing developed areas with water by adding Landsat TM band 7 with the NIR (band 4) band to delineate the inundated areas. Using the band 4 + band 7 images, it becomes easier to choose the density slice for extracting the flood water.

During later stage, SPOT multispectral imageries were also used for flood delineation with similar assumption that water has very low reflectance in the near infrared region of the spectrum. Islam and Sado (2002) used SPOT imageries along with DEM for delineation of moonsoon flood in Bangladesh.

Islam and Sado (2000a) used Normalised Difference Vegetation Index (NDVI) to monitor river inundation from Advanced Very High Resolution Radiometer (AVHRR) images. Although AVHRR images are coarse in resolution and frequently contaminated by cloud cover, its merits lies in its high temporal resolution. This advantages enables monitoring the progress of a flood in a near real-time. Water has a unique spectral signature in near infrared different from other surface features. Therefore, when a surface feature is inundated its value changes considerably from the normal situation.

NDVI is a widely used image transform to monitor vegetation conditions using the AVHRR, for example, examining the ratio of reflected IR to Red wavelengths is a good measure of vegetation health and this is the premise behind the concept of NDVI.

Healthy vegetation will have high NDVI because of its high reflectance of IR and low reflectance of Red light.

The existence of cloud cover appears as the single most important impediment to capture the progress of floods in bad weather (Islam and Sado 2000b). The development of microwave remote sensing, particularly radar imageries solve the problem. Radar systems have all weather capabilities.

Sanyal et al (2003) discussed the use of Synthetic Aperture Radar (SAR) and optical remote sensing imagery simultaneously in flood management. SAR imagery has the advantage in its ability of distinguish sharply between land and water.

A thresholding technique was used by (Minami, 2000) to segregate flooded areas from non-flooded areas in a radar image. A threshold value of radar backscatter is set in dicibel (DB) and a binary algorithm is followed to determine whether a given raster cell is "flooded" or not. Radar backscatter is computed as a function of the incidence angle of the sensor and digital number (DN).

WARPO (1997) used change detection to detect flooded area by acquiring two SAR imageries taken before and after the flood. Two approaches were used. In the amplitude approach, areas estimated as flooded, the radar backscatter was observed to be in considerable decline from before flood to after flood imagery.

In the coherence approach areas are generally identified as flooded where the coherence or correlation of radar backscatters from before and after flood imagery are very low.

Sarti et al (2001) used SPOT multi spectral data for flood detection over Gloucester (UK). First a radiometric calibration and geometric correction of all images was performed (using a DEM), aiming at obtaining comparable and superimposable images (in terrain geometry). Several algorithms of change detection based on ratios and differences between channels (radiometry) of multi-temporal data were tested in order to produce a map of damage assessment.

Mohammed and Mansor (1999) used Landsat-5 Thematic Mapper (TM) data and hydrological modeling for flood prediction in Klana valley, Malaysia. The model involves the calculation of runoff from curve numbers (CN) that relate to land use, soil type, and hydrological condition and soil moisture. In the determination of runoff, land use information was derived from the landsat-5 TM data and land use maps. The runoff values were used in the calculation of concentration time, peak discharge and bankfull discharge. The peak discharge was calculated by the graphical method of SCS TR-55 model whilst the bankfull discharge was derived from the slope area method Flood occurrence was determined by comparing the peak discharge values with bankfull discharge values. Flooding occurs if the peak discharge exceeds the bankfull discharge.

Baba (1998) reported the work done on the application of Lansat data in terrain analysis and flood plain delineation of the Sokoto Rima river system in North Western Nigeria and shows how flood plains could be easily delineated for a large part of the river system. The report demonstrated that radiance from different land cover types could be easily identified, providing opportunity for accurate delineations over large and inaccessible areas.

Olawale (1998) used remotely sensed data (aerial photograph and Landsat MSS image) to study the causes of river flooding of River Osun in Ikere-Ekiti, Ekiti State, Nigeria. The result of the study shows that areas liable to flooding could be easily determined and that the cause of increased flooding in the study area can be attributed to expansion in built up areas (especially towards the flood plains), the presence of large barren land, the extension of agricultural practices at the upper course of the river and deforestation are responsible.

Tate (1998) used photogrammetric techniques to develop digital orthophotographs and digital terrain models for floodplain mapping of Waller Creek in Austin, Texas. Using aerial photographs at scale 1:30,000 taken with a 152.4 mm focal length lens at an altitude of 4600 metres, standard overlap is 60% forward and 15% side, he outlined the operational steps to include:

i. Use a 30-meter DEM to represent the area terrain.
ii. Vectorize the DEM to create a point coverage of terrain elevations.
iii. Construct a bounding polygon from the cross-section endpoints
iv. Eliminate any DEM points that fall within the bounding polygon.

v. Create a TIN using the DEM and cross-section points as nodes, and the stream centerline and bank lines as hard breaklines.

vi. Formulate an algorithm to smooth the interface between the DEM and the vector floodplain data.

Access to better information is paramount, as it is not always possible to map extensively flooded areas quickly enough or homogenously enough using traditional means such as ground-based measurements (ESA, 1998). Satellite data, therefore provide the best alternative data source for flood monitoring. The Herault floods in France in January 1996, for example, caused major flooding and heavily inundated the Orb Valley all the way down to the Mediterranean Sea. During the flooding event, an ERS-1 SAR (radar) image of the area was acquired and used to map out areas being submerged by the flood.

Remotely sensed data and analysis techniques have demonstrated that environmental changes could be modeled efficiently. In the work on the detection and modeling of forest disturbances of Afaka Forest Reserve, Kaduna, Nigeria using multitemporal Landsat MSS, Landsat TM, SPOT XS satellite data and aerial photographs for the period ranging between 1962 – 1994, results indicated the forest reserve was under serious stress of human threats, and projected to become completely extinct by the year 2015 at the established model trend (Nwadialor, 2001).

The review of studies above indicates that remote sensing is an important technique for monitoring the environment. Monitoring the environment involves checking, observing and recording information about the environment. Through adequate environmental monitoring, disasters or environmental problems are easily noticed and can be averted (at least at a reasonable level). Satellite data have been found to provide the most efficient data type for use in mapping out large and/or inaccessible areas under the threat of environmental disasters. This advantage will be fully exploited in this research.

CHAPTER THREE

METHODOLOGY

3.1 Data Source

There are two classes of data for this research. They include SPOT (XS) digital satellite image of the study area obtained in 1996 and digitized x, y and z coordinates from a 1976 topographic map of the study area at the scale 1: 25,000. The image data was used to produce a landuse map and mapping of areas liable to flood. The DEM was generated from the x,y,z coordinated to produce a slope map and overlayed on the satellite data to provide a more appealing perspective view of the study areas.

3.2 Spot Image Data

SPOT Satellite is a French earth resources satellite and is an acronym for System Probatoire de l, Observation de la Terre (a French phrase meaning satellite for earth observation).

SPOT satellites are placed in a sun-synchronous near-polar orbit. The reason is to enable the comparison of imageries of different regions or same region taken at different times. The imaging system consists of two identical High Resolution Visible (HRV) instruments capable of imaging in the visible and near infrared portions of the spectrum over a ground width of 60km. The sensors have three spectral modes of operation as follows (Ndukwe, 1997):

(i) Panchromatic mode 0.50 - 0.75um with 10m resolution.

(ii) Multi spectral mode with 20m resolution

Green	0.50 - 0.59um
Red	0.61 - 0.69um
NIR	0.71- 0.91um

SPOT's oblique viewing capacity makes it possible to produce stereo pairs by combining two images of the same area acquired on different dates and at different angles due to the parallax thus created. Thus single scenes cannot be used to produce stereoscopic view of an area. Lillesand, and Kiefer (1994) have shown that stereoscopic viewing is only possible with at least two revisit scenes. Table 3.1 illustrates the suitability of different sensor products for particular land cover applications.

From the table 3.1 below, it can clearly be seen that the SPOT MSS image gives more clarity to the drainage channel than SPOT panchromatic. It is therefore best suited for studies involving drainage channels. The fusion of both images would greatly enhance details under study. Studies have shown that SPOT is capable of use in mapping stream channel depth, slope and channel widths (Ononiwu, 1990).

