MAPPING OF POTENTIALLY FLOODABLE AREAS OF MINNA ENVIRONS IN NIGER STATE USING REMOTELY-SENSED DATA

BY

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (M.TECH) IN REMOTE SENSING APPLICATIONS

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DECLARATION

This is to certify that I, **SALIHU SAIDU** (REG. NO: M.TECH/SSSE/607/2000/2001), carried out this project, titled "Mapping of Potentially Floodable Areas of Minna Environs in Niger State using Remotely-Sensed Data". 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.

....	27/11/2003
SALIHU SAIDU (STUDENT)	DATE

CERTIFICATION

I certify that this project titled "Mapping of Potentially Floodable Areas of Minna Environs in Niger State using Remotely-Sensed Data" was duly carried out by **SALIHU SAIDU** (REG. NO: MTECH/SSSE/607/2000/2001), 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.

.... 2/12/03

DR G.N. NSOFOR (PROJECT SUPERVISOR) — DATE

.... 2/12/03

DR (MRS.) A.E. ODAFEN (HEAD OF DEPARTMENT) — DATE

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EXTERNAL EXAMINER — DATE

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PROF. J.A. ABALAKA (DEAN, POSTGRADUATE SCHOOL) — DATE

DEDICATION

This project is dedicated to the most poor of the world, who are the chief victims of all forms of environmental problems and poverty in all communities of this planet.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude to God Almighty for giving me the strength and ability to be able to carry out and complete this project successfully.

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I would like to state here that the motivation to do digital image processing for my work is attributed basically to the training obtained at the ESA's European Space Research Institute (ESA-ESRIN), Frascati (Rome), Italy, on the UN/ESA traineeship programme, during the year 2000. Specifically, I would like to commend the effort of my then Supervisor, Dr Juerg Lichtenegger and his colleague Dr Maurizio Fea. I would also like to commend the contributions of other people in the Agency, such as Mr. Andrea Bellini, Mr. Nicholas Walker and a one-time Azerbaijani trainee, Mrs. Sharafat Gadimova (and a host of others) – for their useful contributions.

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ABSTRACT

This work, titled "Mapping of Potentially Floodable Areas of Minna Environs using Remote Şensing Data" was aimed at determining those areas on the outskirt of Minna city that would, in the future, become susceptible to flooding. The assumption was that since the built-up core region of the city is being continuously paved, runoff in the main drainage channels on the outskirt is bound to increase, arising from reduced infiltration upstream. This may lead to severe problem of flooding and other forms of ecological problems in areas banking these drainage channels.

Remotely-sensed satellite data of the study area was used to infer (through radiance of thick vegetation) the most immediate areas along the drainage banks, that could be affected by future flooding. SPOT 3 Multispectral data was used to determine areas of thick vegetation and floodplains that reflect highly in the Near-Infrared band. Another parameter, the Normalised Difference Vegetation Index (NDVI) was also used in the analysis to single out those areas of thick, healthy green vegetation along the banks of the drainage channels. Finally, surface data was produced, through manual digitization of elevation map of the study area to create a Digital Terrain Model (DTM), in which the analysed satellite image was draped on to have a perspective view. Analyses results indicate that remotely-sensed data can be used to map those areas bordering the main drainage channels on the outskirt of Minna city, which could be liable to flooding in the future. The results also demonstrated the potential for using remotely-sensed data for the analysis of large areas and/or inaccessible environments.

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CHAPTER ONE

INTRODUCTION

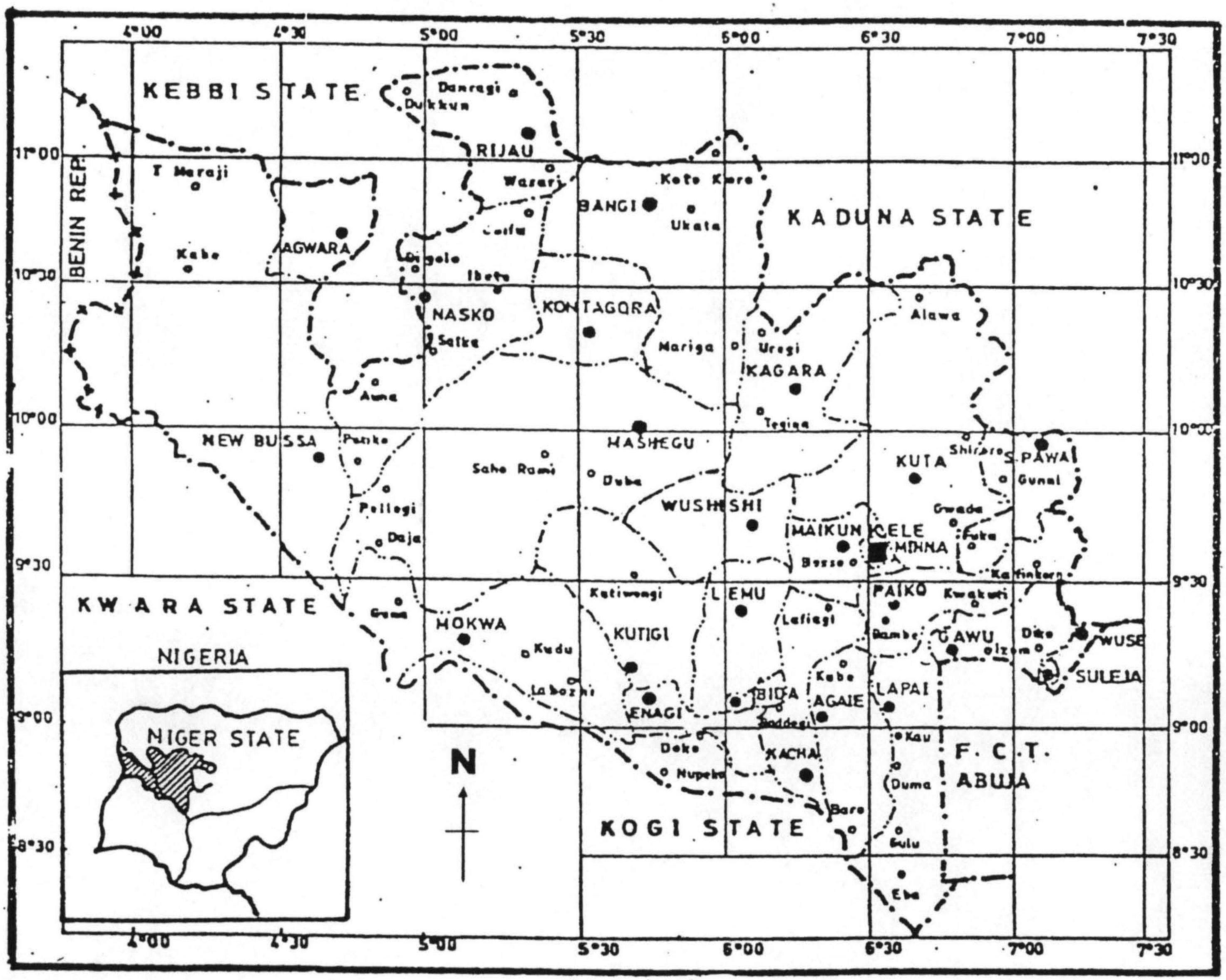
1.1 Background to the Problem

Urbanization is accompanied by concreting of city surfaces. This leads to decreased infiltration and the consequent increase in runoff volumes. Large drains normally terminate around the outskirts of cities, which are then subjected to serious erosion problems. The materials transported are deposited at locations farther on the outskirt locations of the city, which are then consequently blocked, leading to serious flooding.

The outskirts of the city, where the drainages terminate are consequently affected by increased runoff, which tend to produce problems such as erosion and flooding. But because cities (especially cities in the Developing World) are constantly expanding, these areas on the outskirts would in the future be inhabited areas plagued with severe problems of uncontrolled land degradation. Minna (see Fig.1.1), the capital city of Niger State, is one of such cities affected by land degradation around drainages on the city outskirts.

