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SCHOOL OF ENGINEERING

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

MASTER OF SCIENCE IN GEOGRAPHIC INFORMATION SYSTEMS

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Have read the M.Sc. Project for: **CECILIA KALEKYE MUSYOKA** Reg. No. **F56/34967/2019**

Entitled: **MONITORING DESERTIFICATION USING REMOTE SENSING FOR ENVIRONMENTAL MANAGEMENT: Case Study, Kitui County**

I confirm, on behalf of the Examiners of the project that all corrections/amendments recommended by the Examiners have to the best of my knowledge been effected.

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Declaration

I, (Cecilia Kalekye Musyoka, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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MONITORING DESERTIFICATION USING REMOTE SENSING FOR ENVIRONMENTAL MANAGEMENT; A CASE STUDY OF KITUI COUNTY

BY

CECILIA KALEKYE MUSYOKA

F56/34967/2019

A project report submitted to the Department of Geospatial and Space Technology in partial fulfillment of the requirements for the award of the degree of:

Master of Science in Geographic Information Systems

JULY, 2021

Declaration

I, (Cecilia Kalekye Musyoka, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

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Name of student Date

This project has been submitted for examination with our approval as university supervisor(s).

Prof. Faith. N. Karanja…………………………. 08.09.2021… …………………

Name of supervisor Date

Dedication

Dedicated to my little boys for all the time mum was away from you pursuing the course, to my late Mum who was the first person to take me to school. To my husband Raymond, thank you for always encouraging and pushing me.

Acknowledgement

This project could not have been complete without the input of various people who tirelessly went out of their time to ensure that the project and the reporting was done in the right time, my gratitude goes to God Almighty for the gift of life and good health that he accorded me during my study period. Many thanks to my family for the immense support and the ample time that you gave me during my study. To my supervisor Professor Faith N. Karanja for always creating time to supervise and review my work, may God bless you immensely. To my classmates for always being a good team and for embracing team work and group discussions this could not have been achieved without you. Finally, my employer for allowing me to pursue this degree, I will forever be grateful.

Abstract

Desertification is a major environmental hazard that the world is facing today and a major threat in the arid and semi-arid regions. The focus of this project was on monitoring desertification in Kitui County using remote sensing, specifically, Landsat Thematic Mapper (TM) satellite images acquired in 2000 and 2020 were employed. In addition, 2009 and 2019 population density data were used to determine whether there was a direct impact of population growth on desertification. To monitor desertification, various indices such as Normalized Vegetation Index (NDVI), Topsoil Grain Size Index (TGSI) and Albedo which are indices related to vegetation, soil texture and the earth surface reflectance respectively were derived from the satellite imagery. The indices were then reclassified into two classes namely 1 and 2. To map desertification, the various indices were then assessed as a combination of the various categories of either high or low TGSI, Low or high NDVI and high or low albedo high. A raster calculator which is a tool used mostly to create and execute a raster was used to obtain the three indices. In order to identify land degradation which can be identified by a reduction in vegetation cover (NDVI), soil texture (TSGI), which is an indicator of the coarsening of the soil texture is an indicator of land degradation/desertification and Albedo which is a measure of how much of the sun's energy is reflected back. Areas with high vegetation absorb a lot of the energy and reflect only a little energy. the indices derived were then subjected to a raster calculator to come up with three categories of desertification high, medium and low desertification.

From the results obtained the area under low desertification had reduced from 587,319,210 m^2 in 2000 to 93,053,880 m^2 in 2021, the high desertification area had increased from 1420251030 m^2 to 1,668,462,570 m^2 on the other hand the medium desertification had also increased from 1042467480 m^2 to 1,279,643,760m^2 this was a clear indication that the county is under the threat of desertification especially in areas like Kitui south, Kitui west, Mwingi North, some parts of Mwingi east like Nguni and Nuu, some areas in Mwingi west like Ngutani and Kyome thaana. Generally, the high desertification has been increasing even as the Low desertification areas decreases. An investigation in to the major factors causing desertification in the county indicated that human induced factors such as deforestation, poor farming practices, sand harvesting and charcoal burning are some of the major factors that contribute to desertification in the county

with charcoal burning and sand harvesting being the most prevalent factors. the study recommends the County to engage the residents in afforestation programs in order to increase the forest coverage particularly in areas like Kitui south, west, Mwingi North, mwingi east (mostly Nguni and Nuu) and in Mwingi west (Ngutani, Kyome and Thaana).

There's need for the county government to also conduct seminars and field extension studies on better farming practices in order to ensure soil conservation and increase food production.

The study recommends the county government to also revive cotton growing in the county to create an alternative source of income to the residents other than charcoal burning.

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ACRONYMS

ASAL	Arid and Semi-Arid Land
AFR 100	African Forest Landscape Restoration Initiative
ARLI	African Resilient Landscapes Initiative
AVHRR	Advanced Very High-Resolution Radiometer
CBD	Convention for Biological Diversity
DCTF	Desertification Community Trust Fund
ETM+	Enhanced Thematic Mapper Plus
FAO	Food and Agriculture Organization of the United Nations
FMNR	Farmer Managed Natural Regeneration
GIS	Geographic Information System
IEBC	Independent Electoral and Boundaries Commission
IFAD	International Fund for Agricultural Development
IUCN	International Union for Conservation of Nature
LST	Land Surface Temperature
LULC	Land Use Land Cover
NAP	National Action Programme
M&E	Monitoring & Evaluation

NDVI	Normalized Difference Vegetation index
NOAA	National Oceanic and Atmospheric Administration
NGO	Non-Governmental Organization
OECD	Organization for Economic Cooperation and Development
REDD+	Reduced Emissions from Deforestation and Forest Degradation
ROK	Republic of Kenya
SDGs	Sustainable Development Goals (SDGs)
SPOT	Satellite for observation of Earth
TGSI	Topsoil Grain Size Index
TM	Thematic Mapper
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNEP	UN Environment
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey

