ASSESSMENT AND MONITORING OF DESERTIFICATION IN KEBBI STATE USING VEGETATION INDICES DERIVED FROM SATELLITE REMOTE SENSING DATA

BY

ABUBAKAR ALHAJI UMAR

M.TECH/SSSE/837/2001/2002

DEPARTMENT OF GEOGRAPHY

SCHOOL OF SCIENCES AND SCIENCE EDUCATION,

FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA.

JUNE, 2004.

ASSESSMENT AND MONITORING OF DESERTIFICATION IN KEBBI STATE USING VEGETATION INDICES DERIVED FROM SATELLITE REMOTE SENSING DATA

BY

ABUBAKAR ALHAJI UMAR

M. TECH./SSSE/837/2001/2002.

BEING A THESIS SUBMITTED TO THE DEPARTMENT OF GEOGRAPHY, SCHOOL OF SCIENCES AND SCIENCE EDUCATION IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF DEGREE OF MASTERS IN TECHNOLOGY (M. TECH) IN REMOTE SENSING APPLICATIONS OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

DECLARATION

I, ABUBAKAR ALHAJI UMAR, hereby declare that this research work presented for the award of M. Tech. Degree (Remote Sensing Applications) has been carried out by me under the supervision of Dr. Halilu Ahmed and to the best of my knowledge, has never been presented by any student in any form for the award of M. Tech. Degree, but the work of others consulted are acknowledged and referenced.

24/06/04

ABUBAKAR ALHAJI UMAR
M.TECH/SSSE/837/2001/2002

DATE

ACKNOWLEDGEMENT

I wish to, first and foremost praise my Nourisher and Sustainer, Allah (SWT) for endowing me with health, strength and wisdom to reach yet another milestone in my educational pursuit. May the peace and blessing of Allah(SWT) be upon His Great Messenger and Prophet, Muhammed (SAW).

I am sincerely and greatly indebted to my Supervisor, Dr. Halilu S. Ahmed, without whose guidance, steadfastness in doing the right things and thoughtful criticisms of the research process this task would not have been accomplished. Sir, you have been a source of inspiration and I will forever remain grateful. I wish to also express my appreciations to all the lecturers in the Geography Department, FUT, Minna , particularly Prof. Adefolalu, Dr. M.T. Usman, , Dr. A. Okhimamhe, Dr. G. Nsofor, Dr. U.T. Umo (on leave) and Mal. Salihu Saidu for their contributions to the knowledge I acquired in the course of this programme.

To my good friends Buhari Abdullahi and Aliyu G. Mohammed who have always been rendering moral and financial assistance, I sincerely appreciate your efforts and wish to thank you for that. I also express my gratitude to Shuaibu D. Abdullahi, General Manager, KESEPA and other members of staff of the Agency for their support and encouragement to see to the success of my studies.

I wish to thank all members of my family for the confidence they have on me and their continued prayers for my success. Equally, I owe profound gratitude to all members of "the parliament" in Birnin Kebbi for their unflinching support and prayers.

To my course mates, I express my appreciations for your cheerfulness and assistance throughout the period of study, it has been a great pleasure meeting you all.

I also thank my friend Mohammed Y. Danyaya and his brothers Shehu and Bello for their hospitality in Minna. I am also grateful to Mr. Bayo and the Director, Space Applications of NASRDA for the use of their facilities in Abuja. Numerous other individuals have contributed significantly towards the successful completion of my studies and I hereby thank all of you and wish you Gods blessing .

Finally, I owe immeasurable appreciation and gratitude to my wife Hajiya Hauwa Kulu Sandah and my daughter Nafisat for bearing my absence with understanding. May the Almighty Allah (SWT) continue to guide us and shower His abundant blessings on us .Amen.

ABSTRACT

Desertification and desert encroachment are processes of land degradation in arid, semi-arid and dry sub-humid areas of the world resulting from climatic variations and human activities.

In Nigeria, it is estimated that the country is losing about 351,000 hectares of its landmass to desert conditions annually and the desert is advancing southwards at the rate of about 0.6 km per year.

Kebbi State, by virtue of its location, is one of the desert front-line states in the country and shares common borders with Niger Republic to the north. About one-third of its landmass (12,000 sq Km) lies north of latitude 12N which is regarded as semi-arid region. The livelihood of the inhabitants of the area is being threatened such that many families are migrating southwards for better food production opportunities.

Desertification study requires data on land use, vegetation status, soil characteristics, ground water indicators, climatic conditions and socio-economic data of the area. However, vegetation cover is regarded as the most important parameter in assessing the extent and monitoring the trend of desertification in an area.

Consequently, this research used vegetation indices derived through satellite remote sensing techniques to ascertain the vegetation cover status and also monitor the trend in an area in Kebbi State.

Multi-temporal and multi-sensor satellite data comprising of MSS (1976), TM(1986), ETM+(1999) and NigeriaSat-1 (2003) was used to generate vegetation index images of the study area using VEGINDEX module of IDRISI 32.2 software package. Thiam's Transformed Vegetation Index (TTVI) images were then classified and analysed.

The result showed a fluctuating pattern of vegetation distribution depending on the season and the trend over the years could not be established as the images were acquired in different seasons.

TABLE OF CONTENTS

CHAPTER TWO

CHAPTER THREE

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

It has now been well established that mankind is today faced with `myriad of environmental problems which are threatening the supportive ecosystems and indeed, the human existence on planet Earth. One of such problems is desertification.

United Nations convention to combat desertification (UNCCD 1991) defines desertification as " land degradation in arid semi-arid and dry sub- humid areas resulting from various factors, including climatic variations and human activities; Grainger (1990) observed that desertification happens far away from the desert while desert encroachment is the extension of the desert effects of desertification impacts on over one billion people (one- sixth of the World population) in about two – thirds of the countries of the World and covering about one – third of the earth's surface (Jing, 1999; Emam, et al, 2003). The direct economic loss resulting from effects of desertification worldwide is up to $ 42.3 billion per annum (Jing, 1999).

Nigeria, by virtue of its spatial extent, encompasses various climatic regions and physiographical units representing a wide variety of ecological zones such as rain forest, Guinea Savannah, Sudan Savannah, and Sahelian vegetation. The Nigeria's arid and semi-arid zones comprising of Northern Guinea, and Sudan – Sahelian regions lying within latitudes 10 N and 14 N are by nature and characteristics susceptible to desertification process. According to National Report on the Implementation of the UNCCD (1999), the extent and severity of desertification in Nigeria has not been fully established neither the rate of its progression properly documented. Nevertheless, the report added, it is estimated that the country is losing about 351,000 hectares of its landmass to desert conditions annually and the desert is estimated to be advancing Southwards at the rate of about 0.6 km per year. (Also Rayar, 1995). Regarding economic loss, the report concluded, the country is losing about $5.11 billion per annum on environmental problems with desertification accounting for 73% of the amount.

Kebbi state which is one of the desert front –line states in the country between latitude 10N and 13 15 N, and shares common border with Niger Republic to the North. It has a landmass of about one- third (12, 000 sq km) falls within the area lying north of latitude 12 N. this zone has been rendered semi- desert as a result of combined effects of climatic and human induced factors and therefore posing a serious threat to the livelihood of the inhabitants of the area.

Remote sensing is a technique of acquiring information about the environment at a distance and analysing that information qualitatively and quantitatively for application to various environmental disciplines (Olihimamhe, A 1999). These include water resources management, land management, agriculture and vegetation management, conserving biological diversity, atmospheric studies and general land degradation studies.

Vegetation indices derived using remotely sensed images are used to analyse vegetation cover and also to detect change In vegetation patterns. These vegetation elements are the most important parameters in desertification studies. Vegetation indices make use of the strong contrast between the amount of reflected energy in the red and near-infrared regions of the electromagnetic spectrum to show vegetation biomass in its various conditions.

This research therefore seeks to use vegetation indices derived through remote sensing techniques to ascertain the spatial distribution of desertification areas in Kebbi state and also monitor the trend of expansion within a period of 27 years (1976-2003). The findings, it is hoped, will help both the policy/ decision makers and implementing agencies to realise the extent of the problem and to facilitate formulation and faithful execution of a comprehensive programme for combating the menace of desertification in Kebbi state.

1.2 Aims and Objectives

The main aim of this research is to assess the extent of desertification in Kebbi State through analysis of vegetation degradation by developing appropriate NDVI for the area.

The specific objectives are :

(a) Compute vegetation indices for the year 1976, 1986, 1999 and 2003 using satellite remote sensing data for the years.

(b) Compare changes in the vegetation indices of the images over the past 25 years.

(c) On the basis of such changes assess the trends of desertification in the area.

(d) Use the information on changes in vegetation indices to assess the impact of various afforestation programmes in the state with a view of ascertaining their effectiveness.

1.3 Justification Of The Study.

Deforestation (resulting from cutting of trees for fuel wood, agricultural land clearing and heavy lopping of foliage for fodders) and overgrazing are recognized as the main human causes of desertification (Rayar, 1995). These factors results in the removal of vegetation cover the forested areas and the scanty vegetation of the open wood lands which subsequently aggravates desert- like situation. Adefolalu (1999) asserts that in order to get an indication of the extent of exploitation of natural resources by man, vegetation cover evaluation is a way of appraising trends in ecological balance of an area. Based on that evaluation, he adds, future consequences of the degradation can be anticipated if correct assessment is done so that adequate contingency measures may be taken to ensure an equilibrium state of the ecosystem.

It has also been observed through government documents, that there is contradiction regarding vegetation cover status in Kebbi state.

Remote sensing has been used to study desertification process at macro and micro levels all over the world (e.g Adefolalu 1999; Deer, 2000; Emam et al 2003; Hill, 1993; Jing, 1999). In all these studies, vegetation indices were used to assess vegetation changes. However, some studies used vegetation indices as sole parameter for mapping or monitoring desertification while others added soil characteristics and or climatic data.

Based on the foregoing, therefore, this research is aimed at assessing the vegetation cover of the state in order to know the real extent of the degradation and to monitor the trend within a period of time.

1.4 Problem Statement.

Desertification is indeed a major problem posing great challenges to development efforts in Nigeria particularly the northern states of the country.

Kebbi is one of the major desertification – prone states in Nigeria and for development planning and sustainable resources management, there is the need to monitor the level of desertification in the state as well as other equally affected states in the country.

Remote sensing techniques in general, and use of vegetation indices in particular have proved to be good and useful tools of monitoring desertification at both macro and micro levels worldwide.

Despite this, not much research information is available that demonstrates the extent to which desertification monitoring can be carried out in Kebbi State using vegetation index transforms derived from analysis of multi-temporal satellite data.

The problem of research interest to this study therefore is to demonstrate how this can be done.

1.5 Scope And Limitations Of The Study.

Desertification study requires data on land use, vegetation status, soil characteristics, salinization, ground water indicators and climatic data such as rainfall, potential evapotranspiration, temperature, acidity and moisture indices and also socio-economic data of the area. Some of these data can be derived from remotely sensed images while others are obtained through meteorological observations over a period of time and still others are obtainable only through field surveys, laboratory analysis, administering of questionnaire and from statistical records.

The scope of this study is therefore, limited to the interpretation of digitally processed satellite images of the area using remote sensing techniques to derive vegetation indices that would be used to assess desertification in the study area. The dearth of climatic data of the study area during the research period and the relatively short time available for the research limited the use of these data which would have strengthen the quality of the final result to be obtained. At any rate, Jing, (1999) has noted that desertification is directly influenced by the density and growth status of vegetation and therefore surface vegetation is the most important indicator in desertification assessment. Also, Adefolalu (1999) indicated that evaluation of vegetation cover will make it possible to know the direction of tilt of the natural balance of the eco-system and recommended this kind of study in Nigeria where total dependence on natural resources will involve land – surface changes. Thus the approach being adopted in the study seems to be well justified.

1.6 Description Of The Study Area.

1.6.1 Location.

The study area is Kebbi State located on the north –western part of Nigeria between latitudes 10^0 N and 13^0 15' N and longitude 3^0 30' E and 6^0 E (fig 1.1 – 1.3). It shares common borders with Niger Republic to the north and Benin Republic to the west. Internally, it is bounded to the north –east by Sokoto and Zamfara States. It has a landmass of about 36,229 square kilometers. About one- third of this landmass, however falls within the area lying north of latitude 12 N which is characterized by harsh climate with long intense dry season coupled with periodic drought and a short, erratic unreliable rainy season that last for about 120 days.

1.6.2 Rainfall.

The mean annual rainfall in Kebbi state varies significantly from the northern parts, with about 733mm and 793mm in Argungu and Birnin Kebbi respectively to the Southern parts with Yelwa and Zuru having 1045mm and 1008mm respectively. The total number of rainy days in twelve months also vary from 50 days in the northern parts to about 80 days in the southern part of the state. A notable feature of the rainfall in the state is that it occurs mostly during a relatively short but intense localized thunderstorms covering only small areas.