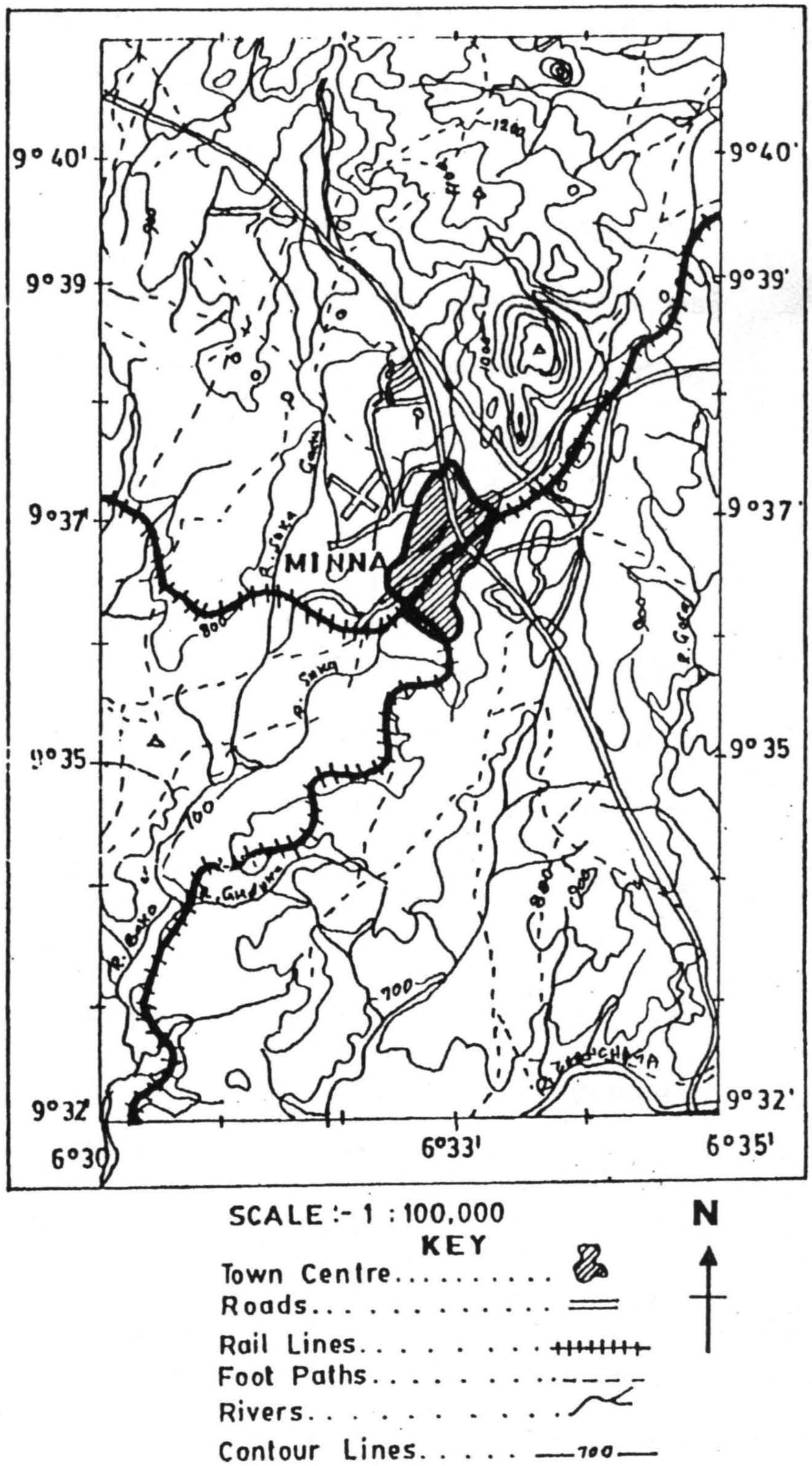
1.2 Problem Statement

With the completion of the Minna city main drainages (during the early 1990s), severe environmental problems have increased around the outskirt areas. No data are available to use for address this problem over a large part of the city



Source: Adopted from Ogunrinde (2000)

Fig. 1.1. Map of Niger State, Nigeria



Source: Minna Topographic Map (1967)

Fig. 1.2 Topographic Map of Minna Area.

- 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 thick, 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.
- Displaying the result of the classified satellite image in three dimensions, so as to better appreciate the morphology of the land, and especially to view possible floodable areas along the drainage channels in an appealing and realistic manner. This was achieved by generation of Digital Terrain Model (DTM) of the study area, through manual digitization of elevations from topographic map of the study area.

1.4 Justification

Environmental degradation problems of erosion and flood types lead to loss of potentially viable lands such as agricultural lands, urban lands and roads. Minna, the Capital of Niger State (like all other cities), is experiencing a rapid expansion arising from the effect of rural-urban migration. The city center is being continuously paved and the major drains are being modified. The outskirts, on the other hand, are being degraded.

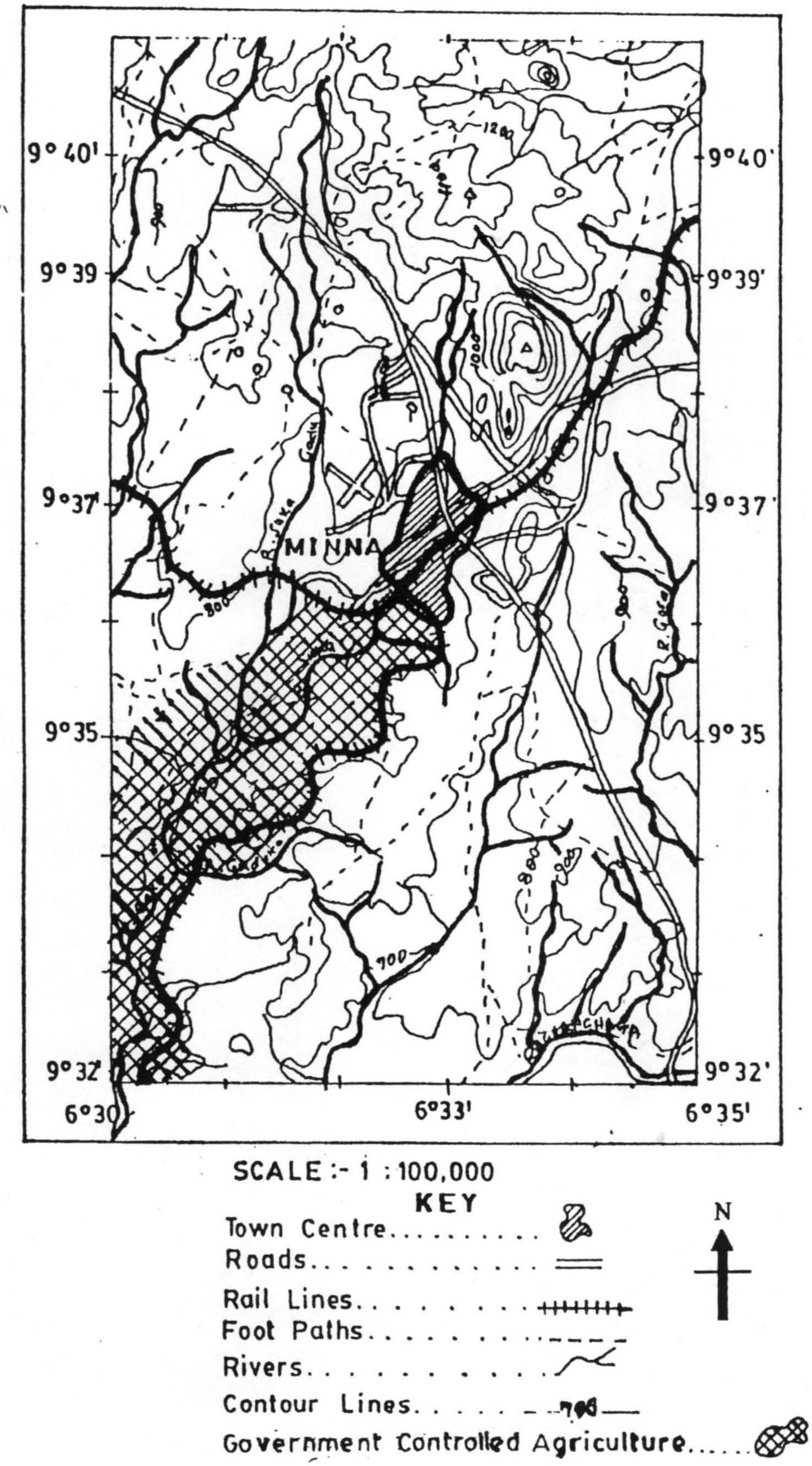
Flood and erosion have therefore reduced in the built-up areas while they increased on the outskirts. It is therefore necessary to map areas on the outskirt of Minna, which may continue to experience future hazards. This would serve as a viable input to policy-makers in management of land degradation problems in the study area. Fig. 1.3 is an Open Space Policy map enclosing the study area showing sections bordering the banks of these major natural drainages, which have been in the past reserved and projected for various future landuses, such as Government Controlled Agriculture. Thus, increased flooding in the study area would mean deterioration of reserved land potentially viable for future landuses.

1.5 Study Hypothesis

Remotely-sensed data and analytical techniques can be used efficiently in mapping potentially floodable areas over large and/or inaccessible areas on the outskirt of cities.

1.6 Study Area

Minna, the Capital of Niger State and Headquarters of Chanchaga Local Government Area is located at 9°37' and 6 °33' (Niger State Government, 1980 and Iloeje, 1981). It lies on a Basement Complex rock of mainly gneiss and magmatite situated at the base of hills to the north and east in an undulating plain (Lawal, 2000).



Source: Niger State Government (1980)

Fig. 1.3 Minna Open Space Policy Map

The general morphology of the land shows steeply sloping rock outcrops forming a physical constraint on the east side while a major drainage valley flows from the center of the town southwestward with many minor drainage channels feeding into it with storm water runoff from the hills to the east (Ibrahim, 2000). The northeastern part of the town is covered by continuous steep outcrop of granite limiting any significant urban development in that direction (Niger State Government, 1980). Fig. 1.2 is a topographic map of Minna, showing the main drainage networks. The area under study is between longitude 6°30′ to 6°35′, and latitude 9°32′ to 9°37′. Fig. 1.3 is an Open Space Policy map, showing areas adjacent to the main drainage networks reserved for future landuses.

