PREDICTIVE MODELLING OF DESERTIFICATION IN JIBIA LOCAL GOVERNMENT AREA OF KATSINA STATE, NIGERIA

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AUGUST, 2018

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M.Sc/SCIEN/27542/12-13

(MSc REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM)

A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE DEGREE IN REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT,

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AUGUST, 2018

DECLARATION

I declare that the work in thesis entitled PREDICTIVE MODELING OF DESERTIFICATION IN JIBIA LOCAL GOVERNMENT AREA OF KATSINA STATE, NIGERIA has been done by me in the Department of Geography. The literature has been duly acknowledged in the text and in a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

Hadiza Ahmed TANIMU

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Name of Student **Signature** **Date**

CERTIFICATION

This dissertation entitled PREDICTIVE MODELLING OF DESERTIFICATION IN JIBIA LOCAL GOVERNMENT AREA OF KATSINA STATE, NIGERI by Hadiza Tanimu AHMED meets the regulations governing the award of the degree of Masters of Science in Remote Sensing and Geographic Information Systems of Ahmadu Bello University and is approved for its' contribution to knowledge and literary presentation.

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Dean, School of Postgraduate Studies Signature Date

DEDICATION

Alhamdulillah, this work is dedicated to my parents Late Alhaji T.A. Kankia my Father my hero may the Almighty grant you highest house in Jannatul Firdausi and my Mother may the Almighty reward you and give you good health Amin.

ACKNOWLEDGEMENTS

This research is the result of valuable support from many individuals. Their contributions in different ways have helped in the successful completion of this study.

I start with Alhamdulillah, it was hectic but the desired result was achieved. I am thankful to the Almighty God for giving me the opportunity to be able to see the successful completion of this research work. Thank You Lord for being there for me all through I am also grateful to my supervisors, Dr. B.A. Akpu and Dr. D.N. Jeb for their guidance and critical suggestions from the inception till completion of this dissertation. I appreciate your valuable contributions in conducting this research which shaped it in the right direction. My appreciation also goes to the entire staff of Geography Department.

My Special thanks goes to my family for their love, support, patience and prayers for me, my husband Malam Mohammad A. Falaki, my children Ghada, Ibrahim, Yusuf and Ahmad also my mother in-law Hajia Ghadatu Falaki. My mother deserves special thanks for her unwavering support and prayers all through. Thanks a lot may the almighty reward you.

I am thankful to my research guides Mallam Mukhtar and Mr. Mohammad Ismail and Mallam Hassan for your advices and contributions. My gratitude also goes to my brother Ahmad, my sisters Zainab and Fatima and my nephew Tanimu for sparing their time to help in questionnaire administration. My deep appreciation also goes to the rest of my siblings for their prayers, love and support.

To my friends and colleagues whom we started this race together Taibat Yusuf, Shamsudeen, Barde, Kassim, Yaks, Paul and all those that helped me in one way or the other. I appreciate you all. While all these people have contributed to the success of this research, I alone stand responsible for any errors made in the process of this research.

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ABSTRACT

Jibia Local Government Area is characterized by low amount of rainfall, high temperature and low humidity which have caused frequent drought in the area and over time this has affected the socio-economic lives of the inhabitants. Therefore, desertification in Jibia Local Government Area of Katsina State, Nigeria' becomes evident. MEDALUS methodology was used to determine the causative factors of desertification in the study area. Landsat TM (1990); Landsat ETM (2000); and Landsat 8 of 2015 were used. Markov model was used to predict changes in desertification process up to year 2030. A total of 400 respondents were sampled using random sampling technique for questionnaire administration. Results on classified satellite imageries showed a considerable decrease in vegetation and an increase in desertification. Between the years 1990 and 2000 (10 years) about 17.8% of the total study area was affected by desertification, that means approximately 1.8% of the area was affected yearly. However, between 2000 and 2015 the rate increased where more than 100% of the total land area was affected at the rate of 8.0% annually. Between 1990 and 2015, total land area affected by desertification amounted to 277.4sqkm. Results on prediction indicated desertification increase from 450.84sqkm in 2015 to 485sqkm of the total land area to be engulfed by desertification by the year 2030. The results obtained from respondents showed that desertification is a menace with serious consequences with majority of the people being aware of for more than a decade. The respondents also believe that climate change and anthropogenic factors are the major causes of the problem. Results also showed that desertification has negative impact on agricultural activities. Recommendations proffered include intensification of afforestation and reforestation exercise, provision of alternative forms of energy for cooking, provision of grazing lands, community participation and enlightenment campaigns, provision of robust database and information banks on desertification.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

United Nations (UN) has paid much attention to the planning and development of arid zones for two good reasons. First, many people are living in arid regions and second, because of the intensive increase in the world population. This suggests that the world is running out of land; thus, land of any kind is going to be at a premium (Tanimu, 2006).

Desertification is a major environmental, social and economic problem in most parts of the world (Breckle and Veste, 2011). Desertification refers to land degradation in arid, semi-arid and dry sub humid areas, resulting mainly from adverse human impact (David and Nicholas, 1994). Desertification can also be defined as the destruction of lands, biological potential and the general degradation of the ecosystem under combined pressures of adverse and uncertain conditions including over exploitation due to human activities leading to dry lands (Yunusa, 2012). It is the process whereby a living environment becomes irreversibly sterile and barren (Nicholson, 2002).

The process of land degradation can be aggravated by reduced vegetation cover, soil organic matter, soil compaction, decreased infiltration, increase in run-off, as well as wind and water erosion (Schreiber, 2013). Thus, desertification is a result of climatic factors but its rate can be exacerbated by a combination of environmental factors (such as deforestation and over cultivation) in relation to man's daily activities for survival (Robert, 2011). Desertification of an area will proceed if certain land components are brought beyond specific threshold, beyond which further change produces irreversible change (Gad and Shalaby, 2010).

Factors contributing to desertification include the degradation of soils and vegetation also climate and also changes in demographic and human activities (World ecology report, 2009). Each of these factors has different variables determining it such as population size, arable land and livestock size. Desertification is caused by the combination of natural events such as drought and human pressure on land, in climatically marginal areas (Olofin, 2012). Drought weakens the resilience of affected areas but under natural conditions such lands recover before next drought event. However, in cases where human activities occur on a drought area before it regains its balance, the process of desertification sets upon such lands (Robert, 2011).

Desertification threatens the livelihood of millions of human beings (Ali and Shariff, 2011). According to the United Nations report, more than one billion people across the globe are affected by drought and desertification (United Nations Convention to Combat Desertification, 2004). The United Nations Environmental Programme (UNEP) has estimated that more than a quarter of the African continent is becoming useless for cultivation because of land degradation such as desertification and erosion (UNEP, 1987). In the drier parts of Africa, millions of hectares of grazing land and rangeland are also threatened by degradation (Robert, 2011).

The United Nations general assembly endorsed the global plan of Action to combat desertification that emerged from the United Nations Conference on Desertification (UNCOD) in 1977, and the desertification branch of UNEP was charged with its implementation. Proposed activities included establishing a sahelian green belt as well as five large-scale transnational projects to manage the region's aquifers and live stock levels (UNCOD, 1978). However, in 1984 UNEP reviewed progression and concluded that the land lost to desertification had continued to rise steadily at same rate earlier reported in 1977 (Toulmin and Brock, 2016).

One of Nigeria's major efforts since independence to combat desertification was the establishment of a Committee on Arid Zones Afforestation in 1977. This committee was created at the Federal level with sub-committees in the then five most affected states of northern Nigeria to curb environmental problems such as desert encroachment and erosion (Tanimu, 2006). Despite this effort, the menace of desertification continues to threaten the economic survival of both humans and animals. The extent and severity of desertification in Northern Nigeria has not been fully established. Prince, Coulstoun, Brown and Kravitz (1998) argues that desertification remains a nebulous, all encompassing concept that is not a single phenomenon and is therefore incapable of simple measurement. Nevertheless, some reports suggested that progression rate of desertification in Northern Nigeria is about 0.6 km per year (Nwafor, 2006). The physical evidence witnessed includes decline in agricultural production due to low soil fertility, migration of birds indigenous to the area, mass siltation and disappearance of water bodies among others (Grainger, 1990). In Nigeria, the effect of desertification is felt in the Sudano-Sahel dry land region. This region comprises of states like Sokoto, Katsina, Kebbi, Kano, Jigawa, Zamfara, Yobe and Borno, often referred to as desertification frontier states (Yunusa, 2012).

Jibia Local Government Area of Katsina State, is one of the worst desert affected Local Government Areas (LGA) in Katsina State and this has over time affected the socio-economic lives of the inhabitants. Drought and desertification have affected the physical, economic and emotional aspects of the inhabitants' lives particularly their agricultural practices considering that majority of the inhabitants are farmers therefore crop failure can be seen as a great obstacle militating against their subsistence food production (Sani, 1996).
Given the complexity of desertification processes, indicators such as soil, vegetation and water indices have been evolved in order to monitor and evaluate the process thereby

developing a provisional methodology for the assessment and mapping of desertification (Drake and Symeonakis, 2004).

Modeling of desertification sensitivity is very vital in visualizing and predicting the expected environmental risk towards desertification (Yunusa, 2012). A number of simulation models have evolved in order to predict and map desertification incidence. Such models can link current knowledge of processes driving vegetation dynamics and allow systematic investigations of the interactions between all relevant factors and their logical consequences (Drake and Symeonakis, 2004). The Modeling of desertification can be made by using either simulation modeling and Geographic Information System (GIS) or parametric method (Rasmy, Gad and Abdelsalam, 2011). Simulation models are sophisticated tools for characterizing and understanding environmental patterns and processes and estimating the effect of environmental change at local, regional and global scales (Louis and Goodchild, 1993). It is a powerful tool for controlled experimental manipulation of a large number of environmental conditions over long time spans (Florian, 2001). Simulation models falls into two broad classes; deterministic model which uses a predictive definition of the function of distance between observation locations and the location of which interpolation is required (such as Markov chain analysis model) and probabilistic model which has foundation in statistical theory (Gribov and Krivoruchko, 2012). These predictors quantify the uncertainty associated with the interpolation values.

Monirsadat, Mohamadhosein and Ghafary (2011) forecasted drought by Markov chain in Ardakan city, Iran. Prediction was carried out based on a 46 years analyzed rainfall data and standardize precipitation index (SPI) was calculated in 3 and 12 months variation to get severity classes. Markov was then applied and the results obtained showed probability transition from one class to the same class was stronger based on 3 to 12 months interval. Probability transition from very wet state to extreme drought condition was zero, increase in monthly probability of wet years occurrence in humid areas and tendency of all areas to reach a normal state.

Mediterranean Desertification and Landuse (MEDALUS) methodology was employed by Gad and Lofty (2013) to calculate the environmental sensitivity of areas to desertification in Egyptian territory. Thematic Mapper scenes, geologic map of Egypt produced by CONOCO 1990 and climatic data were used. Erdas Imagine 8.3systemand Arc GIS 9.0 software was used for computation and assessment of the data for the sensitivity test of the areas to desertification. The results revealed that about 55% of the area on the sensitivity map showed high sensitivity. It was concluded that the Northwestern coast was susceptible to very high desertification sensitivity.

An assessment of desertification incidence in Northern parts of Katsina State of Nigeria was undertaken by Gakkuk (2014) where satellite imageries were used to obtain vegetation decline via Normalized Difference Vegetation Index (NDVI). Results obtained showed vegetation changes in hectares as 85.7%, 77.9%, 58.2% and 50.5% for the years 1976, 1988, 1999 and 2006 respectively. Furthermore, in testing the relationship between rainfall and NDVI, result showed a positive correlation suggesting vegetation decline and active desertification in the area.

Similarly, Bambale (2014) used descriptive statistics to assess farmer's awareness on drought and examined the socioeconomic effects of drought in Katsina State. Results obtained from analyzed rainfall trend revealed a significant decrease in rainfall variations over months which resulted to moderate to severe drought in 1970s to 1990s with peak in 1984.

Therefore, in predicting desertification extent in Jibia Local Government Area, the Markov chain analysis model was used. Markov change model is one of the methods for data modeling and prediction. It is also an analysis technique in time-based reliability and availability analysis and a stochastic process involving a number of random variables depending on the variable parameter which is time (Rabiner, 1989).Thus, Markov model is analyzed in order to determine such measures as the probability of being in a given state at a time, the amount of time a system is expected to spend in a given state and expected number of transitions between the states (Ozah, Adesina and Dami, 2010). There are many researches in this field, for example, Alizadeh (2009) used Markov chain and predicted drought in Khorasan Razavi province 2008.

1.2 Statement of the Research Problem

Desertification has been seen as a major cause of problems in large parts of the African continent and Nigeria is not an exception. The general lack of suitable monitoring method is a factor that compounds the problem. Only in 1977 the first desertification hazard map was provided during the United Nations Conference on Desertification (UNCOD) (Symeonakis and Drake, 2004). A lack of data meant that the best that could be done was an 'educated guess' at the true extent of the problem (Thomas and Middleton, 1994).

Katsina State is one of the worst affected States experiencing desertification in Northern Nigeria. The Katsina State Ministry of Environment admitted in the Leadership newspaper of 1 March, 2012 that desert control remains one of the major challenges facing the State particularly Jibia Local Government Area which is worst hit by this disaster.

Jibia Local Government Area falls within the semi-arid zones of the desert in Northern Nigeria. This region is characterized by low amount of rainfall, high temperature and low humidity. Furthermore, the study area is subjected to indiscriminate cutting down of trees and cultivation of degraded farmlands which have caused frequent drought in the area. Over time, this has affected the socio-economic lives of the inhabitants (Bambale, 2014). Scores of farmers and their families have been forced to move off land that has become barren principally by desertification. The nomadic Fulani are also heading southward in search of grazing areas for their herds. The loss of arable land and pasture are threatening the economy of this mainly farming area, thereby increasing poverty and hardship on the rural poor (Nasir, 2011; Bambale, 2014).

Many Governmental and Non-Governmental agencies have undertaken several projects in Katsina State so as to tackle the environmental problem of desertification, such as the Katsina State Afforestation Project Unit (KTAPU) established in 1988; Katsina State Agricultural and Rural Development Authority (KTARDA) established in 1988; International Fund for Agriculture Development (IFAD) established in 1993; European Economic Community (EEC/KTSG) established in 1987; the Federal Government of Nigeria's efforts and the World Bank's assisted project on drought and desertification control have undertaken several projects towards managing desertification in affected Local Governments of the State which includes Jibia. However, efforts by these agencies have made little impact. Hence, desertification is on the increase because of their inability to identify the major causative factors and their general lack of adequate data, suitable analysis and effective monitoring methods (Nasir, 2011).

None of previous researches employed the MEDALUS methodology and Markov model to predict desertification especially in Jibia LGA, Katsina State of Nigeria. Therefore, for this study a modified MEDALUS methodology was used. MEDALUS methodology has the advantage of checking desertification severity in areas within a single study area base on a set of parameters likely to bring about desertification. Soil, vegetation and climatic indexes were employed to assess the causative factors of desertification in the study area, as well as Cellular Automata Markov model within remote sensing software interface was used to predict desertification in the study area to 2030 to help meet one of the sustainable development goals (SDGs) objectives, which intends to halt desertification as well as reverse degraded lands and protect the bio-diversity by 2030. Effects of desertification were also determined through some set of questions administered to the inhabitants of the study area. The study found answers to the following research questions.

1. What are the causes of desertification in the area?
2. How sensitive to desertification is the area?
3. What is the extent and rate of desertification in the area?
4. What are the effects of desertification in the study area?
5. What will be the scenario of desertification in the area by 2030?

1.3 Aim and Objectives of the Study

The aim of this study was to model desertification in Jibia Local Government Area, Katsina State, Nigeria.

However, the specific objectives of this study were to:

i. identify the causative factors of desertification in Jibia local government area;
ii. determine the sensitivity of areas in the study area;
iii. determine the extent and rate of desertification in the study area;

iv. examine the effects of desertification in the study area;
v. predict desertification extent in 2030;

1.4 Scope of the Study

The spatial scope of this study was delimited to desertification prediction and modeling in Jibia L.G.A of Katsina State. This includes the following communities: Fafarau, Yangaya, Jibia A, Jibia B, Mazanya, Gurbin-Baure, Faru, Bugaje, Gangara, Riko and Kusa. This work focused on the causes and effects of desertification. Indicators such as the soil quality index, vegetation quality index and climatic quality index were used in determining the causes of desertification in the study area. The temporal scope of this study covered the period 1990 to 2015. Current state of desertification was predicted to 2030.

1.5 Justification of the Study

In the African continent, desertification is the major cause of problems such as poverty, poor health and food shortage. However, the general lack of suitable surveying, evaluation and prediction methods compounds this problem (Symeonakis and Drake, 2004).

The extent of desertification is hardly measured or poorly documented in Jibia L.G, which receives little attention in national planning and budgetary allocation (Dregne 2002). The lack of evidence based report on local environmental conditions is lacking which undermines land management efforts at specified risk sites. Geospatial technologies such as satellite imageries, aerial photography, and geographic information systems (GIS) has great potential for improving the quantity and quality of data on degradation trends over large areas as well as provide means for effective management of such information (Schreiber, 2013). It is also believed that dry land degradation can be slowed and reversed if areas undergoing desertification can be identified and properly managed. Therefore, for any management strategy to work effectively, the problem must be well understood, measured and documented. This necessitated the need for desertification to be effectively measured, properly checked, and future scenarios predicted. This will enable better understanding of the graveness of the desertification problem in order to provide effective management strategies to curb the situation.

CHAPTER TWO

2.0 CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 CONCEPTUAL FRAMEWORK

2.1.1 Concept of Desertification

United Nations (UN) defined desertification as the land degradation of dry, semi dry and dry sub-humid lands caused by human as well as natural causes. United Nations Conference on Desertification (UNCOD, 1977) defined desertification as "the destruction of the biological potential of land, that can lead eventually to desert-like conditions", and called it "an aspect of the widespread decay of the ecosystem under the combine pressures of adverse and varying climate and excessive exploitation" (UN, 1977). In another definition, desertification is the deterioration of terrestrial ecosystem under the impact of man (Dregne, 1985). Desertification takes place in dry land areas where the earth is particularly fragile with less rainfall and harsh climate. The result is the destruction of the topsoil followed by the inability of the land to sustain crops, livestock or human activities (Reinaldo, Tomoyoki and Cleyber, 2005).

Socio-economic disturbances, particularly when they occur combined with climatic fluctuations, become the main drivers of desertification (Reynolds and Stafford-Smith 2002). Socio-economic activities affect water balances and lead to land degradation through changes in land-use patterns (Hill, Udelhoven and Stellmes, 2003). Desertification is a gradual process which operates through systems of land use that overtax the inherent bio-productive capacity of land (Oppong, 1993) this process is in stages which are active in arid lands due to scarcity of land and water (Gad and Lotfy, 2013).

2.1.2 Desertification Models

Geographic Information Systems (GIS) are widely used tools for assembling and managing large spatial databases, and also perform analyses to produce effective visual representations and management options. GIS benefits in being able to manage and analyze spatial data in digital format and being able to effectively communicate information visually, just as a paper map could (Schreiber, 2013). People are more inclined to understand pictures (maps and graphs) better than just plain text.

Remote sensing is the science of obtaining information about objects or areas by measuring its reflected and emitted radiation from a distance (Campbell, 2006). The advantage of using remote sensing is that images of areas can easily be obtained at different times (temporal scope). This is important in change detection applications. Remote sensing systems can cover large areas (depending on the sensor), and the users are provided with an overall picture of an area of interest based on the required resolution.

On the other hand, simulation models are sophisticated tools for characterizing and understanding environmental patterns and processes that relates to the science of problem solving as well as estimating the effects of environmental change at local, regional and global scales (Paul, Michael, David and David, 2004). They may include dynamic simulation models of natural processes such as erosion, migration of certain animals e.t.c, or models of social processes such as movement of cars on a congested highway and so on (Rasmy, Gad and Abdelsalam, 2011). These may also include simple calculation for indicators or predictors such as when geographic information is combined to measure the pattern of desertification in arid or semi-arid areas. During the past 10 years, the European Commission has funded numerous dedicated research projects in the field of land degradation and desertification. These projects focused on data collection in specific field sites, detailed methodological studies, assessment and monitoring experiments, and the development of specific modeling concepts. Substantial scientific progress has been achieved and some of these projects succeeded. However, predictive modeling has only been applied in few of the vast areas worldwide affected by the incidence of desertification. Predictive Models are essential tools in forecasting the future state in desertification incidence in areas prone to such problem.

Markov Chain Analysis Model (MCAM) is a stochastic model used to model randomly changing systems where it is assumed that the future states depend only on the present state and not on the sequence of events that preceded it (Rabiner, 1989). Markov Chain analysis model is a random process that undergoes transition from one state to another in which the transition to the next stage depends on that given state and not on how the process has arrived to that state. Markov models have substantial scientific appeal. They are mathematically compact, easily developed from observed data and serve as an effective tool for simulation exercise (Monirsadat, Mohamadhosein and Ghafary, 2011). Figure 2.1 shows a schematic illustration of the inputs and outputs of a Markov chain.