Considering the pattern of moisture balance i.e rainfall amount in relation to run-off-evapotranspiration losses, Kebbi state experiences an annual general water deficiency. During the short wet season (June to September in the northern parts and late April to early October in the southern parts) when 90% or more of the rain is concentrated, the state

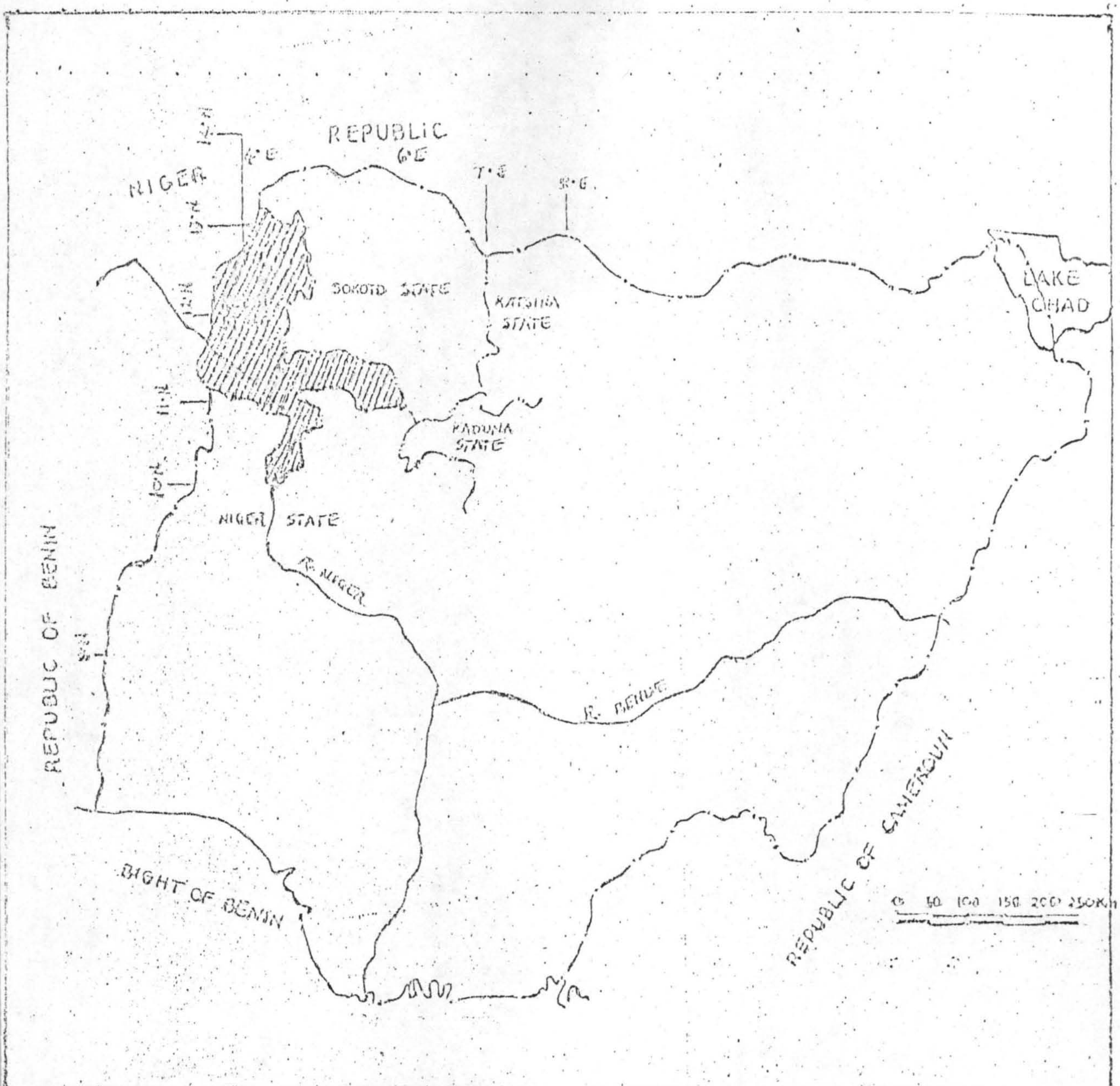


Fig. 1.1 Map of Nigeria showing the location of Kebbi State (Adapted from Kebbi State SEAP Report, 1998).

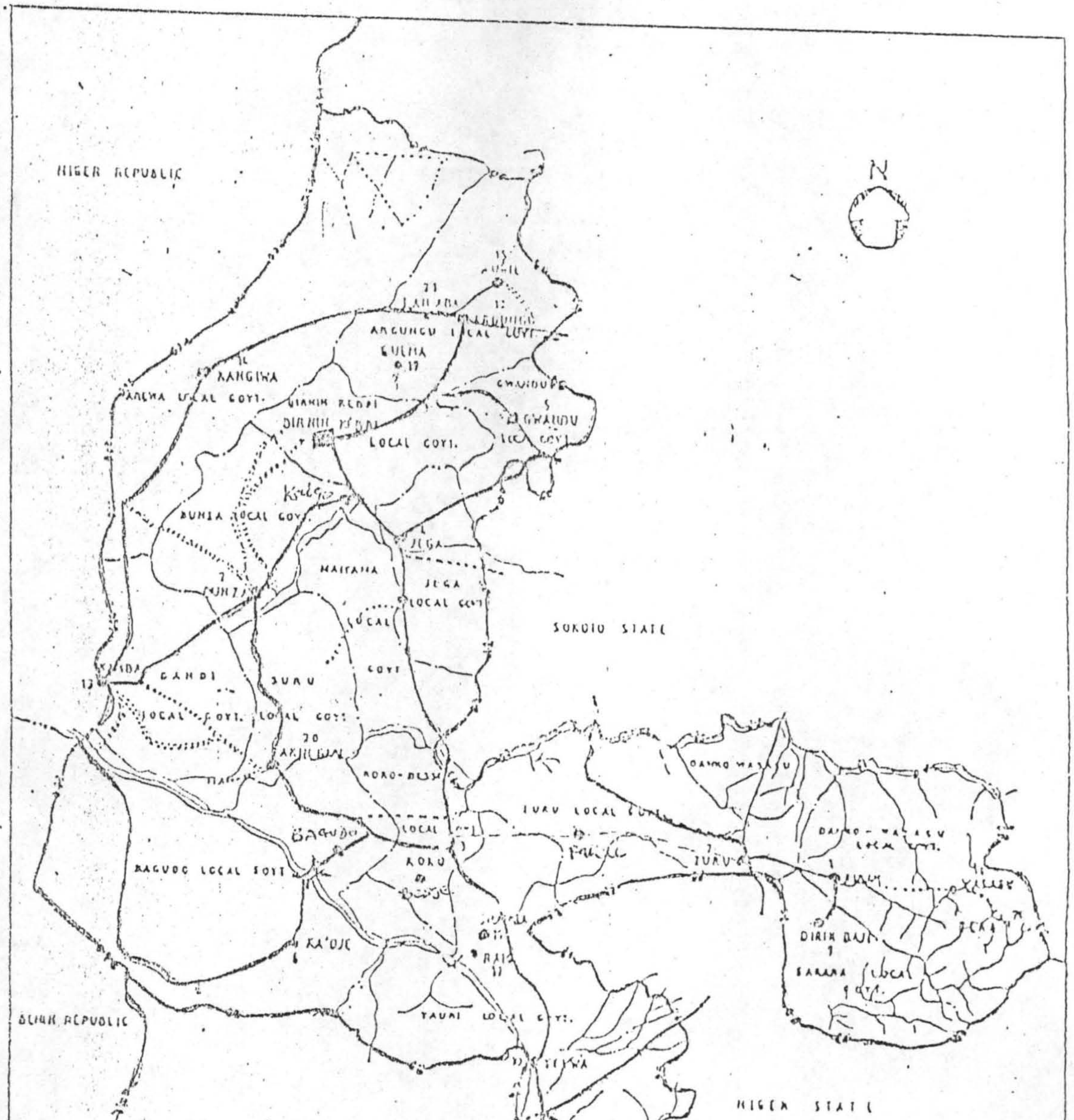


Fig. 1.2 Map of Kebbi State showing location of roads and towns (Adapted from Kebbi State SEAP Report, 1992)

records water surplus because rainfall exceeds evapotranspiration. However during the long dry season, evapotranspiration exceeds rainfall and there is often acute water shortage not only for plants use but also for man and animals.

1.6.3 Temperature.

Kebbi state enjoys a tropical type of climate generally characterized by two extremes of temperature of hot and cold. The state has an annual mean of about 26^0 C varying between about 35°C mean annual maximum to about 20^0C mean annual minimum temperature. The cold harmattan period is characterized by dust-laden winds and fog of alarming intensity usually between November and January.

1.6.4 Soils.

The predominant soil type in Kebbi state is the Ferruginous tropical soils (fig. 1.4). Their main features include a sandy surface horizon underlain by a weakly developed clayey, molted sub soil. Although they are generally considered to be so high in nutritional quality, they are very sensitive to erosion because once vegetation cover is removed the sandy top soil is easily washed off by rain water. The soils show low water holding capacity and are therefore susceptible to drought. A second type of soil in Kebbi state are alluvial soil found in the river valley of the Niger. These soils are eminently suitable for crop production.

The third type of soil found in the state is Lithosols where agricultural productivity has been found to be very low. They are also very susceptible to erosion and used to be protected in order to avoid damaging the more fertile soils that are adjacent, through the spread of gully erosion.

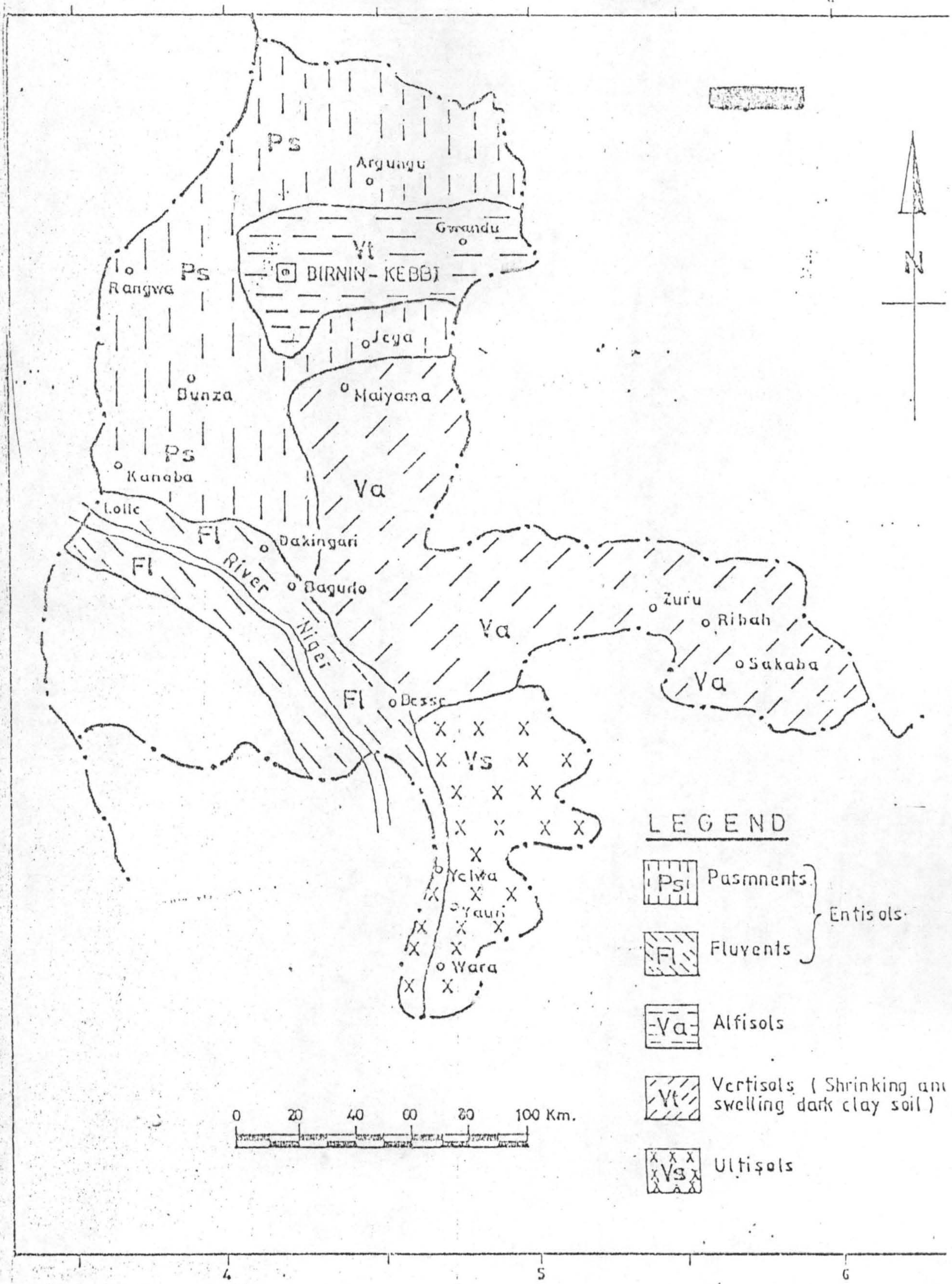


fig. 1.4 Soil of Kebbi State

(Adapted from enwezor etal 1989)

1.6.5 Drainage

The River Niger flows south east across the southern end of the state, the swings southwards and form the Kainji reservoir (fig.1.3). It's main tributary, the River Rima flows southwards and drains the central and northern half of the state. Both the Niger and Rima rivers have extensive flood plains suitable for rice and wheat production and for animal grazing. There are numerous tributaries, which flow to the Niger and Rima

rivers even though a number of them are perennial.