Annual rainfall for Minna is about 1334mm (52 inches). The highest mean monthly rainfall occur in September with almost 300mm (11.7 inches). The rainy season starts on average between the 11th–20th April and lasts between 190-200 days. The mean monthly temperature is highest in March at 30.5°C (87°F) and lowest in August at 25.1°C (77°F).

The present town drains into the River Suka, which runs from northeast, traversing the city center, and then towards the southwestern outskirt of the city, picking up tributary drainage watercourses (see Fig. 1.3). The minor drainage channels feed River Suka with storm water runoff from the hills to the east. In many places, these streams form large areas of floodland. Lands beyond the presently developed strip is suitable for development but needs careful planning to keep engineering cost of culverting, bridges, embankments and drainage works as reasonable as possible (Niger State Government, 1980).

1.7 Scope and Limitations

This project was limited to the southern outskirts of Minna, due to the fact that the topography of Minna indicates a general sloping towards the southern part of the city, and the urban drainages have been modified through the construction of efficient drains. The satellite data used for the dry season period was only for December period, as no other data was available for a much drier date (such as from January to April) in order to provide better contrast between the evergreen vegetation along drains and areas away. Also, the SPOT data format used in this analysis does not have a digital elevation model (DEM). Therefore, a topographic map of the study area was manually digitized and used to supplement the DEM data.

1.8 Structure of Thesis

The thesis is structured in the following order: Chapter One forms the introductory chapter. Chapter Two centers on literature survey conducted for the work. Chapter Three discusses data used and the methods employed in the analysis of the data. Chapter Four centers on the analysis carried out and interpretation of results. Lastly, Chapter Five discusses the conclusions reached and the recommendations for further possible work to be done.

CHAPTER TWO

LITERATURE REVIEW

2.1 Drainage Channel Changes

Rivers, lakes and other hydrographic features are very important in studying the hydrography of a specific geographic area. These elements of the physical landscape are in some instances the only relatively permanent exterior geographical features on many maps.

The flow of water and associated sediments and contaminants in lowland channels is as a result of complex geometry and the seasonal effects of vegetation growth on the bed and banks interacting with changing discharges. Three dimensional variations in channel shape and vegetation characteristics may have an important effect on flow and transport processes by creating zones of increased shear stress at the bed or bank, or 'dead zones' separated from the main flow by localized lines of lateral shear (Carling & Petts, 1992).

Man also contributes significantly to changes in channel morphology. Floods are caused not only by rain but also by human activities on the surface of the earth, such as farming, deforestation and urbanization. These actions increase the runoff from rains; thus storms that previously would have caused no flooding today inundate vast areas (Humanity Development Library, 2000). Two broad types of man-induced changes can be identified: those changes brought about by direct modification to the channel itself, which often take the form of engineering works designed to alleviate the effect of flooding, erosion or deposition; indirect changes resulting from activity in extra-channel areas which modify discharge and load in the stream and ultimately result in stream channel response (Knighton, 1993).

Another factor for man-induced changes on stream channel morphology is land use changes. This has to do with determination of the alteration of runoff and erosion conditions in extra-channel areas to produce a given type and amount of stream channel adjustment. Major similar landuse changes include: forest clearance for cultivation or grazing and urbanization.

Forest clearance leads to accelerated erosion on hill slopes and consequent increased sedimentation. Urbanization represents a more localized change in land use, but its effect may nevertheless be profound downstream. The creation of impervious surfaces and installation of more efficient drainage systems in urban areas increase both the volume of runoff for a given rainfall and the magnitude of flood discharges (Knighton, 1993).

Umoh (2000), reported on the problems of Niger River Basin as related to Climate Change, that urbanization has compounded flood and erosion problems, through alteration of soil cover of woodland savannah, built-up slopes and valleys. As indicated, the sloping landscapes in the Niger River Basin suffer from erosion and wash-off (of topsoils) while the flat bottom terrains are perennially flooded. The report also added that Minna city itself was in the past ravaged by occasional seasonal floods. The study, gave account of the 1986 flood disaster that destroyed lives and livelihoods in the mostly highly urbanized sections of the city, but no account was given for the suburb areas, and especially, sections downstream of the points where the artificial drainage systems terminate.

The outskirt areas are vulnerable to flooding, and therefore, need to be assessed. The aim of vulnerability assessment is to provide decision-makers with information as to where and when interventions should be made, and in what form. Such assessment should also provide indication as to what risks for development exist in specific locations within a watershed basin. In other words, vulnerability assessment should produce information for specific target areas, thus providing an early warning system to alert people to potential dangers from flooding (UN-Habitat, 2001).

2.2 Floods along Drainage Channels

Flood can be defined simply as a flow which overtops the stream banks. Floods affect the ecology of a stream by rearranging streambed habitats, scouring away aquatic or riparian plants and increase the drift of aquatic insects (Gordon et al., 1993).

According to Lillesand and Kiefer (1994), river floodplains are as a result of stream adjustments to its environment in order to carry its load efficiently. They are primarily from deposition of fine sediments on the floodplain at any time flood occurs. This sediment deposition leads to siltation where the stream flows at higher elevation, thereby leading to possible overflowing of the riverbank. Also, Umoh (2000) added that floodplain flooding occurs when excessive discharge cannot be contained within the confines of river channel particularly between the months of July and September in the Niger Basin area.

Knighton (1993) has shown that socioeconomic and anthropogenic activities have been found to induce or intensify flood condition in our environment. Through land use, the basins of streams traversing cities are now made impervious by the roof of buildings, paved surroundings and tarring of roads. In addition, the built-up areas have also increased in most cities.

The result of increased built-up areas is a greater and increased concentration of storm water in river and stream channels and a greater high stream flow. Building and farming activities within a basin lead to increased sediment yield (as a result of erosion of the exposed slopes). Floods can also damage human settlements, force evacuations, damage certain crops (especially tubers), damage food stocks, strip farmland, wash away irrigation systems, erode large areas of land or make them otherwise unusable, and may change the course of streams and rivers (Humanity Development Library, 2000).

2.3 Remote Sensing Image Data for Mapping Floodable areas

Flooding is a major hydrological hazard with a high frequency of occurrence, with an average of about 100 serious floods each year around the world. These significant rise in water level range from severely overflowing streams, lakes or reservoirs to major ocean-driven disasters in exposed coastal regions (ESA, 1998).

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.

Baba (1998) reported the work done on the application of Landsat data in terrain analysis and floodplain delineation of the Sokoto-Rima river system in northwestern Nigeria and shows how floodplains could be easily delineated for a large part of the river system. The report demonstrated that radiances from different landcover types could be easily identified, providing opportunity for accurate delineations over large and inaccessible areas.

Elukpo (1998) reports on the landuse configuration study of Goronyo, Sokoto State, using Landsat MSS imagery. The result of the study indicated that remotely-sensed satellite data provides a viable option for landuse studies, compared to conventional field surveys over large areas, and by the speed of data analysis.

According to Howard (1992), the topography of floodplain is poorly analysed and could be investigated profitably using Remote Sensing techniques. Floodplain topography is enormous, but little studied, due to lack of adequate spatial coverage on conventional field surveys. Studies conducted using Landsat scenes by different researchers also highlight the potential of using remotely-sensed data for identification of flood-prone and potentially floodable areas. As shown by Gammon and Carter (1979), which reported on the use of aerial data in vegetation mapping with seasonal colour infrared photographs, data obtained within the Near Infrared portion of the electromagnetic radiation could be used in mapping inaccessible wetlands with great success.

Patrick and Abdulmalik (1989) reported on the use of aerial photographs and questionnaire methods in studying the impact of dam construction on the downstream morphology and agricultural productivity in Kano State, Nigeria. The report shows that the aerial photographs were used efficiently to map and predict floods, waterlogging and erosion. The report demonstrated that remotely-sensed data is quite the best optional input for delineating different landcover types.

In the report of Olawale (1998), on the use of remotely-sensed (aerial photographs and Landsat MSS image) data in studying the causes of river flooding of River Osun in Ikere-Ekiti, Ekiti State, Nigeria, the study concluded that areas prone to flooding could easily be determined. The report added that both natural and unnatural causes are responsible for increased flooding in recent times in the study area. The report also found that expansion in built-up areas (especially towards the floodplains), the presence of large barren land, the extension of agricultural practices at the upper course of the river and deforestation are responsible.

Owolabi (2000) reported on a work done on water volume seasonal change determination for the Kainji Lake, Nigeria, using SPOT XS satellite image and climatic data. Estimations of water volume were done, using different dates of different seasons of the year by analyzing the width changes of the reservoir from satellite data, and gauge height and evaporation data from hydrometeorological data. Results showed that the large area coverage of SPOT satellite data provided a valuable input for the seasonal varying aerial extent of the Kainji reservoir. Thus, remotely-sensed data serve as a potentially viable tool for most environmental analyses.

Ibrahim (2000) used remote sensing approach to study the transitionality of Abuja vegetation for the period range 1976-1994, using Landsat MSS and SPOT XS data. In the study, vegetation types were classified into four types: woodland, mixed woodland, montane forest and riparian. The changes for the study period indicated that many factors contributed to the destruction of vegetation, among which were farming, animal grazing, fuelwood removal, road construction, expansion of settlement and resettlement. The riparian vegetation for example, consisting of trees growing along the bank of rivers in the study area, has disappeared by 1994 and has been replaced mainly by cropland (with produce like banana and plantain) and partly by transportation routes. The result illustrated the potential of using remotely-sensed data in efficient mapping of different landcover types.