CHAPTER 1: INTRODUCTION

1.1Background

Desertification is a major environmental hazard that the world is facing today and is undoubtedly among the greatest global environmental challenges being experienced today with enormous adverse effects on human livelihood (Cowell, 1995). It is a grave ecological issue that is threatening biodiversity in arid and semi-arid areas. The context against desertification is critical during this era of climate crisis so as to ensure long-term output in the arid and semi-arid areas. The efforts to combat and control desertification are thwarted by the increasing anthropogenic activities as well as the climate change, with the minimum attention and commitment from the National and the county governments to halt the process. Despite the fact that deserts are natural occurrences, desertification is triggered by a blend of both natural and human causes. Majority of developing countries do not have enough economic resources to avert the drivers of desertification, or even to keep track of the procedures involved. It is important to understand desertification causes as well as the implications of desertification prior to monitoring desertification.(Dooley, 2002). Remote sensing is a powerful tool which is used in various disciplines of studies, it provides an efficacious tool for mapping analysis and decision-making. Many studies have been used to depict the application of remote sensing in various fields. (Singh et al., 2016) used remote sensing and GIS to map as well monitor land cover and land-use changes in the Northwestern coastal zone of Egypt. (Hostert et al., 2001) explored the probable of GIS and remote sensing for desertification minitoring and assessment. (Journal et al., n.d.) application of GIS and Remote Sensing in Agriculture.(Kingra et al., 2016) Application of remote sensing and GIS in agriculture and natural resource management under varying climatic conditions among others.

Various approaches have been adopted to map and monitor desertification such as vegetation cover, erosion levels, soil salinization limits among others, the main objective this study was to monitor desertification in Kitui County using Remote Sensing technique by derivation of the various indices namely NDVI (Normalized Difference Vegetation Index), TGSI (Topsoil Grain Index) and Aldedo. The study also aimed at identifying the areas in the county which were susceptible to desertification and also developing desertification maps showing spatial temporal changes for the two epochs.

A report by (Hambly,1996) indicates that the contest against desertification in Africa can be won succeed as a part of a more comprehensive and concerted fight on poverty and underdevelopment and food insecurity. The intensity of desertification is more in developing countries than other areas. Numerous countries encounter the challenge of desertification, and Kenya is not an excluded. In order for Kenya to be able to meet its development goals such as forest conservation and food provision, it is important to combat desertification at an early stage so as to intensify the overall yield in the arid and semi-arid areas. This has however not been easy due to the rise in anthropogenic activities with little devotion from equally the county and the national government. Kitui County is at the threat of desertification due to a number of reasons, it is one of the largest sources of sand to various counties; the continued harvesting of sand has led to many rivers drying up leading to increased water shortage in the county as show in figure 1.1. The use of firewood and charcoal has also contributed to desertification. Other uncontrolled activities like grazing and farming have also had an adverse effect in desertification.

Figure 1. 1 Residents queue for their turn to get water at a water point beside the Mathima earth dam in Kitui South. Source: the star.co.ke,2018

Kitui County is well known for charcoal burning, for decades, the county has been Kenya's charcoal production hotspot given the fact that charcoal burning has been the only source of income for a majority of poor families in the county who do not have any formal employment, as shown in figure 1.2 below. The county relies on wood fuel as the major source of fuel. Despite the ban imposed by the governor in 2018, charcoal burning and felling of trees has continued to take place under the watch of law enforcers. In a tour carried out by the capital FM news in the area, the residents claimed that they did not know the link between rainfall and a healthy or degraded environment and thus they have continually engaged in burning charcoal and bush clearing which is a big threat to the skimpy forest cover in the vast dry region.

Figure 1. 2 Charcoal business in the county, February 23.2018, Source: Capital FM.co.ke

The continued tree logging has had an adverse effect on the indigenous trees. The cutting down of trees for charcoal, craft work, agriculture among other activities resulted in deforestation and death of catchment areas which in return interfere with the volume of rainfall received in the area, this leads to climate change and environmental degradation which translate to low food production. The development of a country cannot be complete without focusing on the challenges of climate change. It is eminent that the County keep in mind that:

Charcoal burning is a source of livelihood for its residents and its consumption goes beyond the county. The ban imposed on charcoal burning in 2018 didn't stop the felling of trees and that the trade has been going on without check. There is a need to put in place a sustainable value chain in forest management and protection of indigenous forests.

1.2 Problem Statement

Kitui County falls in the arid and semi-arid (ASAL) land areas in Kenya. The county is characterized by frequent drought, rapidly increasing population, insufficient food production, and low tolerance to climate crisis. The effects of global warming together with the increasing population has led to increased poverty levels as well as environmental degradation. The Kitui County environmental action plan outlines population changes, ecological dilapidation and global warming as main growth challenges. Due to the increasing impacts of global warming, the county is facing the risk of desertification. The entire County's land is under threat of desertification caused by unsustainable resource use which arises from various activities which include overgrazing, deforestation, overutilization of groundwater resources, poor farming practices plus the excessive use of agrochemicals, and sand harvesting among other anthropogenic activities. These activities have resulted in soil degradation, changes in stream/river flow, increased soil erosion and loss of biodiversity. Soil degradation has led to a decline in soil fertility, this coupled with the insufficient rainfall received in the area has led to low food production leading to food and water insecurity in the county. As a result, Kitui County has occasionally been faced with frequent drought occasioned by the minimum amount of rainfall received in every rain season. A report in the Nairobi star Newspaper published in August 2019 termed the worst affected constituencies as Mwingi North, Mwingi Central, Kitui East, Kitui South, and Kitui rural. The effects of global warming coupled with the increase in population, mining, sand harvesting and other natural factors contribute to desertification.

According to a report published by UNEP on combating desertification in1991**,** there is no accurate data on the current worldwide status of desertification/land degradation. This research will employ remote sensing technology to analyze satellite imagery of the area between 1990, 2005 and 2021. This will be achieved through change detection. This is the process of examining the changes in the state or situations of an item or phenomenon by observing at various times (Singh, 1989). Currently there are no scientific studies which have been carried out on desertification in the county which is the reason for this study

1.3 Objectives

The primary objective of the study was to monitor desertification using remote sensing for environmental management in Kitui County.