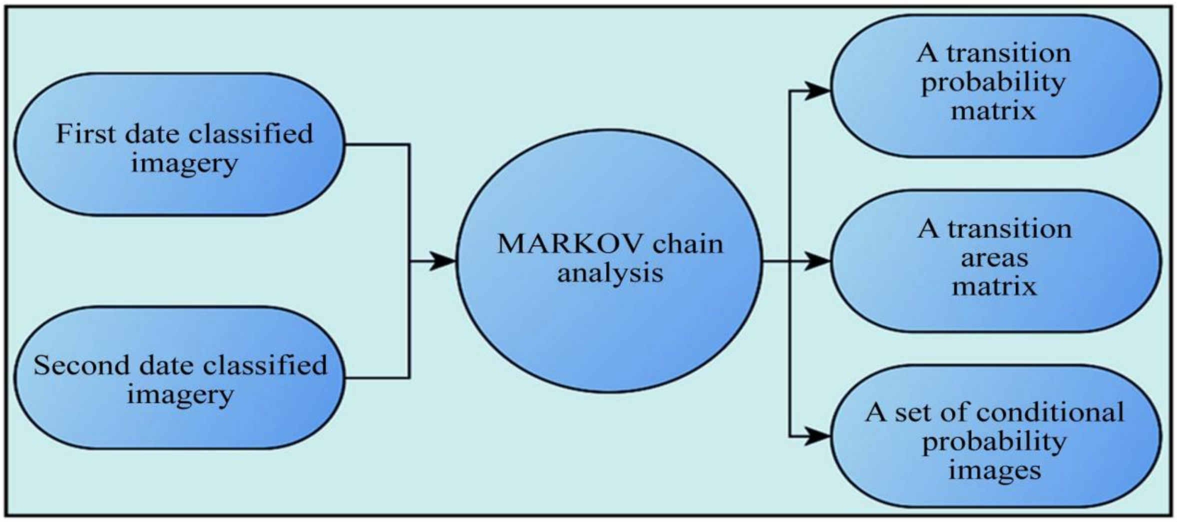

Figure 2.1: Inputs and Outputs of a Markov Chain.

Source: El-Hallaq and Habboub, 2015.

Cellular Automata Markov plays a vital role to simulate the evolution of dynamics of a wide variety of natural and human systems. It presents a powerful simulation environment represented by a grid of space (raster) in which a set of transition rules determine the site attribute of each given cell, taking into account the attributes of cells in its vicinities. This model has been very successful in view of its possible operations, simplicity and ability to embody both logic and mathematics-based transition rules. Hence, this enables complex global patterns to emerge directly from the application of simple local rules (White, Engelen and Uljee, 2000).

The Mediterranean Desertification and Land Use (MEDALUS) methodology of the European commission of 1999 is about identification of areas sensitive to desertification process using Remote Sensing and GIS (Gad and Lotfy, 2013). According to this method, parameters affecting desertification process are identified and scored according to a factorial scaling technique between the scores 1 (good condition) and 2 (deteriorated condition), while the value “zero” is assigned to areas which are not classified (Mohamed and Haroun, 2010). Participation of natural factors and demographic factors in the process is also identified, and then a map is prepared for each of the factors (Sepehr and Ekhtesasi 2012).The MEDALUS methodology is used to verify desertification process and it is also a useful tool in distinguishing areas sensitivity to desertification in a single study region. It may also be generalized to other areas with the same characteristics. Indicators such as Soil Quality (SQI), Vegetation Quality (VQI), Demographic Quality (DQI), Ground Water Quality (GWQI) and Climatic Quality Indices (CQI) are used in calculating the vulnerability of areas to desertification with the help of a set of parameters for each of the indicators. Figure 2.2 shows the conceptual model of calculating the SQI, CQI and VQI.

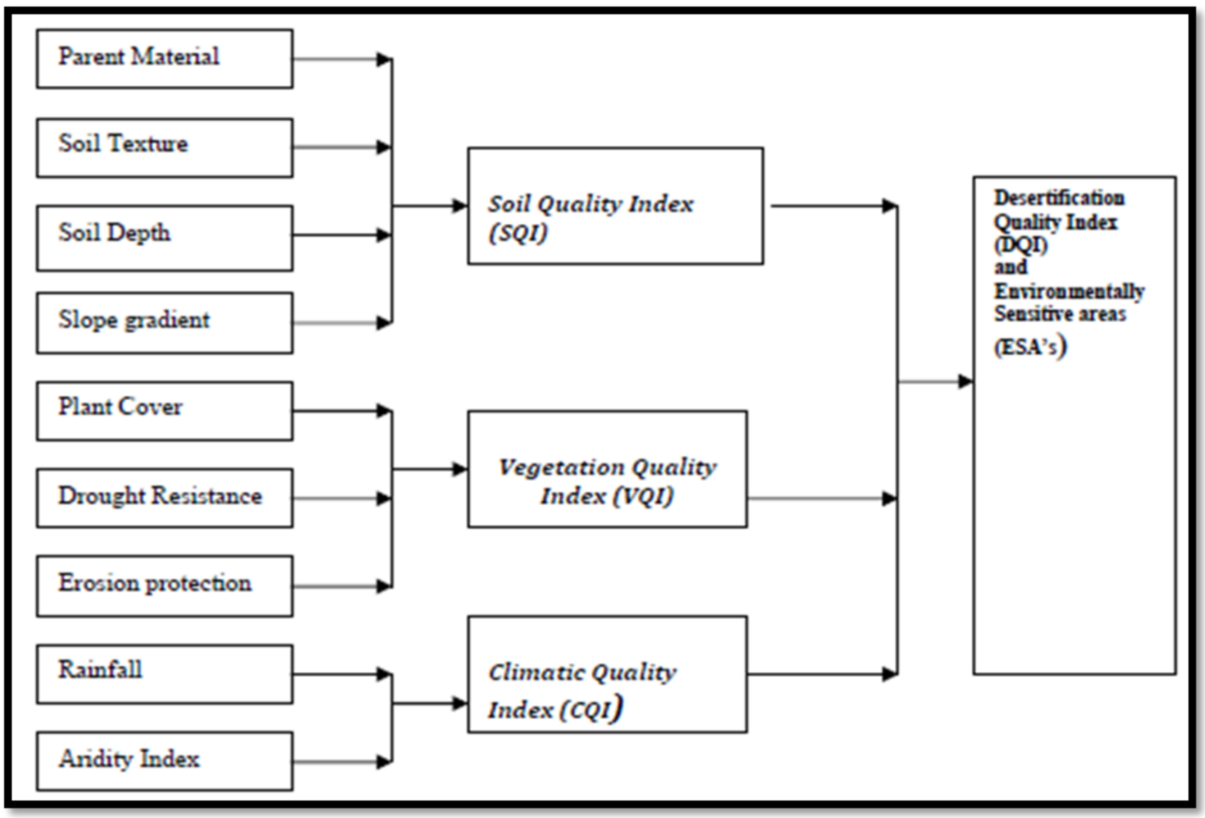

Figure 2.2: Quality Indices responsible for Desertification
Source: Gad and Shalaby, 2010.

Indicators may demonstrate desertification as preceded to its end of irreversibly infertile soils; however, most useful indicators are those which indicate the potential risk of desertification while there is time and scope for remedial action (Kosmas, Kirkby and

Geeson, 1999). Different areas exhibit different sensitivity to desertification for various reasons.

Soil quality indicators for mapping Environmental Sensitivity Areas' can be related to water availability and erosion resistance. Soil is a dominant factor of the terrestrial ecosystems in the semi-arid and dry sub-humid zones. Desertification in a certain landscape will precede when the soil is not able to provide the plants with rooting space, water and nutrients (Monirsadat, Mohamadhosein and Ghafary, 2011). Parameters considered under the soil quality index and their scoring are presented on Tables 2.1, 2.2, 2.3 and 2.4 respectively.

Table 2.1: Soil Texture

Class	Soil Texture	Index	Description
1	Loamy sand, sandy loam	1	Not very light to average
2	Loamy clay, clayey sand, sandy clay	1.33	Fine to average
3	Clayey, clay loam	1.66	Fine
4	Sandy to V.Sandy	2	Coarse

Source: Gad and Lotfy, 2007.

Table 2.2: Soil Slope Gradient

Class	Description	Slope (%)	Index
1	Gentle to flat	<6	1
2	Not very gentle	6-18	1.33
3	Steep	18-35	1.66
4	Very steep	>35	2

Source: Gad and Lotfy, 2007.

Table 2.3: Parent Soil Material

Class	Description	Parent Material	Index
1	Good	Schist, basic, ultra basic, conglomerates, unconsolidated	1.0
2	Moderate	Limestone, marble, granite, rhyolite, lynibute,	1.7
3	Poor	Mart, pyroclastics, porphyritic homolende	2.0

Source: Gad and Lotfy, 2007.

Table 2.4: Soil Depth

Class	Description	Depth(m)	Index
1	Deep	<1.0	2
2	Moderate	1-1.5	1.66
3	Shallow	1.5-2	1.33
4	Very shallow	>2.0	1

Source: Kosmas, Kirkby and Geeson, 1999.

Uneven annual and inter-annual distribution of rainfall, extreme events with the out of phase of rainy as well as vegetative seasons in the semi-arid and arid zones are the main climatic quality indices that contribute to the degradation of land. Land in arid and semi-arid climatic zones is unstable and desertification processes are triggered only if the other land components cross specific thresholds. In a number of years, the prevailing weather conditions during the growing period of annual crops may be so adverse that the soils remain bare, creating favorable conditions for overland flow and erosion. Any loss of volume from these marginal lands greatly reduces the potential for biomass production, ultimately leading to desertification. Desertification at present, threatens only the shallow and severely eroded soils (Kosmas, Kirkby and Geeson, 1999). Parameter considered for rainfall quality index in terms of rainfall distribution is shown on Table 2.5. The index 4 was used to signify a low rainfall of less than 280 as modified by Gad and Lotfy (2007).

Table 2.5: Rainfall Distribution

Class	Rainfall (mm)	Index
1	>650	1
2	280-650	2
3	<280	4

Source: Gad and Lotfy, 2007.

Furthermore, vegetative cover is the dominant biotic land component in terms of desertification. Vegetation cover is very crucial for run-off generation and can be readily altered along hilly areas depending on the climatic conditions and the time of the year. In areas with annual precipitation less than 300 mm and high evapo-transpiration rate, the soil water available to the plants is reduced drastically and the soil remains relatively bare favoring overland water flow. Parameter for calculating vegetation quality index is shown on Table 2.6 below:

Table 2.6: Plant Cover

Class	Description	Plant Cover (%)	Index
1	High	>40	1
2	Low	10-40	1.8
3	Very low	<10	2

Source: Gad and Lotfy, 2007.

Depending on the particular type of management, land resources are subject to a given degree of stress. Moreover, the existence of environmental policies which apply to a certain area, moderate the anticipated impacts of a given land use type compared to the situation where no such policies are in effect (Kosmas, Kirkby and Geeson, 1999).

2.2 LITERATURE REVIEW

2.2.1 Desertification in the African Sahel

Sub Saharan Africa has a very fragile ecological belt known as the Sahel which has been hit by a series of droughts and subsequently by desertification (Ogboi, 2012). The "Sahel" is derived from a local word meaning "edge of the desert" (Grove, 1978). The Sahel is a semi-arid ecological zone between the Sahara and the Savannah lands to the south. These include parts of Mauritania, Senegal, Mali, Burkina Faso, Niger, Nigeria, Chad, Sudan and Ethiopia (Fran, 2015). For many generations, the people of the sahel have lived with consistently unreliable rainfall and long term cycles of periodic drought (Hesse, Anderson, Cotula, Toulmin and Skinner 2013), this area has an average annual precipitation of more than 100mm and less than 600mm. Due to the nature of their lives and livelihood and has been the setting within which they have developed social and environmental strategies to support their prosperity (Hesse, Anderson, Cotula, Toulmin and Skinner, 2013) The Northern parts of the Sahel consist of an area considered useful for nomadic grazing, and rain fed agriculture is only possible in the wetter sites, in wetter years (Tanimu, 2006).

In 1950, people settled in the Sahel region, in areas where there was abundant water. Overgrazing by the settlers caused alarming desertification, perennial shrubs were destroyed and replaced by annual shrubs. Eventually, the annuals crops were grazed out which left bare soil and the topsoil was washed away due to the action of rain and wind, leaving only rocks. Silt turned hard when hit by rain which resulted to lack of plant growth because of the thick impenetrable hard layer. Currently, this region has turned to a desert and continues to expand (Desertification, 1994).

The Sahel stretches from west to east over nine countries such as Mauritania, Senegal, Mali, Burkina Faso, Niger, Chad, Sudan, Ethiopia and Nigeria (UNEP, 1993). Some parts of Northern Nigeria have witnessed consistent droughts and gradual encroachment of desert over the past 30 years. The desert is said to be advancing southwards at the rate of 0.6 percent yearly, resulting in the loss of land and displacement of settlements (Nwafor, 2006). Soil degradation has overtime negatively affected the capacity of Sahelian farmers to grow crops thereby resulting in less grazing land for livestock, which has considerable impacts for people that live not only in, but near, the degraded areas.`

2.2.2 Causes of Desertification

Desertification is caused by both natural and the human induced factors. However, views differ concerning the respective roles of human and climatic impacts. El Baz (1983) viewed desertification as the result of a progressive drying of the climate of Africa that started 5000 years ago. While others like Dregne (1985) consider it to be "man induced phenomenon with no respect for climatic zones". However, Grove (1978) argued that there are both Human and Climatic causes, but that both are difficult to distinguish. However, it has been ascertained that Desertification is directly caused by four main types of poor land use: These are; overgrazing, over cultivation, Poor irrigation management and Deforestation.

2.2.1.1 Overgrazing

Over grazing was not as large of a problem long ago because animals move in response to rainfall. People would move with the animals thereby preventing overgrazing in such areas. Overgrazing is certainly the major cause of desertification of which rangelands accounts for almost 90 percent of such desertified lands (Mabbutt 1985). Overgrazing results when there is excessive livestock density (number per unit area) on the same rangeland, this leads to vegetation degradation, soil compaction and erosion (Grainger, 1990). Overgrazing changes the composition of the vegetation and soil, as well as the entire health of animals, this could also lead to a fall in range land vegetation production and a change in the species composition. Uncontrolled browsing of trees, herbs and shrubs is an aspect of overgrazing with a strong deforestation impact. Overgrazing has contributed to critical levels of deforestation in upland areas leading to flooding and siltation in adjacent lowlands. This is because rains are no longer held back by the sponge effect of the trees which results to flooding at the low lands, carrying with it large loads of eroded soil. Moreover, streams tend to dry up during the dry season thereby limiting the amount of water available for livestock (UNEP 1983). Exposure of the soil due to the degradation of the sparse vegetation makes the soil susceptible to the action of water and wind.

Most of Nigeria's livestock are located in its dry lands supporting about 90 % of the cattle population and two-thirds of the goats, sheep, donkeys, camels and horses (FME, 2000). Nomadic herdsmen graze their livestock right through these areas constantly in search of suitable pastures (FME, 2000).

2.2.1.2 Over cultivation

Cultivating a land more intensively than permitted by its natural fertility and failure to compensate for the export of nutrients in the crops by using artificial fertilizers or fallowing the land so that its fertility can regenerate naturally is referred to as over cultivation. Over cultivation therefore, reduces the fertility of the soil, damages its structure and exposes it to erosion (Grainger 1990).

Another form of cultivation that results to desertification is that of farming an average land which causes desertification worldwide. It is the process in which farmers clear a drought stricken land and use it for cultivation without it regaining its fertility which further takes away the richness of the soil rendering it to desertification influence. However, pastoralism is an excellent way of converting the little vegetation that grows on range land in arid areas as a result of irregular and variable rainy season. The major range land areas that account for almost half of those found in the World’s dry lands is found in the Sahel (Mabbutt 1985).

The effect of shorter fallows in terms of crop cultivation can be seen in depletion of the soil nutrients and organic matter because of insufficient time given for the soil to regain its nutrients before next cultivation. Susceptibility of the soil to erosion becomes inevitable because of low organic matter content and the fact that it is left for longer periods of time without vegetative cover. The exposed top soil is left to the action of the sun, rain and wind thus becomes loose and is washed away either by rain or carried away by wind. There is a possibility of the formation of gullies due to increased run off along the surface. Formation of sand dunes on arable land is only found in certain locations. However, destruction of crops by strong dust bearing winds is a common phenomenon. When soil fertility decreases that means a fall in crop production which will eventually lead to farmers’ intensification of cropping or increase in the size of cropping area, thereby making matters worse.

2.2.1.3 Poor Irrigation Management

Buildup of Salt in the soil mostly in arid regions is a repercussion of poor irrigational practices. Often, irrigation is seen as the solution to food scarcity especially in dry land areas because it is in dependent of the cyclical variations in rainfall, thereby, the threat of crop failure as a result of drought is removed. However, as irrigation proves to be a problem solver and comes with major advantages especially in dry areas, poor management of irrigation also comes with some consequences. These include fall in productivity after a few years of operation. If allowed to continue, this can lead to soil salinization, alkalinization and rise in water table with consequent effect of water logging. Furthermore, this will make the land eventually unproductive and consequently desertification emerges. The problems of irrigation if not properly designed and managed can be devastating, a key to good irrigation is good drainage because it prevents soil water logging and eases cultivation. High temperatures during the dry season increases evaporation levels which makes the soil water saltier, thereby reducing crop yields and eventually leads to abandoned land if situation is not corrected (Dregne 1983). An estimated forty million hectares of irrigated crop land throughout dry lands is affected by salinity, alkalinity and water logging. While about five hundred thousand hectares brought under irrigation becomes desertified annually (Mabbutt 1985).

2.2.1.4 Deforestation

Deforestation or cutting down of plants and/or trees in dry regions is one of the major cause of desertification. People cut down trees to use as a source of fuel. Fuel wood was previously gathered mainly from dead wood, but recently large scale fuel wood cutting is a major problem The role of trees and forest cannot be overemphasized, apart from providing a habitat for wildlife, they conserve the soil, contribute to stable water supplies, provide clean air, provide shade and help regulate the climate (Penny, 2007). Once trees are cut down there is nothing to protect the soil, the soil turns to dust and is blown away by the wind or washed away by rain. There are a variety of products that can be obtained from the forest. The wood is used as fuel for cooking and can be sold. The tree leaves, pods and seeds serve as fodder accounting for about a third of the total annual food supply for animals in the Sahel (Grainger 1990). Others include fruits, gums, honey and medicines (Hoskins 1982).

Deforestation is seen as a dynamic indicator of desertification, it is also a visible and pervasive indicator which reflects long run trends that send trouble signals (Berry, 1984). The effects of deforestation are often experienced far from where it actually occurs. For example deforestation around Niamey has resulted in a whole land degradation process. Soil erosion by wind has increased; sand dunes have been reactivated, including continuing human and animal pressure. This has prevented the regeneration of vegetation and severe desertification is taking place within 40-50 km radius of the city (NRC, 1983). Deforestation in Ethiopian highlands is relentlessly converting large areas into stone deserts through massive soil erosion (UNEP, 1983). Deforestation also causes soil erosion and desertification in an indirect way, when wood land becomes very scarce, people resorts to burning of animal dung in order to fertilize crop and range lands, however, this burning of animal dung exacerbates desertification by depleting the soil fertility (Grainger, 1990).

Desertification in Nigeria is primarily attributed to human activities and adverse climatic conditions. Population needs depend on the ecosystem thereby stressing it in terms of livestock and crop production, availability of fuel wood, construction materials, and other livelihood opportunities (Cotthem 2007). According to Audu (2013) availability, cheapness and tradition makes demand for fuel wood more in rural areas than urban areas. This is because other sources of domestic fuel are nearly absent. On the whole, kerosene constitutes about 54.1% of fuel for cooking in urban areas not because it is available and affordable, but because of the scarcity of wood. This is as a result of high urbanization and scarcity or near absence of other sources of domestic energy. At the national level, the use of electricity and gas only constitute 0.7% each for cooking; while kerosene constitute 22.9%, 74.1% for wood and1.6% for coal. Kebbi State has the highest percentage of 99.2% fuel wood consumption in the country, while Gombe has the least (92.4%) among the desert prone areas. The effect of this continuous harvest of fuel wood is increasing desertification which results in the near absence of trees in the extreme northern Nigeria (Ayuba and Dami, 2011). The above evidence seems to predict that if current rate of tropical forests deforestation continues, the tropical forests could be almost entirely harvested by the year 2050.Furthermore this will lead to devastating climate change, loss of biodiversity, land degradation and desertification (UNCCD, 2004).

2.2.3 Desertification Consequences in Africa

The world's poorest and most vulnerable population often bore the consequences of desertification. In Africa, desertification impacts are among the costliest events and processes due to the continent's dependency on climate sensitive sectors which are mainly rain-fed agriculture (Pius, 2016). Desertification results to water scarcity, economic hardship, food insecurity, social and political unrest. Others include:

2.2.3.1 Loss of top soil: - Soil naturally is at risk due to low carbon and nutrients for plants. If mismanaged, it can have severe consequences on the wellbeing of human population and the environment (Kandji, Verchot and Mackensen, 2006). Loss of the top soil results in food decline which subsequently results to hunger and drought, poverty and finally migration (www.un.org/millennium goals).

2.2.3.2 Loss of Water: - Occasional flash floods often occur in areas without trees and vegetation. It carries the soil away leading to downstream flooding. Evaporation leads to rapid surface water loss thereby, rivers and lakes disappear. Evaporation and sedimentation in lakes, rivers and reservoirs means a loss of water as well as loss of soil displaced (Fran, 2015).

2.2.3.3 Economic loss: - Globally, it has been estimated that forty-two billion US dollars are expended annually in areas affected by desertification (Fran, 2015).

2.2.3.4 Loss of cultural identity and complex living conditions for migrants which undermines social stability:- In Africa, many people have become either internally displaced or forced to migrate to other countries as a result of lack of food, water, basic infrastructures and economic hardship brought about by drought and desertification (Fran, 2015)

2.2.3.5 Loss of biodiversity: - Reduction of biodiversity at local and global level is another impact of desertification. Desertification contributes to the destruction of animals, plants and micro-organisms' habitats. It encourages the genetic erosion of local livestock, plant varieties and species living in fragile ecosystems. Food and health of the local people is affected, who rely on a large number on different animals and vegetable species. Many genetic strains of cultivated plants which form the basis of the food and health of the world's population, originate from dry zones. Hence, their disappearance can affect the possibility of producing plant-based medicines to combat specific diseases or epidemics (Abahussain, Anwar, Waleed, Nabil and Mahmood, 2002).

2.2.4 Modelling of Desertification

Monitoring intensive land conversion has been conducted using Remote Sensing technology, with various techniques. Several methods of land-use dynamic analysis and prediction have been used such as cellular automata and Markov chain as well as Environmental sensitivity of Areas. Some studies have used Cellular Automata (CA) method for many different kinds of land use analyses, both in urban and rural areas (Nurmiaty, Baja and Arif, 2014).