Table 3.1 visibility of topographic features in three types of satellite images

Feature	Spot panchromatic	Spot MSS	Landsat TM
Railways	100	100	100
Motorways	100	100	100
Main roads	100	100	100
Asphalted road	90	70	50
Dirt roads in low-contracts enhancement	30	10	0
In high-contract			
Environment	100	100	100
River	100	100	100
Conals (width 8m)	0	10	10
Hedgesows (width 30m)	100	100	100
Hedgesrows (width 20)	40	80	90
Hedgesrows (width 10m)	40	40	30
Country side houses	90	90	100
House in built up area	80	40	0

Source:- Adopted from Van Der Loan (1987)

3.3 SPOT Corrections

The following correction of the satellite image data of the study area was performed using the ILWIS 3.1 software.

3.3.1 Geometric Correction

Remotely sensed data are usually affected by geometric distortions due to sensor geometry, scanner and platform instabilities, earth rotation, earth curvature etc. The image suppliers correct some of these distortions and others can be corrected referencing the images to existing maps.

The SPOT image used is SPOT 3 multi spectral 1996 dry season digital data. The multi spectral image constrains data in 3 spectral bands; Green (0.5-0.59 um), Red (0.61-0.68um), and near infrared (0.71-0.89um). These bands are optical bands.

The geometry of a satellite image can be distorted with respect to a north-south oriented map:

(a) Heading of the satellite orbit at a given position on earth (rotation).

(b) Change in resolution of the input image (scaling)

(c) Difference in position of the image and map (shift)

(d) Skew cause by earth rotation (shear)

The correction of all distortion at once is executed by a first order transformation called Affine Transformation. The correction was applied by geo-referencing the SPOT image data using reference points from the map. The coordinates for some points in the image are known.

The geo-referencing was done by specifying reference point (tie points) that relate for distinct point their row/column number with the corresponding X,Y coordinates.

The transformation is given by the following polynomials (Ndukwe, 1997):-

$$X = a_0 + a_1 r_n + a_2 c_n$$

$$Y = b_0 + b_1 r_n + b_2 c_n$$

Where:

r_n the row number, c_n is the column number, X and Y are the map coordinates.

A number of points that can be clearly identified both in the image as on the topographic map, the coordinates were determined. The reference points were carefully selected and also the corresponding locations of objects in the image and on the map were addressed and measured since there was large time difference between production of the map and the acquisition date of the image.

3.3.2 Removal of Haze

Smith (2000b) has shown that for the visible band, the smaller wavelength bands are affected more by atmospheric scattering. Therefore, combining the three-multi spectral bands of the SPOT image in a colour composite would require the removal of this haze from the bands most affected.

For this analysis, the ILWIS 3.1 software has shown that when the raw satellite image data is radiómetrically stretched using the linear stretch option, the inherent noise would be effectively removed. A DN value in the low end of the original histogram is assigned to extreme black and a value as the end of the original histogram is assigned to extreme white. The remaining pixel values are distributed linearly between these extremes.

3.3.3 Radiometric Enhancement

Radiometric enhancement is aimed to highlight features that may otherwise appear blurred on the original raw digital image. The ILWIS 3.1 image processing software for radiometric enhancement was used for this operation. It performed both spatial and spectral enhancement operations.

a. Spatial enhancement procedures result in modification of an image pixel value based on the pixel values in its immediate vicinity (local enhancement). The object is to create new images from the original image data in order to increase the amount of information that can be visually interpreted.

   A smoothing filter was used to preserve edge. These filters are designed to emphasize low frequency features and to suppress the high frequency component of an image.

b. Spectral enhancement enhances individual pixel brightness, so as to make clear differences between pixels having very close radiances. It involves image histogram manipulation to adjust radiances.

3.4 Normalised Difference Vegetation Index (NVDI) Extraction

This was done to discriminate between the following land cover types, Green vegetation Water and Bare Soil.

To calculate NDVI values, the map scale function NDVI(a,b) was employed. This function requires 2 satellite bands (one with visible or red values and the other near infrared values). The function performs the calculation (Oyinloye, 1997).

$$(b - a)/ (a + b)$$

where a is the band with the red values and b is the band with the near infrared values of the SPOT imagery. NDVI is always a ratio of 2 bands.

VegInd = NDVI (SPOT Band 2, SPOT Band 3)

3.5 Digital Elevation Model

Surfaces, such as the surface of the earth are contiguous phenomena (fields) rather than discrete objects. To fully model the surface would need an infinite amount of points. There are various ways of representing continuos surfaces in digital form using a finite amount of storage.

The term digital elevation model (DEM) is frequently used to refer to any digital representation of a topographic surface and most often it is used to refer specifically to a raster or regular grid of spot heights.

DEM also referred to as Digital Terrain Model (DTM) is a numerical representation of terrain features in terms of elevation and planimetric measurements obtained by sampling a topographic surface (Ndukwe, 2001). Digital terrain modeling involves a digital representation of terrain feature consisting of a set of x, y, z coordinates of points.

3.5.1 Acquisition of Data for DEM

Acquisition of topographic information is of prime importance in digital terrain modeling. Three main methods are used for generating of topographic information, namely field or ground surveying methods, photogrammetric methods and graphic digitizing methods.

(a) Field or Ground Survey Methods.

DEM data can be acquired using the traditional optical instruments such as theodolite, levels, tacheometers or using the more modern instruments and technologies such as the total station or the GPS. The accuracy of field method can be high but they can be cost effective when a limited area is concerned. For project covering large areal extent, the method can be quite tedious time consuming and uneconomical.

(b) Photogrammetic Methods.

Data acquisition by photogrammetic method involves extracting data from optical stereo-models set up using stereoplotters or analogue instruments. An improved version of this is the use of analytical stereoplotting instruments, which employs mathematical numerical solution for example, mathematical models, instead of optical or mechanical models are formed and terrain data extracted automatically. In this model, the analytical plotter can be programmed to acquire terrain elevation data in a desired pattern and density (Ndukwe, 2001).

(c) **Graphic Digitizing Methods.**

The generation of terrain model data, can be done by digitizing height information (contours) from existing topographic maps. Digitizing refers to the conversion of information or data, which are in an analogue form into a digital format. Two types of data are usually digitized, namely, point data (such as individual objects, spots heights, trees, etc) and line data (such as roads, rivers, walls and fences, rail roads, etc). This approach was adopted for this research.

The graphic digitization method is particularly advantageous when a large area is concerned but is should be noted that terrain data obtained from this method is less accurate than that obtained either by direct field method or by photogrammetric means. The generated DEM will be used for slope determination, drainage and flood analysis.

3.5.2 Uses of DTM

Digital terrain models are used in a number of applications in the earth, environmental and engineering sciences. Quddus et al (2004), listed five main application domains where DTMs are used.

(i) **Civil Engineering:** Civil engineers are mainly interested in using DTMs for cut-and-fill problems involved with road design, site planning, and volumetric calculations in building dams, reservoirs etc

(ii) **Earth Science:** The geo-scientific applications mainly centre on specific functions for modeling, analysis and interpretation of the unique terrain morphology. These include drainage basin network development and delineation, hydrological runoff modeling, geomophological simulation and classification, and geological mapping. Generating slope and aspect maps, and slope profiles for creating shaded relief maps are popular tasks performed in the earth sciences that employ DTMs.

(iii) **Planning and Resource Management:** This is a major grouping of diverse fields including remote sensing, agriculture, soil science, metreology, climatology, environmental and urban planning, forestry, whose central focus is the management of natural resources. Applications that best characterizes this domain include site location, support for image classification and remote sensing, the geometric and radiometric correction of remote sensing images, soil erosion potential models, crop suitability studies, wind flow and pollution dispersion models.

(iv) **Surveying and Photogrammetry:** One of the main objectives of employing surveying and photogrammetry is in building reliable DTMs, evaluating their accuracy towards finally producing high quality contours.

(v) **Military Applications:** The need to understand terrain has always been an essential skill for the military commander. The Military usage of DTMs combines facets and methods of all civil application domains, and their end objectives are very specialized and demanding. Examples of such usage include:

(a) Terrain analysis; battle field management involving tasks such as intervisibility and vehicles/tanks traficability.

(b) 3-dimensional display for missile/weapon guidance systems and planning of communication networks.