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 range 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).

2.4 SPOT Image Data

The SPOT satellite series are satellites that carry High Resolution sensors that image in the optical band of the electromagnetic spectrum (Lillesand and Kiefer, 1994). The High Resolution Visible (HRV) operates in either of two modes of sensing:

i. a 10m-resolution 'panchromatic' (gray) mode over the range 0.51 to 0.73μm; or

ii. a 20m-resolution multispectral mode over the range 0.50 to 0.59μm, 0.61 to 0.68μm, and 0.79 to 0.89μm.

Because the two HRV sensors are positioned to obtain data at off-nadir viewing angles, it is therefore possible (with a suitable image processing software) to view images stereoscopically. This three dimensional impression is useful in studies related to the morphology of the land, such as in the field of major drainage channel morphology studies. However, Lillesand and Kiefer (1994) have shown that stereoscopic viewing is only possible with at least two revisit scenes (stereopairs). Thus, single scenes cannot be used to produce stereoscopic view of an area.

The two SPOT image formats (the panchromatic and the multispectral bands) have their advantages and disadvantages over each other (depending on the application to be used in). Van der Laan (1987) has shown that in some applications the panchromatic band would best be used while in others the multispectral would do best. Table 2.1 illustrates the suitability of different sensor products for particular land cover applications.

Table 2.1 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	80
Asphalted roads	90	70	50
Dirt roads in low-contrast environment	30	10	0
in high-contrast environment	100	100	40
Rivers	100	100	100
Canals (width 20m)	70	90	100
Canals (width 8m)	0	10	10
Hedgesrows (width 30m)	100	100	100
Hedgesrows (width 20m)	70	80	90
Hedgesrows (width 10m)	40	40	30
Countryside houses	90	90	100
Houses in built-up area	80	40	0

Source: *Adopted from Van der Laan (1987)*

From Table 2.1 above, it can easily be seen that for canals of different dimensions, the three types of data (SPOT Panchromatic, SPOT Multispectral and Landsat TM) differ in terms of how visible they could be. For canals of 20 meter width, Landsat MSS shows 100% clarity while SPOT Multispectral and SPOT Panchromatic show 90% and 70% respectively. In the case of canals of about 8-meter width, Landsat MSS shows 10% clarity while SPOT Multispectral and SPOT Panchromatic show 10% and 0% respectively. In all respect, therefore, between the two SPOT image formats, the SPOT MSS image format gives more clarity to the drainage channel than SPOT Panchromatic. It is therefore best suited for studies involving drainage channels. However, the merger of the two types of data would greatly enhance details under study.

Ononiwu (1990) has shown that SPOT is capable of use in mapping stream channel depth, slope and channel widths. Depending on the levels of images in SPOT, a Digital Elevation Model (DEM) can be derived for use in mapping morphological features. But in the case the processing level of the data obtained, or the software to use does not support the DEM extraction process from the raw data, the IDRISI32 Reference Manual (2001) has shown that a DEM extracted manually from digitized elevations on topographic maps can be used to generate height data for use with any kind of satellite data.

The review of studies conducted above indicates that environmental problems (including floods) on the outskirt of urban areas exist, and are being neglected by the society. These problems greatly affect ecosystems and potentially viable areas for future agricultural activities, as well as settlements. 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 various forms of environmental problems. The advantages and facilities provided by these will be explored in the present study.

CHAPTER THREE

DATA AND METHOD OF ANALYSIS

The main objectives of this project work include: performing spectral enhancement on SPOT multispectral satellite image to highlight floodplains and areas thickly vegetated along the natural drainages (riparian vegetation-covering areas liable to flooding) against the surrounding sparsely vegetated surrounding areas; generation of Normalised Difference Vegetation Index (NDVI) image, which would also show areas with thick, healthy vegetation (influenced by moisture from the drains, as such, could be flooded) along the major drainage channels; and, presentation of analysed image in three dimensions, through manual digitization of elevation map to simulate a digital elevation model to be added as height data, to the satellite data, so as to provide a better perspective view of areas within drainage valleys that are potentially floodable. A comprehensive detail of the procedures for the overall analyses is illustrated in a chart in Fig. 3.1.

3.1 Satellite Data

There are two classes of data for this project work. They include: SPOT (*Systeme Pour l'Observation de la Terre*) 3 Multispectral (XS) digital satellite image data, Level 2B format of 3rd December 1994; digitized elevations (Z) and X and Y UTM co-ordinates, from topographic map of the study area, Sheet 164

Fig. 3.1 SPOT XS Enhanced, NDVI and Orthomap images Generation Chart

(1967), on an R.F. scale of 1:100000. The image data was used to analyse and map areas adjacent to the natural drainages that are liable to flooding while the XYZ data was used to generate a digital elevation model, which was added to the satellite data to provide a more appealing perspective view of the study area.

Step1: SPOT Multispectral Data Geometric Correction

The SPOT image used is SPOT 3 Multispectral dry season (Dec., 1995) digital satellite data. The multispectral image contains data in 3 spectral bands: Green (0.5–0.59μm), Red (0.61–0.68μm) and Near Infra-red (0.71–0.89μm). These bands are optical bands. It is a Level 2B, which has a high level of both radiometric and geometric corrections. As such, no further geometric correction need be performed on this data format.

Step 2: SPOT Multispectral Data Haze Removal

The first step in multispectral data image analysis is removal of Haze (Path Radiance). Smith (2000b) has shown that for the visible band, the smaller wavelength bands are affected more by atmospheric scattering. So, combining the three multispectral bands of the SPOT image in a colour composite would require the removal of this haze from the bands most affected.

For this analysis, however, the IRDISI32 software has shown that when the raw satellite image data is radiometrically stretched using the Linear with Saturation Stretch option, the inherent noise would be effectively removed. Therefore, the

Linear with Saturation Stretch operation performed in Section 4.1.1 is expected to have taken care of the haze effect.

Step 3: SPOT Multispectral Data Radiometric Enhancement

Radiometric enhancement is a necessary operation in image processing. It aims to highlight features that may otherwise appear blurred on the originally imported raw digital image.

The subset image discussed above was imported into IDRISI32 image processing software for the radiometric enhancement. Both Spatial and Spectral enhancements were performed on the image. Spatial enhancement is done normally to generalize and/or enhance boundaries between and among different landcover types. Spectral enhancement aims to highlight the differences among pixels with high and low intensities. Spectral enhancement is also performed in many stages, which include Haze (Path Radiance) removal and Histogram and Look-Up Table modification.

Step 3a: SPOT Multispectral Data Spatial Enhancement

Spatial enhancement has to do with image filtering. This allows some level of generalization for some adjacent pixels so as to make features more easily identifiable and interpretable. There are different types of filters used in image processing. But the type used for this work was the 3x3 Median filter. The IDRISI32 Reference Manual (2001) has shown that this filter preserves edges, as well as smoothens local variations of radiances through averaging of pixel values. This is because the areas adjacent to the major natural drainages are characterized by dense vegetation, which, by enhancing the edges and averaging local variations, would bring out clearly, the boundaries between the thickly, and the moderately vegetated areas.

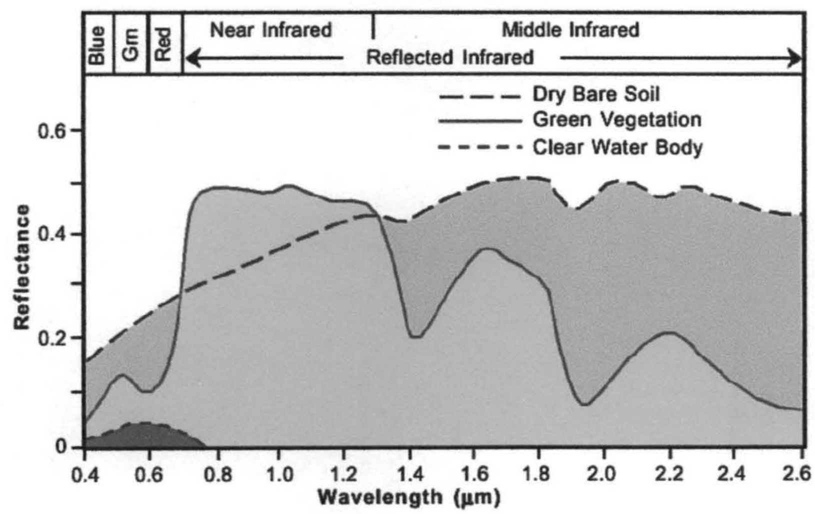
Step 3b: SPOT Multispectral Data Spectral Enhancement

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.

There are three common basic stretching techniques used in spectral enhancement: Simple Linear stretch, Linear with Saturation and Histogram Equalisation stretch. Of these, Hubaux (1987) has shown that the Linear with Saturation stretch is used to modify an image, such that pixel that are bright would appear brighter while dark ones would be darker. This stretching technique was used in this analysis in order to enhance the thickly vegetated areas, which are normally very bright on the Near-infrared Band of the electromagnetic spectrum, along the natural drainages of the study area.