Markov model was employed to study the development of land cover change for southern Senegal in which temporal and spatial Markov models were developed for characterizing land use/land cover change in the study area. The Markov model results were compared to results obtained using other spatial analysis techniques, including joint count statistics and landscape metrics. Though landscape change appears not to be strictly Markovian, pure and modified versions of both the temporal and spatial models appear to have potential for simulation of land use/land cover.

Moreover, Markov chain model was used in Iran to forecast drought in Ardakan city. Prediction was based on an analyzed 46 years rainfall data and Standardize Precipitation Index (SPI), which was calculated in 3 and 12 months variation to obtain severity classes. Markov was then applied; results obtained showed that the area will be in a normal condition with a probability of 50% to 60% and will eventually dry out in the future with a probability of 38% to 50%. Drying will gradually increase and will be fixed after 25 to 40 months (Arasteh and Mianehrow, 2015).

In a study undertaken by Ramalingam *et al* (2015) to assess environmentally sensitive areas and desertification severity for an Indian region, a modified MEDALUS methodology was used. Climatic Quality Index (CQI), Vegetation Quality Index (VQI), Ground Water Quality Index (GWQI), Drought Quality Index (DQI) and Soil Quality Index (SQI) were used to assess temporal variations between the years 2003- 2010. Results indicated that CQI decreased from 1.14 in 2003 to 1.31 in 2010; SQI had a medium quality with soil depth and soil texture playing a significant role; VQI changed severity from low to moderate over the years, while DQI severity increased from 2003 to 2010 due to urban expansion.

In a similar study undertaken by Sepehr and Ekhtesasi (2013) desertification process in Iran was assessed through the use of aerial photos, topographic maps and Lands at ETM plus images. 27 geomorphologic facies were identified in the study area, and severity of desertification fitted within the study unit which was displayed via the MEDALUS model using 5 indices i.e. CQI, VQI, Erosion Quality Index (EQI), SQI and GWQI. Results showed 86.3% of total land area susceptible to severe desertification process, 11.2% showed highly severe desertification, while 2.5% showed a low severe desertification class.

Gad and Lotfy (2013) used GIS and Remote sensing techniques to map desertification sensitivity in North of Western Desert, Egypt. Three quality indices (soil, vegetation and climate) were computed to assess the Environmental Sensitivity of Areas to Desertification. Results obtained showed 55.25% of the study area characterized by high sensitivity to desertification, 42.57% of the area showed sensitivity while 2.19% showed moderate sensitivity.

Furthermore, Gad and Shalaby (2010) used Remote Sensing and GIS to assess and map desertification sensitivity in Inland Sinai and Eastern desert wadies of Egypt. SPOT and Egypt satellite images were used to obtain land use and land cover maps. Geologic and soil maps were utilized as thematic sources for calculating ESAs for desertification. Results showed 33.8% of wadi Al-Astuity having a high sensitivity to desertification, 19.4% have the lowest sensitivity in this location while the moderate sensitive areas occupies 28.6%.

Wadi Al-Arish showed more sensitivity with 74% of its area very sensitive to desertification.

However, desertification studies undertaken in North-Eastern Brazil employed the use of spatial modeling procedures applied to data from the semi-arid portion of the region to measure it’s susceptibility to desertification. Several parts of the study area revealed that from the analysis carried out via integration of geo-environmental variables and the creation of environmental indicators, five different levels were identified; very high, high, moderate, low and very low susceptible levels and increase in degraded soil from 21.34% to 36.22%. The obtained results established a direct association between the different susceptibility levels (Reinaldo, Tomoyoki and Cleyber, 2005).

Symeonakis and Drake (2004) monitored desertification and land degradation over sub-Saharan Africa by employing a system of four indicators derived using continental-scale remotely sensed data of vegetation cover, Rain Use Efficiency (RUE), surface run-off and soil erosion. Normalized Difference Vegetation Index (NDVI) was used to monitor vegetation. The estimation of RUE also employed NDVI and in addition, rainfall was derived from Meteosat cold cloud duration data. Surface run-off was modeled using the Soil Conservation Service (SCS). Soil erosion was estimated via a model parameterized by overland flow, vegetation cover, digital soil maps and a Digital Elevation Model (DEM). The four indicators were then combined to highlight the areas with the greatest degradation susceptibility.

2.2.5 Approaches Towards Combating Desertification

Both human and social objectives should be contained in measures towards combating desertification for them to be effective. Towards achieving more sustainable land-uses, the following have to be put into consideration;

2.2.5.1 Raising awareness of the problem

Heightened awareness and understanding of environmental issues over the last thirty years have significantly influenced development efforts in Sub-Saharan Africa. In particular, the long and severe series of droughts at the end of the 1960s and early 1970s were important in raising awareness concerning desertification in sahelian countries (Sokona, 2007). The convention to Combat Desertification was adopted on 17 June 1994 and in commemoration of the "World Day to Combat Desertification and Drought".

2.2.5.2 Planting and protecting indigenous trees and shrubs

Planting of trees is the first step towards halting desertification, it stabilizes the soil and protects it from; excessive sunshine; strong winds and the progression of sand; intercept the rainfall and protect the soil from splash erosion; retain moisture and help local recycling of rain replenishes soil nutrients and also absorb carbon dioxide (Bjorkdahl,2003).The over-exploitation of indigenous trees and the introduction of non-native species can lead to ecological disturbance. Therefore, regeneration of endangered indigenous species is important. In Tunisia, previous attempts at the introduction of exotic species to improve degraded soil failed, which led attention to indigenous pastoral plants. A gene bank of indigenous arid and desert rangeland plant species was created and included within the national programmes to combat desertification and the national programmes for biodiversity (Fran, 2015).

2.2.5.3 Developing sustainable agricultural practices

Agroforestry is a practice which integrates high-value multi-purpose trees and shrubs into farming systems. These include alley cropping, windbreaks, riparian buffer strips, and forest farming. The trees shelter land and the live stocks provide wildlife habitat and control soil erosion (Fran, 2015).

2.2.5.4 Using alternative sources of energy

Sustainable energy means ensuring enough energy supply for present and future generations, while at the same time protecting the environment. This can be done by cautiously using renewable sources of energy. Another way to save energy is by use of improved cooking stoves with low burning wood. In Eritrea there was the introduction of magogos which is a fuel saving stove (Fran, 2015).

2.2.5.5 Mobilizing and involving people in Decision Making

The United Nations Convention to Combat Desertification (UNCCD) stresses that people who suffer the impact of desertification, and who best understand the ecosystems in which they live, must be involved in decisions about how to restore damaged land, and prevent further degradation (Brekle and Veste, 2011). Therefore, the call for the building of partnerships comprising affected populations and their representatives, the national government, and bilateral and multilateral donors. The purpose of the partnerships is to develop National Action Programmes to tackle the problem of desertification. Action plans should give priority to the application of existing knowledge to local situations.

2.2.5.6 Empowering women

In subsistence economies, women are the major suppliers of food, fuel, and water for their families, and yet their access to land is declining (Omale, 2012). Investing in women is the best way to increase food security, reduce population growth and relieve pressure on the environment.

2.2.5.7 Development of local crops and rural markets

United Nations Conference to Combat Desertification (UNCCD) proposes the promotion of drought-resistant and salt-resistant crops and the development of rural markets (UNCCD, 2004). Attention should be paid to local plants whether they have already been domesticated or not. It is important to grow a wide variety of plants that are suited to local conditions. Bio-diversity of crops helps to ensure both healthy soil and food-security. Organic growing should also be encouraged, as this system reduces the damage to the land and alleviates some of the negative impacts of mono-cropping.

2.2.6 Extent of Desertification in Nigeria.

Desertification progression in Nigeria is difficult to estimate. This is because in Nigeria, desertification has not been seen as a problem requiring much attention until recently (Gakkuk 2014). Hence, there has not been a factual monitoring instrument of the rate at which the arid and semi-arid areas of the country are being degraded. However, there have been estimates by scientists' showing range variation from less than 1 Km to about 15 Km per year. On the other hand, other scientists contend that it is not moving along a linear front but occurs in patches, which expand in various directions and at rates that vary considerably. Recent estimates put the area already lost to desertification at about 351,000 hectares of the country's landmass (Nwafor, 2006).

The desertification map of the world puts about 15% of Nigeria's landmass prone to desertification (Emodi, 2013). It subsumes both arid and semi-arid areas where the evidences of true desertification are showing up on abroad scale. In most of these areas, shrubs have mostly replaced grasses or have spread to an extent that they dominate the flora (Emodi, 2013).

Irrefutable evidence shows that most of that region north of latitude 12°N is at risk to ecological degradation. For example, more than 65 percent of Sokoto State is said to be under threat, while about 55 percent of Borno State is affected. In a village 90 Km north-west of Sokoto (*Gidan Kura*) Sand dunes have been reported to have taken over vast areas of farmland and have displaced a whole village of about 300 houses out of existence (Emodi, 2013).

Yelwa and Eniolorunda (2012) simulate the movement of desertification in Sokoto State and its environs using a one kilometer Satellite Pour I'observation de la Terre - Normalized Difference Vegetation Index (SPOT-NDVI) data. In this study, the Normalized difference vegetation index data was obtained from SPOT at 1 km resolution and was downloaded as ten daily composites after which extracted data about the study area was clipped via the VGT Etract software. Temporal vegetation dynamism assessment was via the Multi-dimensional tool of Idrisi Andes while assessment of the direction and pattern of desertification was done with a first and second order surface trend fitting. Results obtained showed a diminishing inter-annual vegetation vigor trend over the time series, desertification movement was in the North-West to South-East. Areas worst affected by desertification are located at Illela and Bamgi in Nigeria and around Koukadin falls in Niger republic.

In the extreme north of Yobe State, communities such as Bulatura, Kaska, Bukarti Toshu, Tulotuwa, Yunusari, among others, have been either completely surrounded by sand dunes or are about to be buried by them. This has led to population migration southwards to areas around Gashua, Nguru, Kukuna in Yobe State, and Monguno in Borno State all within the fragile environment (Emodi, 2013). Also, in Katsina State, physical evidence of desertification can be seen in adversely affected local government areas such as Jibia, Daura, Mashi and Mani (Emodi, 2013). Today, hundreds of thousands of kilometres squared of arable land have evidently been lost to desertification. This has affected the soil properties, rendering them less fertile and affecting their ability to support plant life in states such as Kebbi, Sokoto, Zamfara, Katsina, Jigawa extreme Northern Kano, Yobe and Borno States (Emodi, 2013).

Sheikh and Nathaniel (2016) assessed the effect of desertification on some selected soil properties in a semi-arid part of Northwestern Nigeria. In this study, one kilometer resolution SPOT Normalized Difference Vegetation Index (NDVI) archived as 10- day composites, Soil Organic Carbon data (SOC) and particle size of the area were used. Maximum value composite was used to recompose the 10-daily composites into monthly and later annual composites. Time series analysis was performed on the NDVI data series to determine the degraded and improved areas from which soil samples were taken. ANOVA was used to test for difference in the measured soil properties at $P<0.05$. Results obtained showed general reduction in vegetation cover. SOC was generally low but high in improved areas; degraded areas were purely sandy, while improved areas were either Sandy clay or Loamy sand. This indicates a relationship between SOC and soil texture.

Similarly, Musa (2000) used GIS and Remote sensing to quantify the degraded environment in Tropical savannah of Adamawa State. Each of the degraded local governments was quantified via satellite images for two time periods (1978 and 1995). The quantified data were transformed into different indices, interpreted and discussed. Results in terms of physical depletion of vegetation cover, vigor and biomass revealed that the northern part of the study area (Adamawa state) was worst hit by land degradation and reduction in vegetation vigor when compared to the status ante in 1978 and only the southern part was stable.

2.2.7 Measures adopted towards Management of Desertification in Nigeria

In Nigeria, the Federal Government within the framework of protecting the environment has given relative importance to the problems brought about by desertification; this has led to the formulation, coordination, implementation and monitoring projections relating to desertification (Medugu, 2011). Desertification is seen to be advancing southwards at the rate of 0.6 km a year from the northern part of the country engulfing about 351,000km2 of Nigeria's land (Nwafor,2006). It has been estimated that between 50%and 75% of states of Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe and Zamfara States in Nigeria, are being affected by varying degrees of desertification (Olagunjo, 2015). There are eleven (11) desertification frontline States in Nigeria out of the total 36 States and the Federal Capital Territory. These states accounts for about 63.83% of the total land area of Nigeria with moderate to severe rate of desertification and about62 million of Nigerians are affected. Between 1954 when the first shelterbelt was established and 1985, about 2000kmof shelterbelts were established (Ojo, Oneyewoto and Ujah, 1987).

In 1994 the Federal Government was signed as member of a United Nations National Action Programme to combat desertification and the effects of drought towards implementation of the convention to combat desertification which was later ratified in 1997. Part of the fulfillment of the convention's objectives is setting up a number of National programs to combat degradation (FGN, 2006). Others include the establishment of Industrial Plantations from 1978, Land Use and Vegetation survey between 1975 and 1978, Production of perspective plan for the period 1990 - 2005 and formulation of a Nigerian Forest Action Program in 1997. An Arid Zone Afforestation Project (AZAP) was established by the Federal Government in 1976 to tackle the problems of desertification through the establishment of woodlots, shelterbelts and windbreaks. About 150 kilometers of shelterbelts, 3,680 hectares of woodlots, 24 boreholes, 70 tree nurseries and Forestry Vocational Schools were established (FGN, 2012).

The European Economic Community supported a pilot project in Katsina State covering a total area of 1.6 million hectares involving the establishment of shelterbelts, windbreaks, woodlots and trees on farmlands in affected Local Government Areas (L.G.As). Training programmes on renewable energy technology, biogas and biomass utilization projects, and solar photovoltaic electrification projects for remote rural areas were put in place by the Federal Government in collaboration with energy commission to check the excessive consumption of fuel wood (Muhammad and Umar, 2014). Furthermore, a number of Poverty alleviation programmes have been put in place as strategies for combating desertification impacts. These include:

1. The North East Arid Zone Development Programme (NEAZDP), funded by the Federal Government of Nigeria with the European Union assistance, commenced in February 1990 with the main objective of motivating and assisting the rural population to improve their standard of living through proper resource use, and management (FGN, 2012)
2. The Federal Ministry of Environment/University of Maiduguri Linkage Centre on Drought and Desertification Control, based at the University of Maiduguri, initiated a model village project at Sabon garin Nangere, Yobe State in 1995.

3. The Katsina State Agricultural and Community Development Project (KSACDP) were conceived as the first stage of an International Fund for Agricultural Development's (IFAD) strategy to speed up and intensify rural development in the dry lands of Nigeria.
4. The Sokoto Environmental Protection Programme covers an area of about 17,500 km2 in the North-eastern part of Sokoto State. The objective of the Programme was to improve the utilization of resources to achieve long-term sustainable growth and environmental protection (Muhammad and Umar, 2014).
5. The Federal Government identified the problem of desertification as serious and cannot be tackled by itself alone so it facilitated the involvement of other actors including the Private Sector, Non- Governmental Organizations (NGOs) Community based Organizations (CBOs) and Donors. At present, a number of NGOs are actively involved in the implementation of Convention to Combat Desertification (CCD) in Nigeria. Some of the NGOs in Nigeria are actively participating in the activities of the Global NGO network on Desertification. As a matter of fact, the Nigerian Environmental Study/Action Team (NEST) is the sub-regional focal point of this network for Anglophone West African countries. Other prominent national and international NGOs that are actively involved in the implementation of CCD include the Nigerian Conservation Foundation (NCF), Forestry Association of Nigeria (FAN) and the International Union for Conservation of Nature (IUCN) (FEPA, 1992).

CHAPTER THREE

STUDY AREA AND METHODOLOGY

3.2 THE STUDY AREA

3.1.1 Location and Size

Jibia Local Government Area lies between Latitudes $12^o40'$ and $13^o10'$ North of the Equator and Longitudes $7^o5'$ and $7^o35'$ East of the Greenwich meridian. It is bordered to the North by Niger Republic, to the South by Batsari Local Government, to the East by Katsina Local Government Area and the West by Sokoto State. It occupies a total land area of about 32177km^2 (Sani, 1996) (Fig. 3.1)

3.1.6 **Climate**

Climate of Katsina State is that of tropical continental marked with seasonal variations. Rainfall in this area starts in May lasting to September covering a period of about five months. Mean annual rainfall in the area is about 600mm per annum. Maximum temperature ranges between 37° to 39° during the hot period and minimum of 19° to 24° during the cold season. However, during the cold season , maximum mean temperature of 17° and 10° are experienced as obtained from Katsina State Airport. This area is under the influence of two winds; the North-Eastern trade wind that originates from Sahara desert. This wind brings along cold and dry weather when conventional wind stir-up the dry surface of the ground. The second trade wind is that of the South-west that originates from the Atlantic Ocean bringing cool and warm weather during the wet season. Heating of air over the hot ground causes temperature inversion and as the lower warm air mass breaks through the higher cooler air and the Local whirl wind are often created (Omale, 2012).

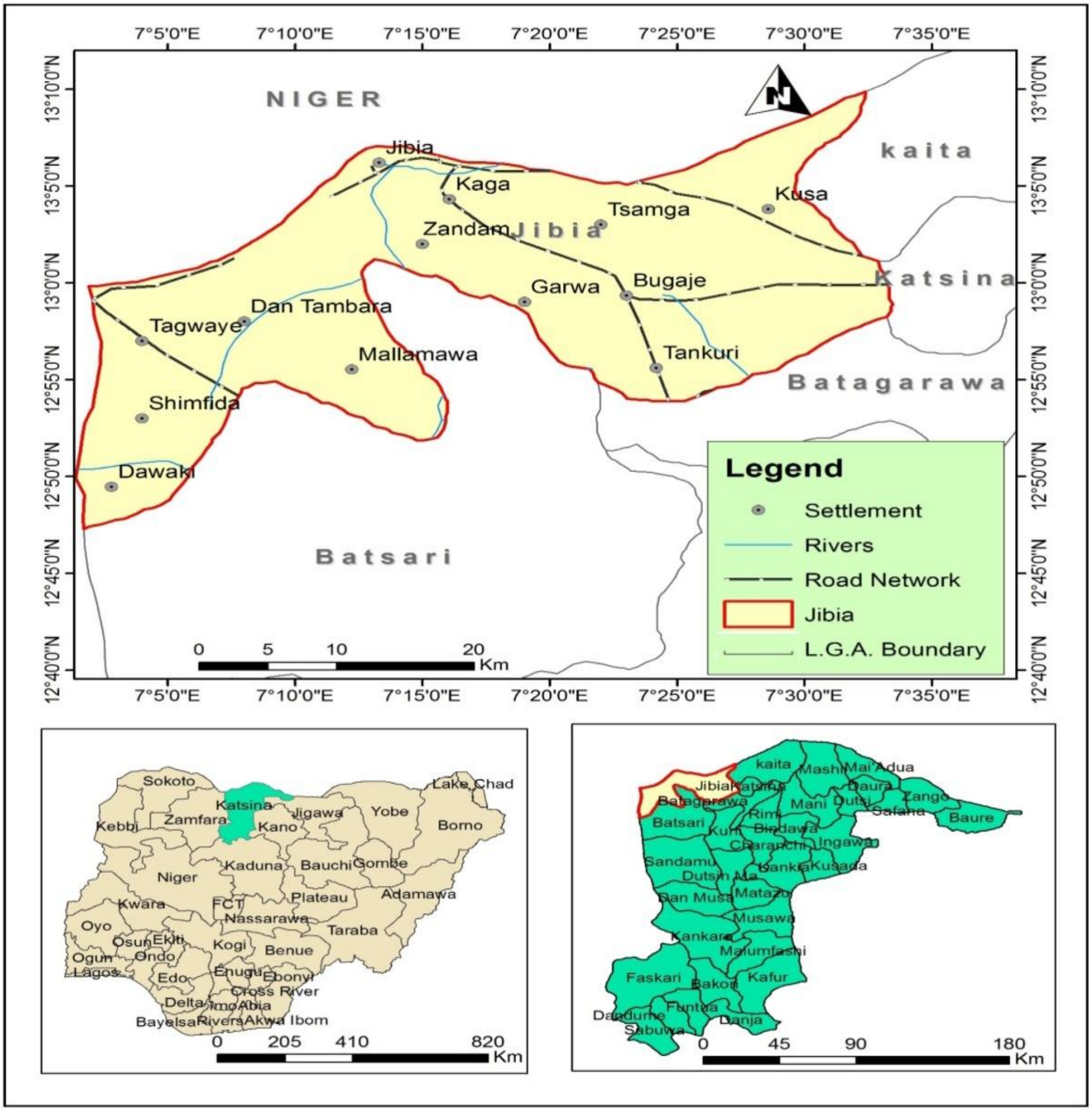

Figure 3.1: Jibia Local Government Area
Source: Ministry of Lands and Survey Katsina State

3.1.7 **Vegetation**

The area falls within the sudan savannah vegetation composed of short grasses that develop underground stems. The grasses wither and dry up during the dry season and their underground stems develop new roots during the wet season. These grasses hardly grow up to 1m at maturity. Pasture in this area is very low and grazing fields are diminishing due to intensive cultivation by the growing population. Shrubs usually dry off during the dry season thereby leaving the soil bare (Sani, 1996). There also exist a variety of scattered trees over an expanse of grass land. These trees are characterized with broad canopies and are hardly taller than 20 metres and larger than the other species or types found in other areas. It includes various types of acacias, neem and scattered shrubs occasionally forming a woodlot which also dries up during the dry season leaving the soil bare. These trees are xylophytic in nature thereby have the ability to resist drought with their presence of long roots, leathery and tiny leaves as well as the development of spines to reduce excessive transpiration (Omale, 2012).