(c) Advance visualization functions such as photorealistic scene display and animation for flight simulation and radar line-of-sight analysis

(d) Site planning suitable for civil engineering purposes (sighting of field command base/post and other military installations especially during an operation)

3.6 Topographic Map Data.

The topographic map data used is that of Kaduna and environs, 1976. The map was on a scale of 1:25,000 with 50m contour interval. The contour information on the map was digitized with the ILWIS software. There are three main methods or digitizing features from planimetric or topographic map. They include:

i. Manual Digitizing method

ii. Semi-Automatic Digitizing method

iii. Fully automatic raster-scan digitizing method.

The manual digitizing method was adopted for this study. The map was mounted on the digitizing table called tablet. Digitizing cursor traces the contour line in a continuos mode and the attribute data consisting of numerical values and feature code entered.

The digitized map was transformed from digitizer coordinates to National grid coordinates and the scale distortions present in the original map minimised using affine transformation. The digital map data was stored after editing as a vector file. This information was converted to a raster using the rasterisation option of the ILWIS software. Rasterisation involves assigning point line and polygon attribute values to raster cells that overlap with the point, line or polygon. To avoid loss of data, the cell should be carefully chosen on the basis of the geometric resolution. A too large cell size may result in cells that cover parts of two or more objects, or in the displacement or even loss of objects. If the cell size is too small, the volume of the raster data can easily become too big.

An important aspect is the selection of pixel size and area of the map. An increase in pixel size will lead to a smoother topography. Especially when the mapped changes in topography occur at distances smaller than the pixel size, the slope angles derived from the DTM may lead to underestimating the actual slope angles in the field. When too large a pixel size is chosen, ridges and small streams may be missed. For the map representation at a scale of 1:25,000, a pixel size of the order 12.5 x 12.5 m was adopted.

3.7 Preparation of Land use Map

The satellite image data was used to prepare a land use map of the study area using the image-processing module of ILWIS 3.1 software. The following map layers were generated. This was achieved through on screen digitisation module.

i. Settlement

ii. Road network

iii. Agriculture

iv. Drainage.

ILWIS software uses different types of objects, namely data objects and service objects as explained below:

(i) Data objects: Raster maps, Polygon maps, Segment maps, Point maps, Tables and Columns. They contain the actual data.

(ii) Service objects: Service objects are used by data objects. They contain accessories that data objects need besides the data itself. Domains, representations, georeferences and coordinate systems are called service objects.

The data structures were represented as follows during the on screen digitization:

(i) Create point map

(ii) Create segment map

(iii) Create table

3.8 Delineation of flood Prone Areas

This was achieved by buffering from the riverbanks. Buffering generates zones within a given distance of a pre-specified set of data. In order to meet the strict environmental guidelines by Kaduna State Urban Planning Development Authority (KASUPDA), a distance of 500 metres was used as the buffer zone to delineate the flood prone area from the natural drainage.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF RESULT

4.1 Image Enhancement and Interpretation.

The main analyses carried out included image enhancement and Normalised Differences Vegetation Index (NDVI) image extraction of SPOT Multispectral data of the study area discussed in Section 3.3.3. The image enhancement procedures include spatial enhancement (image filtering) and spectral enhancement (linear contrast stretch method).

The main aim of the image enhancement operation was to highlight areas along the main natural drainage that may be susceptible to future flood. All the three bands of the SPOT Multispectral image data were enhanced. The process was expected to highlight pixels covering thickly vegetated and riverine floodplain areas.

The role of vegetation in this study is to eliminate the confusion in the interpretation of data, since some areas may be covered by dry bare soils, which may be confused for thick vegetation (because of radiance similarities). Reflection of soil in the near infra red band is also moderately high.

The SPOT Multispectral image data was imported into the ILWIS 3.1 software and both spatial and spectral enhancements were performed on all the bands. Fig. 4.1 shows the Histogram of Band 1 of the original image before enhancement. The image histogram is simply a plot of pixel frequency (i.e. number of pixels) against the radiometric values (digital numbers) with the frequency usually plotted along the ordinate axis while the digital number (DN) is plotted along the abscissa axis (Oyinloye, 1997). The range of the original image occupies a narrow stretch of 67 to 117. The enhancement operation of the ILWIS software carries out amplitude rescaling of each pixel resulting in the image data being linearly mapped over a new range from 0 to 255 as displayed in Fig. 4.2

Fig 4.3 is the colour composite of the SPOT image obtained by assigning Band 1 as Blue, Band 2 as Green and Band 3 as Red. The enhanced SPOT multispectral data was displayed in the red, green and blue colour planes. The NIR channel image data was displayed as red colour plane while the red channel image data and the green channel image data were correspondingly displayed in the green and blue colour planes. The examination and interpretation of this colour composite shows vegetated areas appearing as red/bright red, water appearing as dark while bare soil was seen appearing as gray. Areas with cyan colour represented the built up areas. All these areas were inspected through field survey. The result obtained from the field exercise was in correspondence with the land cover interpretation from the satellite image.

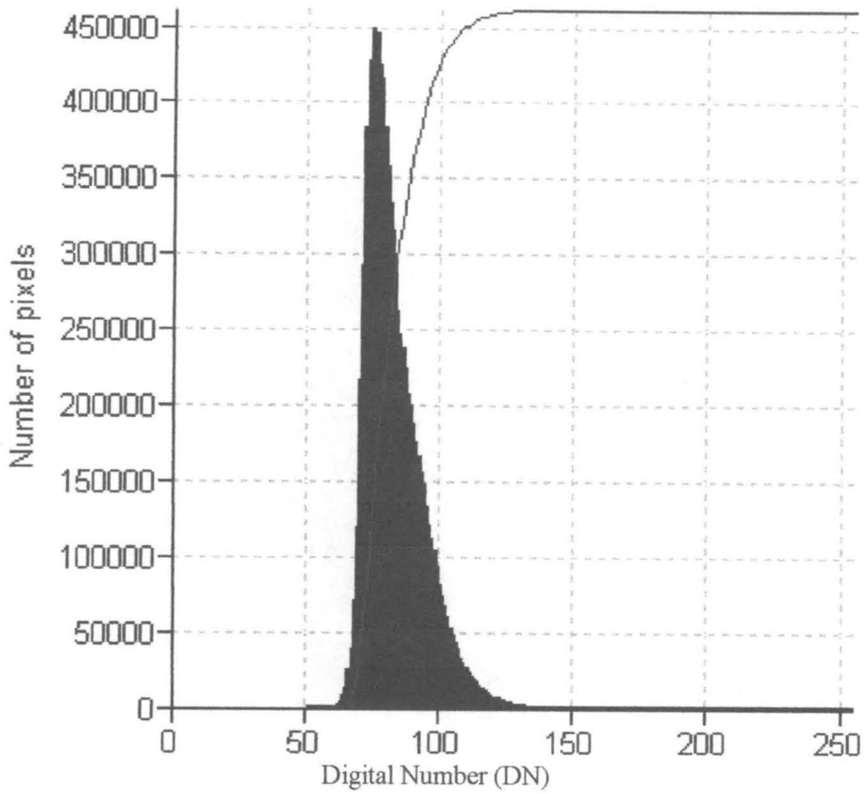


Fig. 4.1 Histogram of Band 1 before Image Processing.