Step 4: Normalised Difference Vegetation Index (NDVI) Extraction

The spectral enhancement discussed in Step 5 above is suitable for highlighting areas with thick vegetation cover. But as the diagram in Fig 3.2 shows, reflection of soil in the Near-Infrared band is also moderately high. This may lead to confusion in the interpretation of data, since some areas may be covered by dry baresoils, which may be confused for thick vegetation (because of radiance similarities). To better confirm the radiometrically-enhanced thickly vegetated areas along the drainage channels from the image operation performed in Step 5 above, another index for determining solely vegetation condition was used. This is the Normalised Difference Vegetation Index (NDVI).



Source: *Adopted from Smith (2000a)*

Fig. 3.2 Spectral Reflectance of Vegetation, Soil and Water.

The NDVI is an indicator of the healthiness (and hence, thickness of vegetation canopy) in a particular area (Richards, 1986; Hubaux, 1987; & Smith, 2000a). The NDVI function computes the ratio of the difference to the sum of the 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 following is the equation for determining the NDVI.

$$NDVI = \frac{NIR - R}{NIR + R}$$

where,

R is the red wavelength band

NIR is the Near Infrared wavelength band

The output values can range from –1 to +1. High resulting values indicate thick, healthy green vegetation while low values indicate absence-to-near-absence of vegetation in an area.

The NDVI analysis would better discriminate vegetated surfaces from baregrounds, which also give some significant reflection in the Near-Infrared band of the Electromagnetic Spectrum.

From the main Menu of the IDRISI32 software, Image Processing was selected, followed by Transformation, and then Vegindex, followed by NDVI and the Output Filename also entered.

3.2 Topographic Map Data

The topographic map used was that of Minna Southwest, Sheet 164 of 1967. The map was on a scale of 1:100000, with an elevation vertical interval of 100m. Manual digitization was carried out on the elevations by the use of a square grid, resulting in digital elevations. The elevations on the topographic map were reproduced at a scale suitable for merger with the SPOT image data set.

Step 1: Digitisation of X and Y (UTM) and Contour Height (Z) Co-ordinates from Map Grid

A grid of 2x2mm dimension was constructed to form raster square grid, for the area covering approximately 6°30′E to 6°35′E and 9°32′N to 9°37′N. About 2,304 elevation points (in feet) were extracted at the grid intersections.

For the digital elevations extracted above, the corresponding X and Y Universal Transverse Mercator (UTM) projection co-ordinates were also determined as well as heights from contours. The geographic bounds for the study area from topographic map (6°30′E, 6°35′E, 9°32′N and 9°37′N) were converted to UTM co-ordinates and the ranges determined. The number of rows and columns for the digitised elevation map were used to divide the UTM ranges into the appropriate number of columns and rows of the digital elevations, so as to tally with the size of the digital elevation map. For simplicity, a computer spreadsheet software package (Microsoft Excel) was used to generate the UTM range values.

Step 2: ASCII File Generation of XYZ Positional Data in Idrisi

The IDRISI32 Reference Manual (2001) has shown that XYZ positional data can be used to produce, using the IDRISI32 software, a three-dimensional Orthomap. But the process first starts with the creation of an ASCII (American Standard

Code for Information Interchange) file. The operation is carried out through manual data entry in the Edit mode of the Modelling option in the IDRISI32 operations menu.

The row values (lines) are transposed and entered as column values. The process involves joining of the row values, one row after the other (from the first top row to the last bottom row), to form a continuous, one column data. The UTM X data are entered for the first column, followed by the Y data in the second column, and Z data forms in the third column.

Step 3: ASCII-to-Idrisi Vector File Conversion

The ASCII file created in Step 3 above has to be converted to an Idrisi vector point file format before it can be handled by the IDRISI32 software itself (IDRISI32 Reference Manual, 2001). This means that the ASCII format has to be imported into the IDRISI32 software before it can be used to represent point data.

From the main Menu of IDRISI32 software, the Import option is selected, followed by the General Conversion tools option for XYZ-to-Idrisi operation. The input ASCII file is then entered (including other necessary reference parameters). The output from the XYZ-to-Idirisi operation is a vector file, containing colours assigned to points at some regular intervals of the height (Z) component data.

Step 4: Surface Interpolation

The vector file created in Step 4 above was then converted to a surface raster image. Surface raster image is a two-dimensional image created with the use of height colour information from vector file to produce a colour map. Each colour represents a particular height for a particular pixel. The Surface image is necessary to be created before an orthomap can be produced.

From the main Menu of the IDRISI32 software, GIS Analysis is selected, followed by Surface Analysis, then Interpolation, and lastly, Interpol. Next the Input Image in this case, the Vector file created in Step 4) was selected, the number of rows and columns needed and the Output Filename was also entered.

Step 5: Toposhape Generation

To have a better impression of relief obtained from surface created from the digitized elevations, it is desirable to simulate the topography using the IDRISI32 oftware, so that a qualitative assessment can be made of the suitability of the opography produced for the analysis, as well as the accuracy of digitization. This operation classifies the image into eleven different morphological feature types: peak, ridge, saddle, flat, ravine, pit, convex hillside, saddle hillside, slope hillside, concave hillside, inflexion hillside and unknown hillside.

From the main Menu of the IDRISI32 software, GIS Analysis is selected, followed by Surface Analysis, then Feature Extraction, and lastly, Toposhape. Next the

Input Image (in this case, the surface image created in Step 5) was selected, and the Output Filename was also entered.

Step 6: Hillshade Image Generation

Using the Surface generated in Step 5 (above), a hillshade image can be generated to show the illumination of slopes relative to the incident low angle solar illumination. This operation yields an image of an area with different shades of gray colour, depicting different forms of the relief.

From the main Menu of the IDRISI32 software, GIS Analysis was selected, followed by Surface Analysis, then Topographic Variables, and lastly, Hillshade. Next the Input Image (in this case, the Surface image created in Step 5) was selected, and the Output Filename was also entered.

Step 7: Orthomap Generation with SPOT Image Drape

According to IDRISI32 Reference Manual (2001), an ORTHO displays and prints three-dimensional orthographic perspective displays of Idrisi images. Lichtenegger (1987) also credited that in some applications, such as assessing ecological and environmental problems, it is very helpful to obtain an oblique view of a landscape. The report added that a pictorial view of such kind can represent an extremely cogent instrument in the hands of planners for evaluating the possible impact of many types of human activities requiring planning, and a convincing argument for political decisions.

Normally the images displayed are surfaces, although any Idrisi image may be viewed with this routine. A second image may also be draped onto the top of the surface displayed. With an ortho image, it is possible to look at the relationship between landuse/landcover and terrain. Colour composite drapes can be very dramatic.

From the main Menu of the IDRISI32 software, Display was selected. From the options ORTHO was selected, which prompts a dialog for surface Input Image, and in this case, the surface image created in Step 6 was selected. Next, Drape image to be selected was the colour composite formed from the radiometrically enhanced SPOT data for the study area. The Output Image filename was entered, and the process Okayed to be carried out.

3.3 Image Interpretation

Samples of known areas having unique spectral radiances were used to infer areas along the banks of the major drainage channels, which could be either thickly vegetated areas, or riverine floodplains. A fieldwork (Ground Truthing) was carried out by sampling some known areas to verify the accuracy of the interpretation procedure. That is, as Hubaux (1987) indicates, through confrontations with external data to quantify the goodness of fit of the interpretation results. Elukpo (1998) also indicates that in computer-aided classification analysis performed for Goronyo landuse mapping (Sokoto State, Nigeria), there was spectral overgeneralization for different vegetal cover types. And so, the report recommended that arbitrarily sampled areas should be chosen for ground surveys, so as to aid in image interpretation.

Interpretation was achieved by field observation of some arbitrarily selected points on areas adjacent to the natural drainage channels to verify on the image, the possible features which they represent. The results obtained will now be presented in the next chapter.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF RESULT