The specific objectives were namely to:

1. Identify the major factors contributing to desertification in the county
2. Map the areas in the county that are most susceptible to desertification
3. Assess spatial-temporal changes of desertification in the county between 2000 and 2020

1.4 Justification for the Study

The research is significant since using remote sensing, it will be easy to identify the areas that are more vulnerable to desertification, and the research will also identify the major factors contributing to desertification in the county. The result can be used by policy makers and NGO to advise the county and national governments on the relevant measures to adopt in order to combat desertification and also improve environmental management in the county. The results and the recommendations of the research can be used in forest management and in enforcing various environmental laws.

The report can also be used by Kenya forestry Agency to help in afforestation. Although there have been other researches carried out on desertification in some areas in Kenya like Kajiado and Machakos county (Boitt and Odima 2017), no scientific research has been carried out about Kitui county and thus this Research is of significant importance to the County.

1.5 Scope of work

Kitui County falls in the arid and semi-arid (ASAL) land areas in Kenya. The region is characterized by frequent drought besides low amount of rainfall received. The Kitui County ecological action plan classifies population change, environmental dilapidation and global warming as crucial progress challenges. Together with the rising effects of climate crisis, the county is facing the risk of desertification. The entire County's land is under threat of desertification caused by unsustainable resource use which arises from various activities like such as overgrazing, deforestation, overutilization of groundwater resources, poor farming methods like the excessive use of agrochemicals, besides sand harvesting among other anthropogenic activities. These activities have resulted in soil degradation, changes in stream/river flow, increased soil destruction and loss of biodiversity. Soil degradation has led to decline in of soil fertility, this coupled with the low rainfall received in the area has led to low food production leading to food and water insecurity in the county. As a result, Kitui County has occasionally been faced with frequent drought occasioned by the minimum amount of rainfall received in every rain season.

1.6. Organization of the Report

The report is structured into five chapters. Chapter one contains background of the study which explains briefly about the area of study as well as the importance of the study. Next is the problem statement which gives the reader an insight on the problems and the gaps the study is solving. The chapter also defines both the overall and the specific objectives of the study, justification of the study which explains the significance of the study and its relevant benefit. Last but not least, the chapter also contains the scope of the study which explains the extend of the research as well as its boundary or limit.

Chapter two delves into relevant literature about desertification. Its outlines on the various categories of desertification, the major factors that lead to desertification in the county, impacts of desertification, indicators of desertification and the action plans required to mitigate desertification. The chapter also discusses the significance of GIS and remote sensing in monitoring desertification, and presents a conceptual framework on the dependant and the independent variables of desertification.

Chapter three discusses the area of study and the research instruments as well as the research methodology used to carry out the research.

Chapter four focuses on the results and analysis as well as the discussion on the results obtained from the research,

Last but not least, chapter three contains presents the conclusions and the recommendations drawn from the research.

CHAPTER 2: LITERATURE REVIEW

2.1 Desertification

The United Nations Convention to Combat Desertification (UNCCD) defined desertification as "land degradation in arid, semi-arid, and dry sub-humid areas resulting from many factors, including climatic variations and human activities" (Millennium Ecosystem Assessment 2005; UNCCD 1994; UNEP 1992). Desertification is a progressive process which overtime reduces the land cover leading to land degradation. Land degradation is simply defined as the loss or reduction in drylands' economic or biological productivity. Desertification occurs when land degradation persists beyond the threshold of recovery, that is, beyond the ability of dryland ecosystems to continue to provide vital ecosystem services. While drylands normally experience fluctuations in the supply of ecosystem services due to stressors such as prolonged dry seasons, desertification occurs when there is persistent reduction in their levels over a prolonged time period. This could be linked to the weakened resilience of dryland ecosystems due to irreversible damaging changes to the ecosystem which means that the supply of ecosystem services is not restored after the stressor is removed. The Princeton University Dictionary defines it as "the process of fertile land transforming into desert typically as a result of deforestation, drought or improper/inappropriate agriculture". Desert areas are habitually thinly populated due to the fact that limited human activities can thrive as a result of the harsh climatic conditions. This forces people to settle in the more productive regions which result to overpopulation hence mere problems.

2.2 Desertification Prevalence

Desertification occurs in all the drylands across the world and is more dominant in developing countries (Millennium Ecosystem Assessment 2005). It is estimated that between 10 to 20% of drylands are already degraded. Dryland ecosystems are susceptible to the process of desertification because of the harsh climate conditions and they experience significant water scarcity due to the erratic rainfall which restrict livelihood options such as intensive crop production, forage and wood production (Millennium Ecosystem Assessment 2005). Water scarcity also increases their susceptibility to the effects of climate variation like increased climate variability. Further, dryland ecosystems are already sensitive to processes such as soil degradation given the fragility of their soils which are susceptible to water and wind erosion and are prone to intensive mineral weathering (Food and Agriculture Organization of the United Nations (FAO) 2021; International Fund for Agricultural Development (IFAD), 2016). Dryland soils have low organic matter content hence low fertility (Food and Agriculture Organization of the United Nations (FAO) 2021). Moreover, drylands are also vulnerable to anthropogenic actions such as overgrazing, unmanageable agronomic practices and deforestation that cause degradation (IUCN 2017).

Despite their vulnerability, they are important ecosystems providing vital ecological services like climate change mitigation and adaptation; provision of water, fiber, forage and crops; and act as reservoirs for biodiversity. They also make significant contributions to national economies. For instance, dry lands provide 50% of the world's livestock (Krätli, 2015).

2.3 Categories of Desertification

According to (Dregne, 1986), desertification can be classified into four categories;

Light Desertification: This is where there is a slight damage in both the vegetation cover and the soil. The damage is minimal since biological capacity of the environment is not affected.

Moderate desertification: This is where the vegetation is damaged at a higher degree, it leads to small sand dune formation as well as soil salinization. Moderate desertification reduces production by 10-25 percent.

Severe Desertification: this type of desertification reduces production by 50%. There is also an increase in erosion leading to reduced vegetation cover. Weeds and shrubs spread threatening the desirable pasture.

Very severe desertification: This the gravest type of desertification, it is characterized by big sand dunes, many valleys and grooves, soil salinization leading to soil and land degradation.