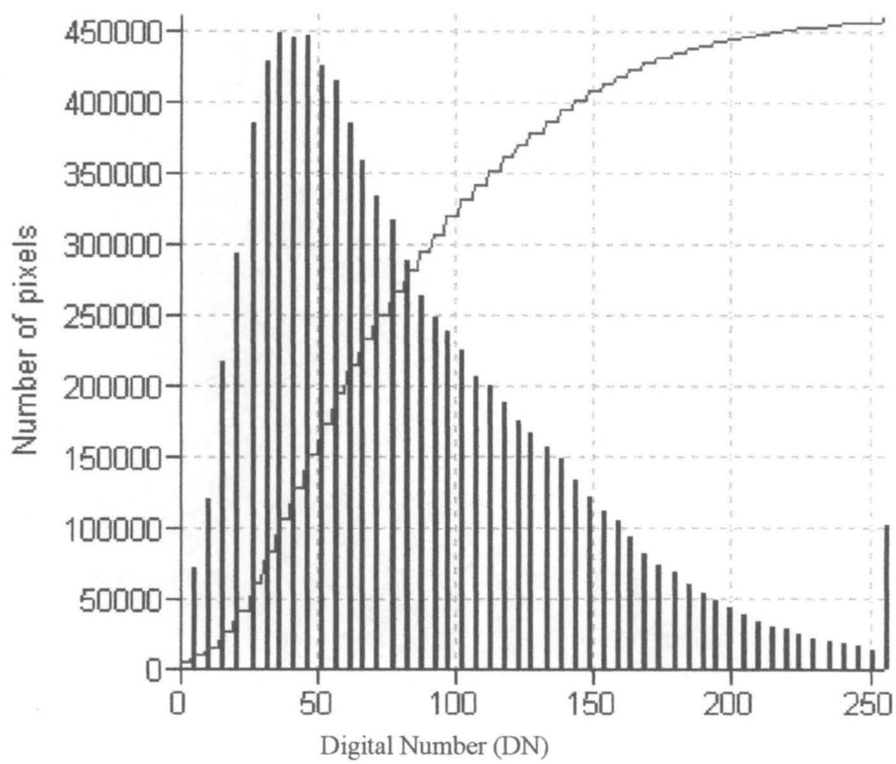
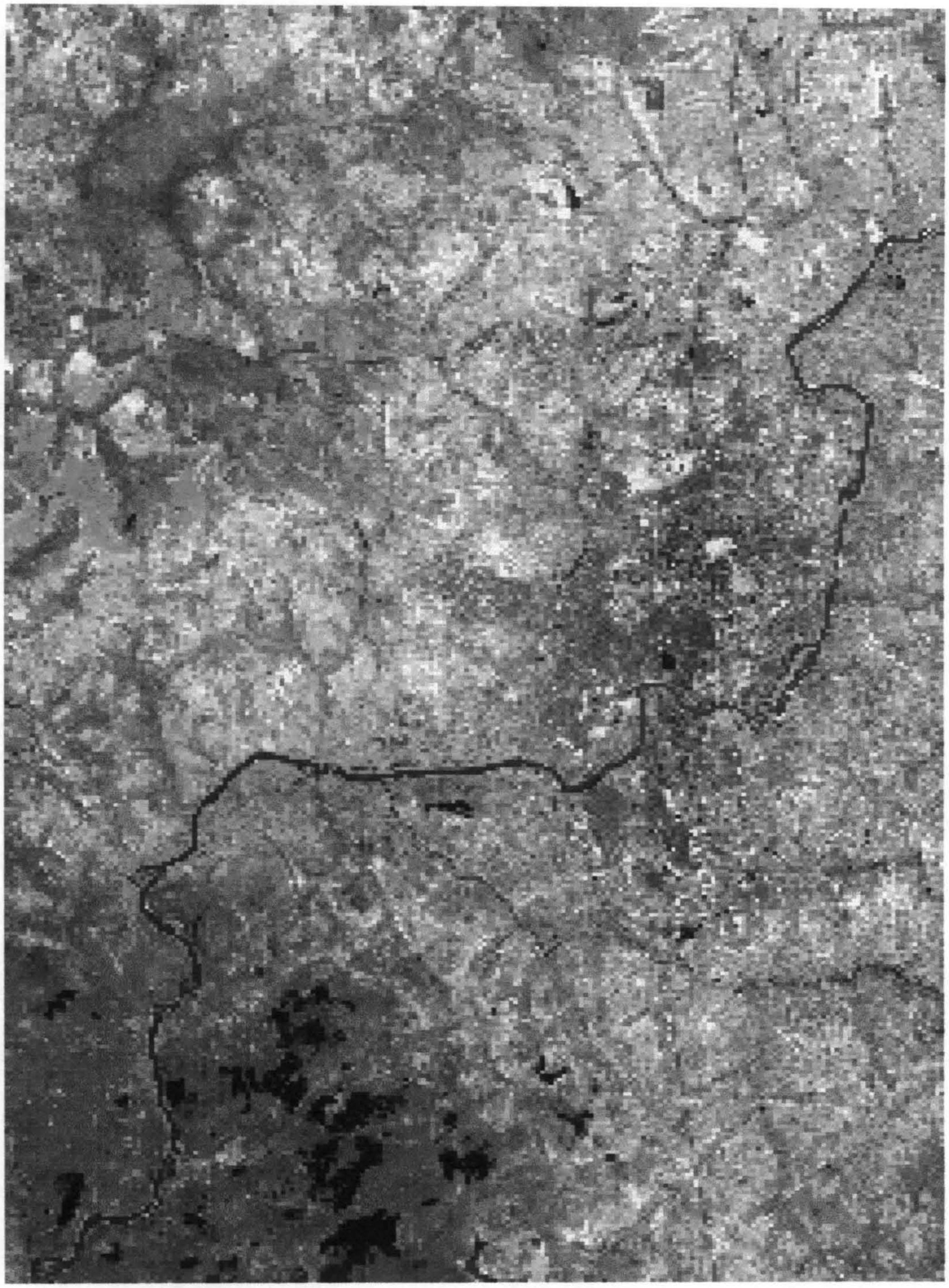


Fig. 4.2 Histogram of Band 1 after Image Processing.



SCALE :-1:200,000

ig. 4.3 Colour Composite of the 3 Bands of SPOT XS Image of Kaduna Township

4.2 Normalised Difference Vegetation Index and Investigation.

The NDVI is an indicator of the healthiness (thickness of vegetation canopy) in a particular area (Smith, 2000). The NDVI function computes the ratio of the difference to the sun of near infrared and red energies. And because the soil does not absorb the red energy, it would then be easy to distinguish between highly reflecting grounds and vegetation.

The purpose here is to obtain a new image channel containing specific information about vegetation in the image. We know that the growing (or active) vegetation shows a very high reflectance in the near infrared (NIR) band in relation to its reflectance in the red (R) band.

To calculate NDVI values, a map scale function NDVI (a, b) is required as discussed in section 3.4. The function performs the map calculation using two satellite bands.

$$\text{Vegetation Index (VI)} = (b - a)/(a + b)$$

Where "a" is the band with the red values and "b" is the band with the near infrared values of the SPOT imagery.

On investigation the output map VegInd contains NDVI range from -1 to +1 and that

a) Vegetation areas yielded high value because of their relatively high near infrared reflectance and low visible reflectance.

b) In contrast, water and clouds have larger visible reflectance than near infrared reflectance. Thus, these features yield negative index values.

c) Rock and bare soil areas have similar reflectance in the two bands and results in vegetation indices near zero.

Fig 4.4 is the NDVI image extracted from band 2 and 3 of the SPOT image of the study area. From the figure areas adjacent to the natural drainage have high values indicating thick vegetation cover and appear linear. A field survey conducted shows that the area with thick vegetation tallies with the floodplain. Thus the resultant NDVI image used to support the analysis carried out has proved to be useful for mapping of possible floodable areas The areas portrayed as thickly vegetated area were associated with moisture supplies from the relatively moist natural drainage channels