3.1.8 **Geology and Soils**

The study area falls within the Gundumi formation of the Sokoto- Rima water basin, in this part cretaceous sediment overlap the crystalline rocks. The study area is underlain by ancient crystalline basement complex rocks. Thus we can distinguish between the soil of the basement complex rock and those on the sedimentary formation (Sani, 1996).

Soil is the dominant factor of the terrestrial ecosystems in the arid, semi arid and dry zones. Agricultural activities and vegetation of an area depends on the soil type of the area. Jibia Local Government Area is characterized with sandy soil constituting about three quarter of the soil type while clayey and loamy soil constitute the rest of the one quarter of the soil type. These soils are less acidic and well drained thereby unable to retain water in soil to support plant growth especially when the water is less (Omale, 2012). This area falls within the Chad formation of sedimentary rocks of cretaceous origin.

3.1.9 **Relief and Drainage**

The area is of the lowest Chad plain with an average of about 15 to 20metres. Depth determines how much an area can hold vegetation. The landforms in the area are sandy plain where sand sheets occupy most of the area. However it is common to find deposits of sand dunes of varying degrees especially when one moves towards the Daddara village northward. These sand dunes are symbols of the desertification existing in these areas. The dunes are formed from the depositions of erosive materials carried along by strong winds from across Sahara desert especially during dry seasons (Omale, 2012). Jibia dam and Kusa dam play a vital role in domestic water supply to Jibia town and its neighboring villages and the creation of barrier against the encroaching desert. Jibia dam is part of the development plan for Sokoto-Rima basin being carried out by the Federal Ministry of Water Resources through the Sokoto Basin Development Authority. The dam is 3.68km long and 21.5m high. The project was meant to provide water for agriculture all year round as well as provide portable water to the study area (Sani, 1996). Water is stored during the brief rainy season in the reservoir which has a capacity of 142 million cubic meters. A 105m intake tunnel passes through the body of the jibia dam, and carries stored water from the reservoir to the irrigation channels to supply water to plants and the river regulation outlets (FMFED, 1991). However, present survey shows that the reservoir is either no more functioning or has been abandoned.

3.1.6 Population and People

Jibia Local Government Area has a total population of 244,547 as obtained from 1991 census and projected to 2015. It consists of some important towns and villages with the main Jibia town serving as administrative headquarter**.** Majority of the inhabitants are Hausa/Fulani (Sani, 1996).

3.1.7 Economic Activities

The inhabitants of Jibia Local Government Area are mostly farmers engaging in subsistence farming, sorghum, millet, cowpea, maize, and groundnut are the major crops cultivated in the area, as well as rearing of grazing animals such as goats, cows and sheep. Almost every household engage in animal rearing which are usually moved by headers especially during rainy season. The inhabitants also engage in irrigation farming by river banks as a source of additional income. Small scale businesses are also carriedout in this area where people engage in activities such as furniture making or carpentry, petty trading and mechanic services. The presence of some banks operating in the area was also noticed (Omale, 2012).

3.3 METHODOLOGY

3.3.1 **Reconnaissance Survey**

Preliminary survey was undertaken as a familiarization tour in the Study area. The trip acquainted the researcher with adequate understanding of the physical menace of desertification. During this survey, efforts were made in observing the physical nature of the area as well as some of the activities undertaken by the inhabitants as a means of livelihood. The number of animal herds seen grazing in the study area confirms mans participation in exacerbating desertification process in the study area. Also previous efforts towards combating desertification in terms of afforestation and reforestation exercises on ground were noticed. Observations pointed towards various afforestation programmes undertaken as means of checking desertification in the study area. This gave the researcher an insight on the graveness of the problem and what has been done in order to combat the situation.

3.2.2 Data Types

Data used for this study includes:

i. Satellite images: These were obtained from Global Land Cover Facility, University of Maryland. Each of the Lands at imageries listed covers an area of 185x185 square kilometers. From these images, Land use and Land cover data was generated. Land use is often known as a contributor to desertification. The satellite images for this study are presented in Table 3.1:

Table 3.1: Satellite images

Type of satellite image	Date of acquisition	Spatial resolution
Landsat Thematic Mapper 1986	7^{th} November, 1990	30m
Landsat Enhanced Thematic Mapper Plus 2000	11^{th} November, 2000	30m and 15m
Landsat 8	17^{th} September, 2015.	30m and 15m

Source: Global Land Facility, 2014

ii. Rainfall data in millimeters between the period 1980 and 2014 covering a period of 34 years was obtained from three stations bordering the study area (Katsina, Sokoto and Jigawa).

iii. Soil map of Nigeria sourced from Sonneveld, B.G.I.S. (1996) obtained from Federal Department of Agricultural Land Resources (FDALR) (1991) was used in identifying the soil textural characteristics of the study area.

iv. Digital Elevation Model (DEM) sourced from Shuttle Radar Topography Mission (SRTM) data was obtained from the National Centre for Earth Resources Observation United States Geologic Survey (USGS) website and used in calculating the slope gradient of the study.

v. Geologic map of Nigeria sourced from Nigerian Geologic Survey Agency (NGSA) (2004) was used in identifying the soil parent material in the study area.

vi. Data on the effects, perceptional causes and management practices towards desertification in the study area was obtained through questionnaire survey.

3.2.4 Sources of data

3.2.4.1 Primary sources of data

3.2.4.1.1 Questionnaire survey

In the course of this study, data on the causes, management practices and effects of desertification in the study area were obtained via questionnaire survey from the inhabitants on their socioeconomic activities and their perception of desertification in the study area. Similarly data on how desertification has affected their livelihood and measures adopted by some agencies to reduce the effect of desertification were obtained.

3.2.3.1.2 Satellite imageries were obtained from global land facility.

3.2.3.2 Secondary sources of data

The rainfall data was obtained from three (3) stations (Katsina, Sokoto and Jigawa) bordering the study location, soil map of Nigeria, DEM data obtained from SRTM data and Geologic map of Nigeria. Also, secondary data on afforestation and reforestation exercises carried out in Northern part of Nigeria, specifically in areas affected by desertification were extracted from Federal Government of Nigeria Reports, Ministry of Environment reports (2006); Federal Environmental Protection Agency's report (1992); and Federal Ministry of Environment's report (2000). Others include Katsina State Agricultural and Rural Development Authority (KTARDA), European Economic Community's efforts as well as Community Based Organisations, Non-Governmental Organization and Donors efforts. Other literature materials were gotten from text books, journal papers, and conference papers. Past published and unpublished thesis, projects and reports were also consulted.

3.2.4 Sample size and Sampling technique

Population of Jibia Local Government Area was obtained from the 1991 census and projected to 2015. Based on the projected population of Jibia 2015 (244,547) Yamane, (1967) formular for sample size determination was used to get the number of respondents for questionnaire administration: $N/1+N(e)^2$

Where N = number of population under study

e = proportion of population given as 0.05%

A total of 399.9984 which was rounded up to 400 respondents were selected for administration of questionnaire. The questionnaire was randomly administered to selected household in the study area. However, the sample size for each ward varied with its population size through the use of: nQ/N

Where: N= total population of the study area; Q= total sample size and n= population of wards. Jibia local government area has a total of 11 wards out of which five wards were randomly selected and administered the questionnaire. Table 3.2 presents a sample size of the selected wards and number of questionnaires administered in each of the selected wards. The questionnaire was divided into two types: General questionnaire with a total of 200 copies questionnaires which was administered to respondents who are not farmers out of which a total of 171 were retrieved while Specific questionnaire was strictly administered to respondents who are farmers and out of the total of 200 questionnaire administered 187 were retrieved which makes up a total of 358 copies of questionnaire successfully retrieved during the period of field survey.

Table 3.2: Sample size by population of the selected Wards.

Wards	Projected population (2016)	Population size of selected wards	Sample size of selected wards
Gurbin-baure	**32946**	**32946**	**73**
Mazanya	15809	-	-
Gangara	8932	-	-
Riko	**16307**	**16307**	**36**
Kusa	6774	-	-
Faru	**15728**	**15728**	**35**
Bugaje	7699	-	-
Jibia A	**35329**	**35329**	**77**
Jibia B	**81342**	**81342**	**179**
Yangaiya	15350	-	-
Farfarau	8331	-	-
TOTAL	244,547	**181,652**	**400**

Source: Author's compilation, 2016.

3.2.4 Image processing

Satellite imageries obtained underwent some basic image processing procedures. However, since the imageries were already geo-referenced and digitally processed or ortho-rectified there was no need for any geo-refrencing; geometric and radiometric corrections and enhancement. Only that, images were obtained in different layers and these layers were stacked together using ERDAS imagine 9.2 software.

3.2.4.1 Image sub-setting

Because of the large scenes of remotely sensed images, the acquired images were sub-set to get the area of interest or the study area (Jibia Local Government Area). By this approach, the extraneous data in the file was eliminated and therefore the computer processing was speeded up due to the smaller amount of data to process. This subset of the study area was obtained using the ERDAS imagine 9.2 software subset tool.

3.2.4.2 Image classification

Categorization of the images to Land use and Land cover (LULC) thematic classes, supervised classification was employed. This technique involves identifying pixels possessing the same spectral features using the Maximum Likelihood Algorithm. Once the computer has determined the signatures for each class, each pixel in the image is compared to these signatures and labeled as the class it most closely resembles digitally.The Maximum Likelihood Algorithm is the most widely used and is perceived as the most accurate classification algorithm (Ojigi, 2006). ERDAS imagine 9.2 software was used for the pixel-based classification that produced an output raster layer. Groups of similar pixels were assembled into classes associated with information of interest.

3.2.4.3 Classification scheme

In extracting valuable information from the imageries, land use land cover (LULC) classification system was developed to compute quantitative area statistics for the desertification trend via the Landsat TM 1990, Landsat ETM 2000 and Landsat 2015 imageries which were used in calculating the extent and rate of desertification in the study area. The images were classified as shown in Table 3.3.

Table 3.3: Land Use/ Land Cover (LULC) Classification Scheme

Classes	Description
Built-up	Residential, Commercial, Industrial
Bare surface	Exposed soils, and areas of active excavation and production
Cultivated land	Cleared forest lands and deforested area, Farm lands
Vegetation	Any species of plants (flora), forest
Water bodies	River, lakes and reservoirs
Rock outcrops	Any type of rock identified

Source: Jensen (2005)

3.2.4.4 Ground truthing and Accuracy assessment

Ground truthing of the study area was carried out so as identify different land cover types in the study area in relation to the land cover types on the images for accurate and efficient assessment. This was done to verify the accuracy of the image classification.

To ascertain the accuracy level of the classification, accuracy assessment was undertaken. Accuracy assessment is a strategy that captures the influence of misallocated boundaries and of misallocated classes (Paul, Michael, David and David, 2004). It determines the quality of information derived from Remote Sensing data (Congalto and Green, 1999). Accuracy assessment can either be quantitative or qualitative. In qualitative assessment maps are checked to see if they are right by comparing what is on the image with what is on ground while quantitative assessments attempts to identify and measure Remote Sensing based map error whereby map data is compared with reference on ground truth data (Pravada and Rahila, 2013). Classification accuracy assessment was performed on the all images classified where the computer was trained to identify random points. One hundred (100) points where identified and located using a stratified random method in ERDAS imagine 9.2 software to represent the different classes identified for each time period used.

In assessing the classification result of this study, a required test sample of 30% was selected from each of the classes from the LULC map produced over which the 100 points were located. The points were checked against the ground truth data and the error matrix was performed by verifying classified and observed classes to ascertain accuracy of the results for each of the time period considered. For each time period, from the computed error matrix; the user's accuracy, producer's accuracy, overall accuracy and kappa coefficient were computed.

3.2.5 Data analysis

In order to achieve the stated objectives of this study, the following data were collected in line with the stated objectives of the research.

(i) To identify the causes of desertification in the study area: - The MEDALUS (Mediterranean Desertification and Landuse) methodology of European Commission, 1999 was adopted, modified and used. Each of the indices (soil, climate and vegetation) were determined and scored based on the MEDALUS methodology. Scoring was based on the identified classes for each of the parameters ranging from 1 (good condition) to 2 (deteriorated condition). The indices and their parameters were as follows:

a) Soil quality index (nature of parent soil material, soil texture, soil depth and soil slope gradient).

b) Vegetation quality index (nature of plant cover, their resistance to drought and erosion protection).

c) Climatic quality index (rainfall data, aridity and aspect).

The parent soil material and soil texture were digitized from existing geological and soil maps of Nigeria respectively. Soil depth was determine from the DEM (Digital Elevation Model) by subtracting the lowest elevation from the highest height and finally for the soil slope gradient, DEM was obtained from SRTM data using the spatial analyst tool in ArcGIS 10.1 environment. Vegetation quality index parameters were achieved through supervised classification of satellite images; and finally the climatic quality index rainfall data was sourced from three stations bordering the study area i.e. Katsina, Sokoto and Jigawa. Aridity was extracted from an existing aridity map of Nigeria and Aspect of the study area which signifies the slope direction was obtained from the Digital Elevation Model (DEM) using the spatial analyst tool in ArcGIS version 10.1.

The quality indices (soil, vegetation and climate) were displayed within the map of the study area showing severity of desertification depending on each of the indices in the study area.

(ii) To determine the environmental sensitivity of the study area to desertification; ESAs (Environmental Sensitive Areas) index was obtained as a geometrical average of the quality indices. This was computed after Kosmas, Tsara, Moustakas and Karavitis (2003), given as:

$\mathbf{ESA} = (\mathbf{SQI} * \mathbf{CQI} * \mathbf{VQI})^{1\backslash 3}$

Where SQI= Soil quality index (parent soil material*soil texture*soil slope*soil depth)$^{1/4}$

CQI= Climate quality index (rainfall*aridity*aspect)$^{1/3}$

VQI= Vegetation quality index (vegetal cover*drought resistance*erosion protection)$^{1/3}$

Environmental sensitivity area map of the study area was produced by multiplying the SQI, CQI and VQI using the raster calculator in ArcGIS 10.1.

(iii)To determine the extent and rate of desertification in the study area; using the bands for the scenes of the resultant imageries in ERDAS imagine 9.2, the features were recognized based on elements of visual interpretation. The extent of the desertification was estimated for 25years period (1990 to 2015) in the study area. The observed area coverage statistics of the classified imageries for each year

(1990, 2000 and 2015) was compared and the percentage changes that occurred within the stipulated period of study were determined. This was computed by the formula:

Percentage change = $\frac{x}{y} x 100$ (Yeates and Garner, 1976)

Where x is the observed change and y is the sum of change.

However, for the rate of change, percentage change was divided by 100 and multiplied by the number of study years 1990 – 2000 (10years), 2000 – 2015 (15years) and 1990-2015 (25years).

(iv) To examine the effects, perceptional causes and measures adopted towards desertification in the study area, the data obtained from the questionnaire were further analyzed and presented using frequency tables.

(v) To predict desertification process up to 2030. This objective was achieved by applying the, Cellular Automata Markov Chain analysis, embedded in IDRISI Kilimanjaro software from Clarks Labs. A Markov Chain CA integrates two techniques:

a) Markov Chain analysis describes the probability of land cover change from one period to another by developing a transition probability matrix between $t1$ and $t2$. The probabilities may be accurate on a per category basis, but there is no knowledge of the spatial distribution of occurrences within each land cover class.

b) Cellular Automata was integrated into the Markov approach. The CA component of the CA-Markov model allows the transition probabilities of one pixel to be a function of the neighboring pixels. CA-Markov will model the change of several classes of cells by using a Markov transition matrix, a suitability map and a neighbourhood cell (Poesen, vanWesemael, Benet and Bunte, 1998).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.3 CAUSES OF DESERTIFICATION IN THE STUDY AREA

In order to determine the causes of desertification in the study area, factors such as the Soil Quality index (SQI), Climatic Quality Index (CQI) and the Vegetation Quality Index (VQI) were examined.

4.3.1 Soil quality index (SQI)

Soil is an essential factor in evaluating the environmental sensitivity of an ecosystem, especially in arid and semi-arid zones. Soil properties related to desertification phenomena affect the water storage, retention capacity and erosion resistance. Soil quality index of the study area was determined from four soil parameters in relation to water availability and erosion resistance. These are: soil parent material, soil texture, soil depth and slope gradient. The weighting factors which were assigned to each category of the considered soil parameters were adapted from Kosmas, Ferrara, Briasouli and Imeson (1999) MEDALUS project methodology.

4.3.1.1 Parent soil material

Soils derived from different parent materials react differently to soil erosion, vegetation and desertification. Two parent soil materials were identified and mapped. These were: coarse porphyritic homeblende granite, limestone and shale (Table 4.1). Limestone and shale produces shallow soils with a relatively dry moisture regime. Areas with soils in limestone were characterized by high erodibility and slow vegetation recovery. Similarly, acid igneous parent materials such as porphyritic homeblende granite produce shallow soils with high erodibility and high desertification risk (Kosmas, Ferrara, Briasouli and Imeson, 1999). Figure 4.1 shows the map of the soil parent material while the classification is shown in Table 4.1.

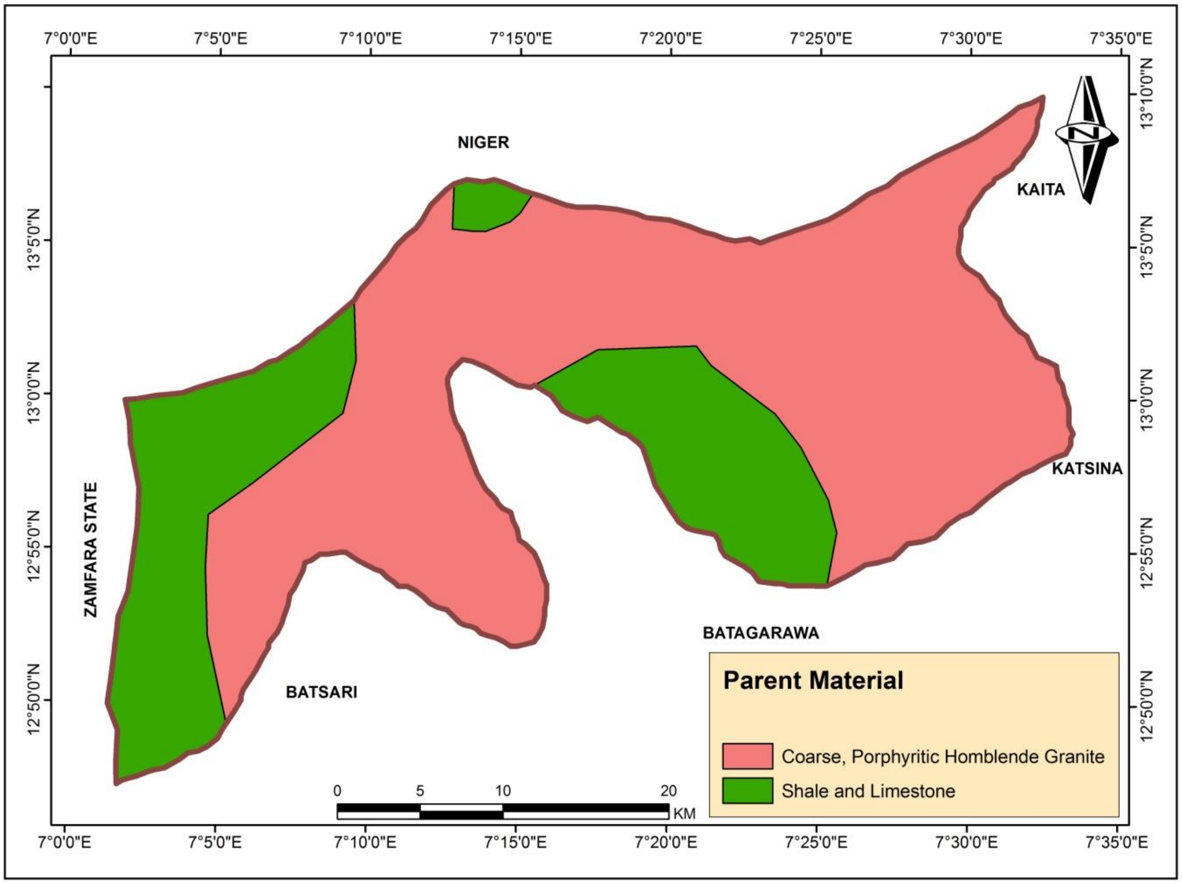

Figure 4.1: Parent Material of the Study Area
Source: Nigerian Geologic Survey Agency (NGSA), 2004

Figure 4.1 shows that the study area is dominated by the coarse, porphyritic homblende granite and some parts especially in the western and southern consist of the shale and limestone.

Table 4.1: Soil Parent Material of Jibia L.G.A.

Parent Material	Score/Index	Class
Coarse, Porphyritic Homblende Granite	2	Poor

Shale and Limestone	1.7	Moderate

Source: Author's Analysis, 2016

According to Medalus project methodology of European Commission (1999) and the score value adopted from Gad and Lotfy (2007), the coarse, porphyritic homblende granite with score of 2 have poor sensitivity to desertification while the shale and limestone with a score of 1.7 is characterized by moderate sensitivity to desertification. It can be observed from the result that the eastern and central areas have more sensitive parent material that makes the area vulnerable to desertification than the western and southern areas.

4.3.1.2 Soil texture

Soil texture is one factor that contributes to desertification. According to Poesen, Torri and Bunte (1994); Danalatos, Kosmas, Moustakas and Yassoglou (1995) rock fragments have a great but variable effect on runoff and soil erosion, while van Wesemael, *et al*. (1995) believe rock fragments to have uneven effect on soil moisture conservation, Poesen and Lavee (1994) believe it to have considerable effect on biomass production so playing an important role on land protection. Generally, runoff and sediment loss are greater from stony than stone-free soils. Figure 4.2 shows four (4) soil texture categories in the study area. It can be seen from Figure 4.2 that the area is dominated by sandy soil located in central area; clay-loam in the western and eastern area. The clayey-sand texture is found more in the southern area and the clay and sandy-loam is more concentrated within the northern area. The score assigned to each soil texture category and the sensitivity to desertification is further presented in Table 4.2. The scoring was done according to Medalus project methodology of European Commission (1999) and the score value adopted from Gad and Lotfy (2007).