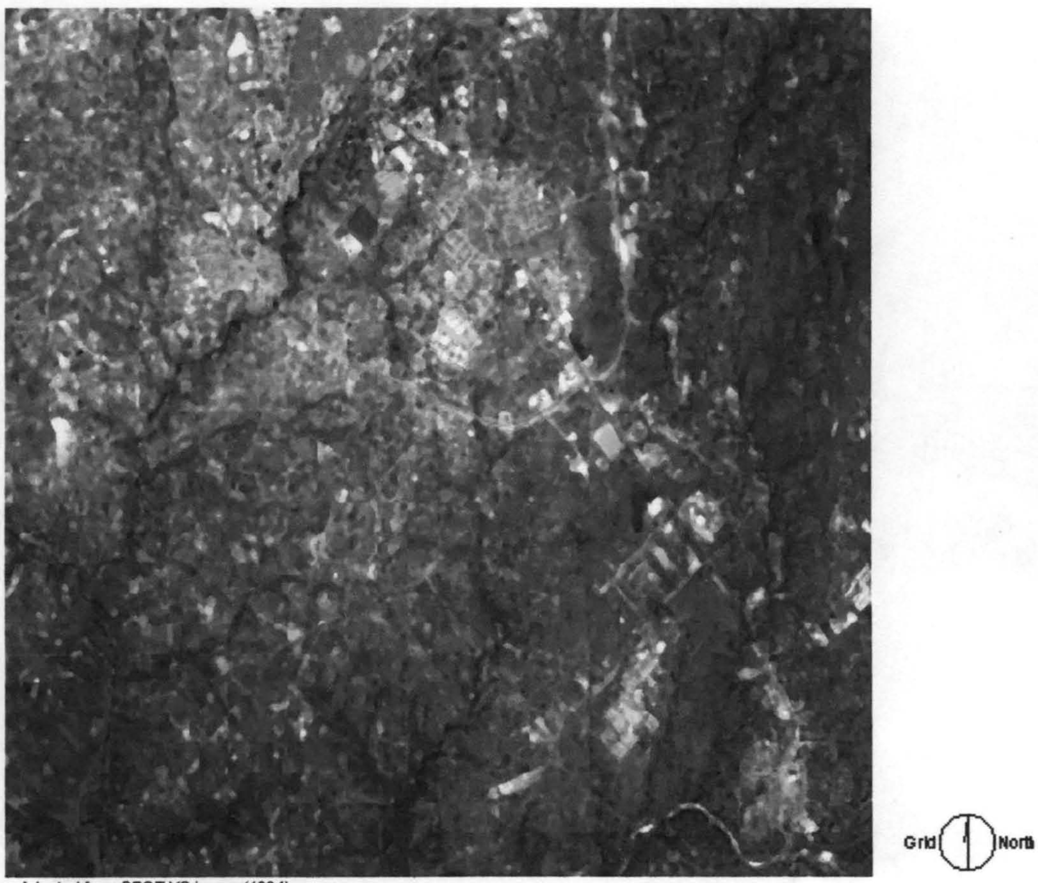
4.1 DATA ANALYSIS AND RESULT INTERPRETATION

The main aim of this project work was to map areas around Minna main drainage channels on the outskirts of the city that may become susceptible to flood disasters, using remotely-sensed data. To this, the objectives set out were to analyse satellite data to provide radiance information on riverine floodplains and thickly-vegetated areas which are influenced by moisture from the drains. These were the areas expected to be the most immediate to be affected, in terms of future flood events. The resulting images were expected to be displayed in three dimensions, using a digital terrain model (DTM) extracted from topographic map of the study area.

The main analyses carried out include image enhancement and Normalised Difference Vegetation Index (NDVI) image extraction of SPOT Multispectral data of the study area. The image enhancement procedures include spatial enhancement (image filtering) and spectral enhancement (Linear with Saturation Stretch method). The NDVI image extraction process was used to supplement information for the image enhancement procedure, by obtaining information on vegetation cover only. This was done in order to distinguish them with surfaces that may have strong reflectance, but may not be either vegetation or riverine floodplains. The results of these analyses are presented and discussed below.

4.1.1 SPOT XS Satellite Data Image Enhancement and Interpretation

The main aim of the image enhancement operation was to highlight areas along the main drainage channels on the outskirt of Minna city that may be susceptible to future flood disasters. This was hoped to be achieved using the spatial enhancement (image filtering) and spectral (radiometric stretching of pixels). The processes were expected to highlight pixels covering thickly-vegetated and riverine floodplain areas on the banks of the drainage channels.



Source: *Adapted from SPOT XS image (1994)*

Fig. 4.1 SPOT Multispectral Colour Composite Image of Minna southern suburb

The digital SPOT XS image data was imported into the IDRISI32 software, and spatial and spectral enhancements were performed. The colour composite of the 3 bands of the SPOT image data was produced, using Band 1 as blue, Band 2 as Green and Band 3 as red. The composite image was radimetrically stretched using the Linear with Saturation stretching method, so as remove the effect of Haze (see Section 3.1.1) and to bring out vegetation along the drainage channels much more clearly. The result is shown in Fig. 4.1.

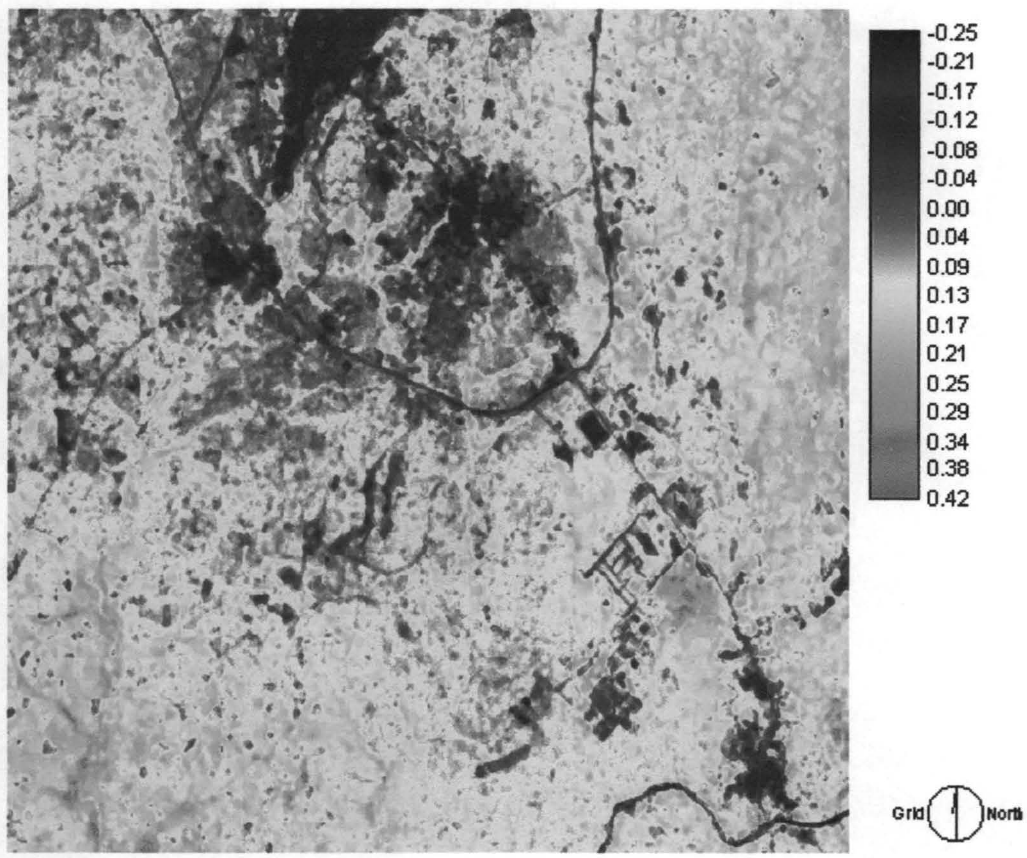
The SPOT multispectral data set has been spectrally and spatially enhanced to produce a composite of the data. The resulting composite image was obtained by assigning Band 1 as Blue, Band 2 as Green and Band 3 as Red (see Fig. 4.1).

Band 3, which is the Near Infrared band, is shown to portray the thickly vegetated areas adjacent to the natural drainages of the study area with high reflectance. The areas, therefore, are covered by riparian vegetation associated with moisture supplies from the relatively moist drainage channels. These 'green' areas therefore, have been inspected through field surveys. The result of the field survey tallies exactly with the landcover interpretation from the satellite image. Areas that appear as bright red linear features seen on the left side of the image agreed totally with thick vegetation adjacent to the drainage channels. Areas that appear in cyan colour are the built-up areas on the southern suburb of Minna. This is because of absorption of Near Infrared (taken for Red in the colour composite image), and reflection of bands 2 and 3 energies by urban cover structures. Areas appearing as white are bare soils showing strong reflections in all three bands of the electromagnetic spectrum used.

River Suka, which is the main drainage channel traversing the city is seen as a linear feature flowing through the southwest, having bright-red colouration on its adjacent banks. The red colouration indicates that there is a strong reflection of the Near Infrared (Band 1) energies while bands 2 and 3 energies were absorbed. Field observation carried out revealed that these areas were covered by thick vegetation of trees and shrubs along the banks of the river. These are areas that may, in the future, become accustomed with flood disasters. It should also be noted that riverine floodplains exist only on the larger Chanchaga river (appearing in white on the southeastern part of the study area).

4.1.2 Normalised Difference Vegetation Index (NDVI) Image Analysis and Interpretation

The image of Fig. 4.1 produced and discussed in Section 4.1.1 was used to identify areas covered by thick vegetation (and for any possible riverine floodplains) along the banks of the major drains. But it could not be used to differentiate thick vegetation cover areas from other baregrounds that could also portray strong reflectance in the Near-Infrared energy band (Band 1 of the colour composite). To isolate areas along the banks of the drains that are covered by thick healthy green vegetation, the NDVI image was then produced. The resulting image is shown in Fig. 4.2.



Source: *Adapted from SPOT XS image (1994)*

Fig. 4.2 An NDVI Image of Minna southern suburb

Fig. 4.2 is the NDVI extracted from bands 2 and 3 of the SPOT image for the study area. Areas with high values are shown in green colour, indicating thick vegetation. From the figure, it can be easily seen that areas adjacent to the drainage channels, having thick vegetation cover, appear linear with bright-green colouration. These are seen to occur generally on the western part of the study area. Thinly-vegetated areas appear yellowish while baregrounds and built-up areas appear in brown and purple colours. Other major green area in the image is an extensive area covering the eastern part of the study area. These are areas having rugged terrain of high relief, and so, are not normally cleared of vegetation for any major agricultural activity. Trees and shrubs, therefore abound in these part of the study area.