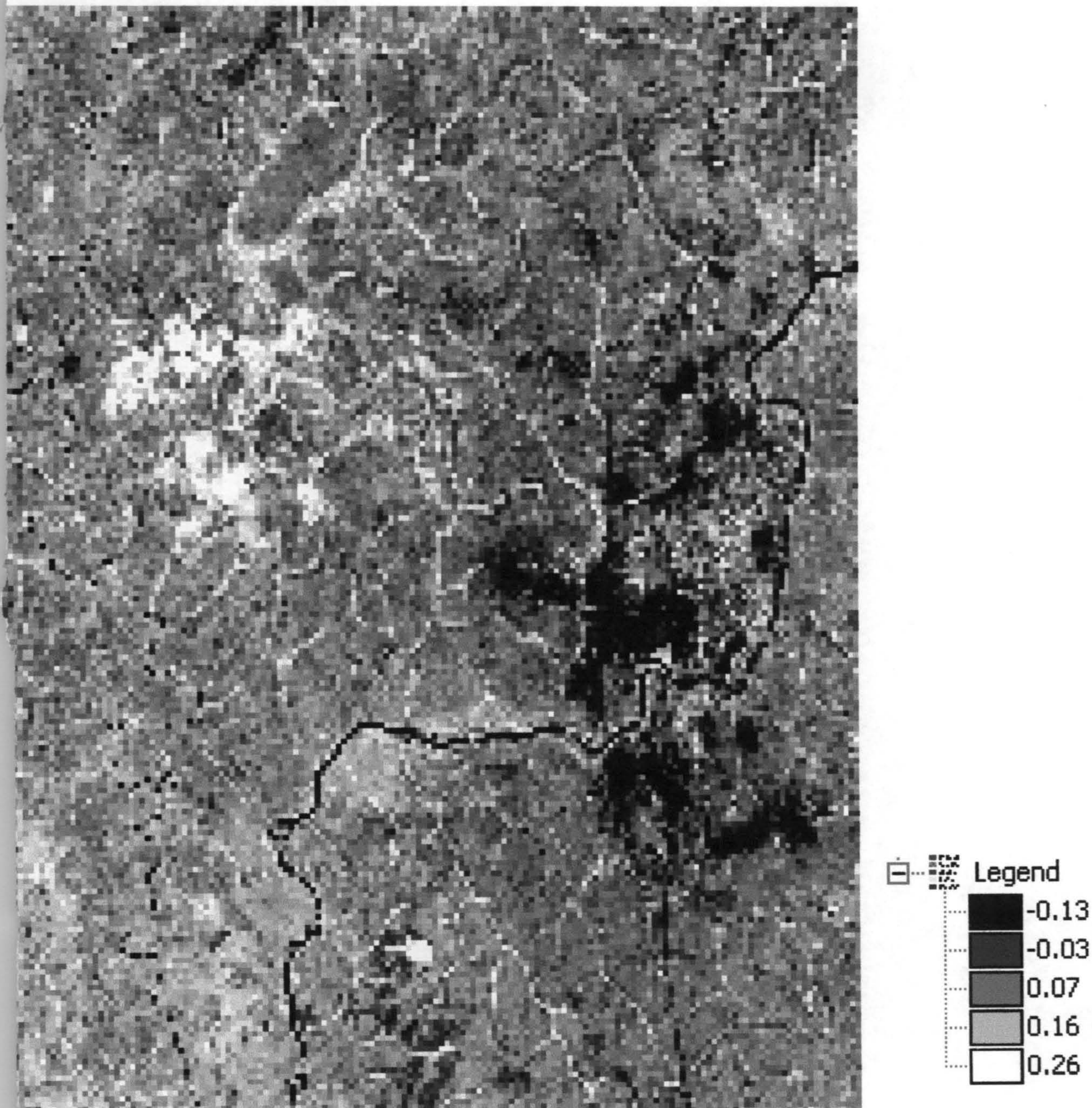
4.3 Generation of a Topographic Map.

By overlaying and matching the polygon maps, point maps and segment maps of different entities covering the project area; a digital topographic map was obtained. This is produced as Fig 4.5. The graphic database provides the location and relationship information of the geographic entities at the feature level. The attribute database provides the functional description for the geographic entities. The ILWIS software uses data objects and service objects as described in section 3.7. During the on screen digitization of the colour composite image, the data structures were represented as follows:

(i) Create point map

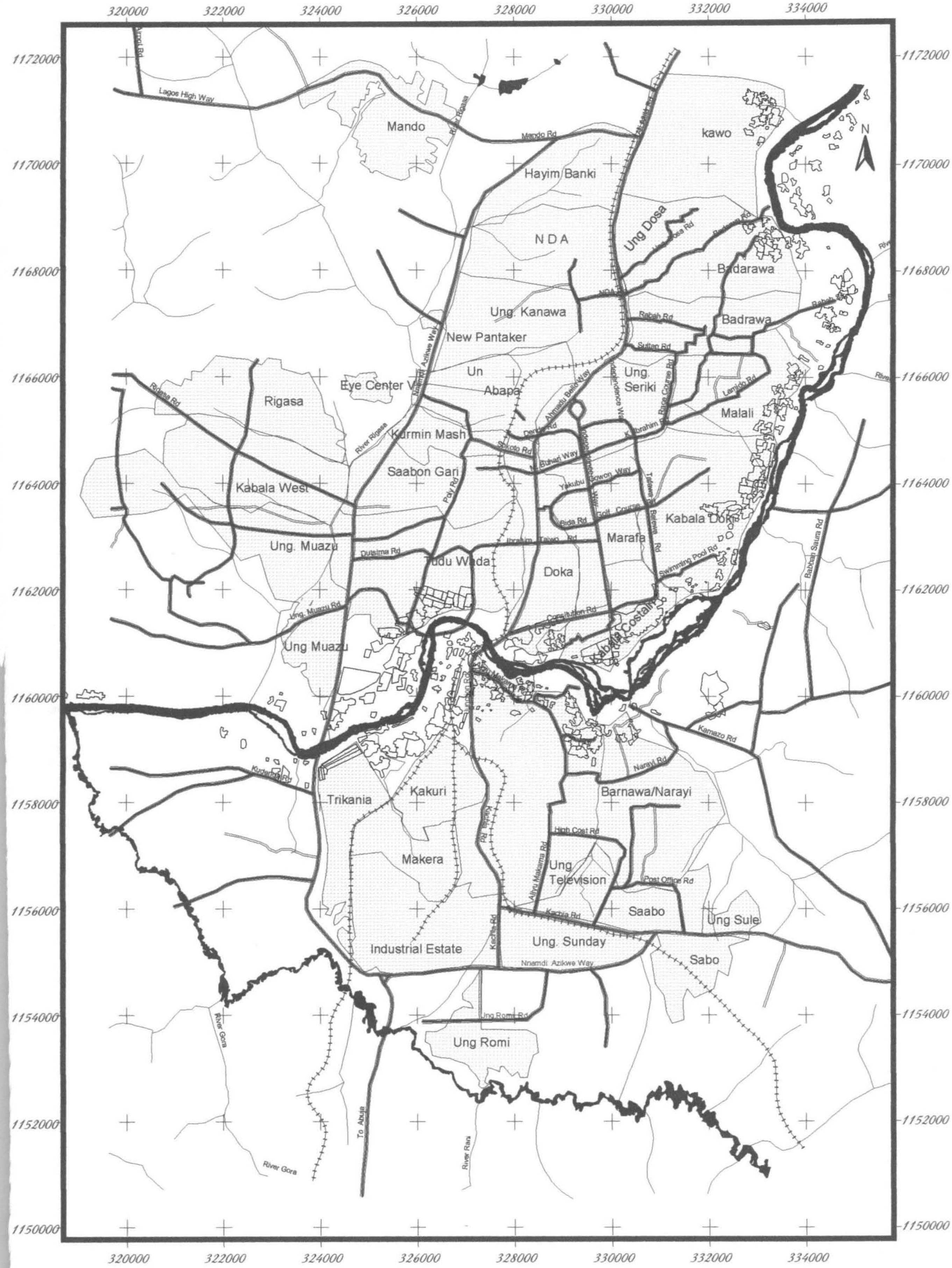
(ii) Create segment map

(iii) Create table



SCALE:- 1: 200,000

Fig. 4.4 NDVI Image Extracted of Bands 2 & 3 of the XS Data



Source: SPOT XS Image 1996

SCALE:- 1:100000

Fig. 4.5 Digital Topographic Map of Study Area

LEGEND

- Major River
- Rail Line
- Dual Carriage Way
- Main Roads
- Other Roads
- Streams
- Closter of Building
- Built_Up Area