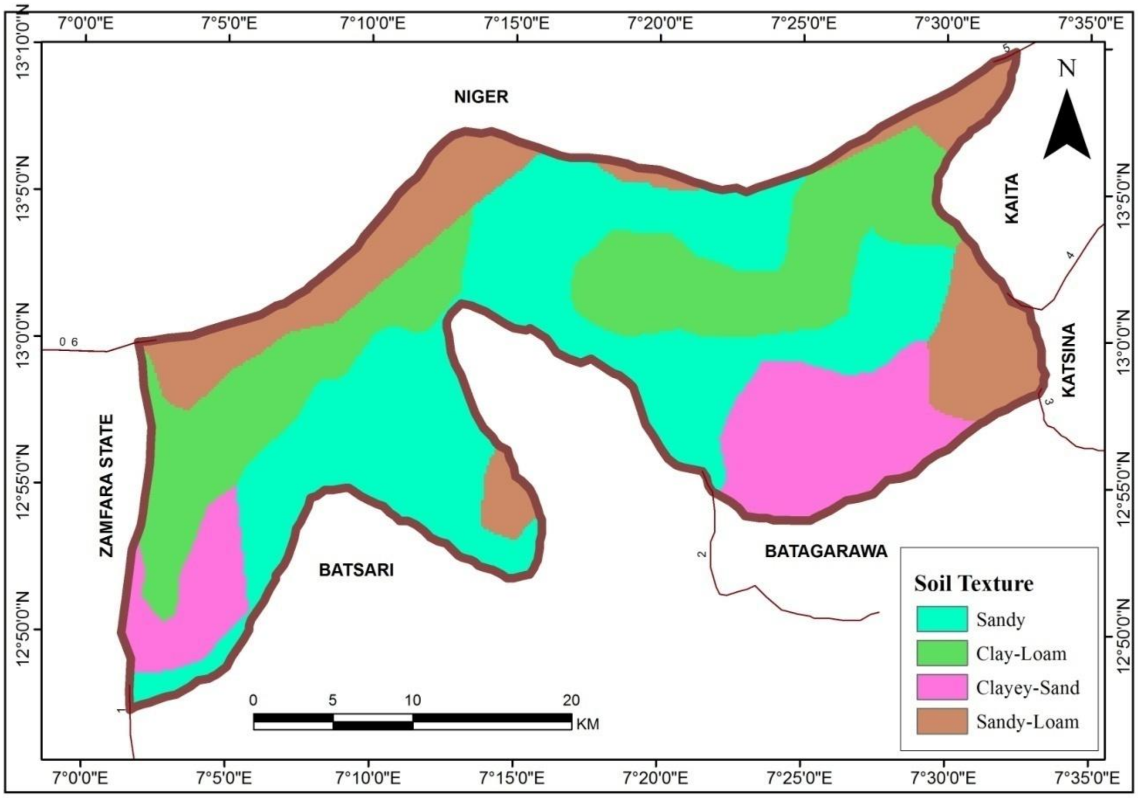

Figure 4.2: Soil Map of the Study Area
Source: Federal Department of Agricultural Land Resources (FDALR), 1991

Table 4.2: Soil Textural Class of the Study Area.

Soil Texture	Score/Index	Class
Sandy	2	Very Poor
Clay-Loam	1.66	Poor
Clayey-Sand	1.33	Moderate
Sandy Loam	1	Good

Source: Author's Analysis, 2016

The result in Table 4.2 revealed that the sandy soil with a score of 2 has very poor sensitivity to desertification, clay-loam (1.66) has a poor sensitivity, and the clayey-sand

(1.33) is characterized to have a moderate sensitivity. Areas with good desertification sensitivity constitute the areas with sandy-loam soil texture.

4.1.1.3 Soil depth

Soil depth is a very important factor for determining the susceptibility to desertification. It is closely related to the possibility of establishing or maintaining various types of vegetation which play a fundamental role in preventing desertification, the deeper the soil the less sensitive to desertification and vice versa. Soils with shallow depth have low tolerance to desertification and erosion and, under hot and dry climatic conditions and severe soil erosion; rain fed vegetation cannot be supported in such areas thereby leading to desertification (Kosmas, Ferrara, Briasouli and Imeson, 1999). The soil depth map of the study area is shown on Figure 4.3 while the classification is presented in Table 4.3.

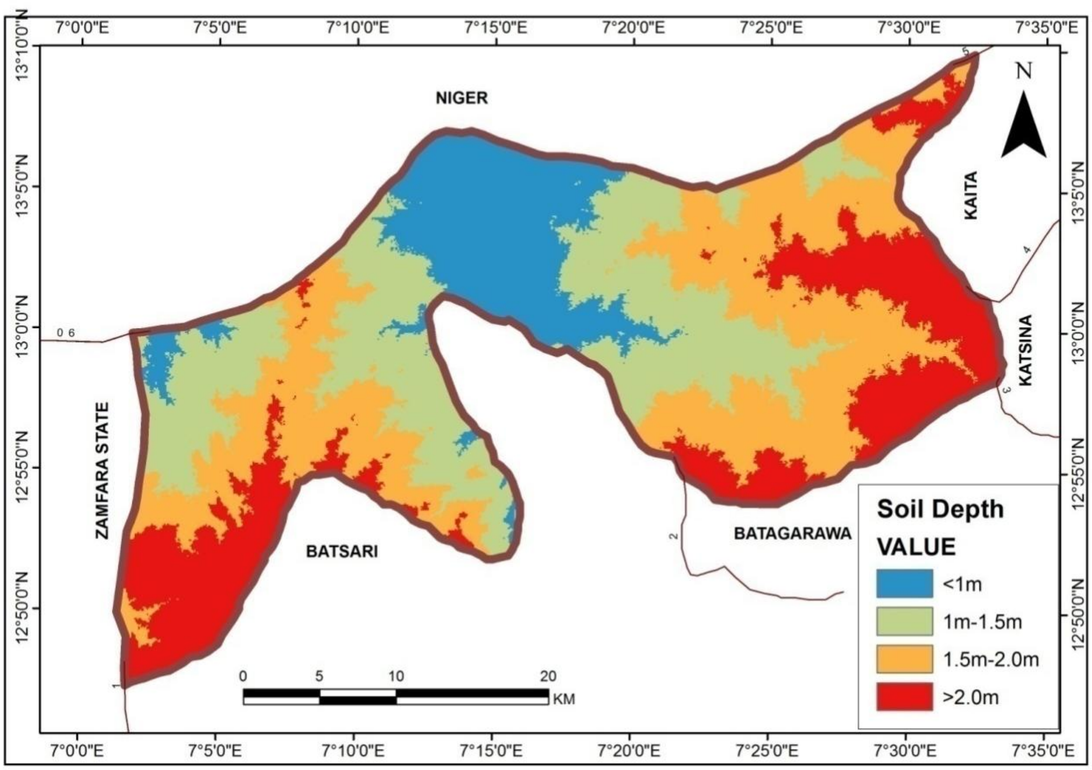

Figure 4.3: Soil Depth of the Study Area
Source: Author's Analysis, 2016

Table 4.3: Soil Depth of Jibia L.G.A.

Soil Depth	Score/Index	Class
<1m	2	Very Thin
1m -1.5m	1.66	Not Deep
1.5m -2.0m	1.33	Moderately Deep
>2.0m	1	Very Deep

Source: Author's Analysis, 2016

The result in Figure 4.3 and Table 4.3 shows four identified classes of soil according to its depth (i.e. Very deep, not deep, moderately deep and Very thin soil). The very thin soil is the most susceptible to desertification, and takes a score of 2 on the desertification sensitivity index while the very deep soil is 1. It can be seen from the result that the very thin soils (i.e. the soil more susceptible to desertification) are located within the northern area while the very deep soil are in the western and eastern parts of the study area.

4.1.1.4 Slope

Soil surface slope is another very important factor for determining the susceptibility to desertification. Erosion becomes acute when slope angle exceeds a critical value and then increases logarithmically (with time). Severely eroded soils are often found on moderately steep to very steep slopes in semi-arid zones. While moderately eroded soils have the highest probability of occurrence under similar slopes in the dry sub-humid zones (Poesen, Torri and Bunte, 1994). The soil surface slope of the study area is composed of two classes: gentle slope with score equal to 1 (<6%) not very gentle with score of 1.33 (ranges from 6% to 18%). The result of the variation in slope is shown in Figure 4.4 and the classification of the slope presented in Table 4.4.

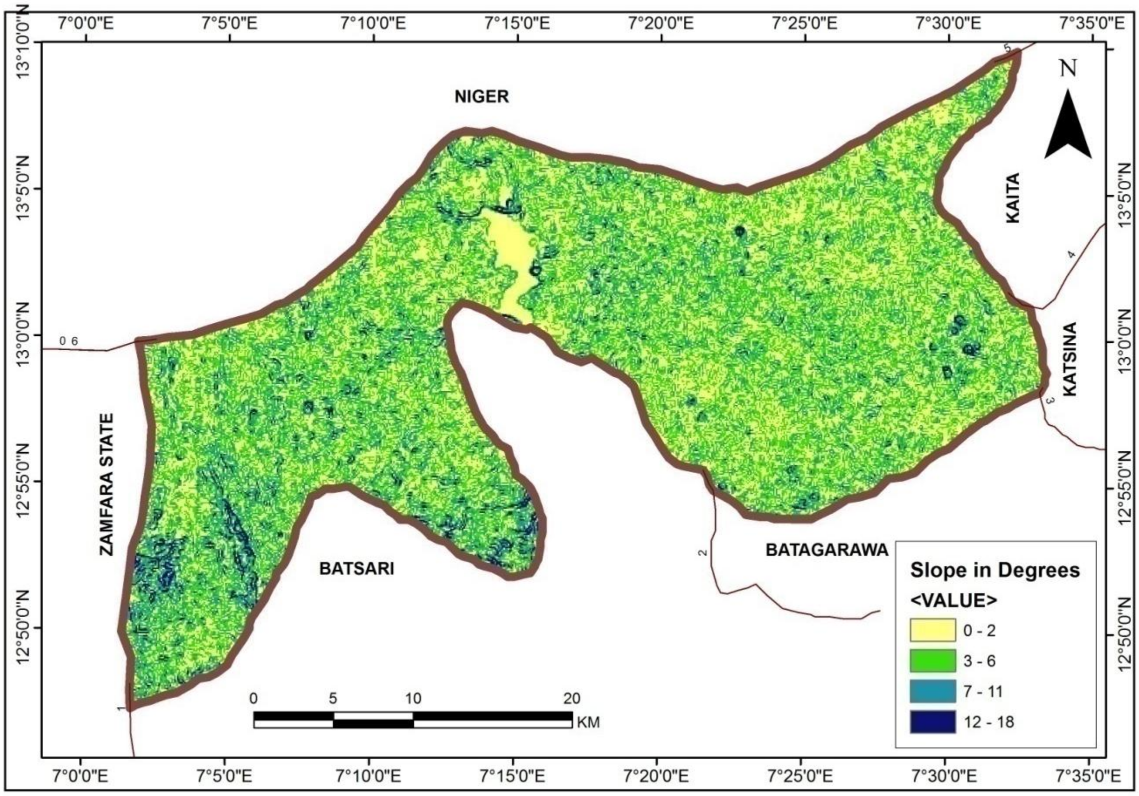

Figure 4.4: Slope Map of the Study Area
Source: Author's Analysis, 2016

Table 4.4: Slope Variation of Jibia L.G.A.

Slope	**Score/Index**	**Class**
<6%	1	Gentle
6% - 18%	1.33	Not Very Gentle

Source: Author's Analysis, 2016

The result in Table 4.4 shows that the gentle slope soil with surface slope of <6% is the least susceptible to desertification and is found within the areas close to water bodies. The not very gentle undulating class with the surface slope of between 6% and 18% which is moderately susceptible to desertification has the highest percentage in the study area and takes a score of 1.33 on the desertification sensitivity index and is found towards the western parts of the study area. The result of slope variation shows that slope plays little or no vital role in desertification incidence in the study area.

4.1.1.5 Soil quality index (SQI)

The soil quality index map was determined from the overlay of four soil parameters (i.e. soil parent material, soil texture, soil depth and slope gradient). Figure 4.5 shows the distribution of the Soil Quality Index (SQI) of the study area. The blue colour represents areas of low sensitivity or high quality area, the yellow is moderate quality and the red represents areas with low quality or areas with high sensitivity which dominates the western and eastern parts of the study area.

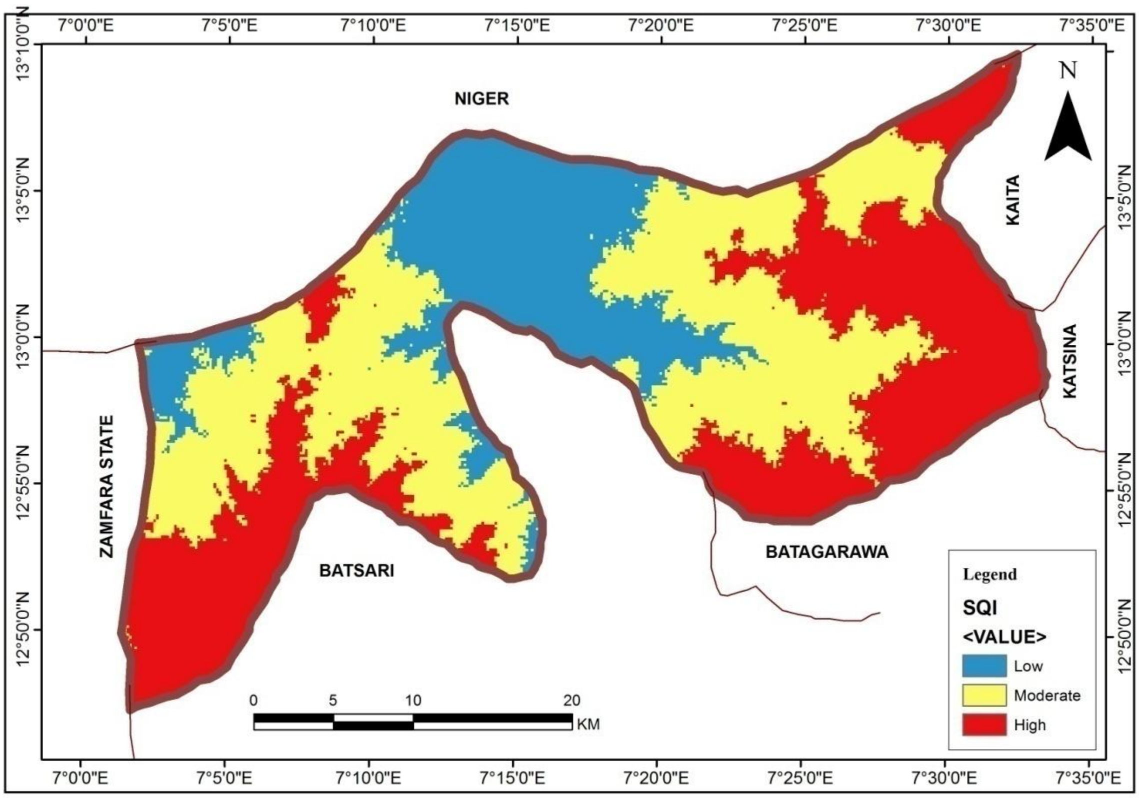

Figure 4.5: Soil Quality Index of the Study Area
Source: Author's Analysis, 2016

Figure 4.5 shows that areas of high quality are within the gentle slope region and the low quality are within sandy-loam region. The SQI is an indicator of erosion resistance and water availability of the soil. The result indicated that the high quality areas are places not affected or places with very low sensitivity to desertification while the low quality areas are places that are very sensitive to desertification.

4.1.2 Climatic quality index (CQI)

Climatic quality was assessed by using parameters that influence water availability to plants such as the amount of rainfall, slope aspect and aridity, which might inhibit plant growth (Thornes, 1995)

4.1.2.1 Rainfall

The amount of rainfall and its distribution are the major determinants of biomass production. Decreasing amounts of rainfall combined with high rates of evapo-transpiration drastically reduce the soil moisture content available for plant growth. Reduced biomass production, in turn, directly affects the content of organic matter of the soil and the aggregation and stability of the surface horizon to erosion (Kosmas et al 1993).The average amount of rainfall of the study area was estimated from the interpolation of data obtained from three meteorological stations bordering the study area. The rainfall of the area was categorized into two classes. Table 4.5 and Figure 4.6 show the distribution of rainfall in the study area and the assigned scores of the rainfall based on the MEDALUS project methodology.

Table 4.5: Rainfall of the Study Area

Rainfall (mm)	Score/Index	Class

778.8-870.8	1.5	Poor
870.9-946.3	1	Moderate

Source: Author's Analysis, 2016

The result shows that the areas that fall between 778.8mm and 870.8mm with score of 1.5 are susceptible to desertification while places with an annual rainfall of 870.9mm to 946.3mm are less susceptible to desertification.

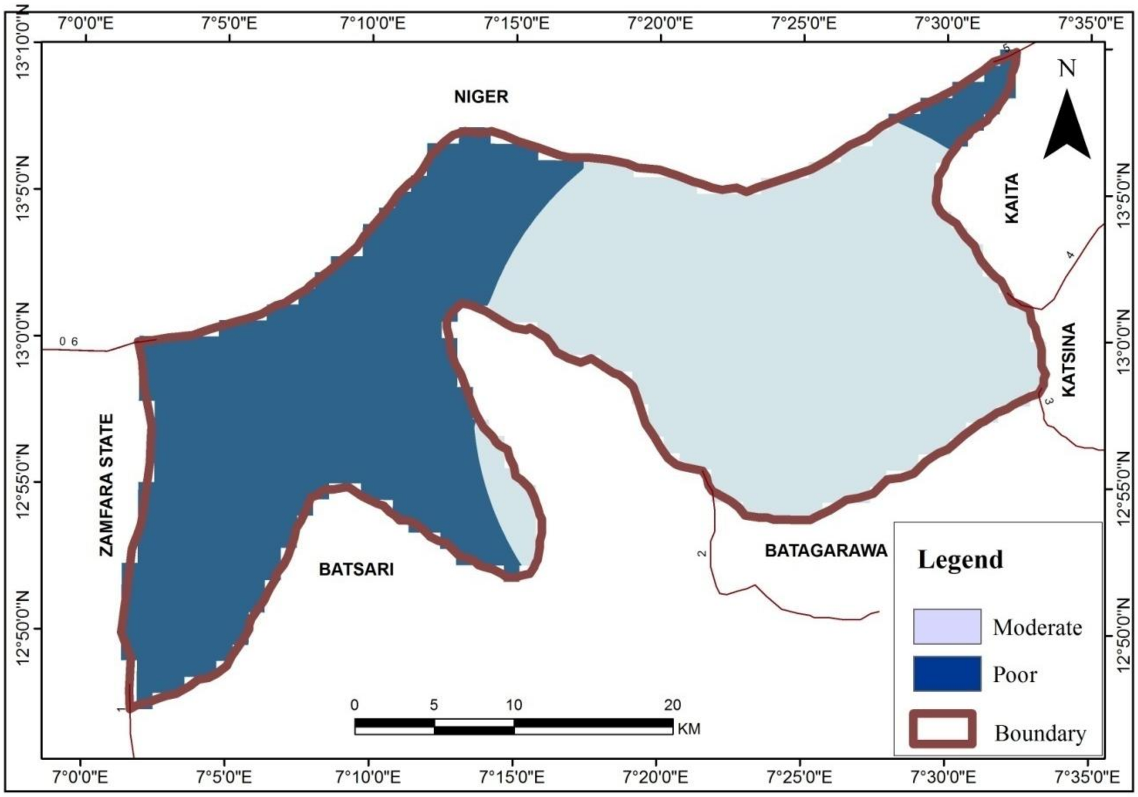

Figure 4.6: Rainfall Distribution of the Study Area
Source: Author's Analysis, 2016

4.1.2.2 Aridity

Aridity is a critical environmental factor in determining the evolution of natural vegetation by considering the water stress which may occur reducing vegetation cover. Aridity is defined as the deficiency of moisture resulting from permanent absence of rainfall.

Vegetation cover increases with increase in soil depth and decrease in aridity. The aridity of the study area was classified into two that is: the semi-arid (with little annual rainfall) and the arid area (lacking sufficient water/rainfall) as shown in Figure 4.7 and Table 4.6

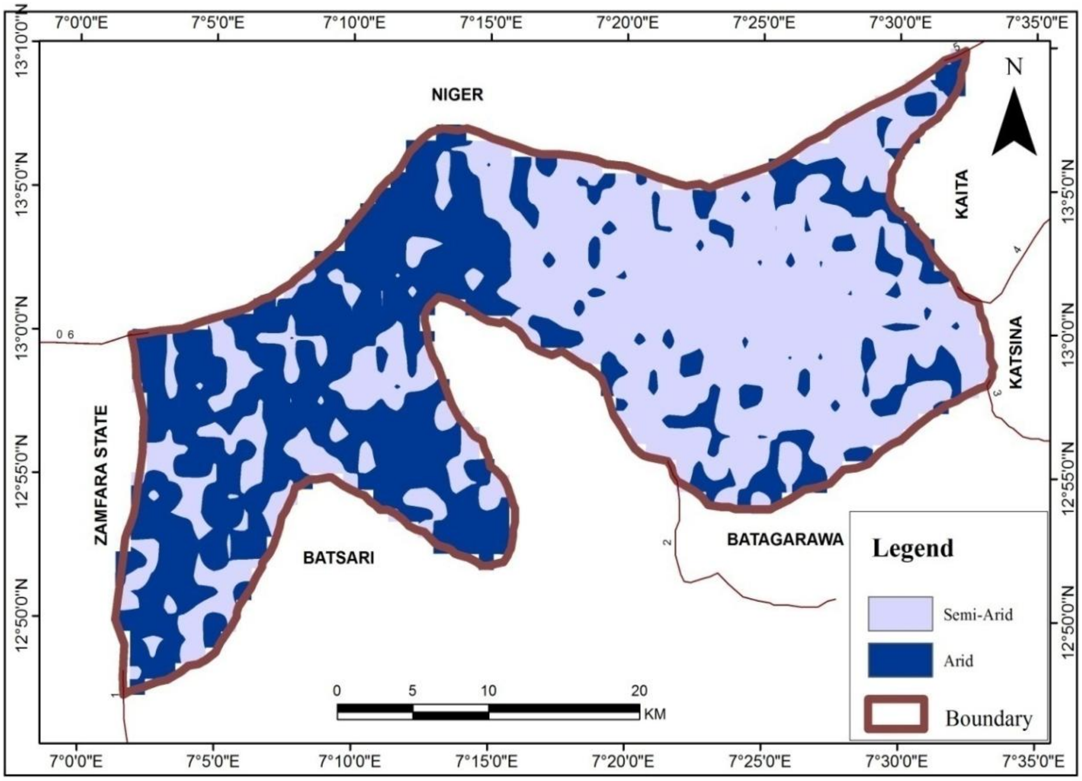

Figure 4.7: Aridity of the Study Area
Source: Author's Analysis, 2016

Table 4.6: Aridity of the Study Area

Aridity	Score/Index	Class
Arid	2	Poor
Semi-Arid	1.5	Moderate

Source: Author's Analysis, 2016

Table 4.6 shows that the arid areas with score 2 have more vulnerability to desertification and located westward while the semi-arid areas which have moderate sensitivity to desertification were dominated in the eastern parts of the study area.