2.4 Major Causes of Desertification

Desertification is triggered by various factors which vary from one area to another, and that often act in connection with each at variable degrees. According to Geist and Lambin (2004), desertification occurs as a result of four major causal agents:

- High aridity
- agronomic effects, including livestock production and crop farming
- cutting down of forests, and other commercial vegetation removal; and
- extension of infrastructure, this includes irrigation, road expansion, settlements, and growth and expansion of extractive industry (e.g. mining, oil and gas).

The research concluded that only a few case studies were due to a single cause. Only 5/% was caused by aridity, and another 5% was as a result of agricultural impacts. The other 30%was attributed to a blend of the two causes that is increased aridity and impacts of agriculture. Other case studies were a combination of either three or four proximal causal factors. The main objective of Geist and Lambin's (2004) research was to find out the general global patterns in causation of desertification. The study established some explicit agents as more or less significant in particular areas and specified that these agents originate from fundamental forces related with specific mixture of socio-economic (including technology) and biological factors associated with particular areas.

The expansion of infrastructure is also associated with desertification especially in areas like Asia, Africa, and Australia. Desertification is frequently associated with development of various infrastructure. For example, irrigation infrastructure, development of water reservoirs like dams, canals and borehole. For instance, in Africa and Asia establishment of irrigation infrastructure leads to growth of human settlements due to food security.

Ecological factors, related to decrease in rainfall are also major drivers of desertification. Other causes of desertification globally are as demonstrated in Figure 2.1

As shown in figure 2.1, desertification is caused by various factors which include increase in population, wood extraction(deforestation), climatic factors, poor farming practices and other factors like economic, technological, cultural and climatic factors which contribute to desertification in the world.

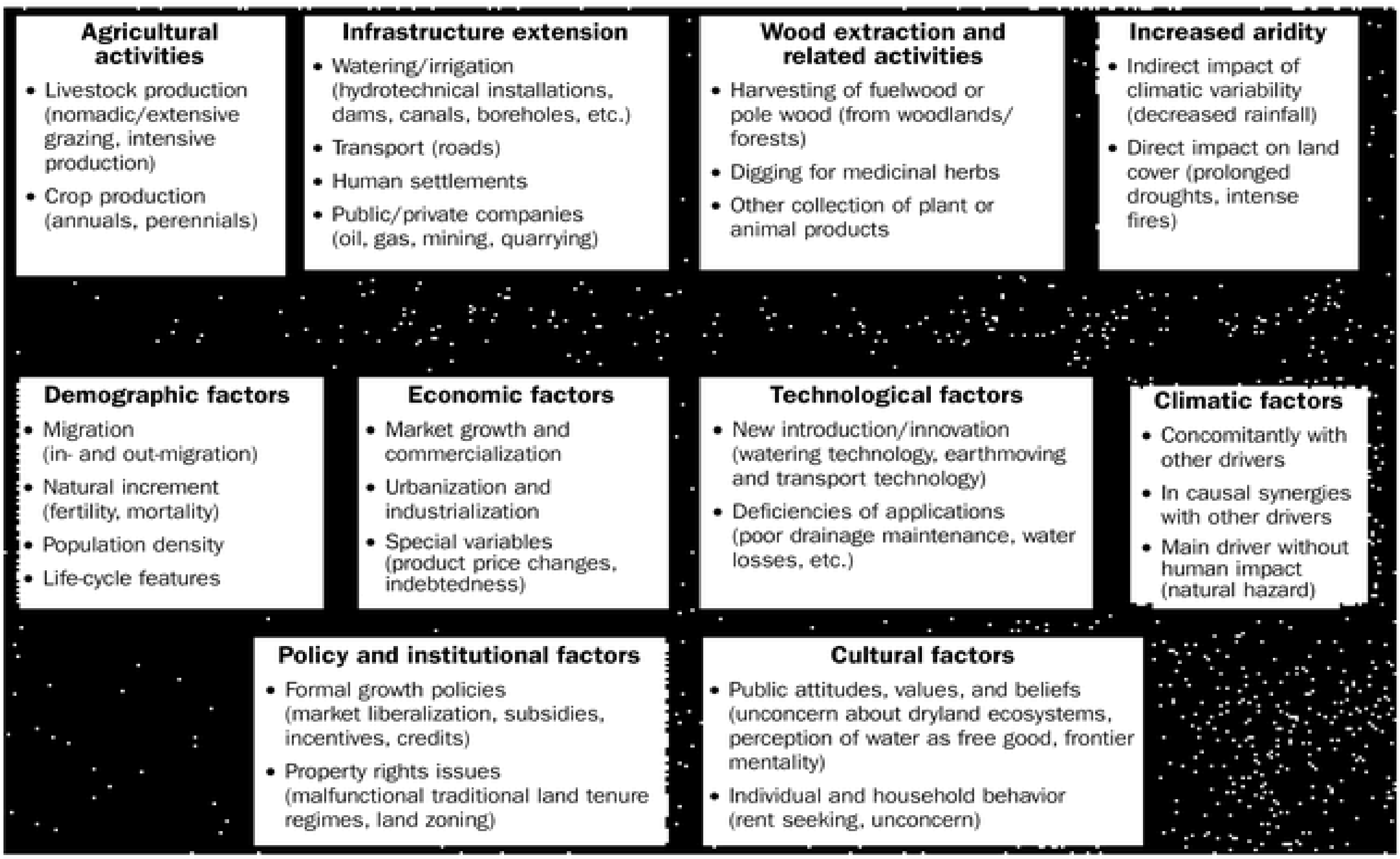

Figure 2. 1 Causes of desertification globally.

(Downloaded from https://academic.oup.com/bioscience/article/54/9/817/252974 by guest on 25 April 2021)

2.4.2 Desertification in Africa

(Prăvălie 2016) observed that 46 out of 54 countries in Africa are prone to desertification. According to a research by (Tolba, 1986), desertification in Africa is largely due to natural causes which are attributed to climate variability especially drought as well as human induced activities.