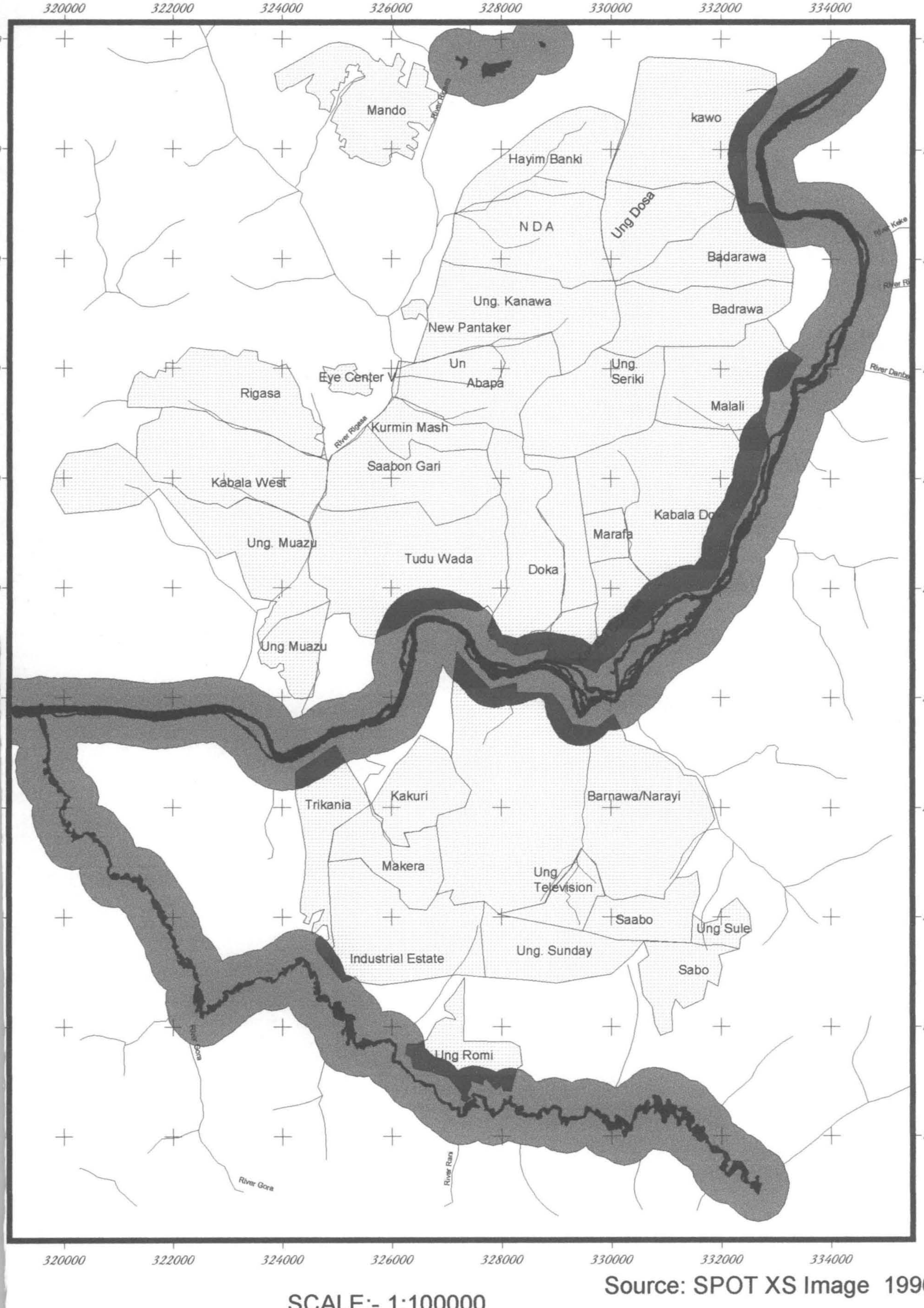
The topographic map was used in conjunction with the delineated flood prone area maps to generate GIS queries to show the built up areas affected by flood and the area covered in square metres.

4.4 Delineation of Flood Prone Areas.

The delineation of the flood prone area was achieved by polygonising the natural drainage of the segment map "friver". A raster map "friver" was then generated and buffered. Buffering generates zones within a given distance of a pre-specified set of data. In order to meet the strict environmental guidelines by Kaduna State Urban Planning Development Authority (KASUPDA), a distance of 500 metres was used as the buffer zone to delineate the flood prone from the natural drainage. The flood prone area is shown as Fig. 4.6

The drainage network was edited for several reasons to eliminate gaps, insert centerlines for lakes and braided channels, eliminate loops and create a less dense stream centerline. Presence of gaps in the natural drainage network can lead to a significant decrease in the area draining into the river. Gaps are eliminated, by extending one river segment to another.

A query was generated to overlay the map obtained with that of the built up area map of the digital topographic map. The result of the query is displayed as Table 4.1



Source: SPOT XS Image 1996

SCALE:- 1:100000

Fig. 4.6 Flood Prone Area

Table 4.1 Attribute Table of Affected Area (500 Metre Buffer Zone)

Attributes of Zone3.shp

Shape	*Name*	*Area*	*ID_*	[illegible]
Polygon	Trikania	2362994	3	429135
Polygon	Doka	3625148	11	352950
Polygon	Kabala Costa	873870	12	464489
Polygon	Malali	3524716	22	443617
Polygon	Ung Romi	1831954	39	690123
Polygon	Industrial E	4669523	40	95281
Polygon	Barnawa/Nara	14668871	41	1083848
Polygon	kawo	5618657	44	620058
Polygon	Kabala Doki	7105355	52	1616007
Polygon	Kabala West	1650449	54	802058
Polygon	Badarawa	2945074	56	398224
Polygon	Tudu Wada	6848154	57	693451

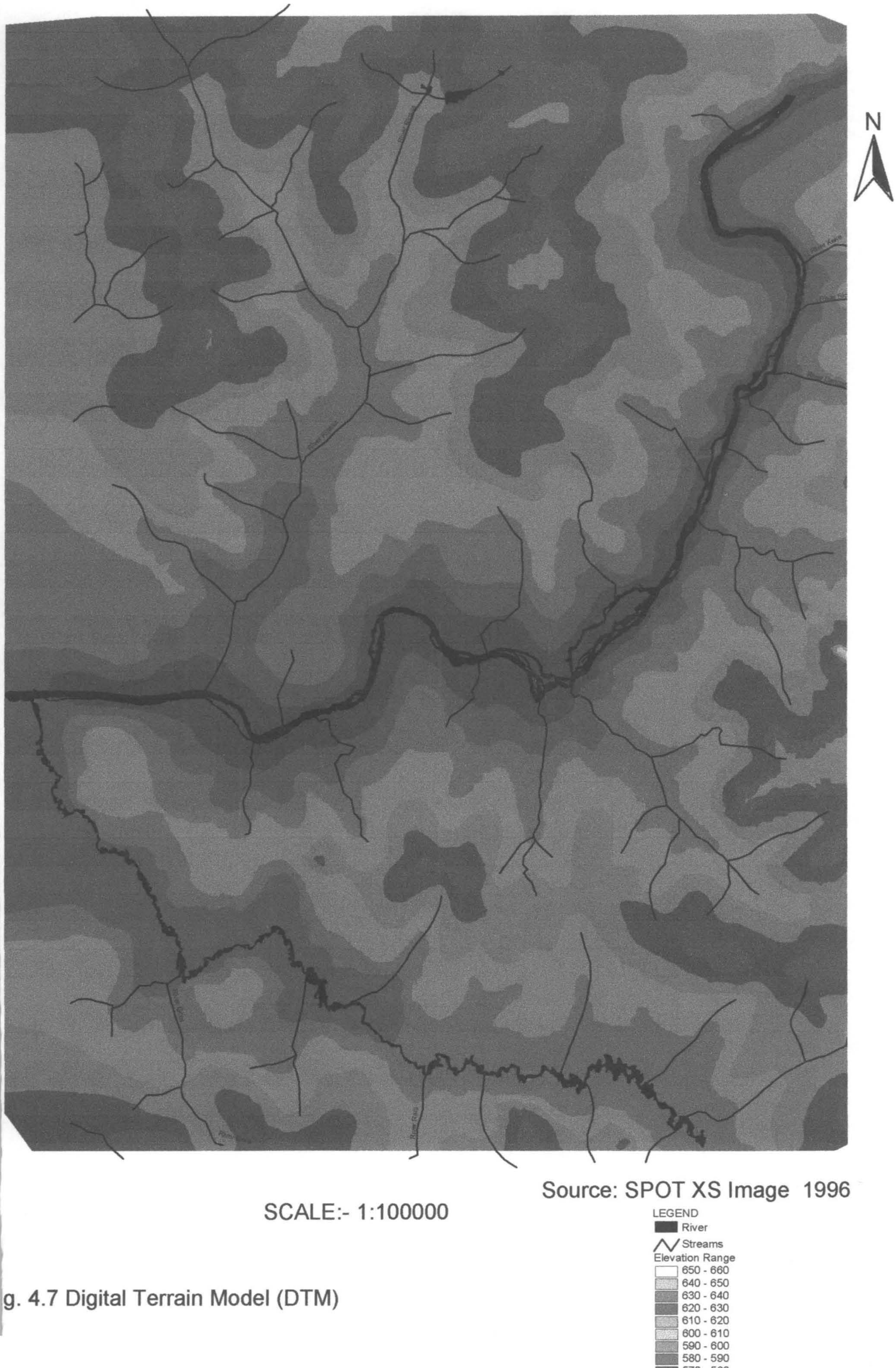
4.5 Generation of Digital Terrain Model (DTM)

The creation of a DTM from the contour segment map "fcontour" was done with the contour interpolation operation. The operation works in two steps:

i. The segment map "fcontour" was converted to raster using the segment to raster conversion module of ILWIS 3.1

ii. A linear interpolation was made between the pixels with attitude values to obtain the elevation of the undefined values in between the rasterised contour lines. The output of this contour interpolation was a raster map "fcontour" in which each pixel in the map has a value.