4.1.2.3 Aspect

Slope aspect is considered an important factor for land degradation processes (Kosmas et al, 1993). Aspect affects the microclimate by regulating isolation. The angle and the duration at which the sun rays strikes the surface of the soil depends on the slope aspect. Figure 4.8 represents the slope aspect of the study area.

Aspect generally refers to the horizontal direction to which a mountain slope faces. In the northern hemisphere north facing slopes receive very little heat from the sun in mid-winter. Conversely, south facing slopes receive much more heat. Therefore, south facing slopes tend to be warmer than the northern sides. According to (Poesen,, van Wesemael, Bunte, and Benet, 1998) lands with southern and western aspects are warmer and have higher evaporation rates and lower water storage capacity than northern and eastern aspects. So a slower recovery of vegetation is expected in southern and western aspects and higher erosion rates than in northern and eastern aspects. As a consequence, southern exposed slopes usually have a lower vegetation cover than northern exposed slopes.

4.1.2.4 Climatic quality index

The Climatic Quality Index (CQI) was determined by integrating the rainfall distribution, aridity and slope aspect of the study area. The result was further classified into high, moderate and low quality. Figure 4.9 represents the CQI of the study area.

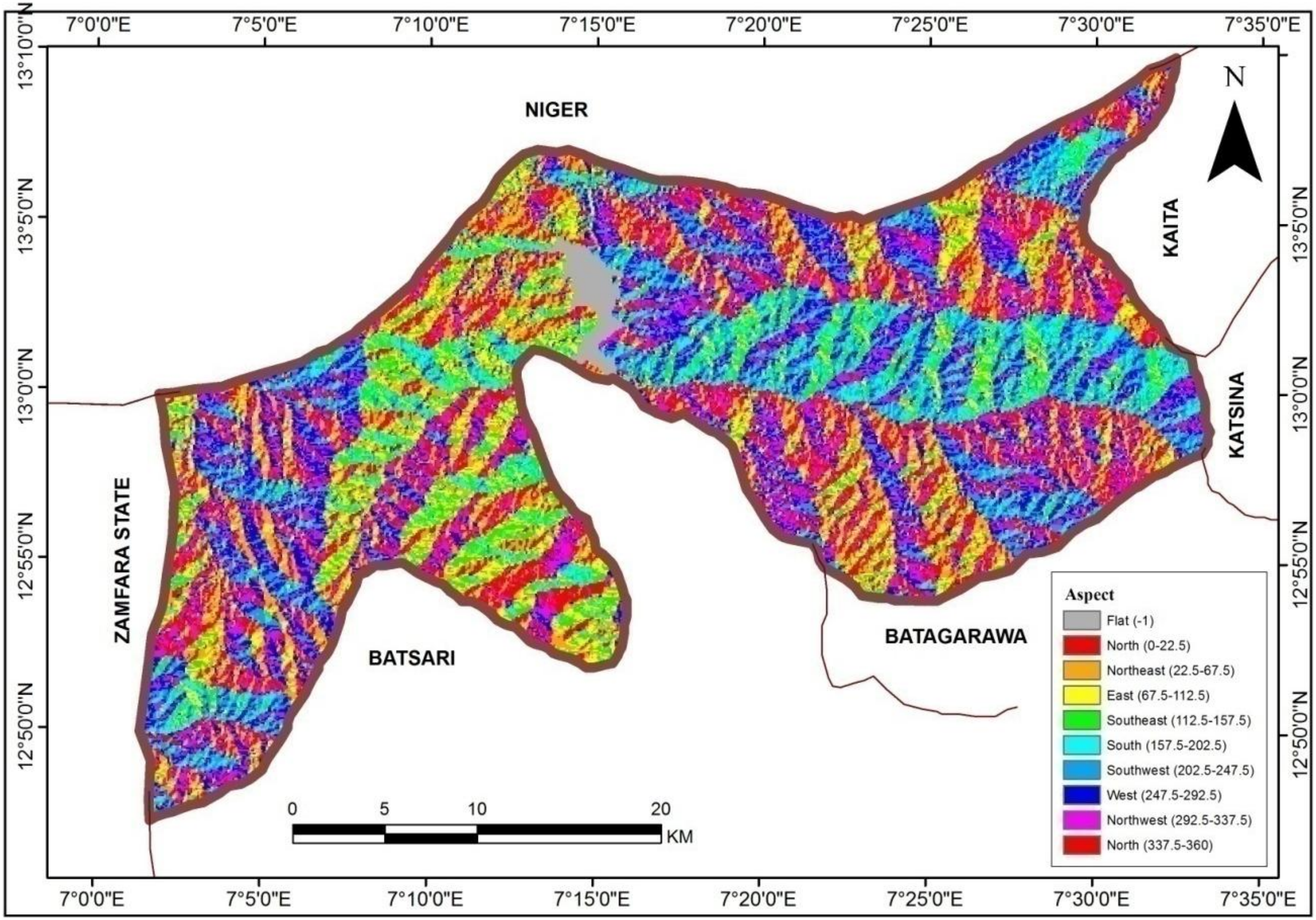

Figure 4.8: Aspect of the Study Area

Source: Author's Analysis, 2016

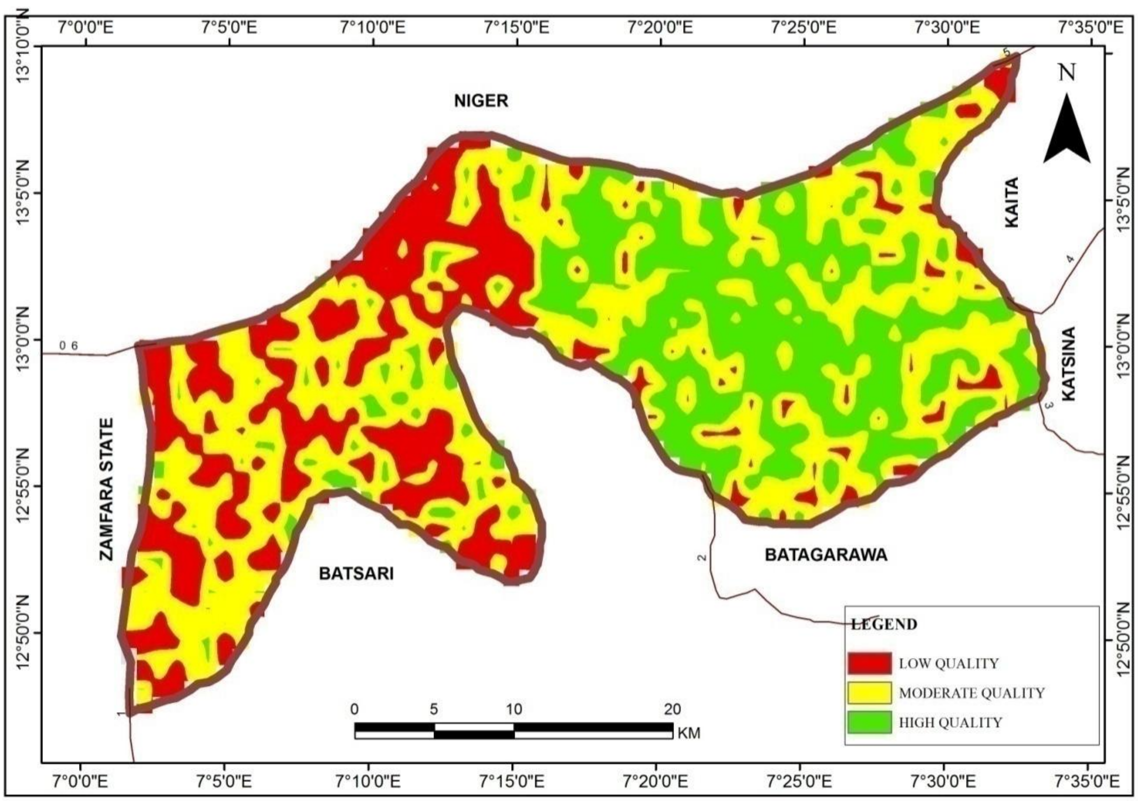

Figure 4.9: Climatic Quality Index of the Study Area

Source: Author's Analysis, 2016

Figure 4.9 shows that the high climatic quality areas are places with low sensitivity to desertification shown with the colour red, the moderate sensitive areas is shown in yellow while the highly sensitive areas are the low quality shown with blue. The result also shows that the high quality areas lies in the region where the amount of rainfall is relatively higher and low quality areas lies where the rainfall is lower.

4.1.3 Vegetation quality index (VQI)

Vegetation quality of the study area was evaluated according to Basso, *et al* (2000) in terms of three aspects (i.e. erosion protection to the soils, drought resistance and vegetal cover).

4.1.3.1 Vegetal cover

Vegetation cover plays an important role in mitigating the effects of desertification and land degradation. The percentage of vegetation is a function of both man-made agriculture and natural vegetation coverage (Gad and Lotfy, 2007). Elwell and Stocking, (1976), Lee and Skogerboe, (1985) Francis and Thornes, (1990) have reported an exponential decrease in runoff and sediment loss as the percentage of vegetation cover increases in most environments. A piece of land is considered desertified when the biomass productivity drops below a certain threshold value (Thornes, 1995). Therefore, percentage of vegetation cover is a necessary input in assessing the vegetation quality index. Table 4.7 and Figure 4.10 show the percentage vegetal cover of the study area.

Table 4.7: Vegetal Cover of the Study Area

Vegetal Cover	**Score/Index**	**Class**
Urban/Waterbody	0	No Resistance
Vegetation >10%	1.66	Moderate
Vegetation <10%	2	Poor

Source: Author's Analysis, 2016

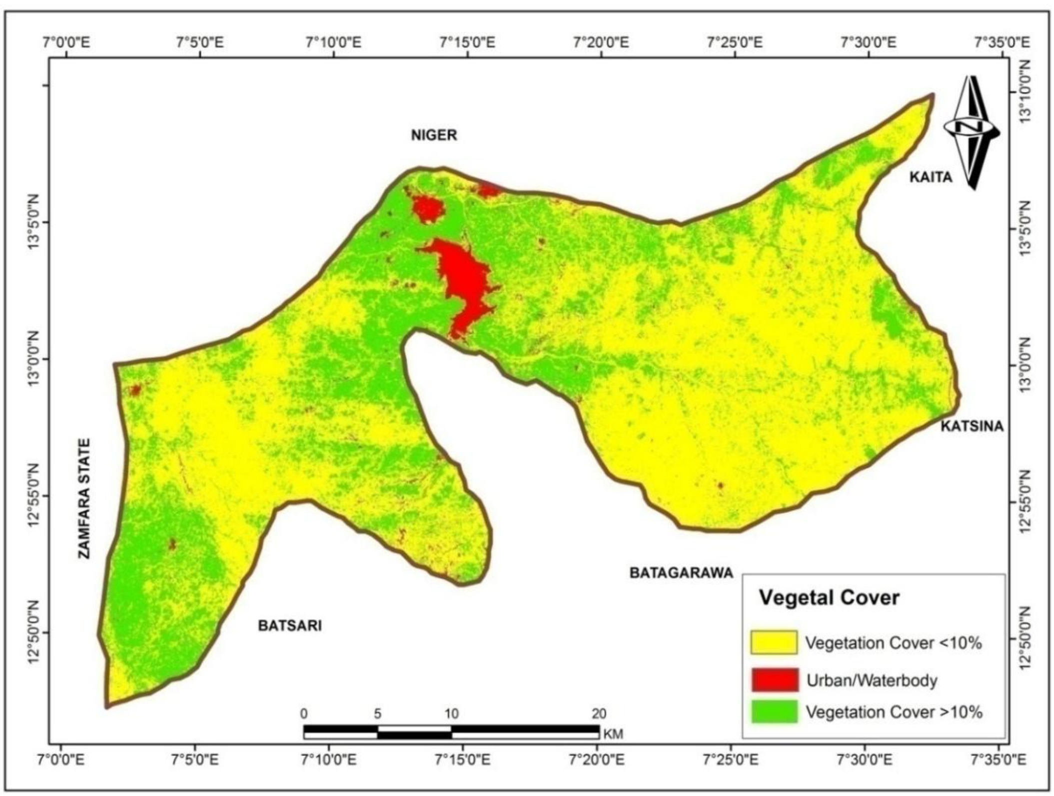

Figure 4.10: Vegetal Cover of the Study Area
Source: Author's Analysis, 2016.

The result in Table 4.7 indicates that the urban and water bodies have no effect in the occurrence desertification, the vegetal cover greater than 10% have moderate sensitivity while the vegetal cover less than 10% have poor sensitivity. Generally speaking, this means that the higher the percentage of vegetation cover the higher the resistance of land to desertification.

4.1.3.2 Vegetation drought resistance

According to the Medalus project methodology of European Commission (1999) standard classification for the susceptibility of vegetated land to drought and therefore its resistance, the study area in reflection to vegetation cover was classified into four categories of drought resistance (Figure 4.11 and Table 4.8).

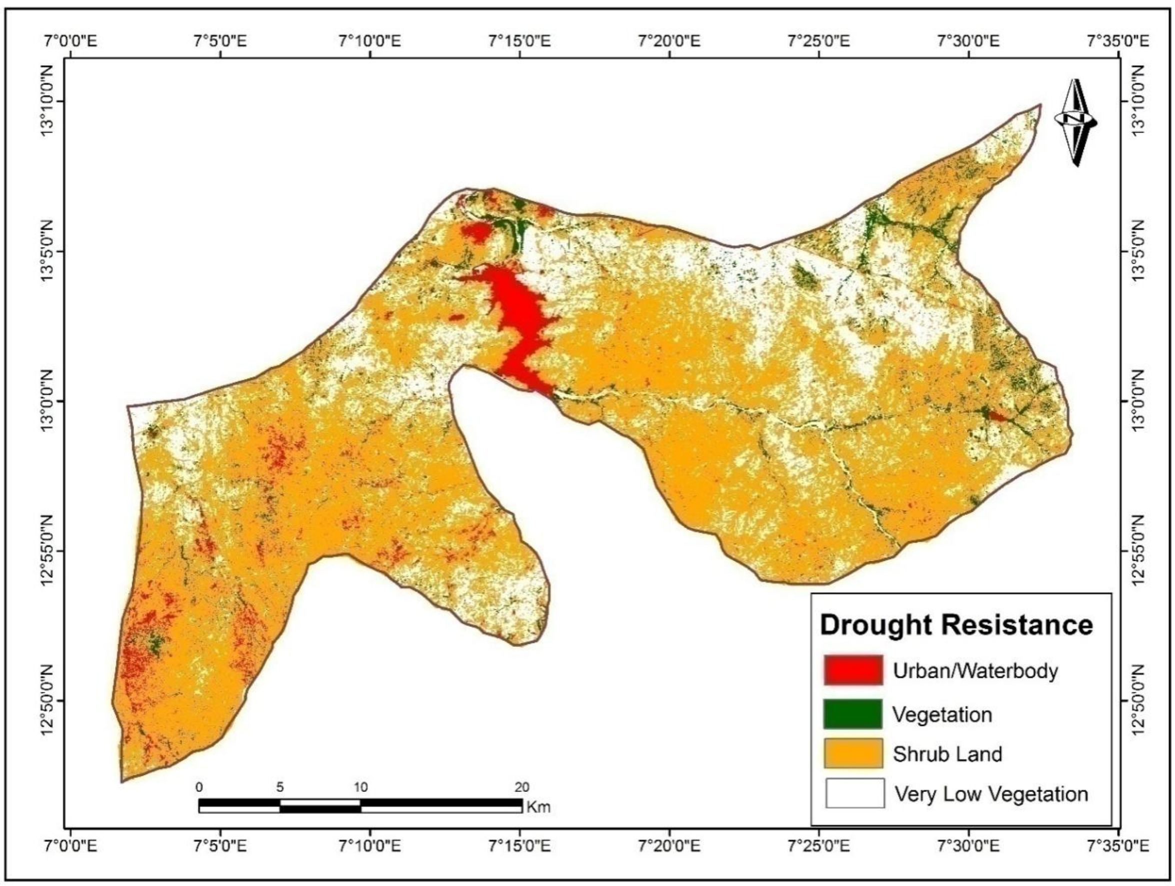

Figure 4.11: Drought Resistance of the Study Area

Source: Author's Analysis, 2016

Table 4.8: Drought Resistance of the Study Area

Drought Resistance	Score/Index	Drought Resistance
Urban/Water body	0	No Resistance
Vegetation	1	High
Shrubs	1.66	Moderate
Very Low Vegetation	2	Poor

Source: Author's Analysis, 2016

The results in Table 4.8 indicate that urban areas and water bodies scored zero have no resistance to desertification. It can be seen that the vegetated areas scored 1 have high resistance to drought while the shrub land with a score of 2 have a moderate resistance. Areas that are characterized with very low vegetation have poor resistance and are highly susceptible to desertification. According to Clark (1996), the main factors affecting the evolution of the vegetation, in the long term, are related to the irregular and often inadequate supply of water, the long length of the dry season, and perhaps fire and grazing. Also, the main response of the plants to increased aridity is the reduction in leaf area index. Severe droughts that cause a reduction in leaf area index may be beneficial in the short term as it reduces transpiration, but such drought will increase the probability of enhanced soil erosion when rain eventually falls, as protective vegetation cover is reduced.

4.1.3.3 Vegetation erosion protection

Vegetation erosion protection shows how much land, and its vegetation cover is resistant to erosion. The study area reflects four categories of vegetation cover mapped by supervised classification. Figure 4.12 and Table 4.9 presents the vegetation erosion protection of the study area.

Table 4.9: Vegetation Erosion Protection of the Study Area

Erosion Protection	Score/Index	Erosion Protection
Urban/Waterbody	0	No Protection
Dense Vegetation	1	High
Shrubs	1.33	Moderate
Bare Surfaces	2	Poor

Source: Author's Analysis, 2016

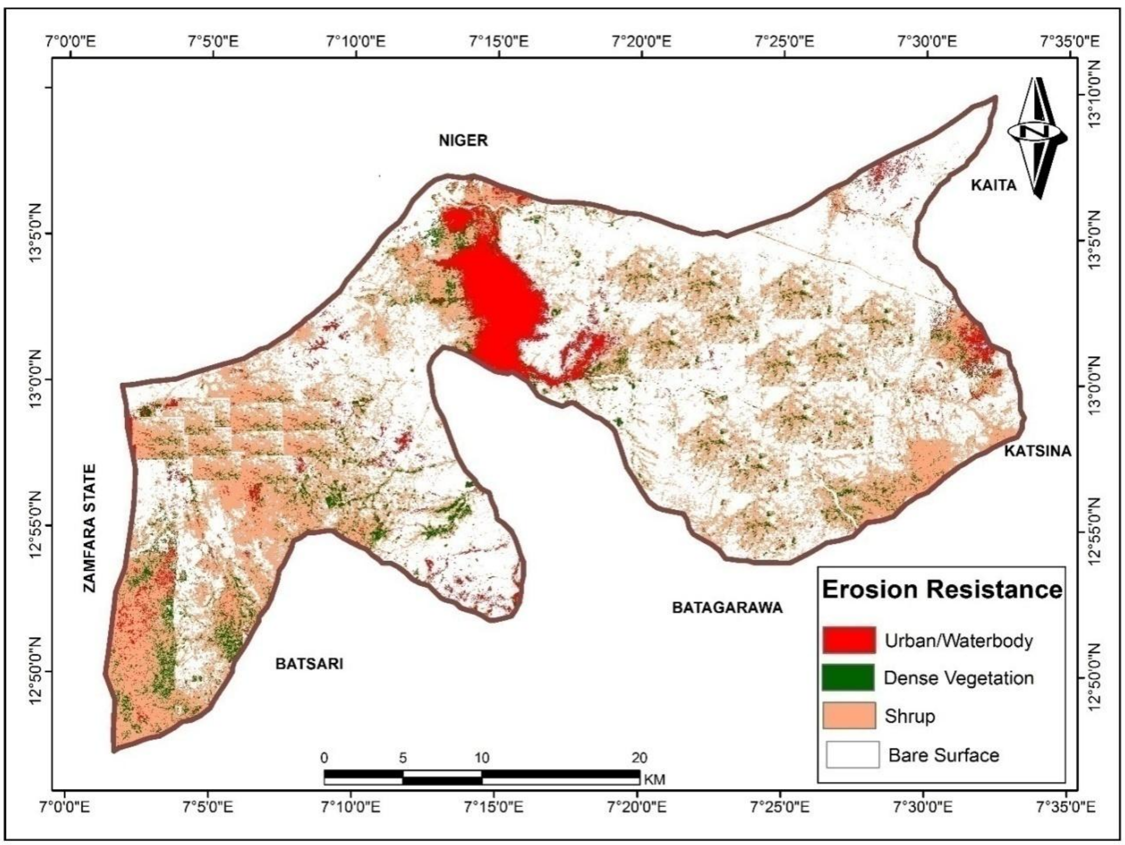

Figure 4.12: Erosion Resistance of the Study Area
Source: Author's Analysis, 2016

The result in Table 4.9 shows that the urban areas and water bodies have no protection to soil erosion, the densely vegetated areas with a score of 1 have high protection to soil erosion, while the shrub land have moderate protection with a score of 1.33 and the bare surface with a score of 2 have poor protection. The result also revealed that densely vegetated areas have high erosion protection and the less dense vegetation and bare surfaces have poor protection to erosion and therefore increase the rate of desertification.