2.4.3 Major causes of desertification in Kenya

Generally, desertification is triggered by a mixture of various aspects that vary over time and differ by location, they include indirect causes like population burden, socioeconomic and policy factors, and global trade as well as direct influences such as land use patterns and practices and climate associated procedures. (Zafar Adeel ... et al.,2005) al large population in Kenya is socio-economically poor and totally depend on natural resources for survival. According to (Kamotho, 2002) desertification is escalating and expanding all over Kenya, risking loads of populations and drastically lowering land production capacity. The united Nations Environment Programme (UNEP) attributes this dilemma to a rising inequity between people, resources, progress and environment. Famine and population burden are regarded as main triggers of desertification in Kenya as per the National action Plan (NAP).

2.5 Causes of Desertification in Kitui county

Desertification in the county is triggered mainly by natural and human induced causes.

2.5.1Drought

The UNCCD define drought as a naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. Famine is one of the most predominant natural hazards in Kenya striking largely Eastern region in which Kitui county falls among other regions. The recurrent drought coupled with unmanageable land use practices have led to grave land dilapidation hence low yield. Recurrent drought have a lasting effect on the land since it accelerates soil erosion leading to land degradation hence desertification. The main attributes of drought include a relentless decrease of water content in the soil which causes parchedness that cannot hold vegetation thus leading to people walking for long miles in search of water or even depend on relief supplies(UNDP, 2007).

Factors contributing to the severity of drought

- Insufficient water retention capacity
- Clearing of forests for agriculture, charcoal burning, settlement, recurrent forest fires and cutting down of trees without replacing them.
- Encroachment of catchment area by clearing of forests and bushes as well as plants which inhibit soil erosion without proper conservation procedures.
- Farming on river banks and steep hills. This causes erosion of the topsoil, which results in siltation of dams which are usually, used as dry weather water reservoirs.
- Failure to come up with proper policies for managing water and drought
- Un uniform distribution of water resources

2.5.2Climate change

Global warming which occurs as a result of atmospheric accumulation of carbon dioxide and other gases released by fossil fuel also contribute to desertification. Any rise in global temperatures accelerates the process of desertification as evaporation rates increase. Climate crisis has an unfavorable consequence on biodiversity and may aggravate desertification as a result of increase in evapo-transpiration which causes a decrease in rainfall in arid and semi-arid areas like Kitui county leading to desertification. Climate change plays a vast role in desertification. Rises in temperature leads to an increase in drought periods which leads to desertification. If climate change is not slowed down, large areas of the county will become desert.

According to UNCCD chapter 3, Desertification and climate change, together or separately resolve to a reduced supply of rangeland ecology services and reduce biodiversity well-being, together with losses in habitat. Desertification and varying weather are also expected to lead to a decrease in harvest and animal production.

Temperature change is likely to hasten soil organic carbon (SOC) turnover, owing to the fact that the putrefaction of the soil organic matter by bacterial commences with little soil water availability, while the moisture is inadequate for plant production (Austin et al., 2004) due to erosion (Lal, 2009). This leads to a decline in soil organic carbon in the drylands thus transferring the carbon to the atmosphere (LAL, 2009).

2.5.3Population Pressure

The growing population has played a vital role in land dilapidation, for instance county's population has risen from 819,250 in 1999 to 1,136,187in 2019 as per the Kenya population census statistics, this has piled a lot of pressure on the arable land with an overflow into the bordering areas, forests and steep slopes. The increase has caused a lot of pressure on the ecosystem which has led land degradation as a consequence of various human activities like deforestation, poor land use systems, mining, charcoal burning, overgrazing among other factors which have greatly contributed to desertification in Kenya. The population increase also comes with an increase demand for food which culminates to extension of cultivated land. This leads to a reduction of the marginal land which becomes hard to practice shift cultivation resulting in low productivity and land degradation.

2.5.4 Human induced causes

These are the major triggers of desertification in the county (Kambua, 2014), they include;

a) Charcoal burning

Charcoal continues to be a vital source of energy for many Kenyans with an increased demand attributed to the increase in urbanization. The major economic activity in Kitui county is subsistence farming whereby the crop production is limited by unreliable rainfall, infertile soils coupled with poor farming practices resulting to crop failure. With the recurrent drought, the community has been forced to turn to charcoal burning as an alternative source of income to supplement their food source. Charcoal burning is a common business in the county and it is major lifelines for many residents who are vulnerable due to food insecurity during drought season. A report published by Kenya News Agency (KNA) in August 2020, indicated that despite the charcoal ban that was imposed by the governor in 2018, the illegal charcoal burning and selling is still thriving. Charcoal burning in the county is mainly unselective, this according to Kitui County Ecosystem Conservator Joyce Nthuku, mainly because the loggers prefer indigenous trees that take decades to mature with little efforts made to replenish the environment after the wanton destruction. The closeness of Kitui County to Nairobi and Thika, has made it a preferred source of charcoal by transporters. In the recent years, the demand and consumption for charcoal has greatly increased due to rapid population increase, urbanization and the escalating cost of alternative fuels. The unmanageable charcoal production has led to serious land degradation which if not controlled will render the county into a desert. Given that a large number of the residents in the county are unemployed and with low income, charcoal burning is a major source of livelihood to a bigger percentage in the county which makes charcoal burning to be a major cause of desertification in the county.

b) Sand harvesting

Kitui county has witnessed decades of uncontrolled and illegal sand mining in riverbeds. The National Environment Management Authority (NEMA) has issued a warning against illegal sand harvesting in rivers across Kitui County citing extensive environmental degradation and depletion of water resources. According to Wambua (2015), the rapid state of urban expansion in the nearby towns and counties surrounding Kitui county such as Thika, Garissa, and Nairobi among others derive sand for construction from rivers in Kitui county which has worsened the rate of sand mining. The sand mining takes place in an unregulated manner across all the rivers in the county. The research done by Wambua on the environmental and social impact of sand harvesting in the county in river Kivou catchment, Mwingi sub-county confirms that most rivers are on the verge of drying up with river banks destroyed and water points drained. The effects of sand harvesting include loss of vegetation and top soil as well as drying of underground acquirers.