The digital elevation model was visualized in 3 Dimension using a georeferencing 3D. The view created is shown as Fig. 4.7. The river network was overlayed on the DEM to illustrate the configuration of the terrain.



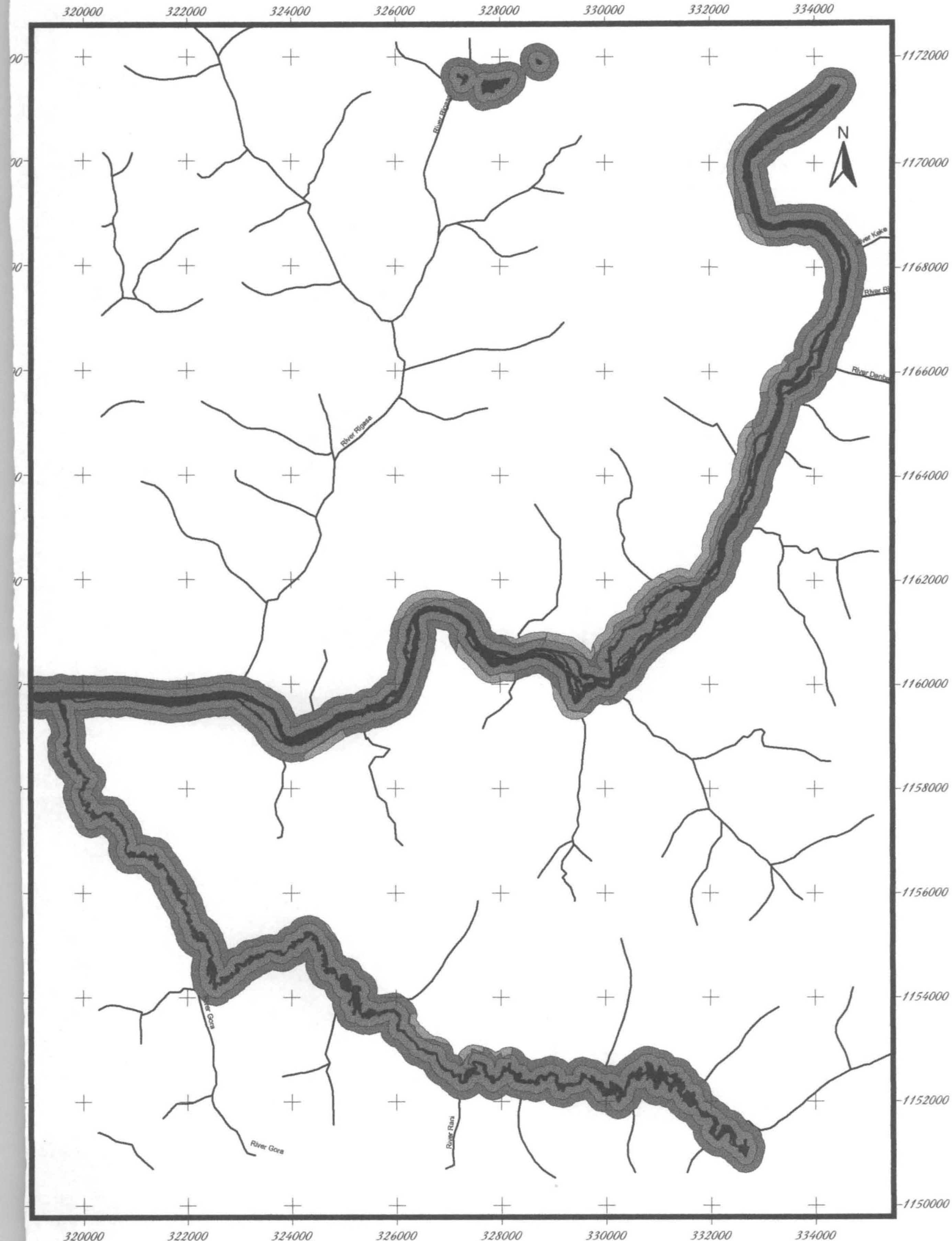
SCALE:- 1:100000

g. 4.7 Digital Terrain Model (DTM)

4.6 Delineating Flood Zones.

A social survey was conducted at Kabala Doki, Kawo, Rigassa, Barnawa , Malali, Angwan Rimi, Angwan Telivision and Tudun Wada area of the study area, to ascertain the distance from the bank of the river to area covered by flood at peak and off peak period of heavy rainfall and discharge from the rivers many tributaries. The average distances obtained were approximated to 300 metres and 150 metres respectively. These distances were buffered from the riverbanks and show as Fig 4.8. The resultant figure was overlayed with the built up areas of the digital topographic map. The result of the query is indicated as Tables 4.2 and 4.3. The area covered by flood in each settlement area where flooding occurs as shown in the tables can be used for risk assessment.

The 3 maps were overlayed and the result is the flood hazard map of the study area shown as Fig. 4.9 with the following representations; .Zone 1 is the Vèry High Risk Area, Zone 2 is the Medium Risk Area and Zone 3 is the Low Risk Area. This map produced identified the communities that are particularly susceptible to damage or destruction by relating risk to human settlements and their structures. It showed areas likely to be covered by water during floods of given magnitude.



Source: SPOT XS Image 1996

SCALE:- 1:100000

Fig. 4.8 Delineated Flood Zones and Drainage Pattern

LEGEND
High Risk Zone
Medium Risk Zone
River
Buffer of 150
Buffer of 300
Streams

Table 4.2 Attribute Table of Affected Area (300 Metre Buffer Zone)