4.1.3.4 Vegetation quality index

The Vegetation Quality Index (VQI) was mapped from the overlay of the vegetal cover, drought resistance and the vegetation erosion protection of the study area. The result of the overlay is shown in Figure 4.13.

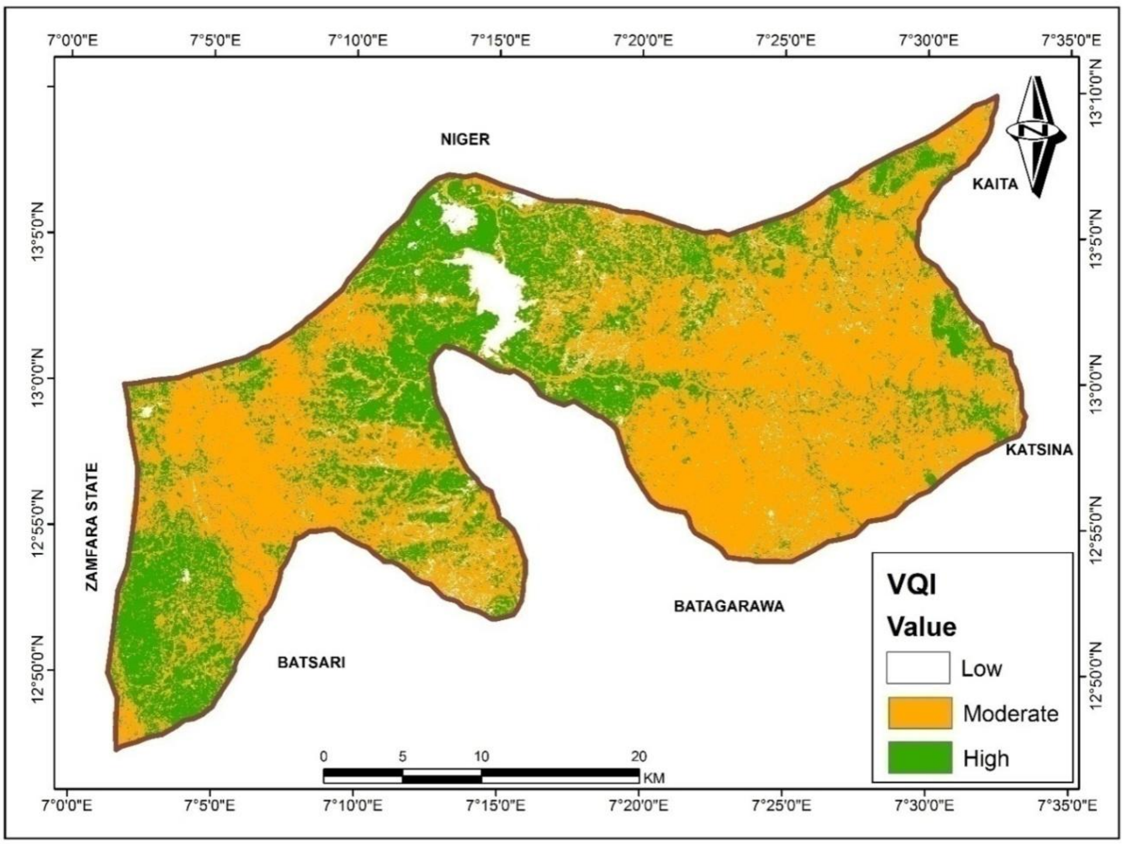

Figure 4.13: Vegetation Quality Index of the Study Area
Source: Author's Analysis, 2016

Figure 4.13 shows three categories of vegetation quality and it is classified into high quality, moderate quality and low quality. It can be seen from the result that the high quality areas are places characterized by vegetation cover and these areas are less susceptible to desertification. The moderate quality areas are places covered by shrub land and have moderate susceptibility to desertification while the low quality areas are those areas that have high susceptibility and are characterized of bare soils.

4.2 Areas Sensitive to Desertification in the Study Area

The soil, vegetation and climate indexes were combined together to assess the environmentally sensitive areas (ESA's) to desertification by weighted overlay in ArcGIS version 10.1 spatial analyst tool. The coverage of each environmental sensitive area was estimated and the result is presented in Table 4.10 and Figure 4.14.

Table 4.10: Environmental Sensitive Areas of Jibia L.G.A.

Environmental Sensitive Areas	Area in Sq. Km	%
Very Low Sensitive Areas	114.91	11.08
Low Sensitive Areas	222.84	21.49
Moderately Sensitive Areas	221.25	21.33
Sensitive Areas	111.61	10.76
Very High Sensitive Areas	366.51	35.34
Total	**1037.12**	**100**

Source: Author's Analysis, 2016.

Table 4.10 and Figure 4.14 revealed that very high sensitive areas to desertification covers an area extent of 366.51Km^2 occupying about 35.34% of the total area and were observed in the eastern part of the study area. The sensitive areas occupy 10.76% of the total land. The very low sensitive areas or areas less affected by desertification were found westward and covers 11.08% of the land. From Table 4.10 it is evident that desertification is very high in the study area and has rendered a vast land to be precise 366.51ha less productive and in need of urgent attention. Most of the affected areas are located in the east part of the study area in relation to Figure 4.14.

In general, it can be observed in Figure 4.14 that the sensitivity of the study area to desertification increases as we move from the west to eastern part of the study area. Also, the very high sensitive areas were located where rainfall is higher and vegetation cover is less. This could be attributed to the fact that there is tendency of high water runoff due to the dominance of sandy soil, clay-loam and clay-sandy soil which have poor sensitivity to desertification over the sandy-loam which is less susceptible to desertification and also due to the removal of top soil by wind due to the absence of the vegetal cover. It can also be observed from the Figure 4.14 that very low sensitive areas were located where aridity is higher but the area is characterized by good soil quality.

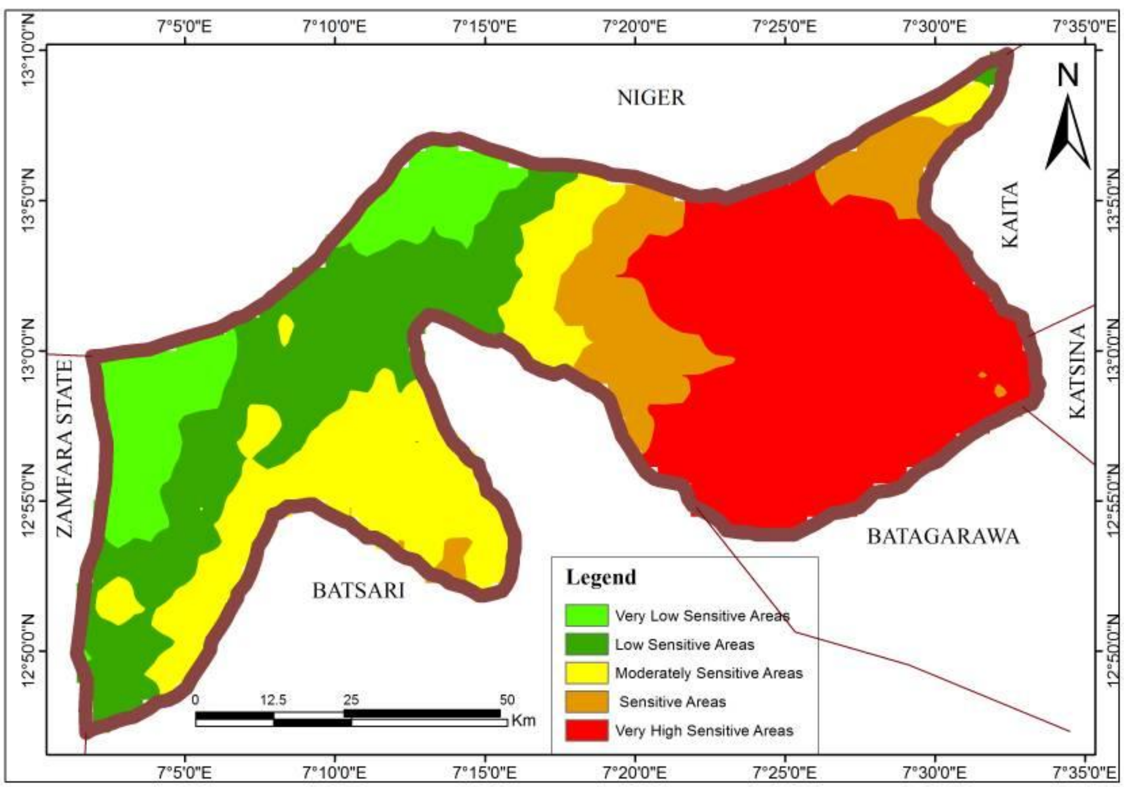

Figure 4.14: Environmental Sensitive Areas of the Study Area

Source: Author's Analysis, 2016

4.4 Extent and Rate of Desertification in the Study Area

The magnitude and rate at which desertification is changing per year was derived through the characterization of classified satellite imageries into LULC classes. The reliability of the LULC classes was ascertained through accuracy assessment as presented below.

4.4.1 Accuracy assessment for Land use/Land cover using confusion matrix

Land use and land cover classification results was ascertained through accuracy assessment which was obtained by computing error matrix for the three images used for the classification. The overall accuracy result, error matrix and kappa coefficient for 1990, 2000 and 2015 imageries are presented on tables 4.11, 4.12, and 4.13 respectively.

Table 4.11: Confusion Matrix for Maximum Likelihood Confusion of 1990

	Ground Reference Data						
Classified Data	Veg	BS	WB	CL	BU	Total	User's A
Vegetation	19	0	0	0	0	19	100
Bare Surface	2	32	0	1	0	35	91.4
Waterbody	0	0	1	2	0	3	33.3
Cultivated land	0	1	0	35	0	36	97.2
Built-up	0	1	0	0	6	7	85.7
Total	21	34	1	38	6	100	
Producer's A	90.5	94.1	100	92.1	100		
	Overall Accuracy = 93%			Kappa Coefficient =		0.90	

Source: Author's Analysis, 2016.

In all the confusion matrix tables, for the ground reference data, Veg represent vegetation, BS represent bare surface, WB represent water body, CL represent cultivated land and BU represent built-up. Rock out crop is not included because it has same reflectance as bare surface.

Result on Table 4.3 shows vegetation was extracted without any misclassification thereby having a high user's accuracy, while water body, cultivated land and built-up were also extracted without much misclassification.

Table 4.12: Confusion Matrix for MLC of 2000

	Ground Reference Data						
Classified Data	Veg	BS	WB	CL	BU	Total	User's A
Vegetation	17	0	1	0	0	18	94.4
Bare Surface	0	25	0	1	0	26	96.2
Waterbody	0	0	25	2	1	28	89.3
Cultivated land	1	1	0	16	0	18	88.9
Built-up	0	1	0	0	9	10	90
Total	18	27	26	19	10	100	
Producer's A	94.4	92.6	96.2	84.2	90		
Overall Accuracy = 92%				Kappa coefficient= 0.89			

Source: Author's Analysis, 2016.

Results on table 4.4 showed little misclassification of all the LULC classes thereby having higher user's and producer's accuracies. This can be related to the spatial resolution of all the imageries used for the classification.

Table 4.13: Confusion Matrix for MLC of 2015

	Ground Reference Data						
Classified Data	Veg	BS	WB	CL	BU	Total	User's A
Vegetation	23	0	0	0	0	23	100
Bare Surface	0	20	0	1	1	22	90.9
Waterbody	0	0	24	0	0	24	100
Cultivated land	0	0	1	17	0	18	94.4
Built-up	1	1	0	0	11	13	84.6
Total	24	21	25	18	12	100	
Producer's A	95.8	95.2	96	94.4	91.7		
	Overall Accuracy =	95%		Kappa Coefficient =		0.99	

Source: Author's Analysis, 2016.

On Table 4.5 results shows a higher accuracy of all the LULC classes than all the other imageries. This can be attributed to the resolution of the Landsat 8 used. Therefore little misclassification is observed on all the classes used.

Results of the error matrix showed an increasing trend in overall accuracy of 93% in 1990 and 95% in 2015, however there was a fall of 1% in 2000 where the overall accuracy recorded was 92%. Overall accuracy recorded was good enough which agrees with Anderson et al., (1996) who suggested a minimum level of interpretation accuracy in identification of land use land cover category for remote sensor data should be at least 85%. Hence, classification accuracy for this study can be acceptable. Furthermore, none of the Kappa coefficients for the three imageries was less than 0.87 which signifies that the accuracy classification was good enough which agrees with the research of Mary (2012); Anthony, Viera and Joanne, (2005) which states that a Kappa result of 0.81- 1.00 shows an almost perfect agreement.

Table 4.14: Extent and Rate of Desertification between 1990 and 2015

Desertification			**Extent of Desertification**		**Rate of Desertification**	
Period	Year	km^2	km^2	%	km^2/Year	%/Year
1990-2000	1990	173.44	30.93	17.8	3.1	1.8
10Years	2000	204.37				
2000-2015	2000	204.37	246.47	120.6	16.4	8.0
15Years	2015	450.84				
1990-2015	1990	173.44	277.4	159.9	11.1	6.4
25Years	2015	450.84				

Source: Author’s Analysis, 2016.

The extent and rate of desertification were calculated through the use of classified Landsat images of 1990, 2000 and 2015. The results revealed that the extent of desertification between 1990 and 2000 increased by 30.93km^2 (17.8%) at the rate of 3.1km^2 per year (1.8%/ per year). Jibia L.G.A. experienced an increase in desertification between 2000 and 2015 by 246.47km^2 (120.6%) at rate of 16.4km^2 per year (8.0%) annually. It can also be observed that from the entire period of study, the desert areas have expanded by 277.4km^2 (159.9%), at the rate 11.1km^{2}per year (i.e. 6.4%per year). It is obvious from the result that the constant increase of desertification was due to loss of vegetation cover as pointed out by the MEDALUS methodology. The parameters responsible for the loss of vegetation cover in the study area includes: soil parent material where the coarse porphyritic homblende granite is the dominant parent soil type which has poor sensitivity to desertification with a score of 2 due to its failure to support plant life, sandy soil dominates the area with low water retention capacity there by unable to support plant life , soil depth where the very thin and not deep soils dominate the area thereby affecting plant rooting and survival and less rainfall where a mean annual rainfall of 778.8-870.8mm is mostly experienced. This affects vegetation therefore leading to low vegetal cover percentage. Intense animal grazing, land clearing for agricultural purposes and fuel wood and other anthropogenic activities of the inhabitants further leads to loss of the little available vegetation in the study area as stated by a study conducted by Sani (1996).

This conforms to the study of Gakkuk (2015) which showed that there was vegetation decline between 1976 and 2006 though rainfall has been variable (sometimes high and sometimes low) in Local Government Areas of Jibia, Kaita and Mani of Katsina State. The study attributed the desertification process to low amount of vegetation cover as a result of anthropogenic activities. Also, Omale (2012) observed a decrease in vegetation cover between 1976 and 2012 in Jibia and

Kaita Local Government Areas of Katsina State which was attributed to land clearing for agriculture, grazing of animals and increase in human population that resulted to desertification increase.

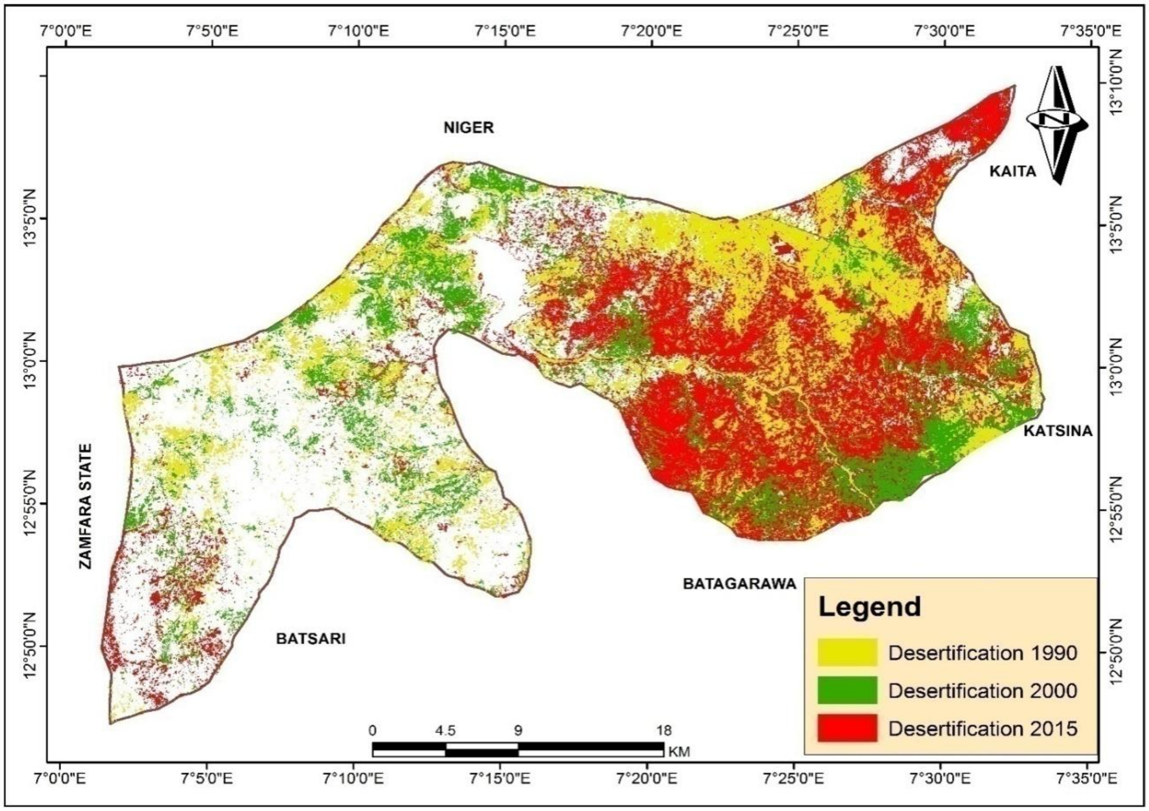

Figure 4.15: Extent and Rate of Desertification

Source: Author's Analysis, 2016

4.3 Effects of Desertification in the Study Area

The analysis of the questionnaires is as follows:

4.3.3 Socio-economic Characteristics of Respondents

The socio-economic characteristics considered include; age, educational qualification and occupation of respondents and is presented on Table 4.15.

Table 4.15: Age, Occupation and Educational Qualification of Respondents in the study area.

Respondent	Frequency	Percentage%
Age		
15 – 25	48	13.4
26 – 35	125	34.9
36 – 45	98	27.4
46 – 55	87	24.3
56 above	0	0.0
Total	**358**	**100.0**
Occupation		
Civil service	64	17.9
Business/trading	80	22.3
Farming	187	52.2
Artisans	27	7.5
Total	**358**	**100.0**
Educational qualification		
Koranic	30	8.4
Primary	45	12.6
Secondary	203	56.7
Tertiary	80	22.3
Total	**358**	**100.0**

Source: Author's Analysis, 2016

The age of 26-35 years constituted the highest proportion of respondents with 34.9% as indicated in Table 4.15 This result could be a function of questionnaire administration because most of the respondents encountered were younger aged, who were engaged in outdoor work during the survey period. This aid the researcher in getting required information from the questionnaire administered as the younger generation are more educated and therefore have more understanding of desertification.

Educational attainment sometimes reflects the nature of occupation and in turn may influence an individual's perception on desertification. It is shown in Table 4.15 that a high percentage of the respondents have attended one form of formal education or the other. However, the result reveals that majority (56.7%) of the respondents have gone to secondary schools. Only 22.3% of the respondents have undergone tertiary education.

Table 4.15 further revealed that 52.2% of the respondents were farmers. However, majority of the people were in the informal sector, about 22.3% were traders and businessmen while civil service constituted about 17.9% and a smaller proportion of 7.5% consisted of artisans composed of carpenters, mechanics shop owners, fishermen and vegetable vendors etc. However, it was also observed that though there is a high proportion of the population in the informal sector, but still those in the informal sector also partially engage in any of the agricultural activities. Therefore, have more awareness to desertification incidence.

4.3.4 Level of Awareness of Desertification

Table 4.16 deals with the perception of the respondents on their awareness to the occurrence of desertification in the study area.

Table 4.16: Level of Awareness of Desertification in the Study Area.

Awareness	Frequency	%
Yes	343	95.8
No	15	4.2
Total	**358**	**100**

Source: Field Survey, 2016

From Table 4.16, it can be observed that 95.8% of the respondents were aware of desertification in the study area while few of the respondents are unaware of the process. It is obvious that majority of the respondents were of the opinion that there is change in the land as a result of the desertification process meaning that they are educated enough to understand and notice change in their environment.

4.3.5 Perception of Respondent on Desertification in the Study Area

This sub-section deals with individual perception on what desertification is and evidence of the process of desertification. This is one of the questions with multiple options for respondents to thick. Table 4.17 presents the perception of the respondents as regards to desertification in the study area.