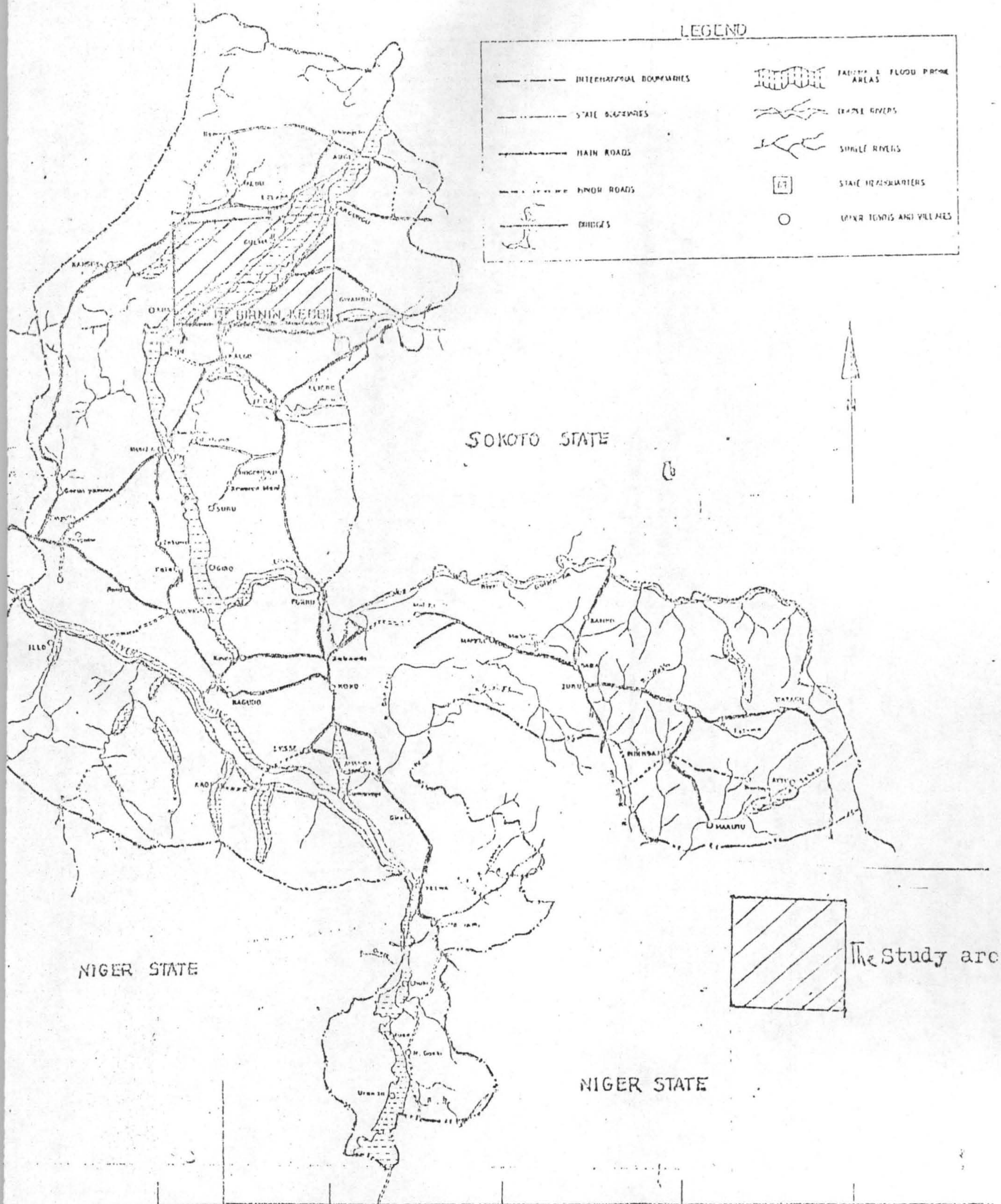
1.6.6 Vegetation

As noted earlier, the state falls within two vegetation zones, viz: Northern guinea, Savannah and Sudan savannah. Within the two broad categories, however, three main vegetation groups can as well be identified as wooded savannah, woodland and the flood plain complexes. Furthermore, the wooded savannah is usually divided into three subtypes i.e. savannah woodland, tree savannah and shrub savannah.

1.7 Organisation of the Thesis

Chapter one covers the introduction of the thesis which highlights the background information of the research, the formulation of the research question, the justification of the study, the objective of the study, scope and limitations of the study, description of the study area in terms of location, climatic conditions, soil, drainage and vegetation. The chapter is closed with the organisation of the thesis which highlights the content of each chapter.

Chapter two comprises the relevant literature reviewed through reference to published books, journals, articles and reports which gives the theoretical background and previous efforts at solving similar problems in different perspectives. It also reviewed a comparison of different transformation and classification methods.



. 1.3 Map of Kebbi State showing location of the study area and drainage
(Adapted from Kebbi State SEAP Report, 1998).

Chapter three deals with the research methodology, highlighting methods of collection and analysis of data.

Chapter four is where the data analysed in chapter three is presented in graphical and numerical forms. The resultant data is interpreted and discussion of findings is done.

Chapter five gives the summary of the most important points resulting from the analysis made and conclusion contains the main findings made from the research and the inferences made from the findings while the recommendation proposes solutions to the research problem based on the inferences and conclusions reached.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Remote Sensing And Desertification Studies.

The relevant literature reviewed for the purpose of this research was the use of remote sensing (and GIS where applicable). The studies were on mapping, modeling or monitoring of desertification and /or land degradation in different parts of world. Hill (1993) pointed out that land degradation (also termed desertification) usually develops in areas where the vegetation cover has been seriously damaged and the unprotected topsoil becomes subject to severe soil erosion process. It follows therefore, that changes in vegetation conditions provide the first important indication of desertification process. Together with determining soil conditions and erosion features, they constitute the core parameters for monitoring the degradation of an areas ecosystem.

In the course of the review, it was observed that various studies have been carried out on desertification at macro- level (global, continental and regional) all using NOAA- AVHRR data (Pahari and Murai (1995; Ochi and Murai (1995); Jing (1999) and Harah sheh and Tateishi (2000).

In desertification estimation and monitoring in China, Jing(1999) used vegetation index (VI), temperature index (TI) and moisture index (MI) as indicators for desert classification based on severity. Through image processing and analysis, a scattergram of NDVI and TI images was obtained and a graph of ground conditions in NDVI and TI space was mapped according to scatter distribution. He found that desertification is directly influenced by the density and growth status of vegetation. Also high temperature was indicated by high brightness value on channel 4 of AVHRR, which is a reflection of drought surface, and drought is one of the characteristics of desertification. He therefore concluded that NDVI and TI are important parameters for desertification monitoring and evaluation and are very effective in desertification studies of large areas.

This study clearly showed the importance of vegetation cover as a critical parameter in desertification monitoring especially for large areas.

Similarly, Harahsheh and Tateishi (2000) used integrated remote sensing and GIS to map desertification in West Asia (including Middle East). They derived a land cover – map of the area using vegetation index data of NOAA- AVHRR. Other data integrated into GIS include soil, climatic, topographic, satellite, land degradation and socio-economic. For assessing desertification, a combination of vegetation degradation, water erosion, wind erosion, and salinization were used as criteria. However, to determine the level of vegetation degradation, decrease of forage productivity and decrease of vegetation cover percentage were used and the resulting maps merged into one. Also, wind erosion and water erosion were merged into one map of " soil erosion". The two resulting maps were finally combined with the salinization map. The final classes of desertification were arrived at namely: slight, moderate, severe, very severe and sand.

The findings of the research showed that 6% of the area is slightly desertified, 21% moderately, 31% severely and 11% very severely. Sand covered 31% of the area. It was noted that vegetation degradation affected 40% of the area severely and very severely. It concluded that desertification is a very serious problem in the area and vegetation degradation contributed significantly to the situation.

In monitoring Global Vegetation Degradation using NOAA NDVI data, Ochi and Murai (1995) pointed out that Agenda –21 of the UNCED emphasized the importance of assessing land degradation and desertification. However, they noted that results of some studies indicated that long – term observation using data of several decades is required for this assessment at global and continental scales (Justice, et al (1985); Tucker, et al (1986). So they decided to assess vegetation degradation because it is more amenable to remotely sensed data and " it is considered to be very closely related to land degradation and desertification."

Data used in their study was extracted from NOAA Global View Dataset, which comprises:

1. Monthly GVI data (for 45 months).
2. Leemans and Cramer IIASA climate data.
    (a) Average monthly air temperature.
    (b) Average monthly precipitation.
3. Baily Ecoregion of Continents (10 minutes resolution).
4. Monthly NOAA NDVI data (8 km resolution).

The methodology used was overlaying ecoregions map with the drawn mean GVI characteristics. In this way, fluctuation pattern of mean GVI for each ecoregion category, the vegetation growing and declining patterns were found. Then a vegetation degradation index, which showed the degradation tendency, was defined and calculated for each region. A table of vegetation degradation index (VDI) and categories was presented in which minus value of the index means the tendency of vegetation is declining thus the less the degradation index the more the vegetation degradation is proceeding in the category. Generally, it was observed that categories whose average GVI are low have the tendency of increasing vegetation degradation while those whose average GVI are high have a declining vegetation degradation activity.

The research concluded that the index has shown reasonable output about vegetation degradation especially in the tropics where the mean GVI is high. However, some parts of temperature zone, such as

Japan were recognized as areas where vegetation degradation is on the increase. This they termed as an error and recommended statistical modification of the original GVI.

Yet in another study for Modelling of Global Land Degradation using remote sensing and GIS, Pahari and Murai (1995) regarded land degradation as desertification. In the research, the extent and nature of global desertification was studied using two approaches, viz; climate modelling based mainly on rainfall and temperature data and physical or bio- process modelling in which water erosion, wind erosion and vegetation cover are the parameters.

The climatic model consists mainly of modelling aridity and moisture indices calculated on the basis of temperature and rainfall data from many points around the globe. Moisture index was calculated using annual rainfall against potential evapotranspiration. The aridity index of Martonne as slightly modified by Murai and Honda (1991) was used by considering the annual precipitation against sum of monthly mean temperature for an area. On the basis of the value of these indices, different areas were classified into various zones and percentage.

The findings from climatic modeling revealed that aridity zoning indicated the global forest area of about 42%. But they pointed out that the actual amount of forest is less than this, approximately 33% as found by some authors, Murai and Honda (1991) who did actual vegetation mapping. Also the moisture index values showed smaller areas of hyper arid and arid zones and larger areas of humid zones when compared to the results of the desertification atlas of UNEP(1992). The reasons for the difference, they adduced, may be due to different methods used for calculating the potential evapotranspiration. They concluded that climatic model has demonstrated the usefulness of GIS for classifying the globe into different aridity and moisture index zones, which are important indicators of desertification.

The physical process model research was still going on. However, remote sensing data of NOAA GVI was used for estimation of water erosion while for wind erosion, inferences about wind conditions based on rainfall data also derived from GVI is being used. For vegetation degradation, net primary productivity is taken as an indicator of land degradation also derived from GVI as the relationship was established, by various authors such as Box and Bai (1993). When finally completed, the physical process model would be linked to the climatic model and the result assessed.

This study, even though still on-going, revealed that vegetation cover assessment is a pre-requisite in desertification process analysis especially at macro-level.

Another study on desertification status and risk estimation at regional level was conducted by Emam, Fakhi, Emam and Alimadian (2003). Soil, groundwater and land use were used as indicators and evaluated using GIS with Arcview 3.1 software. Mediterranean Desertification and Landuse (MEDALUS) of European Commission (1999) methodology was modified and adopted. The risk of desertification was evaluated on a regional level by defining and using ESA (Environmental Sensitive Area) index. ESA method considered three broad systems of indicators, such as:

Soil quality indicators (EC, SAR, texture and organic matter), groundwater indicators (water table, colour, EC and SAR) and landuse indicators (agric land, range land, poor and degraded rangelands and barren land).

Each indicator was weighted in relation to it influence on desertification process by assigning a score ranging from 100 (best) to 200(worst). Value zero was assigned to areas not appropriate or not classified e.g water bodies, urban areas, etc. Each layer of indicator was therefore classified and scored accordingly. The result was shown in both tabular and map form for each layer index. All the various layers of each index were then collected and overlaid in order to calculate the index as the geometric mean of the parameters related to each single index based on an equation. Values of three indices were subdivided into three classes of high, medium and low. A composite map of ESA index was then produced indicating the levels of not classified, absent, low, medium and high.

In another study, monitoring land degradation and soil erosion was carried out by Hill (1993). He used Landsat TM data sets for multispectral data analysis in a technique he called spectral mixture analysis. He also used spectral end members selected from a library of high spectral resolution measurement of vegetation elements and various soil and rock surfaces of the study area. He developed a soil map through combination of cluster analysis and automatic classification of renormalized fraction images. A map of erosion hazard was also produced by recombining soil development classes with the spectoral mixing patterns. Additionally, a vegetation map was also produced by using linear spectral mixing analysis in which the effects of background reflectance of soils and rocks was greatly reduced. When all the maps were combined, it was observed that large part of the region (about 40%) was affected by considerable loss of natural vegetation, which is an indication of desertification. In other areas it was found that severe degradation resulting from soil erosion was caused by severe loss of vegetation in the area. The study concluded that desertification of vegetation cover and also destruction of vegetation cover aggravates soil degradation and erosion process.