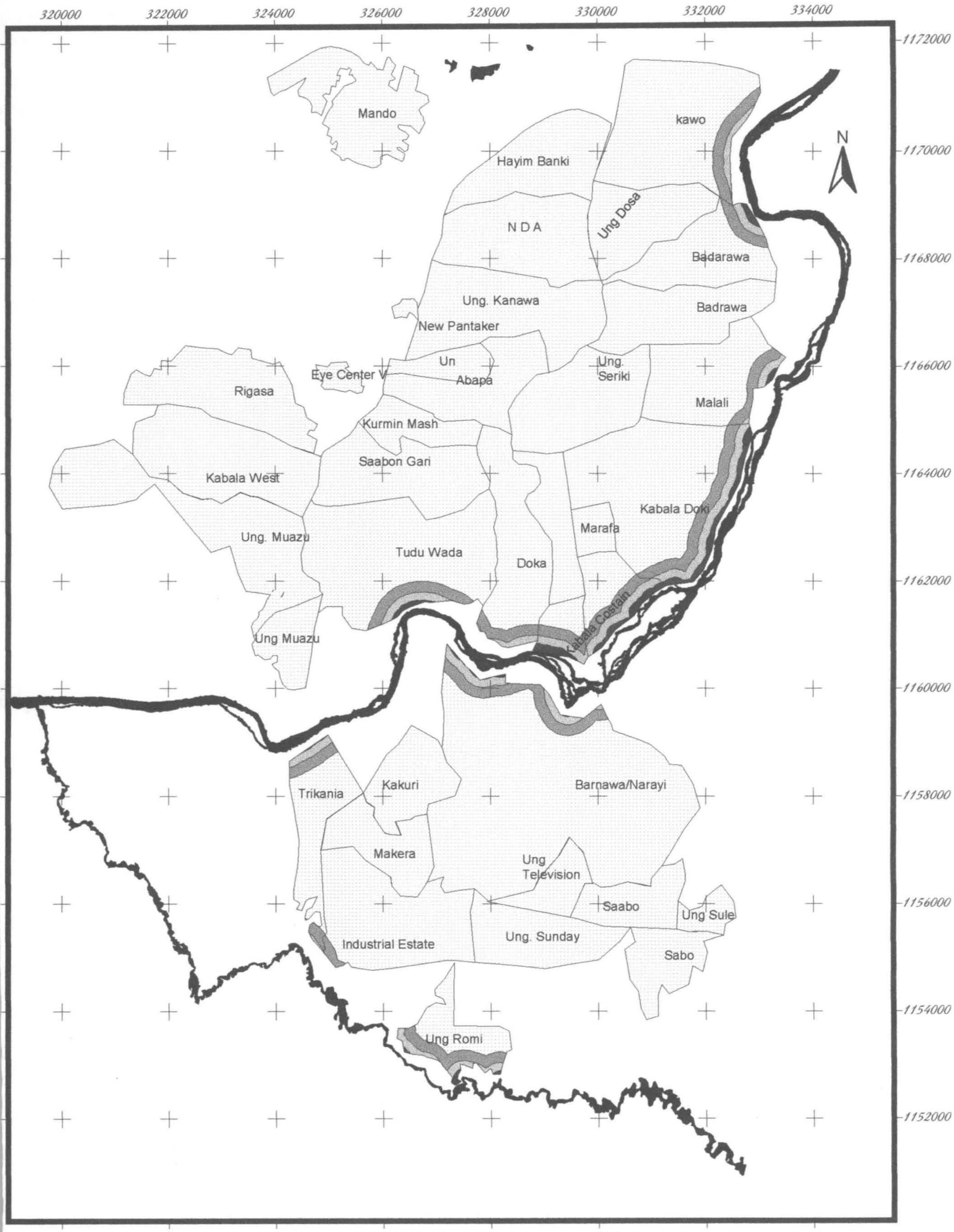
Attributes of Zon2.shp

Shape	Name	Area	ID_	AffectedArea
Polygon	Trikania	2362994	3	151938
Polygon	Doka	3625148	11	97239
Polygon	Kabala Costa	873870	12	262152
Polygon	Malali	3524716	22	142576
Polygon	Ung Romi	1831954	39	258743
Polygon	Industrial E	4669523	40	327
Polygon	Barnawa/Nara	14668871	41	363595
Polygon	kawo	5618657	44	164709
Polygon	Kabala Doki	7105355	52	886310
Polygon	Kabala West	1650449	54	481521
Polygon	Badarawa	2945074	56	167873
Polygon	Tudu Wada	6848154	57	255689

Table 4.3 Attribute Table of Affected Area (150 Metre Buffer Zone)

Attributes of Zone1.shp

Shape	Name	Area	ID_	AffectedArea
Polygon	Trikania	2362994	3	7114
Polygon	Kabala Costa	873870	12	103333
Polygon	Malali	3524716	22	27406
Polygon	Ung Romi	1831954	39	40222
Polygon	Barnawa/Nara	14668871	41	24404
Polygon	Kabala Doki	7105355	52	332998
Polygon	Kabala West	1650449	54	182462
Polygon	Badarawa	2945074	56	53110
Polygon	Tudu Wada	6848154	57	57420



Source: SPOT XS Image 1996

SCALE:- 1:100000

ig. 4.9 Flood Risk Zones

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

The study was aimed at delineating flood prone areas and creating a flood hazard map showing the various degree of vulnerability of the study area. Serious flooding in our communities always leads to massive loss of means of livelihoods and in some cases human lives.

The remotely sensed data used for the analysis was the SPOT Multispectral image dry season of December 1996. The chosen SPOT image was able to distinguish the contrast between areas bordering the natural drainage riverine floodplains and areas away from the natural drainage that have little or no moisture cover at dry season. In addition the image was also able to display this contrast.

Computer hardware and software were used for the analysis. The ILWIS 3.1 image processing software was used for the analysis. The satellite image and the Digital Terrain Model (DTM) data obtained from a topographic map of the study area were imported into the ILWIS software, analysed and the resulting images were queried and the result printed with the text report.

The SPOT Multispectral image data was enhanced using both spatial and spectral methods. The median filter and the linear contrast stretching method were adopted. This was to highlight those areas along the natural drainage that may be susceptible to future flood. The process was expected to highlight pixels covering thickly vegetated and riverine floodplain areas.

In order to compliment the satellite data derive information for proper interpretation of analysed results, points along the natural drainage were arbitrarily selected and groundtruthing was done. The groundtruthing involved a field survey carried out in order to compare radiances on the satellite image with information on the ground.

A digital topographic map was generated from the colour composite of the 3 bands of the SPOT's image data. The digital topographic map shows the settlement patterns, road networks and drainage system. A field survey was carried out for field completion, which centred around collection of names for settlements, roads and rivers where possible.

Analysis of the composite image shows that the area having a riparian vegetation throughout the seasons of the year are influenced by moisture supply from the natural drainage and therefore expected to become flood prone areas in future.

A normalized differential Vegetation Index (NDVI) image was produced. The purpose was aimed at distinguishing areas that are covered by vegetation from those covered by baregrounds (which also show strong reflection property close to that of vegetated areas). These baregrounds in reality are neither floodplains or vegetated. The resultant image shows that the areas that are thickly vegetated along the main natural drainage runs from the west to the eastern sub regions

The floodplain was delineated using the Kaduna State Urban Development planning law for buffering. Field survey was carried out to delineate the other flood zones at peak and off peak periods of rainfall. An overlay of this flood zones was used to prepare a flood hazard map that was classified as very high risk, high risk and low risk areas.

5.2 Conclusion

It may be observed that Geographic Information System (GIS) provides a broad range of tools for determining area affected by floods and for forecasting areas that are likely to be flooded due to high water level in a river. Spatial data stored in the digital database of the GIS in the form of a digital elevation model (DEM) can be used to predict the future flood events. The GIS database may also contain agriculture, socio-economic, communication, population and infrastructural data. This can be used in conjunction with the flooding data to adopt an evaluation strategy, rehabilitation planning and damage assessment in case of critical flood situations.

Remote sensing on the other hand as a tool can very effectively contribute towards identification of hazardous areas, monitor planet for its changes on a real time basis and give early warnings to many impending disasters. Satellite data can be used very effectively for mapping and monitoring the flood inundated areas, flood damage assessment, flood hazard zoning and past flood survey of river configuration and protection work.

Terrain analysis plays a significant role in the understanding of the dynamic of the process resulting in flooding. It is also seen that a topographical map plays a significant role in this direction. The use of traditional land surveying methods to produce a topographical map is time consuming. The best option to meet up with the challenge of threat posed by these phenomena is by embracing the use of aerial photographs / and satellite imageries.

5.3 Recommendation

In the present era of electronic communication, the Internet provides a useful platform for disaster mitigation communications. The government can launch a well-defined web site, which is a very cost effective means of making an intra-national and international presence felt. It provides a new and potentially revolutionary option for the rapid, automatic, and global dissemination of disaster information. A number of individuals and groups, including several national metrological services, are experimenting with the Internet for real-time dissemination of weather observation, forecasts, satellite and other data. In the most critical phase of flood disasters, electronic communications have provided the most effective and in some instance perhaps the only means of communication with the outside world.

The armed forces of the country can play a vital role during flood disasters emergencies providing prompt relief to the victims even in the most inaccessible and remote areas. The organizational strength of the armed forces with their disciplined and systematical approach, and even with their skills in technical and human resource management make them indispensable for such emergency situations.

Natural disasters are huge economic burdens on developing economies such as Nigeria. It is absolutely necessary to create awareness amongst the public as well as decision makers for allocating resources for appropriate investments in information technology (GIS and remote sensing).

Any future studies should include the use of high spatial resolution images so that boundaries of potentially floodable areas would be easily seen and demarcated. To this, the SPOT Panchromatic data (having a 10 metre spatial resolution) can be used to improve details of surface features. Also, high-resolution image data sets like aerial photographs and those generated by other earth observation satellite like Ikonos and Quickbird provide data at 1 metre (or less) resolution and can therefore be used to achieve a much improved and better results.

For this study, the Digital Terrain Model (DTM) was derived from a topographic map of the study area. Future studies should include the use of data with satellite derived DTM files, for ease and convenience of DTM extraction and for better perspective display of results. Data format of the SPOTOrtho (from spot 4 and 5 satellite) image format provides elevation data for every pixel of the image.

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