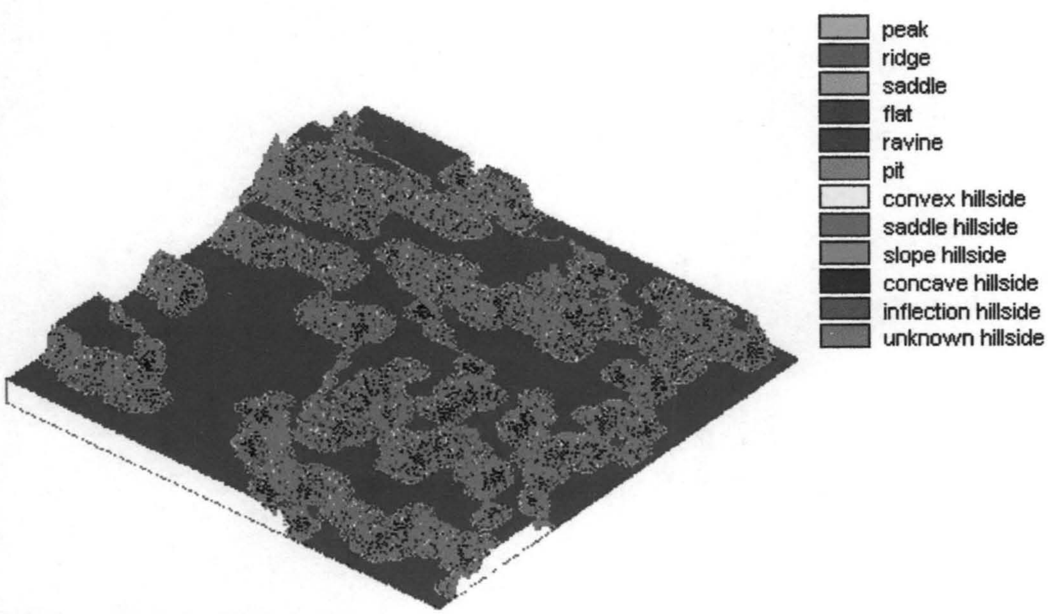
The NDVI image clearly singled out the main drainage channels in the study area, by portraying linear features appearing with green colouration in the western parts. The pattern clearly defines the potentially floodable areas, through the contrasts in colouration with other features seen on the image. Comparison of Fig. 4.2 with field survey data showed that the areas with thick vegetation along drainage channels tallied and agreed in all cases. Therefore, the resulting NDVI image used for this analysis has proved to be a useful tool for the mapping of potentially floodable areas adjacent to drainage channels.

4.1.3 Topographic Data Analysis and Interpretation

The main aim of the generation of the topographic data for use with satellite data was to display the final resulting image in three dimensions. This was to clearly display the drainage channels dramatically in low elevation channels, relative to other areas away from the drains. This was therefore aimed at improving the readability of the final resulting image(s), so that one can have a better impression of the relief on ground.

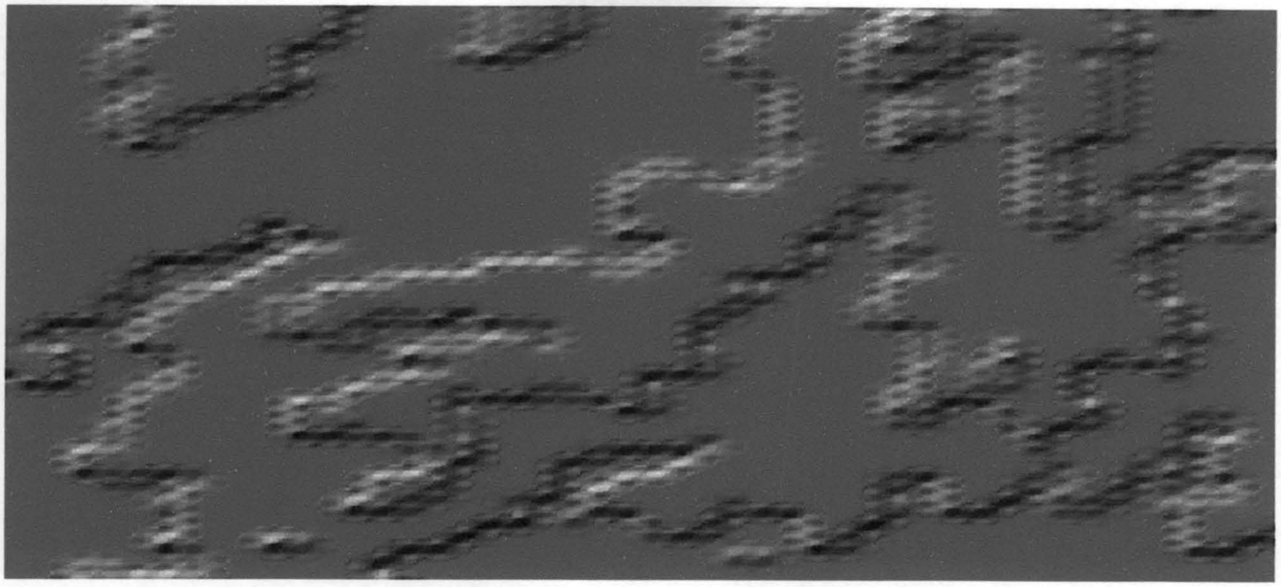
The elevations in Fig. 1.2 were digitized for the area between 9°32′N to 9°37′N, 6°30′E to 6°35′E, using a 2x2mm raster grid, yielding a 48x48 (column-by-row) raster data. The data was later arranged in XYZ columns of positional data and saved as ASCII file in the IDRISI32 software. The ASCII data file was later imported and converted to Idrisi vector point data format. The vector file was then converted to surface data using a 462x462 pixel dimension area to conform with the satellite data dimension.

The Surface data generated was used to create the Toposhape, which is displayed orthographically to illustrate the configuration of the terrain, using the Ortho operation of the IDRISI32 software (see Fig. 4.3). Also, a hill shading operation was carried out to show how the study area would look like under the illumination of light at low angles. Figure 4.4 is the resulting hill shading image.



Source: *Adapted from Minna Topographic Map (1967)*

Fig.4.3 Toposhape Image of Minna southern suburb



Source: *Adapted from Minna Topographic Map (1967)*
Fig.4.4 Hillshade Image of Minna southern suburb

Using the Surface created, the Toposhape and Hillshade images of the study area were created to simulate the shape of the terrain. Fig. 4.3 is the Toposhape image and Fig. 4.4 is the Hillshade image generated from the digitized elevations. The perspective view nature of these features produced makes them suitable and comprehensive for interpretation of the relief of the study area.

From the Toposhape and the Hillshade, it can be seen that generally, the upper right part of the image portrays an area of high relief, which conforms with what was obtained from the source topographic map (see Fig. 1.2). The lower left part of the Toposhape and the Hillshade, which corresponds with the southwestern part of the study area, generally indicates a low elevation area. This also tallies with the source data from topography of Fig. 1.2.

The resulting Toposhape and Hillshade therefore manifest accurate digitization of the elevations of the study area (Fig. 1.2), and therefore suitable for use to create a perspective view for the satellite data of the study area.

4.1.4 Orthomap Image Analysis and Interpretation

The radiometrically-enhanced image of the study area of Fig. 4.1 and the Surface created in Section 4.1.3, were used to produce the Orthomap image of the study area. The result is shown as a three-dimensional image of the study area in Fig. 4.5. (It should be noted that computer processing of the three dimensional image resulted in some sections of the image being highly exaggerated vertically).