This study further confirms the relationship between vegetation cover status and desertification process even though it is more detailed in soil characteristics mapping and monitoring. The most relevant lesson to the present study is the need to maximize vegetation cover status by reducing the effects of soil reflectance, illumination and radiometric disturbance in the images.

Forest monitoring is another important application of remote sensing. Susilawati and Weir (1990) carried out a case study of forest monitoring of a central area in Java, Indonesia where forest changes over a period of 15 years were analysed by comparing landsat MSS images of 1972 and 1987. For both set of images a multispectral classification was used based on maximum likelihood using bauds 4, 5 and 7 together with leaf area index (LAI). By comparing the results of the two images, it was discovered that 25.6% of the area had changed from dense vegetation cover to low vegetation cover or to bare land. A further 293 ha had changed to bare land from low vegetation cover. These figures indicate that 31.7% of the area had been affected by forest clearing. On the other hand, only 12.8% of the area had changed from low vegetation to high vegetation cover. On the basis of these results, it was concluded that timber felling is proceeding faster than the forest is being re-established through planting and natural growth.

This case study showed a straightforward application of remote sensing in forest mapping and monitoring. The value of the information obtained would be very critical in sustainable development of forestry resources especially in desert – prone areas. This method can equally be applied to map the level of vegetation degradation as an index in desertification studies while also monitoring can equally be achieved by comparing results of multi temporal datasets and the trend studied.

Closer home, in yet another vegetation cover related topic, Adefolalu (1999) presented a case study report on Niger State. The methodology involved analysing trends in vegetal cover of Niger State from 1977- 1987, acquiring composite maps of the area in 1987 and 1988 and employed 4-Quadrant pixed method for ground –truthing.

In the analysis of the trends between 1977 and 1987, he found that:

Forest mosaic has increased from 3-5% to 15-20%, there was increase in the sahelian vegetation of about 15-20%, farmlands decreased from 33% to 15%, woodland also decreased from 60% to 40% while grassland cover remained the same 10%.

Inferences regarding these situations were that the forest reserves accounted for the increase in the percentage cover while the reduction of farmlands implied that they have become less productive and therefore abandoned with possible consequence of encroaching into tree/woodland.

In the analysis of the 1987/88 composite, Adefolalu(1999) noted that percentage cover of Sahel-type vegetation, showed an average maximum of 20% but in dry seasons some areas had 25% or more. Furthermore, the appearance of this vegetation cover signifies the dangerous trend of desertification in Niger state.

Based on observations on farmland and shrub/grassland in the state, a composite of both ecozones with 20% or more land cover was prepared and inferences derived thereon were:

- Southern parts of Mariga/Lavun LGA's and the western sector of Lavun form the main "virgin" forest of the state and therefore recommended development of forest reserves due to edaphic factors in the area.
- Evidence of over –exploitation of shrub/grass and farmlands in southeast sector, which may become pure-sahel grassland in the near future. Thus this area is facing imminent desertification.
- The upstream part of the catchment basin of river Kaduna appear to be susceptible to drought and desertification

contrary to normal expectation. This is evidenced by very little farmland in Mariga and Chanchaga LGA's.

This study has clearly and unambiguously linked the vegetation cover status of an area to desertification process. It has also given a comprehensive trends analysis "so that adequate contingency measures may be taken to ensure an equilibrium state of the ecosystem" Adefolalu (1999).

The present research is expected to accomplish similar scenario for Kebbi state.

From all the studies reviewed, the following major points are noted:

(a) Desertification and / or land degradation studies are carried out at both macro – level (global, continental, regional) and micro- level (national and local).

(b) For macro – level studies, NOAA –AVHRR imagery is the most dominant data being used while at micro –level, high spatial resolution imagery such as Landsat MSS, TM and Spot is prefared.

(c) Desertification studies considers many parameters such as climatic, physical, topographical and socio-economic indicators.

(d) In all desertification studies, land cover or vegetation cover is regarded as one of the most important parameters and always feature in each study whether at macro or micro levels.

(e) There is, as at now, no " optimal" desertification study procedure and even the definition is not universal (Rayar, 1995) it has different variations under various disciplines.

(f) There is no enough literature on desertification studies in West African sub- region.

(g) Desertification is indeed a very serious, complex and devastating phenomenon, which need to be studied and continuously monitored so as to proffer meaningful and sustainable mitigation measures.

2.2 Comparison of different transformations and classification methods.

Remote sensing digital image classification is the numerical process of extracting information of features from the image according to their defined classes while transformation seeks to enhance the quality of the image. Various techniques and method have been applied on different kinds of data. This section reviews the comparison of transformation and classification methods from the literature.

In an assessment of various image transformation techniques using Landsat TM data for forest classification, Fernendes, (1993) used TM data of 1992 to digitally classify a forest area using the following linear enhancement techniques: untransformed bands (UNT), normalized difference vegetation index (NDVI), vegetation index (VI), transformed vegetation index (TVI), principal component analysis (PCA) and tasseled cap transformations (TCT) 3 and 4. Maximum likelihood classifier was used for classification in each case. Accuracy was assessed by comparing the classified images and "time pixels" (collected randomly over the study area derived from a recent aerial photo) and a forest management map of the area.

A confusion matrix and Kappa statistics results were used to get the reliability and accuracy of the classified images, accuracy per class and overall accuracy. The findings for the overall accuracy were ; UNT, (80.30%), NDVI (71.25%), VI (67.30%), PCA (85.78%) and TCT (94.27%). The Kappa value generally showed agreement among the classes in each classification. The conclusions were summarized as follows: -

- Linear transformation to enhance TM data prior to image classification for forest mapping purposes shows very good results; overall accuracies of all classifications exceeded 65%.
- Among all the transformations used, the TCT presented the highest overall classification accuracy.
- NDVI and VI were least useful for forest classification.
- Kappa analysis showed no significant difference between all the techniques.

In this paper, the conclusions reached seem to be contradictory with regard to overall accuracy of all the techniques and the Kappa analysis. Also the untransformed bands (UNT) has higher overall accuracy than NDVI and VI which means these two techniques are least useful for forest classification in contrast to many studies and applications which favor especially NDVI for vegetation cover studies (Deer, P. 2000). Nevertheless a useful lesson for the present research is the need to perform linear transformation for image enhancement prior to classification.

In another study of agricultural classification comparisons using Landsat TM data, Haack, and Jampoler,(1994) used various classification strategies in differentiating agricultural crops in a specific dataset. The method used was to apply maximum likelihood classification of the study site using each of the following (a) supervised signature extraction of the site (b) unsupervised signature extraction (c) a band selection technique: transformed divergence (d) a data reduction strategy: principal component (e) a post classification spatial filtering on one of the classification and also (f) minimum distance classifier using supervised signatures (g) Mahalanobis classifier also using supervised signatures and (h) maximum likelihood classifier using supervised signatures and a prior statistics from the ground truth. The Earth Resources Data Analysis Systems (ERDAS) was used for signature extraction classifications and accuracy assessments. The analysis strategies are summarized as follows:

(a) Supervised signatures- fifteen training sites selected from a display of the TM data, was used to classify the whole data set using maximum likelihood classifier.

(b) Unsupervised signatures- the dataset was clustered using all pixels resulting in 19 cluster signatures which were later used to classify the dataset using maximum likelihood classifier. The resultant image was compared with the ground truth and four signatures were rejected. The standard deviations for these signatures are generally larger than those for the supervised.

(c) Supervised and filtered- a 3X3 pixel majority filter was applied to classified results from the supervised signatures.

(d) Principal component data reduction- a PC transformation based on the covariance matrix using all pixels in the original bands was applied as a data reduction method. From the resulting 7 PC bands, the first three were selected for extraction of class statistics. The same 15-training sites used for the supervised analysis were applied to the PC data using maximum likelihood classifier.

(e) Transformed divergence band selection- transformed divergence calculations were used to identify the best three bands to be used. Bands 3, 4, 5 were selected and supervised, class statistics for the same fields identified earlier were extracted and the dataset was classified using the max likelihood classifier. This was done in order to assess the effect of using fewer bands in the classification, and also to compare the results with the use of three PC bands.

(f) Minimum distance classifier- supervised signatures were used to classify the dataset with this classifier.

(g) Mahalanobis classifier- this classifier was used with the same 15 supervised signatures to classify the supervised dataset.

(h) Minimum likelihood with prior information – the dataset was classified using this classifier and the supervised signatures with a prior statistics from the ground truth were incorporated into the classifier.

The results of the numerical classifications accuracies is given in Table 2.1.

Table:2.1 comparison of classifications using LandSat TM data.

Method	Overall %	Locational %
Supervised signatures	93.3	82.5
Unsupervised signatures	89.4	76.6
Supervised and filtered	94.7	85.4
PC data reduction	91.6	81.1
Transformed divergence (3 bands)	91.2	80.9
Minimum distance classifier	80.7	70.3
Mahalanobis classifier	93.4	82.7
Max. Likelihood with a priori	93.9	82.9

In conclusion, the classification accuracies were very acceptable and comparable to previous studies using TM data in similar environments. It was noted, however, that the post classification filtering improved results only slightly while the use of 3 PC's did not significantly improve results when compared with the best three bands. This indicates an advantage in choosing fewer bands, but not necessarily using PC's as a data reduction method. The use of max. likelihood with a prioric statistics did not improve results.

This study, even though limited to TM data and for agricultural purpose can also be applied to other remote sensing data of comparable spectral and spatial resolution like Spot XS, and also can serve as a good reference even in desertification and vegetation cover studies since the test site comprised of significant forested area and bare ground.

In another study by Patrono, (1996) on synergism of remotely sensed data for land area, he analysed the accuracy of three different dataset using maximum likelihood classifier and compared each results with a common ground truth set. The datasets were :

(i) Landsat TM georeferenced image

(ii) Resampled TM and Spot pan

(iii) Resampled TM and aerial photo mosaic all of the same area.

For TM band 1, 4, & 5 were used for classification, for (ii) TM 4, 5 and Spot pan were used while for (iii) TM 4,5 and aerial photo mosaic were used.

The final accuracy was assessed using confusion matrix of each data set –and the results showed (i) with 87.8%, (ii) 83.7% and (iii) 82.1% respectively. In conclusion, the author remarked that the TM classification were excellent and in terms of mapping potential, TM seems to be the best solution for delineating classes with very heterogeneous edge areas. Noting the relatively small discrepancies between the 3 sets, he assets, highlighted the benefits of the combined use of different sensors.

This study has affirmed the superiority of TM data over the remote sensing data in that category and for the current study use of TM data will generally improve the results expected.

Finally, Deer, (2000) has carried out a through review of digital change detection techniques in civilian and military applications. He pointed out that " change detection" in remote sensing involves detection of change normally in location and extent, and sometimes the identification (i.e. what change occurred). However, analysis (i.e. causes and implications of the change) is normally left to a human analyst.

In categorizing change detection techniques he identified two basic approaches: the comparative analysis of independently produced thematic labeling or classification of imagery from different dates; or simultaneous analysis of multi- temporal data sets.

He then pointed the main techniques resulting from the two approaches as: post classification comparison (normally applied in detecting changes e.g non –urban to urban, forest to cropland, changes in general land use, wetlands and forest),

- Direct multi – date classification (also referred to as temporal /spectral classification), has been used to detect changes in coastal zone and forests (one study of forest achieved an accuracy of 90.6% for a full (12-band) image and interestingly, 90.4% for a PCs reduced 6-band image).

- Image differencing –has been used in coastal zone environments, mapping of change in tropical forest, desertification and change studies in temperate forests.

- Image regression.

- Image rationing: used in determining urban change, and less sensitive than differencing to noise in SAR imagery.

- Vegetation index differencing: the most common index being the normalized difference vegetation index (NDVI) in which a correction to account for soil background effects is sometimes advocated. Used in the study of desertification and gypsy moth forest defliotation. It can also be used to enhance many features other than vegetation by defining the indices.

- Principal components analysis (PCA) which he noted is "especially useful in multi-temporal analysis because standardization can minimize the differences due to atmospheric conditions or sun angle". Can also be used to interpret images indicating brightness, greenness, change in brightness and change in greenness.

- Change vector analysis – has been used in forest change analysis and general land use change.

- Statistical tests- they do not yield much useful information on the nature of change, or its specific location within the image rather they only indicate that a statiscally significant change has occurred somewhere in the image under investigation.

- Miscellaneous techniques- new trends in change detection including computer vision, image understanding, knowledge based expert systems and fuzzy set theory.

The author then gave an assessment and comparison of all the mentioned techniques as they are applied in different studies.

On other issues he considered image registration and rectification, selection of threshold values, radiometric correction /calibration and accuracy assessment as potential problem areas which must be addressed before undertaking digital change detection.

The review was concluded by highlighting that the differences between the various change detection techniques are less than their names imply and that as at now there is no universally "optimal" change detection system- the choice is dependent on the application.

This study is so important in guiding a researcher as to what technique or combination of techniques one should choose in carrying out a research which involves change detection.

Overall, this review of comparison of different transformations and classification methods has revealed the following:

(a) There is a wide variety of choice of methods and techniques in carrying out classification task.

(b) The area under study and the materials available are the determining factors on the choice of classification method or technique.

(c) In the absence of available data for ground –truthing or the area is not very familiar for "training –site" selection, unsupervised method of signature extraction can be used to achieve a satisfactory result.