Table 4.17: Perception of Respondents on Desertification

Meaning of desertification	**Frequency**	**%**
Drought and poor agricultural yields	205	42.4
Disappearance of trees	112	17.3
Productive land becomes unproductive	137	21.2
Absence of food for animals	177	27.4
Others	15	2.3

Source: Field Survey, 2016

From Table 4.17, it can be seen that 205 respondents (42.4%) were of the opinion that desertification is when there is poor or fall in agricultural yield which may be as a result of less rainfall in the area. This option has the highest percentage considering the fact that most of the respondents are farmers and the first indication they noticed is in relation to their means of sustenance. 177 of the respondents (27.4%) believe that is the disappearance of trees and this is attributed to the absence of vegetation. About 21.2% of the respondent agreed that desertification is when the land becomes unproductive, which is more relative to erosion while 17.3% of the respondents believed that it is when there is no food for animals. Few percentage of the respondent (2.3%) of which are mainly females, gave other reasons relating to the occurrence of desertification such as intense heat, death of animals and diseases (Field survey, 2016).

4.3.6 Time Respondents Started Experiencing Desertification in the Area.

This subsection was embarked upon to analyze the views of the respondents in the area on the time at which they started experiencing the problem of desertification. The duration at which the problem was observed by the respondents is shown in Table 4.18.

Table 4.18: Period of Experiencing Desertification in the Area

Duration	**Frequency**	**%**
5 – 10	33	9.2
11 – 15	41	11.5
16 – 20	100	27.9
21 – 24	156	43.6
25 above	28	7.8
Total	**358**	**100**

Source: Field Survey, 2016

Table 4.18 signifies that desertification is not a new problem in the study area. From the table, 43.6% of the respondents observed the problem of desertification in the study area from 21-24 years ago. This can also be attributed to the age range of respondents encountered during the period of study. Also, 27.9% have observed the problem for 16 to 20 years. About 11.5 % observed the change between 11 and 15 years while 7.8% of the respondents observed desertification process as far as 25 years and above.

4.4.5 Causes of Desertification

This is also another question where respondents can have multiple opinions. Table 4.19 shows the respondent’s perception on major causes of desertification in the area.

Table 4.19: Causes of Desertification in Jibia L.G.A.

Causes of desertification	Frequency	%
Climate	113	25.6
Cutting of wood for fuel	114	25.9
Overgrazing	59	13.4
Population pressure	65	14.7
Over cultivation of marginal lands	72	16.3
Others	18	4.1

Source: Field Survey, 2016

From the Table, about 25.9% agreed cutting of wood for fuel as the major cause of desertification the study area. Some of the respondents gave their reasons as regards to the afforestation exercises undertaken in the study area towards desertification management. Climate was found to be second cause with 25.6%, a slight difference of 0.3% with the cutting down of fuel wood. In here, the respondents pointed to the rainfall variations experienced over the years. This partly support the work of Gakkuk (2015) that observed climate change as the major cause of land degradation in northern part of Katsina State. Over cultivation of marginal lands was also observed as a cause of desertification in the area with 16.3% while population pressure, overgrazing as closely related was found to be 14.7%, 13.4% respectively. Also, few (4.1%) of the respondents attributed the cause to other factors such as nature.

4.4.6 Intensity of Desertification

The perception of the respondents on the intensity of desertification in the area is shown in Table 4.20. This was embarked upon to know whether the process of desertification is increasing or decreasing as perceived by the people of the study area.

Table 4.20: Intensity of Desertification in the Study Area.

Intensity	Frequency	%
Increasing	185	98.9
Decreasing	2	1.1

Source: Field Survey, 2016

The result in Table 4.20 shows that 185 (98.9%) of the respondents are of the opinion that the problem is increasing year after year as there are reports of cases where desertification has been observed recently. Also the people perceived that the land gets drier with less moisture. Only two (1.1%) of the respondents believed that desertification is decreasing.

4.4.7 Changes Observed in the Area due to Desertification

Table 4.21 shows individuals' opinion on the change they have observed as a result of desertification in the study area.

Table 4.21: Changes observed due to Desertification in the Study Area.

Changes on land	Frequency	%
Land becomes dry and barren	144	40.2
Soil become loose	108	30.2
Formation of sand dunes	25	7.0
Plants refuse to grow	73	20.4
Others	8	2.2
Total	**358**	**100**

Source: Field Survey, 2016

The Table shows that 40.2% of the of the respondent agreed that the land becomes dry and barren which they say is easily noticed even within their settlements, 30.2% of the respondents believes that the soil becomes loose where the soil is more of sandy, just 20.4% of the respondent from the result of the field survey were of the opinion that plants refuse to grow because most of them believed that as a result of land becoming dry and barren, plants cannot have the support to grow, while 7.0% of the respondent believed that formation of sand dunes is a signal of desertification. Very few (2.2%) of the respondents agreed the changes on the land was due to other reasons.

4.4.8 Effects of Desertification

The perception of individuals on the effects felt by desertification was also examined and the result is shown in Figure 4.22

Table 4.22: Effect of Desertification in the Study Area

Effect felts	Frequency	%
High temperature	132	25.5
Water shortage	119	23.0
Crop cultivation reduction	187	36.2
Loss of cultural identity	15	2.9
Loss of biodiversity	57	11.0
Others	7	1.4

Source: Field Survey, 2016

The result on the perception of the people of Jibia L.G.A. revealed that reduction in crop cultivation bares the highest with 36.2% which can lead to hunger and starvation of the resident of the study area considering the fact that most of the inhabitants are farmers. This was followed by high temperature with 25.5% and water shortage is the next with 23.0% others include loss of biodiversity and loss of cultural identity since people are forced to move off land that becomes barren as a result of desertification.

4.4.9 Methods Adopted to Reduce the Effect of Desertification

The problem of desertification in the study area can be tackled by the government and the people in various ways. Table 4.23 shows the opinion of the people of the study areas and how desertification can be tackled.

Table 4.23: Strategies to Reduce the Effect of Desertification in the Study Area

Methods adopted to reduce effects	Respondents	%
Planting of trees	111	31.0
Shifting cultivation	108	30.2
Reduce deforestation	71	19.8
Saving water	100	27.9
Using alternative energy source	18	5.0
Others	21	5.9
Total	**358**	**100.0**

Source: Field Survey, 2016

It can be seen from the result that as perceived by the respondent planting of trees (31.0%) was the best way to tackle the problem of desertification in the study area. They believe to some extent desertification has reduced as a result of the afforestation exercises embarked upon by some governmental and nongovernmental organisations in the study. This is followed by shifting cultivation where land is left for sometime to regain its fertility before cultivation with 30.2%. The respondent opines that water saving (27.9%) is also a means of tackling the problem such that even with less rainfall plants can have water to grow and animals and humans can have water to drink. Reduce deforestation, using alternative energy source were also highlighted as strategies to reduce the effects of desertification in the area and in this aspect they want the government to be actively involved in making others sources of energy readily available at a cheaper rate to the common man.

Despite the effort made by the state government in planting of trees as stated by Danjuma (2012), Gakkuk (2015) observed that the trees planted are not cared for and often die from harsh weather conditions. And also most times the tree planting activities are just mere ceremonies captured on televisions but not really translated on ground so the government is actually fighting a grim battle to combat desertification without practical sustainable policies.

4.5 Prediction Extent of Desertification

The section deal with the prediction of the Land use and land cover considering the desert areas in particular for fifteen (15) years (from 2015 to 2030) using the CA-Markov Chain analysis model. The result of the prediction is presented in Figure 4.16.

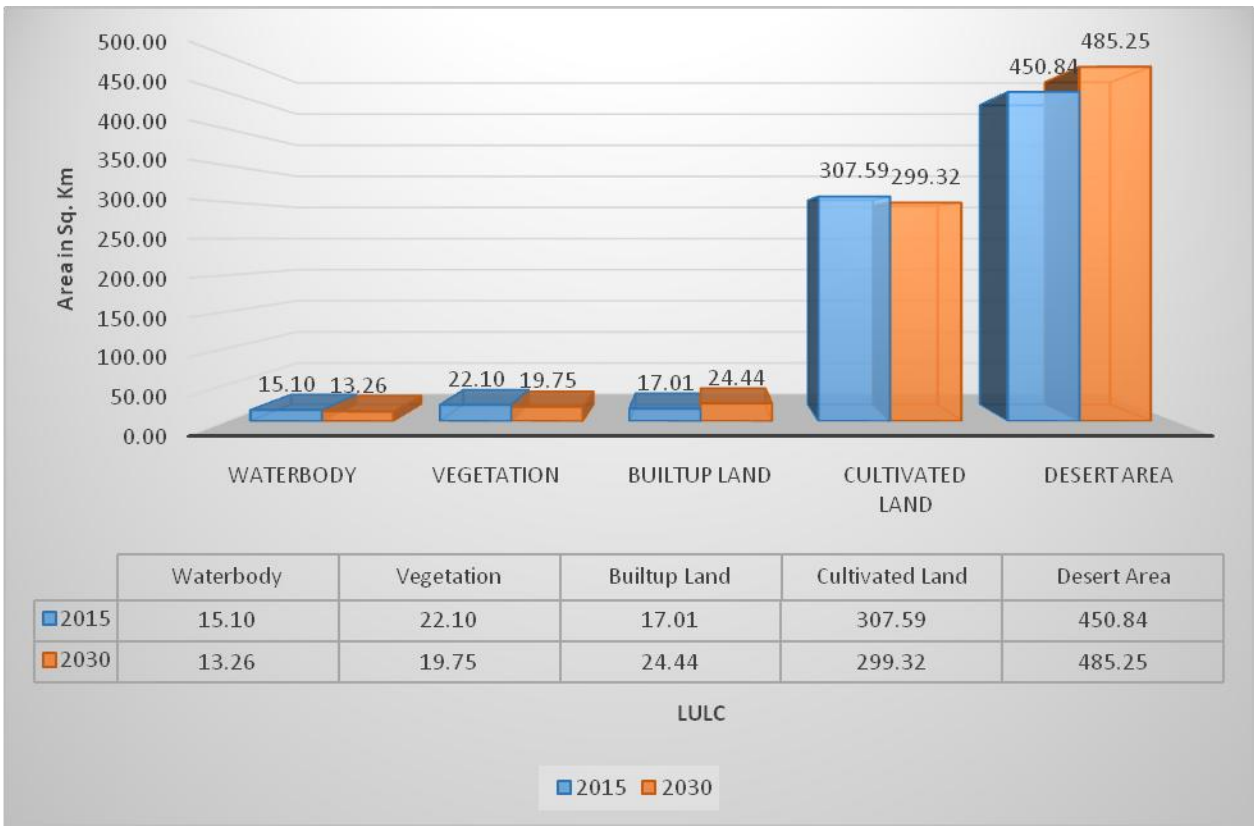

Figure 4.16: Prediction of Desertification in the Study Area
Source: Author's Analysis, 2016

It can be seen from the result that the desert areas which occupies 450.84Km^2 in 2015 will experience increase to 485.25Km^2 in 2030. Agricultural land, water bodies, vegetation is expected to decrease in 2030 from their original coverage while the built-up land is expected to increase in 2030. The result of this study is a clear indication that constant decrease in water bodies, vegetation, cultivated land and increase in the built-up land may result to constant increase in the desert areas as a result of urban expansion (population growth) and the loss of bio-diversity if not given consideration. Figure 4.17 further reveals the nature of LULC by the year 2030.

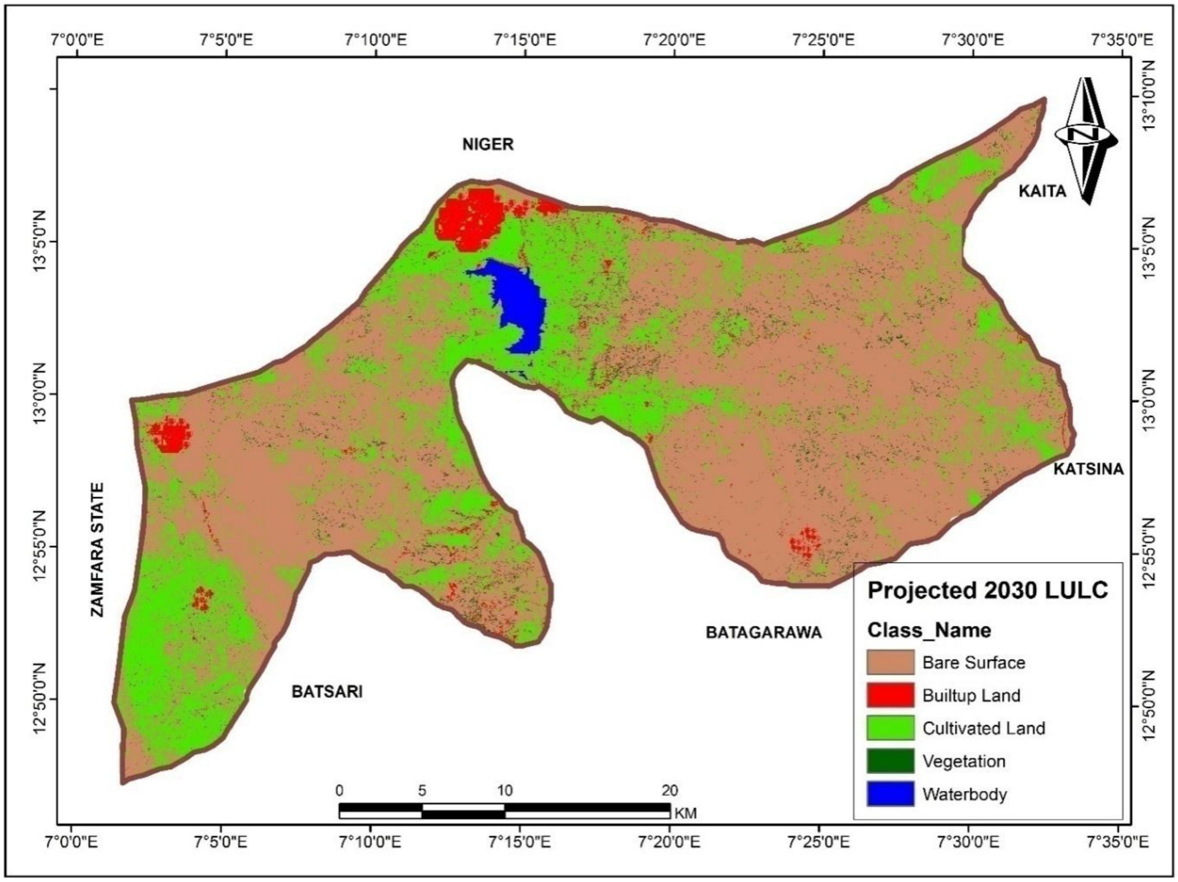

Figure 4.17: Prediction of Desertification
Source: Author's Analysis, 2016

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY

The study was carried out to identify the causative factors of desertification in Jibia local government area, determine the how desertified the area is, determine the extent and rate of desertification, examine the effects and also to predict desertification process up to 2030. The sensitivity was determined by assessing the soil quality index, climate quality index and vegetation quality index. Finally the prediction of desertification was made by the CA-Markov Chain Model. The study made a number of findings from the data analysis which includes/

The high quality areas (areas less sensitive to desertification) were found within the gentle slope region and the low quality areas (areas more sensitive to desertification) are within sandy-loam region of the study area. The SQI is an indicator of erosion resistance and water availability of the soil. The study also indicates that the high quality areas are places not affected or places with low sensitivity to desertification while the low quality areas are places that are very sensitive to desertification. The high climatic quality areas are places with low sensitivity to desertification shown with the green colour, the moderate sensitive areas is shown in yellow while the highly sensitive areas are the low quality shown in red. The result obtained also shows that the high quality areas lies in the region where the amount of rainfall is relatively higher and low quality areas lies where the rainfall is relatively low. The high quality areas for the climatic quality are places characterized by vegetation cover and these areas are less susceptible to desertification. The moderate quality areas are places covered by shrub land and bare soils.

The very high sensitive areas to desertification are areas observed in the eastern part of the study area. The very low sensitive areas or areas not affected by desertification were found westward.

The sensitivity of the study area to desertification increases as one move from the west to eastern parts of the study area. Desertification extent was observed to have a tremendous increase between the years 1990 and 2000 at a rate of 1.8% per year which has led to a total landmass of 277.4sqkm engulfed by desertification for the entire period of study (1990-2015).

Results from questionnaire administered showed that the majority of the inhabitants (about 95.8%) were aware of the menace of desertification for over two decades in their area. They also believe that climate change and anthropogenic factors such as over cultivation, deforestation (which is their main source of energy for cooking) and over grazing are the major causes of their environment becoming hotter and drier. Though the government and people have developed various strategies to fight desertification however desired result is yet to be achieved therefore desertification is on the increase with 98.9% of the respondents saying that desertification is on the increase. The respondents opine that afforestation (31%) and water saving (27.9%) are means of tackling the problem. Reduce deforestation, using alternative energy source were also highlighted as strategies to reduce the effects of desertification in the area. Furthermore, study revealed that desertification will continue to engulfed vast hectares of land from 450.84sqkm by 2015 to 485.25sqkm by the year 2030if the situation continues.

5.3 CONCLUSION

The severity of desertification varies from place to place because of various parameters. In this study, the MEDALUS methodology of 1999 was adopted and modified to assess various desertification parameters using Remote Sensing and GIS. Three major indices each comprising of several sub-indicators were analyzed. Also, the Markov Change model was used to predict the process of desertification in the study area.

It can be concluded that the very high sensitive areas to desertification covers an area extent of 366.51km² and is mostly observed in the eastern part of the study area. The very low sensitive areas covers an extent of 114.91km² and located where aridity is higher but the area is characterized by good soil quality. It was also observed that desertification was increasing for the period of the study.

5.4 RECOMMENDATION

Based on the findings of this research on the occurrence of desertification in Jibia L.G.A. of Katsina State, the following are recommended:

i. Afforestation and reforestation programmes taking place in the study area have been the major efforts towards combating desertification and therefore, should be intensified since desertification tends to be higher in areas with less vegetation. Agencies charged with the responsibility of supervision of these programmes should have a strong legal backing so that they can take legal action on individuals involved in indiscriminate felling of trees. Punishments should be meted to these individuals.

ii. The government should make available alternative energy sources at a cheaper cost and use of wood as source of energy should be discouraged. However for families, schools and organizations that cannot afford or do not prefer the alternative sources of energy; the government should encourage them to establish their own sources of firewood for their consumption.

iii. The government and some of the nongovernmental organizations currently working in the study area should place emphasis on reducing the number of grazing animals on land in an uncoordinated manner. Efforts can be geared towards provision of grazing lands either in areas where irrigation farming takes place to support feeding of the animals during dry season or in more fertile areas capable of supporting the grazing activity.

iv. Community participation and enlightenment campaigns are highly essential; the immediate community of the affected areas should be part and parcel of programmes of desertification control, the community knows their environment better and with their knowledge and acceptance that desertification do exist in the study area, the work of the government will be much easier because they are willing to participate towards curbing the problem.

v. Since most of the inhabitants of Jibia government local government are farmers, therefore the Government should intensify agricultural extension services. Farmers should be enlightened on proper agricultural practices and encouraged to engage in tree planting and contour planting on their farms for their own benefits.

vi. There is need for the stake holders (Government and Non-government organizations) in regards towards combating desertification to efficiently make available robust database and information bank and adequate man power for monitoring, planning and guiding the overall strategic response to the dynamics of desertification. Because with adequate data and information base the government will be able to respond to the problems of desertification promptly and successfully.

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QUESTIONNAIRE

This questionnaire is a sample designed to obtain information for a research study titled: Desertification Predictive Modelling in Jibia Local Government Area of Katsina State, Nigeria.

Fill in or tick [√] where appropriate

1. Ward of respondent…………………
2. Sex : Male [ ] Female [ ]
3. Occupation
   (i) Farming [ ] (ii) Civil servant [ ] (iii) Business/Trading [ ] (iv) Artisan [ ]
   (v) Others (specify)....................
4. Age (i) 15- 25 years [ ]
   (ii) 26-35 years [ ]
   (iii) 36- 45 years [ ]
   (iv) 46 -55 years [ ]
   (v) 56 above [ ]
5. Educational qualification: Koranic [ ] Primary [ ] Secondary [ ] Tertiary [ ]
   Non formal [ ]
6. Are you a Subsistence [ ] or Commercial [ ] farmer?
7. What is the size of your farmland (in hectares) or average size of animal herds you keep ----------------------.
8. If you are a farmer, what kind of farming system are you involved in?
   Traditional [ ] Mechanized [ ]
9. What type of crops do you cultivate?
   Sorghum [ ] Millet [ ] Beans [ ] Groundnut [ ] others [ ]
10. Do you observe any problem of desertification?
    Yes [ ] No [ ]
11. If Yes in (11), when did you start observing the problem? ------------------
12. What do you think is the cause of desertification in your area? Climate [ ] poor irrigation practice [ ]Over cultivation [ ] forest wood exploitation [ ] Over grazing [ ]others specify……………………….
13. Is the intensity of the problem increasing or decreasing? Increasing [ ] Decreasing [ ]

21. Describe any changes that you have observed about your land?

....…………………………………………………………

………………………………………………………………………………………

………………………………………………………………………………………

22. How has the problem of desertification affected your socio economic activities?

....

....

23. Is desertification a problem in this area?

Yes [ ] No [ ]

24. If yes, what do you regard desertification to be?

Drought and poor agricultural yields[ ] Disappearance of trees [ ] productive land becomes unproductive [ ] Absence of food for animals [ ] others specify…………………………………….

25. What are the causes of desertification in this area? Cutting of wood for fuel [ ]

Overgrazing [ ] Population pressure [ ] Over cultivation of marginal lands [ ]

Others specify……………………………………..

26. What are those effects felt? (i) High temperature/intense heat [ ] (ii) Water shortage [ ] (iii) Reduction in crop cultivation [ ] (iv)

27. What are the methods you have undertaken to reduce the effects?

……………………………………………………………………………………

28. What do you think should be done to fight against the menace of desertification?

(i) Sustainable tree planting activities/ Afforestation [ ] (ii) Sensitization campaigns involving the people [ ] (iii) Shifting cultivation [ ]

Others specify………………