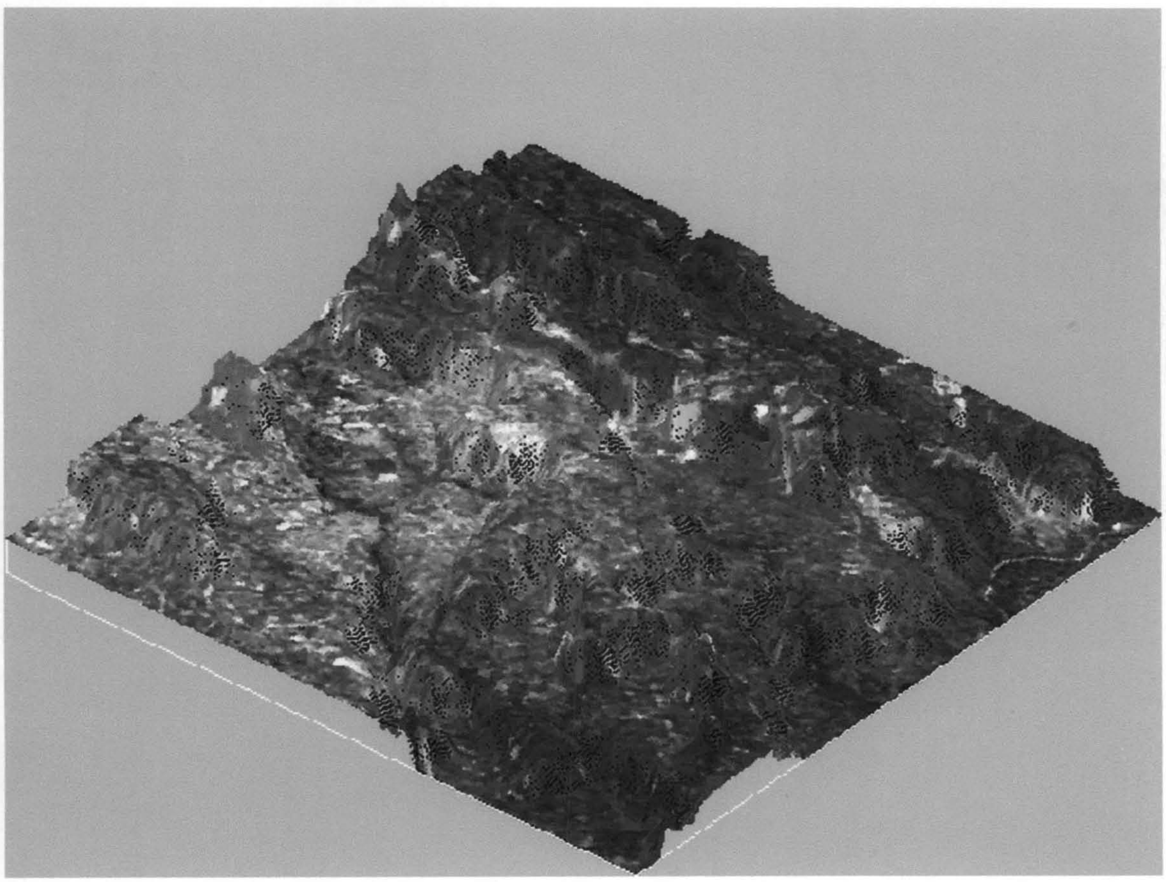


Fig.4.5 Orthomap of Minna southern suburb

Fig. 4.5 portrays a perspective view of areas adjacent to Minna main drainage channels. The dramatic view seen sheds more light and provides a better impression of the terrain, as compared with any two-dimensional view of the analysed data that may be produced. The figure represents the orthomap of the study area, produced using the Surface created in Section 4.1.3 and stretched SPOT XS satellite image (Fig. 4.1) of the study area.

From the figure, it can easily be seen that areas with thick vegetation along the major drainage channels generally to the left side of the image within the study area are viewed as bright-red lineaments and adjacent areas resting within low elevations. Areas further away from the drains, such as shrublands and baregrounds are seen as greenish to brownish coloured areas and, orthographically, on much higher elevations than the drainages. Built-up areas are portrayed in cyan, as shown to the top of the image, part of central Minna city; to the center, the Tunga settlement; to the left of Tunga, the suburb area of Kpakungu; and to the lower right, the Chanchaga settlement. The built-up areas are also generally located in much more plain areas.

Although an NDVI image was also produced (Fig. 4.2), it was not possible to produce an orthomap of it, as it was done for the stretched image of Fig. 4.1 because of the fact that such operation requires an input file with only integer values. The pixel values for the NDVI image were real numbers (floating point), which contain decimal parts. So, it could not be used to produce the orthomap.

In summary, the analyses carried out and the interpretation of results in this section of the report have clearly demonstrated that the potentially floodable areas of Minna southern outskirts are located on the southwestern parts. Analyses of images, using image processing techniques have led to some important results, in the form of important images that shed more light to vegetation condition along the main drainage channels. The thickly vegetated areas were inferred to be the potentially floodable areas in the future.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

The causes of serious flooding in our communities lead to massive loss of livelihoods, and in some cases, even human lives. To ameliorate the effect of flooding, especially in cities, drainage channels are being constructed. But these drainage channels do not take care of potentially viable outskirts of cities. As a result, flood cases decrease in the city built-up sections while they increase on the outskirts.

This study was aimed at attempting to use remotely-sensed data to map areas on the outskirt sections of Minna, which are under the threat of future flooding, arising from increased runoff from the built-up, paved sections of the city. The use of remotely-sensed data to assess such areas that may be too large for conventional field surveys was being exploited. Additionally, such data may provide other viable information in other regions of the electromagnetic spectrum that cannot be obtained with what the eye can see.

The study area spanned 9°32′N to 9°37′N and 6°30′E to 6°35′E. It covered the southern part of Minna suburb, which is the section through which all the major drainage channels tend towards, as a result of the general sloping of the land towards this direction.

The remotely-sensed data used for the analysis was that of dry season SPOT satellite Multispectral image (December 1994). The choice of the dry season image was to display the contrast between areas bordering the drainage channels that are evergreen (covered with riparian vegetation), riverine floodplains, and areas away from the drainage channels that have little or no vegetation cover at that time of the season. The evergreen areas maintain their being through the moisture influence from the drains, and so, are deemed to become floodable in the future as discharge in these drains increase.

For the analysis carried out, computer hardware and software were used. An image processing software, IDRISI32 for Windows was used for the analysis. The satellite image and the Digital Terrain Model data were imported in to the software, analysed and the resulting images were exported to the word processing software, Microsoft Word, in order to be printed together with the text report.

The SPOT satellite image data was enhanced using both the spatial and spectral methods and by the use of median filter and Linear with Saturation stretching method. This was to highlight those areas on the image that show contrasts with their surroundings, in terms of radiance, and are, therefore, deemed to be floodable in the future.

To complement the satellite-derived information for proper interpretation of analysed results, a field survey was carried out at some arbitrarily selected points along the drainage channels, in order to compare radiances on the satellite image with what was obtained through field surveys.

The results of the work done on determining areas that are potentially floodable on the outskirt of Minna have shown that southwestern outskirt region is a potential disaster area. Analyses of radiances from SPOT multispectral satellite image data have shown that, generally, areas adjacent to the main drainage channels on the outskirt of Minna would be much more prone to future flood disasters.

Analysis of colour composite of the 3 bands of the SPOT image data (shown in Fig. 4.1) has shown that areas influenced by moisture supplies from the drainages are areas having riparian vegetation throughout the seasons of the year. And since runoff from the urban areas is bound to increase (due to reduced infiltration of rain water, as a result of continuous paving of the city surfaces), these areas are therefore, expected to become flood-prone areas in future.

The Normalised Difference Vegetation Index (NDVI) image (Fig. 4.2) produced for the study area also showed that areas that are thickly vegetated are located along the major drainage channels. The analysis aimed to distinguish areas that are covered by vegetation from those covered by baregrounds (which also show strong reflection property close to that of vegetated areas), but in reality are neither floodplains nor vegetated areas. The resulting image shows that the areas that are thickly-vegetated along the main drainage channels of the study area are mostly confined to the western suburb region.

The three-dimensional perspective display of the images also highlighted and portrayed dramatically, the nature of the problem. These areas neighbouring the drainage channels would therefore, in the future, become inhabitable, unsuitable for any human activity (especially agriculture) and could be accustomed with different types of ecological disasters (such as erosion and loss of biodiversity).

5.2 Conclusion

The results from this study have shown that areas along main drainage channels in Minna city outskirt would, in the future, be highly susceptible to flooding. Because most of the areas on the outskirts are relatively inaccessible and cover large areas of the land, conventional field surveying method would not have provided the efficiency needed for mapping those areas. The results clearly demonstrated that remotely-sensed data is quite suitable for environmental monitoring, through the large spatial coverage and the unconventional information derivable using different sections of the electromagnetic energy.

5.3 Recommendations

This work was aimed at determining areas that are floodable on the outskirt of Minna, through the analyses of remotely-sensed data. Results obtained using the SPOT satellite image data indicated that areas bordering the major drainage channels would be affected by future flood problems, aggravated by increased surface runoff resulting from increased paving of the built-up parts of the city and its suburbs. Based on these results, some recommendation for future possible research work are made, which include that:

1. Based on the threat of future flooding identified for areas banking the major drainage channels from the results of this study, it is recommended that the authorities concerned should take necessary steps to prevent the impending disaster. This, therefore, calls for the extension of the artificial drainage channels to reach the reserved areas.
2. Any future studies should include the use of higher spatial resolution images (other than SPOT Multispectral data), so that boundaries of potentially floodable areas would be easily seen and demarcated. To this, the SPOT Panchromatic data (having 10-meter spatial resolution) can be fused in the Red-Green-Blue-Intensity (RGBI) composite image to improve details of surface features. Also, high-resolution image data, such as aerial photographs, and those generated by other satellite platforms like Ikonos and Quickbird provide data at 1-meter (or less) resolution, and can therefore be used to achieve much better results.

3. Future studies should also involve quantitative extrapolation of surface area to which flooding in the study area would affect. This is necessary, since as our results indicated, these surface boundaries of the drainage channels would continue to shift due to increased runoff, arising from increased paving of city surfaces. This would then form a surface model of potentially floodable areas for some future time

4. For ease and convenience of Digital Terrain Model (DTM) extraction and for better perspective display of results, it is recommended that future work should include the use of data with satellite-derived DTM files. Such data format like the SPOTOrtho (from the later SPOT 4 & 5 satellites) data formats provide elevation data for every pixel of the image. In addition, interferometric techniques, using radar data such as ERS-1, ERS-2, Envisat and RadarSat tandem radar image data can be employed to extract the DTM suitable for use in perspective displays more easily.

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