(d) Pre- classification linear transformation to enhance the remote sensing data is advisable for improving the overall accuracy of classification especially in vegetation cover studies.

CHAPTER THREE

3.0 MATERIALS AND METHODS.

3.1 Data and Sources

The data used in this research are multi-temporal and multi-spectral satellite images and different types of maps of the study area. These are:

(a) A Landsat Multi- Spectral Scanner (MSS) scene of the study area acquired on April 12, 1976. (courtesy: Global Land Cover Facility @http://glcf.umiacs.umd.edu)

(b) A Landsat Thematic Mapper (TM) scene of the study area acquired on October 21, 1986.(courtesy:GLCF)

(c) A Landsat Enhanced Thematic Mapper Plus (ETM+) of the study area acquired on November 18, 1999.(courtesy: GLCF)

(d) A Nigeriasat –1 scene of the study area acquired on December 2, 2003.(courtesy: National Centre for Remote Sensing, Jos)

(e) Different Maps of Kebbi State:

- Forest management maps of different areas in the state at a scale of 1: 250,000.
- Forest Reserves location maps at a scale of 1:750,000.
- Administrative map of the state at a scale of 1: 400,000.
- Topographical Sheet of Birnin Kebbi at a scale of 1:100,000.

3.2 Equipment

The equipment used for digital image processing are all located in the DIP/ GIS Laboratory of Geography Department, Federal University of Technology, Minna. These include Desktop computers with their peripherals at terminals A, C, and D; IDRIS 32 version 2, ENVI 3.5, PCI Geomatica 9, and WinZip Software packages and HP 1125C DeskJet Printer.

3.3 Methodology.

3.3.1 Digital Image Processing Preparation.

This stage comprises of the following:

(a) Loading the datasets into the main drive of computer.

(b) Creating a filing code for the numerous data input and output files (Appendix I).

(c) Creating the working Folders in the Project Environment Module of the IDRISI system.

(d) Separation of bands for each dataset using ENVI software.

(e) Transfer of the different bands of each dataset in file from the main drive to the IDRISI working Environment file.

3.3.2 Data Enhancement for false colour composites (FCC) formation.

Data enhancement was performed for each dataset in order to improve the visual distinction between features in a scene so that they become more interpretable. Bands 4, 3 and 2 of the MSS, TM and ETM+ while bands 3, 2 and 1 of Nigeriasat-1 were used to represent the red, green and blue (RGB) configuration (see band designation in appendix II). Each dataset was enhanced by using linear stretching techniques and a false – colour composite of each image created using COMPOSITE module of IDRISI. These composite images proved very useful in visual interpretation of the datasets.

Fig. 3.1 is the composite image of the study area made of MSS image of 1976. 3.2 is that of the TM (1986) while figure 3.3 showed the composite image of the ETM+ (1999) and figure 3.4 is that of the NigeriaSat-1 of 2003.

Fig 3.1 Composite Image of the study area using band s 4,3,2 of MSS (1976)

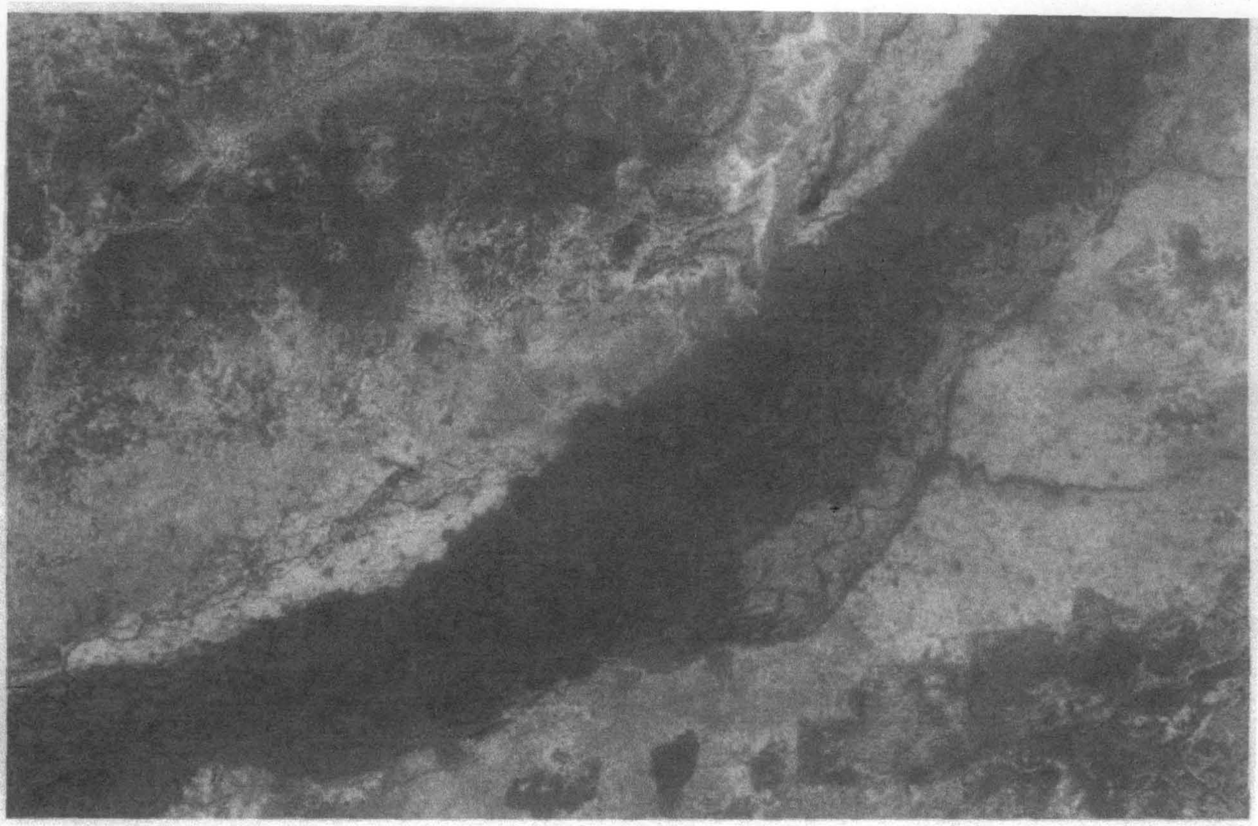


Fig 3.2 Composite Image of the study area using bands 4,3,2 of TM (1986)

Fig 3.3 Composite image of the study area using bands 4,3,2 of ETM+ (1999)

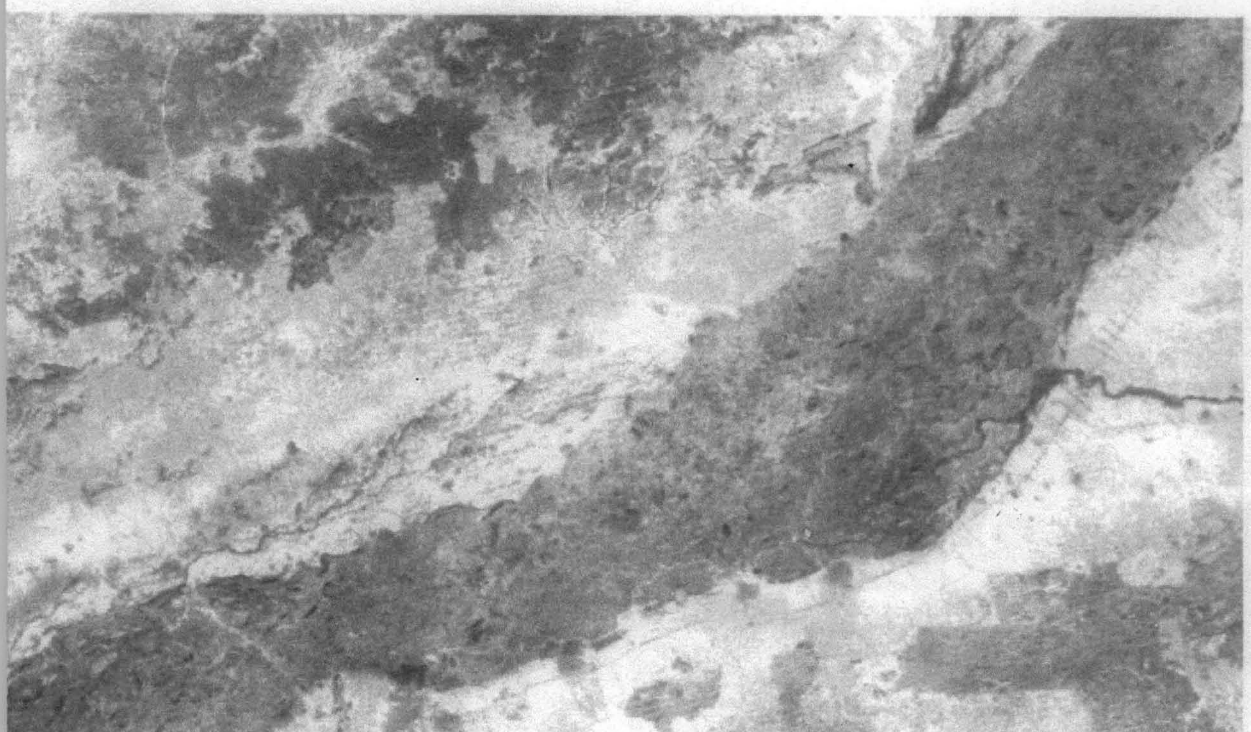


Fig 3.4 Composite image of the study area using bands 3,2,1 of NigeriaSat-1 (2003)

3.3.3 Georeferencing of the data.

Resampling is a procedure for spatially goereferencing an image to its known position on the ground. This procedure is used to register an image to a universally recognized coordinate reference system such as latitude/ longitude or Universal Transverse Mercator (UTM). All the Landset datasets used in this research were already georeferened to the UTM. The Nigeriasat-1 image was therefore georeferenced with respect to the Landsat image using the PCI Geomatica 9 software. This was carried out using the facilities of the National Space Research and Development Agency (NASRDA) at Abuja.

3.3.4 Changing reference system.

The images used were referenced to the UTM 32n. In order to change the reference system to the lat/long which the supporting maps are all in, the PROJECT module of IDRISI was used and all the dataset transformed to the lat/long system using the bilinear transformation.

3.3.5 Co- registration of the images.

Since the different datasets were taken at different dates, it became necessary to register each image with the other so as to make analysis between them. In this research, this was achieved by using WINDOW method of IDRISI. The lat/long of the study area was used to carve out the area on each dataset since they were all georeferenced.

3.3.6 Creating vegetation index images.

Vegetation index images are used for the detection and quantitative assessment of green vegetation.

This is one of the most important applications of remote sensing for environmental resource management and decision making.

In IDIRISI, vegetation index models use only the red and near-infrared imagery bands. The red band is the primary region in which chlorophyll absorbs energy for photosynthesis thus most readily distinguishes between vegetated and non -vegetated surface. On the other hand, the near- infrared band is where plant species typically show their differentiation and water is strongly absorbed thus highly distinctive in the region.

The IDRISI VEGINDEX module contain about 19 vegetation index models. The model used in this research is the Thiam's Transformed Vegetation Index (TTVI). This model was selected because it can serve the purpose of the study of arid and semi-arid regions and yield numerical results that are easy to interpret. The equation for TTVI is as follows:

$$TTVI = \sqrt{ABS\,(NDVI + 0.5)}$$

Where $NDVI = \dfrac{NIR - RED}{NIR + RED}$

NDVI= Normalized Difference Vegetation Index

NIR = Near Infrared Band

RED= Red band

ABS = The absolute value and the 0.5 is a constant to eliminate negative values.

For each dataset, the NIR and the red bands of the sensor were used as input to generate vegetation index image of that sensor. (see appendix II for band designations).

3.3.7 Classification of the VI images.

Image classification is the use of quantitative techniques to identify and group pixels of similar spectral radiance into a 'theme'. A collection of 'themes' thus represent an interpreted map of different features from remotely sensed images.

The vegetation index image of each sensor was analysed in context with its accompanying brightness values (the vertical colour bar and the corresponding values at the right sides of figures 4.1 – 4.4).

Table 3.1 shows the categorization of the brightness values of each sensor and the feature(s) they represent.

V.I image	Brightness value	Classification	Feature
TTVI 76	0.00- 0.70	1	Cleared area/bare land
(MSS)	0.70 – 0.99	2	Scanty vegetation
	0.99 – 1.19	3	Dense vegetation
TTVI 86	0.0 – 0.80	1	Cleared area/bare land
(TM)	0.80 – 0.90	2	Scanty vegetation
	0.90 – 0.97	3	Dense vegetation.
TTVI 99	0.00 – 0.69	1	Cleared area / bare land
(ETM+)	0.69 – 0.90	2	Scanty vegetation
	0.90 – 1.08	3	Dense vegetation.
TTVI 03	0.00 – 0.69	1	Cleared area / bare land
(NIGERIASAT-1)	0.69 – 1.05	2	Scanty vegetation
	1.05 – 1.22	3	Dense vegetation

Table 3.1-Classification scheme of VI images.

In this study, RECLASS module of IDIRISI was used to classify each vegetation index image into three segments, namely:

1. Cleared area / bareland
2. Scanty vegetation
3. Dense vegetation

3.3.8. Change Analysis.

The classified vegetation index images of each dataset was used to analyse areas that have undergone significant change between the scenes. Both qualitative and quantitative approaches were used.