This has worsened water scarcity in the county which falls in the arid and semi-arid areas forcing multitudes to trek for tens of kilometers in search of the precious commodity. The uncontrolled illegal sand harvesting has degraded several riverbeds as reported in the Ministry of Environment and forestry publication on Friday May 21, 2021. Sand mining in Kitui county is rampant, unregulated, uncontrolled and is being carried out at a disturbing rate. This has highly contributed to dryness in the county since sand harvesting causes soil erosion which begets land degradation and damage of catchment areas. According to Mutisya (2006), rapid growing populace in Kenya's town areas have greatly promted to the ever-increasing clamor for sand in order to satisfy the overwhelming demands of the building and construction business. This has forced the sand harvester to raid the periodic rivers in the arid and semi-arid areas like Kitui mainly due to its proximity to the big cities, in search of the vital commodity. This has resulted to unsustainable harvesting of sand beyond replenishment levels. The paper reveals that sand harvesting has had some severe environmental which comprise drying of aquifers, riverbank, riverbed erosion, reduced water table and loss of valuable trees which could lead to desertification. According to Makanya (2008), sand harvesting has severe effects on the environment which lead to destruction of topography of a region rendering the area river banks bare, this has been witnessed across the county and could be attributed to one of the main causes of desertification in the county.

c) Deforestation

Deforestation is one of the key determinants of land dilapidation which leads to reduction in vegetation and forest cover. A report published by NEMA in 2001 indicated that deforestation reduces the water catchment potential which aids landslip and siltation. Deforestation is the prime mover land degradation which in return leads to desertification.

In Kitui, forest cover is decreasing rapidly due to various anthropogenic activities which include clearing of forests to pave way for settlements, cultivation, timber for both commercial and domestic use and wood fuel. The Kitui county forest cover stands at paltry 7% which is below the national target of 10%. According to the Kenya Forest Service. The rate of deforestation is increasing as forests are being cleared for fuel, building materials, to pave way for settlement and farming land among other activities. Majority of the County's residents rely on wood fuel as their sole source of energy for cooking. Most people in both in the urban and rural areas rely on both charcoal and firewood which mainly come from indigenous trees. According to Mallo 2009, fuelwood cutting and gathering is the major cause for land dilapidation and desertification in third world country, as published in the Kitui online website, Nuu forest is facing the risk of desertification due to deforestation to pave way for farming settlement and charcoal burning.

d) Overgrazing

Overgrazing is a main trigger of desertification globally. Kitui county has been suffering particularly from overgrazing of pasture land, which is a major cause of human-driven desertification. Majority of the resident graze in the open with pastoralists invasion from the neighboring Garissa and Wajir counties who majorly depend on animals for their living. On the other hand, the insufficient and unreliable rainfall received in most arid areas results in low grassland productivity. The increase in livestock population exerts a lot of pressure on the pasture leading to land degradation as a result of trampling which increase crusting of soil, reduce soil infiltration exposing the soil to erosion. Overgrazing lowers the productivity of range lands leading to desertification.

e) Unsustainable land management practices

Unstainable farming practices like cultivation on steep slopes, improper irrigation management, over cultivation without allowing the land to go fallow and unbalanced fertilizer use among other practices have devastating impacts on the land resource**.** Over cultivation in arid and semi-arid areas leading to exhaustion of soil nutrients which causes a decrease in agriculture. Farming also exposes the top soil to agents of erosion which lead to land degradation eventually leading to desertification.

f) Forest fire/Wildfire

Forest fires have a direct impact on the vegetation, the fauna and the soil. Burned ecosystems lack plant cover over a period of time which exposes the topsoil to agents of erosion leading to land degradation. Forest fire is a trigger of desertification, since it lowers plant cover and rises over-spill and soil run-off, reduces soil fertility and interferes with the soil microbial community, Vega et al., 2005

harsh forest fires generate disruption in the diverse organic biodiversity that drive them to lose various components which degrade and lower the ecosystem state. This causes them to lose their original state rather than recovering it. Instead, the ecosystem declines to a new but disturbed state whereby it takes centuries to recover to its original state (Yackinous 2015). High temperature coupled with severe drought across some dry areas are prone to wildfire occurrence.

Recurring fires trigger the initial process of desertification and could even prolong its recovery. According to Geist and Lambin2004, it is eminent that new acute fires are scorching into older fire scars and exacerbating desertification by hastening plant type conversion, species diversity loss, and erosion while other ecological impacts amplify the severity of desertification. Forest fires lead to destruction of vegetation, loss of various plant species, invasion of exotic plants, destruction of animal habitat, increased soil erosion, floods, watershed function decline, water supply disturbance, and air pollution. Cumulative and recurring wildfires over a large area could lead to desertification. In the last two decades, wildfire has presumed a vital part in desertification (Neary et al. 2005). Mega-fires are wildfires that are remarkably big and complex and hard to control. (Williams and Hamilton 2005; Heyck-Williams et al. 2017).

g) Urbanization and other types of land development.

Urbanization and land development causes people to cut and destroy plant life. This interfere with soil structure which causes land degradation. With the growth and expansion of Kitui county, more and more land is being cleared to pave way for towns and centers causing desertification. Urban encroachment is an irreversible desertification process (Shalaby et al. 2004) The expansion of subcounty centers as a result of economic growth and the increasing population is gradually pushing the agricultural and the forest land into an ecologically fragile land leading to desertification. The continually rising population comes with a high call for environmental resources as well as a growing demand for food and water supply which may have detrimental impacts on the land and the environment in general.

h) Waterlogging and salinity

In dry areas like Kitui county, irrigation has been one of the major methods that has been adopted to counter the severe consequences of frequent droughts through irrigation though at small scale along the major rivers, the county has been able ensure a continuous supply of food for its rising population. in spite of the temporary gains gauged by an increase in crop yields, irrigation-founded farming has been filled with instability. Kassas (1987) labeled irrigation of drylands “one of the seven paths to desertification”. According to Hillel (1982), poor management of irrigation schemes leads to their self-destruction. all too often make them self-destructive.