(a) Qualitative analysis

This involve visual comparison of images in order to determine area where changes in vegetation are evident. The 1976 classified image was compared with that of 1986, 1986 with that of 1999 and that of 1999 with the 2003 image. Also the total change of vegetation cover spanning 27 years was determined by comparing the 1976 image and that of 2003. The different maps of the study area were used as guide to specific area.

(b) Quantitative analysis

This involves computing the area of the classified features using the IDIRSI AREA CALCULATOR. The areal extent are then converted into percentages of the total area in the image. Analysis of change is then carried out based on percentage representation for each feature and its corresponding year.

CHAPTER FOUR

4.0 DATA PRESENTATION AND DATA ANALYSIS

4.1 Data Presentation

The image data presented in this section are the output of different image bands of the various sensors used as input in the different phases of digital image processing. The output images are: the vegetation index images and the classified vegetation index images all covering the study area.

4.1.1 Vegetation index images

As mentioned earlier, the red and near- infrared bands of each sensor were used in the Thiam's Transformed Vegetation Index (TTVI) to derive the vegetation index (VI) images of the study area. Figure 4.1 is the VI image from the MSS sensor. Figures 4.2 4.4 are the VI images of the same area from the TM, ETM+ and NigeriaSat-1 sensors, respectively.

Fig 4.1 TTVI vegetation index image of the study area using bands 2,3 of MSS(1976)

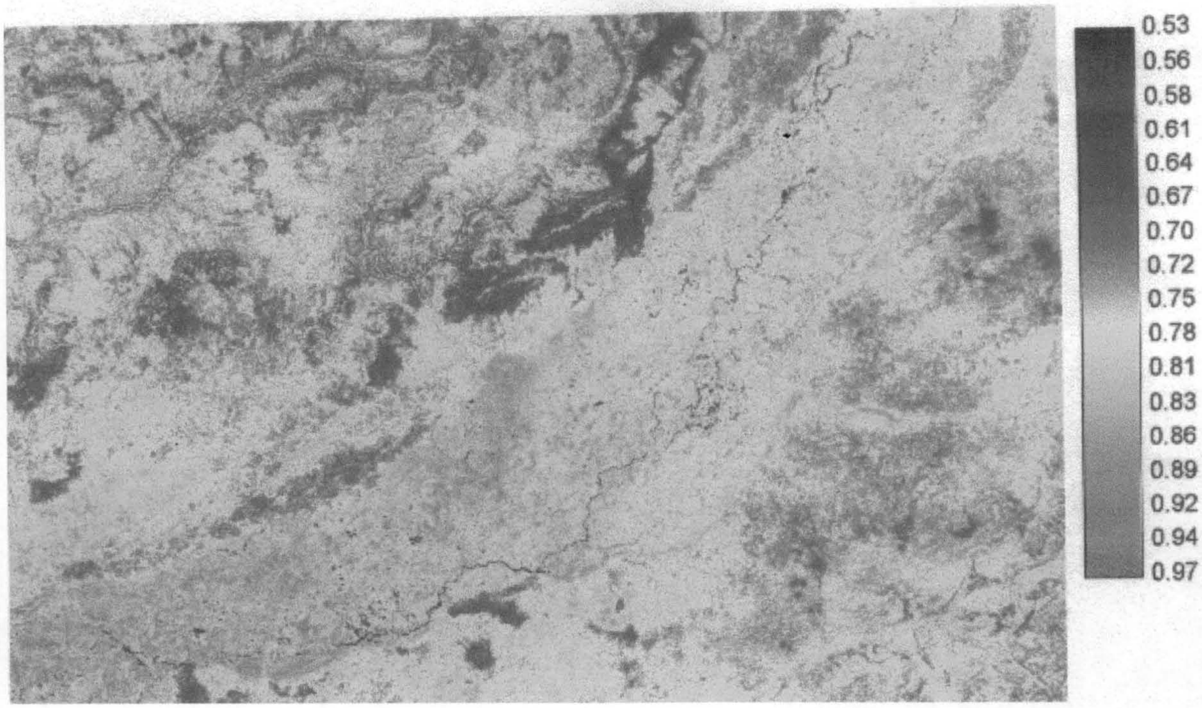


Fig 4.2 TTVI vegetation index image of the study area using bands 3,4 of TM (1986)

Fig 4.3 TTVI vegetation index image of the study area using bands 3,4 of ETM+ (1999)

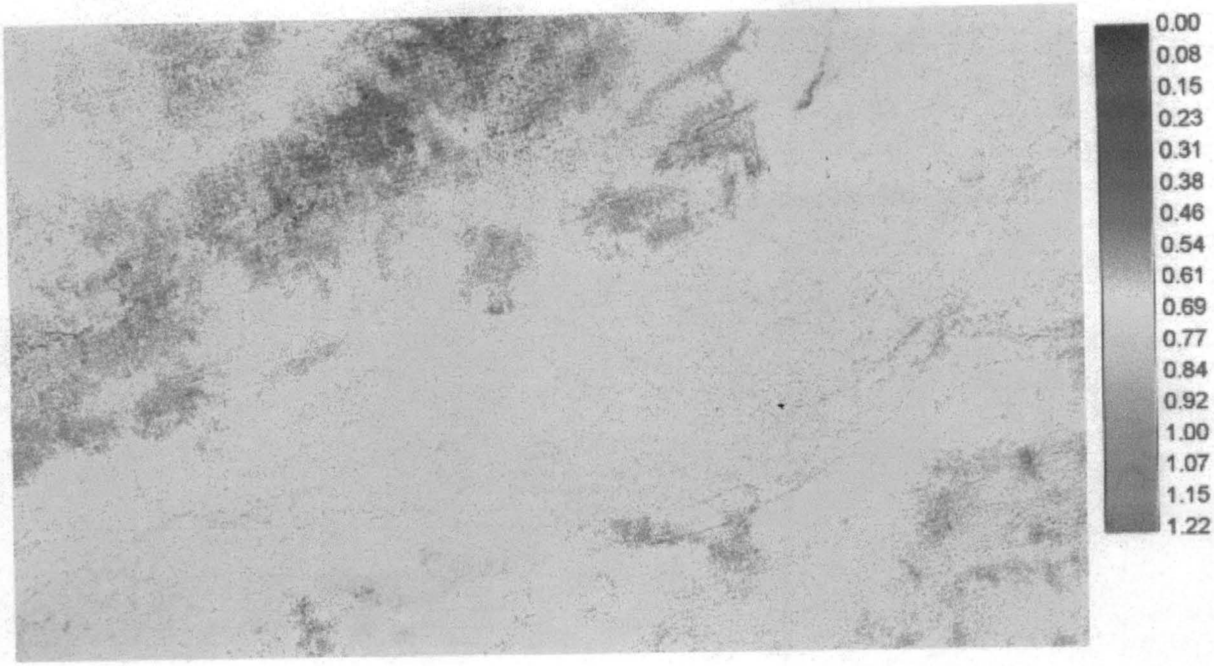


Fig 4.4 TTVIV vegetation index image of the study area using bands 2,3 of NigeriaSat- 1 (2003)TM (1986)

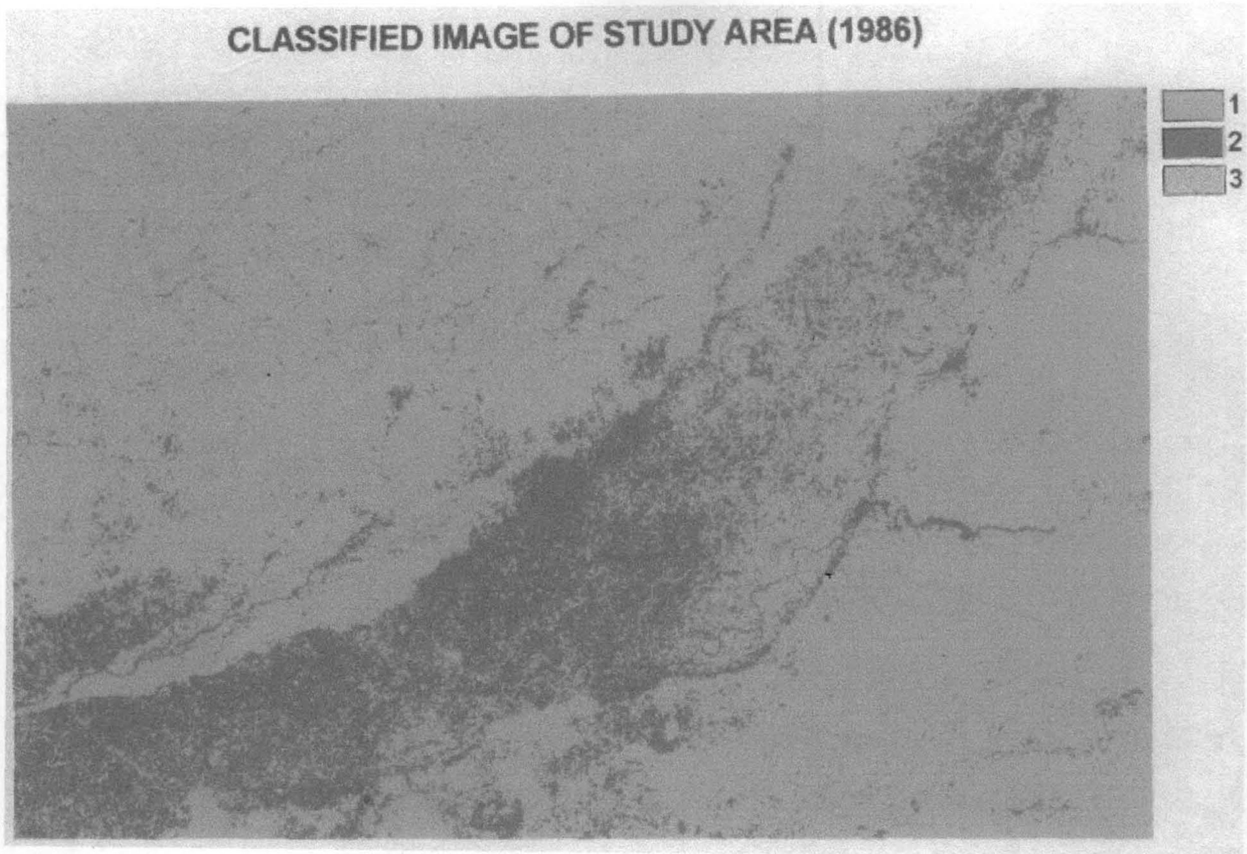
4.1.3 Classified Vegetation Index Images

figures 4.5 to 4.8 are the VI images of the study area for the MSS, TM, ETM+ and NigeriaSat-1, respectively.

CLASSIFIED IMAGE OF STUDY AREA (1976)

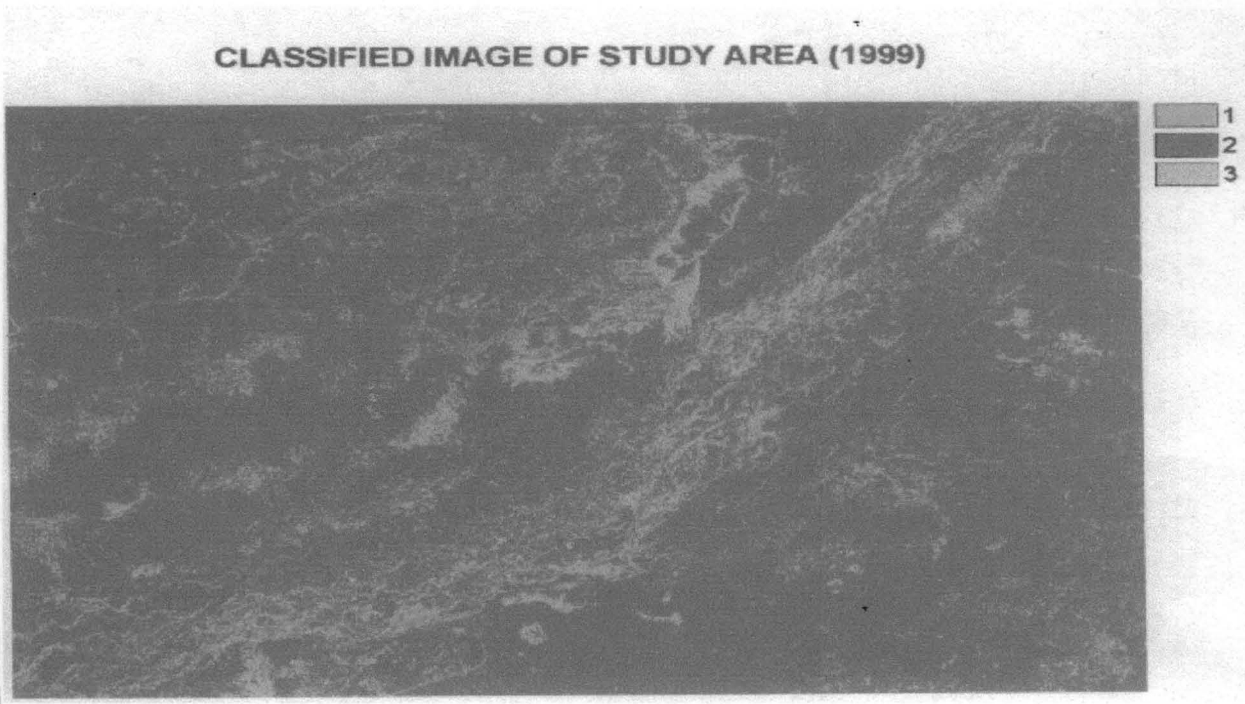
1- bare land / cleared area
2- scanty vegetation
3- dense vegetation

Fig 4.5 Classified VI image of the study area using MSS (1976)



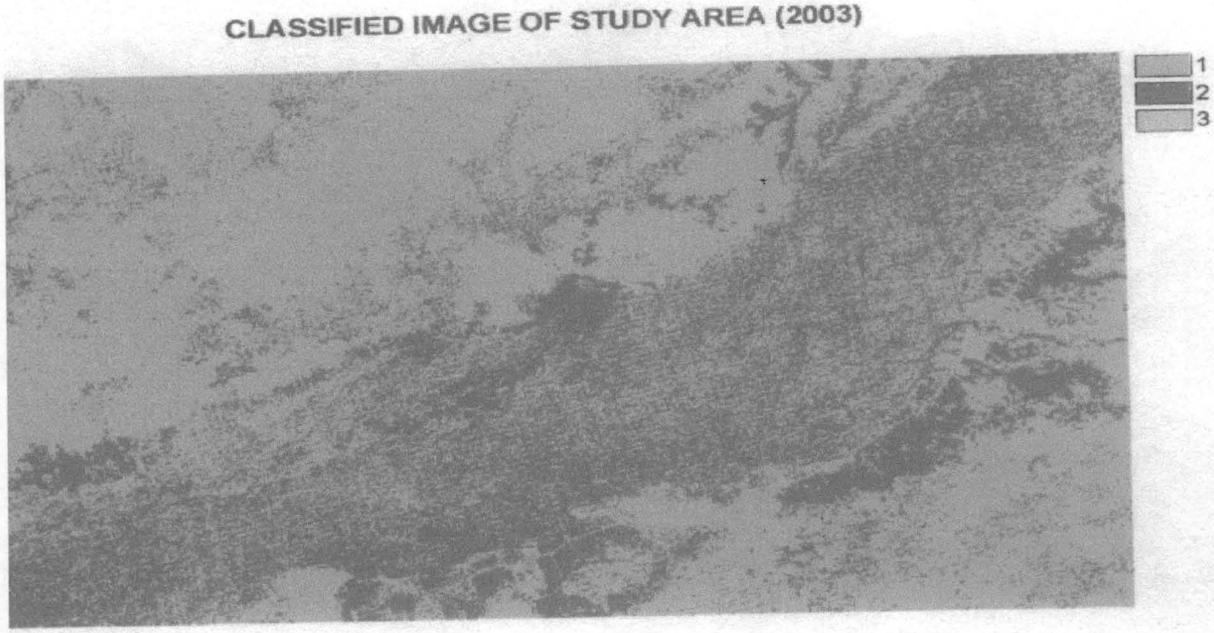
1- bare land / cleared area
2- scanty vegetation
3- dense vegetation

Fig 4.6 Classified VI image of the study area using TM (1986)



1- bare land / cleared area
2- scanty vegetation
3- dense vegetation

Fig 4.7 Classified VI image of the study area using ETM+ (1999)



1- bare land / cleared area
2- scanty vegetation
3- dense vegetation

Fig 4.8 Classified VI image of the study area using NigeriaSat- 1 (2003)

4.2 Data Analysis

In this section, a general description of the study area as represented by the false- colour composite of each data set in given so as to get familiar with its characteristics. Interpretation of the VI images and then that of the resulting classified VI images then follow this. Change analysis between the different data sets is carried out using qualitative and quantitative approaches in order to determine the trend of vegetal cover in the area over the years.

4.2.1 Data Interpretation

4.2.1.1 False – Colour Composites

The MSS composite image (fig. 4.1) showed the study area comprising of the Fadama floodplain of River Rima, adjoining seasonal rivers and farmlands along Birnin Kebbi – Argungu road. The image was acquired in April of 1976 thus the vegetation is scanty and dry at this time of the year. The fadama flood plain is clearly shown in a darker tone covering wide area stretching from the lower left corner to the upper right corner of the image. The darker tone of the fadama is indicative of the loamy and clayey soils of the flood plains in contrast to the lighter tone of the surrounding areas of sandy soils. The reddish tone found along the few rivers and rivulets showed green vegetation while the faint red line is the road from Birnin Kebbi to Argungu. The grayish tone of the entire image may be due to non-induction of band 1 (green) of the MSS (which was detected after the processing) and also non-availability of blue (0.45 – 0.52) wavelength in the sensor, which could have improved the contrast in the image.

The TM composite image (fig. 4.2) showed greater contrast in delineating the features than the MSS partly because of the improved spatial resolution of the sensor (30m as against MSS's 80m) and also bands combination selected. The TM image was acquired in October when the rains had stopped but the vegetation is thriving throughout the area. The blue tone generally signifies flooded\marshy areas containing water as shown along the floodplain and the adjoining rivers. Green portions indicate bareland/cleared area in clayey soils while gray tone indicates bareland/cleared area in sandy soils. Reddish tone represents healthy vegetation while light blue tone indicates a low vegetation cover. The road is shown in faint blue line.

The ETM+ composite image (fig 4.3) was made of images acquired in November 1999. This period is the on- set of dry season in the area but the marshy and flooded areas of the flood plain especially along river channels still contain floodwater as indicated by blue tone in the image. Light blue tone show areas of healthy vegetation while light green tone indicates scanty vegetation. Gray tone indicates cleared area\bareland in sandy soils while dark green tone showed cleared area\bareland in loamy and clayey soils. The road is shown in faint dark line with strips of shelterbelt also appearing in dark tone.

The NigeriaSat-1 composite (fig 4.4) was made of images acquired in December 2003. In the study area, this time of the year is in dry season thus vegetation is generally dry and scanty. There are, however, few areas of healthy vegetation mainly around water bodies as indicated by blue tone in the image. Gray tone represents areas with light vegetation while the green and dark tones indicate cleared areas or bareland with no vegetation depending on the nature of the soil. The road is shown in slight dark line with strips of shelterbelt appearing in slightly darker tone.

The above interpretation of composite images was limited to qualitative extraction of information based on the basic image properties, which aid the detection and identification of visible features on the image (tone, texture, contrast, pattern, shape, size, location and topography). Understanding the characteristic spectral response pattern of the sensors, the knowledge of the study area and reference to appropriate maps and charts were all applied to aid the interpretation process.

4.2.1.2 Vegetation Index Images.

The VI image of MSS (1976) in fig 4.1 shows overwhelming presence of scanty vegetation as light green and considerable amount of bareland/cleared area represented by brown colour. There are very few areas of high vegetation as shown by dark green tone mainly along some rivers and rivulets. Few spots of blue indicate ponds. This image correlates with the features observed in fig

3.1 in that the images were acquired in the extreme dry season when scanty vegetation dominates the area.

The V.I image of TM (1986) as shown in fig 4.2 depicts an area with relatively high vegetation cover mainly along the flood plain of the fadama and the adjoining rivers as represented by green tone. The dark brown and brown tones, which seems to dominate the image, depicts cleared area/bareland, which is normally the case in this period. Scanty vegetation as represented by light green tone in the image is in transition from high vegetation to bareland. It is worthy to note that in the study area at this time of the year; only rice is still in the field thus the reason for high vegetation along fadama flood plains and the rivers. There are some water bodies along the fadama even though not in sufficient quantity.

On the other hand, the V.I image of ETM+(1999) as shown in fig 4.3 is overwhelmed with light green tone indicating scanty vegetation and pockets of brown and dark brown colours showing cleared/bareland in the main fadama channel. This is indicative of some rice fields already harvested and cleared as the period of rice harvesting in the area is from October through December. The green and dark green signifies areas with water, loamy soil and relatively high vegetation cover. Gray tone indicates areas awash with sandy soil and therefore no vegetation cover.

The V.I image of NigeriaSat-1 (2003) shown in fig 4.4 depicted a large portion of scanty vegetated area. The period of image acquisition was in December, which is in the dry season. There are very few areas with dense vegetation mainly surrounding water bodies. The greater part of the fadama plain has been harvested and cleared thus scantily vegetated. The brown and dark brown tones indicate areas of bareland with no vegetation at all.

4.2.1.3 Classified Vegetation Index Images.

The classified V.I images of the study area using LandSat MSS sensor (1976) as shown in fig 4.5 is composed mainly of scanty vegetation throughout the image as indicated with blue colour. Cleared area\bareland as evident mostly along the fadama flood plain traversing from lower left to the upper right corners of the image. This is represented in green colour. Areas with dense vegetation in banana yellow colour are very few thus not shown on this image.

This classified image gives a generalization of features from the V.I image and therefore portrays the general characteristics of the area during the extreme dry season. As noted in paragraphs 4.2.1.1 and 4.2.1.2; there is very little amount of dense vegetation in the study area during this season; therefore, its non-appearance in the classified image is not surprising.

The classified image of the LandSat TM (1986) as shown in Fig.4.6 signifies a considerable percentage of cleared area\bareland especially outside the main fadama flood plain as indicated by green colour. The figure showed availability of vegetation along the flood plain and adjoining rivers in blue colour while areas of dense vegetation are scattered along the fadama flood plain especially from the lower left corner to the centre of the image as depicted in banana yellow colour. Also, as noted earlier in 4.2.1.1 and 4.2.1.2, by this time of the year (October) all the crops have been harvested from the farmlands with only rice remaining in the fields. Even with rice, the early growers must have harvested their fields thus the relatively small dense vegetation areas may indicate late growers around pockets of water bodies.

Figure 4.7 shows the classified image of the LandSat ETM+ (1999). Green colour represents the bareland\cleared areas most apparent in the fadama flood plain and its upland. There is considerable amount of scanty vegetation throughout the image especially outside the main fadama channel as represented in blue colour. There is, however a relatively large percentage of dense vegetation especially around the river channels and flooded areas in the fadama as well as in the loamy soil areas upland. These are depicted in banana yellow colour.

The presence of water which flooded the area of the study in this period (November) and consequently the availability of both dense and scanty vegetation may be attributed to the release of water up stream from the Bokolori & Goronyo dams in Zamfara and Sokoto states respectively. This is sometimes done in order to allow farmers along the Sokoto\Rima Rivers to participate in dry season farming.

Figure 4.8 is the classified image of the NigeriaSat-1 (2003). The image was acquired in December which is in dry season thus the apparent availability of light vegetation throughout the area especially along and around fadama flood plain as shown in blue colour. There are very few areas of dense vegetation mainly around river channels adjoining the main flood plain as depicted in banana yellow colour. The green colour represents the bareland\cleared areas and these occur mainly outside the main fadama channel.

4.2.2 Qualitative Change Analysis

In this study, qualitative change analysis involves visual comparison of a pair of classified vegetation index images with a view to detect and identify the areas of the vegetation change between them. The change between successive pairs will also be analyzed in order to understand the trend in the vegetation cover of the study area over the years.

Figure 4.5 is the classified V.I image of MSS acquired in the extreme dry season (April, 1976). The image showed overwhelming presence of scanty vegetation with the fadama flood plain being bareland with no vegetation. On the other hand, the classified V.I image of the TM (fig 4.6) was acquired roughly a month after the rain stopped (October, 1986) but showed over half the image being bareland with no vegetation while the fadama flood plain is covered with scanty and dense vegetation. By comparing the two images and their periods of acquisition it is apparent that there is anomaly in representation of both images. For the extreme dry season image (April, 1976) bareland\cleared area outside the fadama is expected to dominate the image with the fadama being scantly vegetated. But the reverse is the case in the image. Also, for the image with relatively short period after the rainy season (October, 1986), scanty vegetation is expected to dominate the image not only in and around the fadama but at other locations with bareland\cleared area occurring in few areas but here also reverse is the case. However, there is presence of dense vegetation especially along the fadama channel. In general, the 1976 image showed more vegetation than the 1986 image but logically this shouldn't be the case.

In comparing the 1986 image with that of 1999 (Fig.4.7), it is observed that the 1999 image showed more vegetation cover than that of 1986 even though the 1999 image was acquired roughly two months after the rain stopped (November, 1999) thus one month after that of 1986. Also, there is more dense vegetation (spread across all parts of the image) in the 1999 image than that of 1986 (dense vegetation found only in the lower left corner to the centre of the fadama channel). It can therefore, be concluded that considering the period of image acquisition and features representation, the 1999 image is more logical and have balanced representation than both the 1986 and 1976 images respectively.

The NigeriaSat-1 image was acquired in relatively drier season (December, 2003) than the 1999 image, and its classified image (Fig 4.8) showed less vegetation compared to that of 1999. Interestingly, greater part of bareland in the 1999 image appeared as bareland in the 2003 image and most of the dense vegetation in the 1999 image have turned into scanty vegetation in the

2003 image. These two images (the 1999 and the 2003) with acquisition periods (November and December, respectively) have shown consistency in their feature representation with respect to their acquisition periods, thus the 1999 image has more vegetation than the 2003 image.

In assessing the trend of vegetal cover in the study area over the years as represented by the classified images, it is observed that there is more vegetation cover in 1976 than 1986, more in 1999 than 1986 and more in 1999 than 2003. It is equally observed that by comparing the 1976 and the 2003 images, there is more vegetation cover in the 1976 image than in 2003 image. In ranking the imagery years based on vegetation cover, 1976 has the highest amount of vegetation, followed by 1999, 2003 and 1986 respectively.