The problems related with irrigation are as a result of the wasteful and the ineffective utilization of the irrigation water before or after reaching the farm for its application to the field. The passage of irrigation water through poorly seamed canals leads to leakage which results in the rising of the water table.

the unrelenting oozing of water over time from unlined canals and huge network of distributors and irrigation excess water from the field have contributed to a rise in the water table leading to water-logged conditions. Poor water management lead to salinization, which lead to degeneration of irrigated lands, (Anjum et al. 2010). High evapotranspiration coupled with low rainfall cause inadequate leaching leading to accumulation of salts in the roots.

Salinization is the development of salt affected soil. Salinization causes soil dilapidation which leads to desertification. Salt pileup in the soil leads to inability of soil to partially or completely supply the essential amount of water to plants, this could end up altering productive lands to "deserts". In most cases, the salinization process creates an irretrievable soil chemical, and physical degradation. Universally, a big percentage of land is affected by some type or level of salinization, with 350 million ha already completely "decertified". Even though the salt impacted soils may be found in almost any climate, they are more regular in arid and semi-arid climates, and in flat and low lands. It is believed that about 25 million ha of lands have been salinized through man interference since the advancement of irrigated cultivation many years ago (Szaboles, 1989; WRI-IIED-UNEP, 1988).

i) Mining

Mining is another factor leading to desertification in Kitui county, large amounts of coal are being extracted in order to meet the industrial demand, this has resulted to large areas being excavated which causes pollution as well as desertification. By the time the coal mining will be over, the mining area as well as the soil will have been damaged significantly, the land will irrecoverable leading to desertification.

2.6 Impacts of Desertification

The impacts of desertification include:

2. 6.1 Reduced Human Well-Being:

According to (Krätli 2015), an estimated 2.5 billion people (close to a third of the world’s inhabitants and 40% of Africans) live in drylands Furthermore, 72% of drylands are found in developing countries (Krätli, 2015). Desertification disproportionately adversely affects the well-being and livelihoods of dryland populations especially in developing countries. Several reasons are responsible for this (Krätli 2015 and Millennium Ecosystem Assessment 2005):

Half of the dryland population live in poverty and all populations greatly depend on dryland ecosystems and their services for their livelihoods and sustenance which are fragile thus vulnerable to various kinds of stressors. These populations are already lagging far behind compared to the rest of the world with respect to human well-being and advancement pointers for example per capita income and infant death rate. A good example is the per capita income of Organization for Economic Co-operation and Development (OECD) countries is almost 10 times larger than developing countries' drylands while infant mortality rate is 10 times higher than the usual rate in individual industrialized countries. This situation is worse in Asian and African drylands. Drylands are often marginalized and under-developed thus their population are unable to participate in making policies that impact their well-being.

2.6.2 Environmental and Health Impacts

The impacts of desertification extend beyond the borders or drylands. Vegetation loss in drylands, for example, can result in dust clouds which contribute to respiratory health problems in other heavily populated areas which are numerous kilometers away from them. Desertification, global climate change and biodiversity loss are linked. For instance, desertification leads to biodiversity loss which affects the ability of dryland ecosystems to offer crucial ecosystem benefits such as soil conservation, water and local environment regulation. The impacts of climate change like high temperatures resulting from global warming increase soil water loss (through evaporation) and reduced rainfall decrease plant and forage production. At the same time, some dryland species growth is boosted by the increased carbon dioxide. As such, there is a need for the joint implementation of policies and strategies to deal with issues which include climate change, biodiversity conservation and desertification such as the United Nations Convention to Combat Desertification (UNCCD), Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC).

2.6.3 Social Political Impacts

One of the coping mechanisms of dryland populations desertification is migration. Migration from drylands to town centers or even other nations can have adverse effects on the political and economic stability of these areas.

2.7 Indicators of desertification

There are various specific, observable and measurable characteristics that can be used to show changes or progress of desertification. The indicators of desertification include (Asfaw et al.2016; Millennium Ecosystem Assessment 2005; Sharma 1998).

- Soil degradation indicated by excessive soil loss or erosion, decline in soil fertility and loss of water retention capacity of the soil. Vegetation composition changes or shifts coupled with reduction in vegetation cover e.g. grassland to scrubland.

- Regional climate system change.

- Reduced supply of all categories of ecosystem services provided by drylands.

- Reduced land productivity indicated by reduced crop and forage productivity.

- Biodiversity and habitat loss.

- Hydrological indicators which include: reduced surface areas of water bodies, increased rates of surface runoff thus reduced rainwater infiltration rates, diminishing/deteriorating groundwater resources, reduced or deteriorated water quality and quantity through soil erosion and sedimentation

2.8 Action plans/Mitigation

It's important to note that the prevention of desertification is more cost effective and easier than the rehabilitation of degraded lands (Millennium Ecosystem Assessment 2005). Some mechanisms for preventing desertification include:

a) Implementing management and policy approaches at regional and global levels that promote the tenable use of land and other innate resources.

b) Cultivating a culture of prevention promoting conservation strategies and alternative livelihoods. Such a culture requires a shift in the attitudes of people and governments.

c) Leveraging on the long-term experience and innovation of the dryland population to improve grazing and crop cultivation in a sustainable manner.

The restoration and rehabilitation of degraded land is also another approach once land is degraded. However, the attainment such initiatives depends on the availability of resources (human, financial and infrastructure), policies and technologies that promote and support them. Examples of approaches to restore and rehabilitate degraded lands include: reforestation, farmer managed natural regeneration (FMNR), managed grazing and contour trenching.

According to the Millennium Ecosystem Assessment (2005), several knowledge and data gaps have been identified which are instrumental in understanding desertification that are hindering mechanisms to prevent and combat it. These include:

- Scientific, tough and reliable baseline information on the degree of land degradation and desertification. This data will aid in the determination of priorities and long-term monitoring the impact of actions. Such data and information can be collected using, for example, the use of integrated remote sensing or aerial photography and ground-based observations to monitor trends in vegetation cover changes. The ground-based observations will include assessments or observation of rates of soil fertility, soil compaction rate and soil erosion rates, vegetation cover, biological productivity and evapotranspiration. Long lasting monitoring is also essential to differentiate between the role of climate variability and human activities such as overgrazing on the productivity of vegetation. There is also a need for more knowledge on the interactions between socio-economic factors and changing environmental or ecosystem circumstances to appreciate the effects of desertification on human well-being. Thus, monitoring, baseline development and assessment are required.