4.2.3 Quantitative Change Analysis

This approach of change analysis was as a result of area computation of the classified images using the IDRISI AREA CALCULATOR. Table 4.1 shows the percentage coverage of each vegetation against the corresponding year.

Type of Veg./Year	**1976 (April)**	**1986 (Oct)**	**1999 (Nov)**	**2003 (Dec)**
	%	%	%	%
Bareland/cleared area	2.9	61.0	20.0	51.5
Scanty vegetation	97.0	35.5	72.5	47.5
Dense vegetation	0.1	3.5	7.5	1.0
Total	**100.0**	**100.0**	**100.0**	**100.0**

Table 4.1: Percentage coverage of classified areas.

From the table, the MSS (April, 1976) showed overwhelming presence of **vegetation (97.1%) and bareland/cleared area making 2.9% of the total area.** This period is in the extreme dry season when the vegetation is scanty and dry.

The TM (October, 1986) indicated a total vegetation cover of 39% as against bareland area of 61%. When compared with 1976 data, this season showed a marked difference in the increase of bareland and decrease of vegetation cover even though it is just the beginning of the dry season.

The ETM+ (November, 1999) has a to total vegetation over of 80% and bareland of 20%. This data also showed a marked difference of increase in the vegetation (80%) as against October's (39%) even though it is more in the dry season. This increase, however, may be attributed to the seasonal release of water from the Bakolori/Goronyo dams to the downstream and/or the year (1999) witnessed heavy and longer wet season (up to September).

The NigeriaSat- 1 data (December, 2003) showed a decrease in the vegetation cover to 48.5% and increase in the bareland to 51.5% compared to November's data. This is in line with the expectation that the month (December) should witness less vegetation and more bareland/cleared areas as the dry season intensifies.

In general, it is observed that the quantitative approach of change analysis tallies with the qualitative approach discussed in 4.2.2. In ranking the years based on vegetation cover, 1976 has the highest amount (97.1%) followed by 1999 (80%), 2003 (48.5%) and 1986 (39%). Conversely in terms of bareland/cleared area, 1986 has the highest (61%), followed by 2003 (51.5), 1999 (20%) and 1976 (2.9%), respectively.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary Of Findings

The classified VI image of 1976 showed the presence of scanty vegetation throughout the study area with only few areas of bareland notably along the main fadama channel.

Ten years later, as depicted in the image of 1986, most of the study area has turned into bareland with notable exception of the fadama and adjoining river channels, which contain some scanty vegetation. This is an indication of serious vegetation degradation associated with desert-like conditions.

In 1999 i.e. about thirteen years later, there is a definite increase in vegetation cover throughout the area with dense vegetation increasing not only along the fadama and river channels but in other loamy soil areas. This improvement may be due to the state governments massive afforestation programme especially the shelterbelt project that is apparent in the 1999 and 2003 images. However, some portion of the Fadama channel appeared barren which could be as a result of siltation along the channel.

By the year 2003, there is considerable reduction in vegetation cover (both dense and scanty) and thus some scantly vegetated areas in 1999 have become barren land. However, the amount of vegetation in the year still exceeded that of 1986 and the general condition of the area is not desert-like.

5.2 Conclusions

This study has proved that vegetation indices of successive years can be analysed to assess the extent and nature of vegetal cover of an area as a proxy to desertification studies.

- Comparison of vegetation indices of an area for successive years can facilitate monitoring the changes in the vegetation cover.

- Analysis of the classified vegetation indices of this study area has revealed a fluctuating pattern in the distribution and type of vegetation cover from year to year.

- The level of vegetation cover and its type in the study area is strictly season-dependent. Consequently, this research could not establish the actual trend over the years as the images used were of different seasons.

- State Government afforestation programmes especially the shelterbelts seems to have significantly improved the vegetation cover in the study area as observed in the images of 1999 and 2003.

- The TTVI method adopted in this study proved not very efficient in correcting background soil brightness especially in this vegetation sparse area. Thus, the VI images were " noisy" and consequently reduce the classification accuracy.

- The analysis of the images of the study area in the various seasons confirmed its semi- arid nature in terms of vegetation cover. Areas of dense vegetation are mainly limited to locations around water bodies even in wet season while barelands exist in the area even in wet season.

- The main flood plain channel area, which is distinctive in all images of the area, seems to be having siltation problem, as more of its areas are becoming bareland even in wet season.

5.3 Recommendations

In order to effectively monitor changes and establish trend of the state of vegetation cover over successive yeas, it is strongly recommended to acquire images of the same season (possibly the same month) of the years being considered.

- This study was carried out using TTVI method of creating vegetation index. TTVI in slope–based method, which is not particularly efficient especially in arid and semi- arid regions. Therefore, it is recommended that this study can be replicated with a distance–based vegetation index method.

- Desertification studies entail combination of various parameters one of which is vegetation cover. Other parameters include climatic data, soil data, aridity index, and e.t.c. It is therefore recommended that one or more of the above parameters can be added to the present study to reinforce the final result.

- Considering the fragile nature of the semi-arid region such as the study area and the seeming improvement in terms of vegetation cover as a result of afforestation programme, governments (Federal, State and Local) are advised to intensify more efforts in meaningful tree planting campaigns and also come up with strategic policies for conserving and protecting our environment.

REFERENCES

1. Adefolalu, D.O (1999). Micro scale mapping of Ecological Zones of Nigeria – a Case Study Report on Niger State. Working paper at the First National Summit on Ecology and Environment, The Presidency, Abuja.

2. Deer, P.J.(2000). Digital Change Detection Techniques: Civilian and MilitaryApplications.www.gsfc.nasa.gov/ISSSR-95/digital.htm

3. Digital Image Processing. http.//www.ecoman.unc.edu.au/IBRMSAL/RS/chapter4.htm

4. Emam, A.R., Fakhri, F., Emam, A.N.R and Ahmadian, A. (2003). Desertification Vulnerability in Varamin Plain –Central Iran. MAP India.

5. Federal Republic of Nigeria. "Combating Desertification and Mitigating the Effects of Drought in Nigeria". National Report on the Implementation of the UNCCD in those countries Experiencing Serious Drought and/or Desertification, Particularly in Africa(CCD). For Submission at the Third Session of the Conference of the Parties, Recife, Brazil, November, 1999

6. Fernendes,A(1993). An Assessment of Various Image transformations Techniques using Landsat TM data for forest classification. ITC Journal, 1993-4 pp 415.

7. Grainger, A (1990). The Threatening Desert, Controlling Desertification. Earthscam Publications Ltd. London.

9. Hill, J.(1993). Monitoring Land Degradation and Soil Erosion In Mediterranean Environments. ITC Journal, 1993-4 .pp323-331.

10. Hack, B and Jampoter, S (1994). Agricultural Classification Comparison using Landsat thematic mapper data. ITC Journal, 1994-2. pp113-118.

11. IDRISI MANUAL, Version 32.20, Clark Labs, Clark University, Worchester, MA. USA.

12. Jing, L. (1999). Desertification Monitoring and Estimation in China From AVHRR Data. ACRS,1999.

13. Justice, C.O.; Townshend, J.R.D., Holden, B.N and Tucker, C.J Analysis of Phonology of Global Vegetation Using Meteorological Satellite Data. International Journal of Remote Sensing, 1985, vol .16 No8, pp 1271-1318.

14. Kebbi State Government: Environmental Problems in Kebbi state. Prepared for: Course 22 of command and staff College, Jaji. January, 2000.

15. Kebbi State Government: Desertification and it's Control in Kebbi State. A position paper by Forestry II Project and Department of Forestry, M.A.N.R, Birnin Kebbi Presented at the meeting of Committee of Experts on Desert Encroachment and Afforestation in the Region at the SSSG's Office, Kano. 7-8 October, 1999.

16. Murai, S and Honda, Y. (1991); "World Vegetation Mapping from NOAA GVI Data" in Murai, S (Ed.) Application of Remote Sensing in Asia and Oceania. AARS.

17. Ochi, Sand Murai, S. (1995). Monitoring Global Vegetation Degradation using NOAA NDVI Data. ACRS. 1995.

18. Okhimanhe, A.A (1999). Introductory Lecture Notes on Remote Sensing Applications.Department of Geography FUT, Minna.

19. Pahari, K. and Murai, S.(1995). Modeling for Global Land Degradation using Remote Sensing and GIS. ACRS. 1995.

20. Patrono, A (1996). Synergism of remotely Sensed data for land Cover mapping in heterogeneous alpine areas: an example combining accuracy and resolution. ITC Journal, 1996-2. pp101-109.

21.Rayar, A.J. (1995). Desertification and Soil Degradation in Arid And Semi – Arid Regions of Nigeria .Inaugural Lecture Series 93/94 Session, No 55, University of Maiduguri Press.

(1990)

22. Susilawati, S and Weir, M.J.C. GIS Applications in Forest Land Management in Indonesia: Case Study on Forest Monitoring with Satellite Images. ITC Journal, 1990-3 pp 236-244.

(1986)

23. Tucker, C.J. Maximum Normalized Difference Vegetation Index Images for Sub- Saharan Africa for 1983-1985. International Journal of Remote Sensing, vol.7, No.11, pp 1383-1384.

APPENDIX I

DIGITAL IMAGE PROCESSING FILING CODE USED

Main working folder – c:/ my documents / Kebbi

MSS Dataset	- 0412761	NigeriaSat- 1 Dataset	- 031
	- 0412762		- 032
	- 0412763		- 033
	- 0412764		
TM Dataset	- 1021861		
	- 1021862		
	-1021863		
	- 1021 864		
	- 1021865		
	- 1021866		
	- 1021867		
ETM+ Dataset-	- 1118991		
	- 1118992		
	- 1118993		
	- 1118994		
	- 1118995		
	- 1118996		
	- 1118997		

- Composite image of the area using MSS Data : BK 76 Comp
- Composite image of the area using TM Data : BK86 Comp
- Composite image of the area using ETM+ Data : BK99 Comp
- Composite image of the area using NigeriaSat- 1: BK2003 Comp

- Vegetation index image of MSS: ttvi 76

Vegetation index image of TM : ttvi 86

Vegetation index image of ETM+: ttvi 99

Vegetation index image of NigeriaSat-1: ttvi 03

- TTVI images after change of reference from UTM to lat/ long system:
    - ttvi 76 REFTRAN
    - ttvi 86 REFTRAN
    - ttvi 99 REFTRAN
    - ttvi 03 REFTRAN

- Classified TTVI images:
    - ttvi 76 REC
    - ttvi 86 REC
    - ttvi 99 REC
    - ttvi 03 REC

- Window of Composite images:
    - Wincomp 76
    - Wincomp 86
    - Wincomp 99
    - Wincomp 03

- Window of images used in generating VI's

MSS –	win 762
-	win 763
TM -	win 863
-	win 864
ETM+ -	win 993
-	win 99
NigeriaSat-1 –	win 032
	win 033

APPENDIX II

BAND DESIGNATIONS

MULTISPECTRAL SCANNER (MSS)

LandSats 1-3	LandSats 4-5	Wavelength(micro meter)	Resolution (meters)	Designation
Band 4	Band 1	0.5 – 0.6	80	Green
Band 5	Band 2	0.6 – 0.7	80	Red
Band 6	Band 3	0.7 – 0.8	80	NIR
Band 7	Band 4	0.8 – 1.1	80	NIR
Band 8				
Land Sat 3 only	N/ A	10. 4 –12. 6	237	TIR

THEMATIC MAPPER (TM)

LandSat 4-5	Wavelength (micrometer)	Resolution (meters)	Designation
Band 1	0.45 – 0.52	30	Blue
Band 2	0.52 – 0.60	30	Green
Band 3	0.63 –0.69	30	Red
Band 4	0.76 – 0.90	30	NIR
Band 5	1.55 – 1.75	30	MIR
Band 6	10.40 – 12. 50	120	TIR
Band 7	2.08 – 2.35	30	MIR

ENHANCED THEMATIC MAPPER PLUS (ETM+)

Landsat 7	Wavelength (micrometers)	Resolution (meters)	Designation
Band 1	0.45 – 0.52	30	Blue
Band 2	0.53 – 0.61	30	Green
Band 3	0.63 – 0.69	30	Red
Band 4	0.78 – 0.90	30	NIR
Band 5	1.55 –1.75	30	MIR
Band 6	10.40 – 12.50	60	TIR
Band 7	2.09 –2.35	30	MIR
Band 8	0.52 – 0.90	15	PAN

SPOT XS AND P

SPOT HRV	Wavelength (micrometer)	Resolution (meters)	Desigantion
Band 1	0.5 – 0.59	20	Green
Band 2	0.61 – 0.68	20	Red
Band 3	0.79 – 0.89	20	NIR
SPOT P	0.51 – 0.73	10	PAN

NIGERIASAT –1

NigeriaSat-1	Wavelength (micrometers)	Resolution (meters)	Desigantion
Band 1	0.52 – 0.62	32	Green
Band 2	0.63 – 0.69	32	Red
Band 3	0.76 – 0.9	32	NIR

NIR – Near – Infrared

MIR – Mid – Infrared

PAN- Pandiromatic (Black and White)

HRV – High Resolute Visible