- Reducing uncertainties in the understanding of desertification requires the exploration of the impact of strategies for poverty decrease policies on ecosystem services and desertification. This is because the linkage between poverty and ecosystems is usually ignored in poverty related policies. There is therefore a need to ensure the role of ecosystems services in poverty alleviation is mainstreamed into poverty alleviation programs. Moreover, understanding the role of dryland urban areas in desertification is important. Finally, noticing limits beyond which dryland systems attain grave or irrevocable changes is instrumental in reducing uncertainties.

In recent decades, desertification has been recognized as a major risk to sustainable development and human well being given its contribution to poverty, food, water and energy insecurity, increased climate vulnerability and even peace and stability particularly in developing countries (Besseau et al. 2018; Djenontin et al. 2018).

Consequently, several conventions and multilateral agreements have been put in place to deal with the issue of desertification at all levels - international, national, subnational- that countries have committed to. This includes several sectoral approaches. For example, desertification is accepted as a major risk to the environment thus several nations have established Biodiversity Action Plans as stipulated under the Convention for Biological Diversity (CBD) to combat its effects, mostly regarding to safeguarding of the vulnerable flora and fauna.

internationally, a number of agreements and conventions that champion landscape restoration for multiple benefits for instance climate crisis mitigation and adaptation, biodiversity conservation exist including the United Nations Convention to Combat Desertification (UNCCD), United Nations Framework Convention on Climate Change (UNFCCC), Bonn Challenge, Reducing Emissions from Deforestation and Forest Degradation (REDD+) and the 2015 Paris Climate Agreement. The declaration of the UN Decade on Ecosystem Restoration 2021 -2030 is yet another boost to landscape restoration.

At a continental level, there are initiatives like the African Forest Landscapes Restoration Initiative (AFR 100) and Latin America's Initiative 20 x 20. In Africa, for example, around 30 African countries have vowed to recover 100 million of hectares degraded lands under the AFR 100 by 2030. For example, Kenya has dedicated to recover 5.1 million hectares of its degraded lands by 2030. AFR 100 will help African countries achieve other commitments such as the African Union Agenda 2063, the African Resilient Landscapes Initiative (ARLI) along with several Sustainable Development Goals (SDGs).

Kenya developed a National Action Programme (NAP) as a guide for fighting desertification as stipulated under the United Nations Convention to Combat Desertification (UNCCD). The UNCCD is a global mechanism to address desertification through concerted efforts as well as synergies among the nations of the world. It came about due to the recognition that desertification is a universal matter that cannot be undertaken effectively by a single state.

Kenya signed the UNCCD in 1994 and ratified it in 1997. The NAP is a mechanism for guiding the implementation of the convention at national level. Kenya's NAP aims to address the constraints identified in past actions to fight desertification which date back to the 1930s.

According to the NAP, the constraints to the success of past actions to combating desertification in Kenya include (ROK 2002):

- Inadequate policy and regulatory frameworks.

- Sectoral approaches to programs or a lack of cross sectoral approaches to program implementation.

- Inadequate participation or participation of local citizenry in decision making and programming.

- Insufficient and uncoordinated funding.

- unplanned and regular shifts of the mandate of dryland management and development across government institutions

- insufficient capacity for the execution, monitoring and evaluation of programs and projects aimed at preventing and addressing desertification.

- Limited access to production resources by communities.

The NAP was formulated through a consultative bottom-up approach and stipulates priority actions for implementing the UNCCD. These priority actions are grouped into three major clusters that are described further below:

- The 1st cluster comprises mechanisms, that is, activities and measures to create an environment that allow combating desertification. These include:

- Setting up sufficient and powerful policies, lawful and formal structures to enable the effective participation of all stakeholders (including local communities) in projects and programs aimed at combating desertification. This includes environmentally valid land use plans or zoning policies which include land and resource tenure policies.

- Providing adequate information on desertification, that is, its causes, its processes and measures to control it. This includes furthering or advancing the existing knowledge in this area.

- Implementing continuous actor-specific awareness raising programs on desertification and the National Action Programme (NAP) to facilitate a common understanding of the NAP and cooperation.

- Setting up strategies to promote and support community initiatives through a) financial support b) education and awareness creation on desertification and the role of communities in the management of natural resources and projects.

- Setting up sustained financing mechanisms to support projects and programs.

- proper training for all relevant institutions and stakeholders.

The 2nd group of actions and measures are basically sectoral priority areas for investments or in which investments could be made for appropriate management of natural resources and restoration of degraded lands. These activities are inclusive of innovative ways of alternative livelihood systems creation particularly for the growing population. These sectoral priority areas are: a) plant cover and animals, b) forest conservation, c) energy, d) soil management, e) agriculture and pastoralism and f) water resources management.

The third group is composed of cross sectoral measures and activities to support sectoral investment programs as well as those aimed at creating an enabling environment. These measures are:

- Gender mainstreaming into all programs and projects related to desertification.

- Poverty and environment.

- Early warning systems.

- Science and Technology.

The status, key issues and priority actions are stipulated for each of these key priority areas. The NAP also outlines the implementation strategy for these actions, financing mechanisms for all the priority areas (such as the Desertification Community Trust Fund (DCTF)) and monitoring and evaluation (M&E) using an Environmental Information System.

2.8.1 Role of GIS and Remote Sensing in monitoring desertification

Remote sensing has demonstrated that it is an efficient tool for detecting desertification as well as detecting changes in natural vegetation, land use, and soil. Multi-temporal coverage provided by satellite data enables the application of remote sensing images to detect changes in land coverage and usage over a period of time. Remote sensing and GIS data are vital for extracting useful information which is vital for evaluating ecological variations and land quality in a given area. Several methods in remote sensing coupled with analytical procedures such as NDVI and classification offer key data that is used to evaluate desertification processes. Numerous key pointers of the processes of desertification are determined whereby remote sensing can be used to detect, monitor, and map affected areas. Researchers uses various indicators to detect and monitor desertification such as land use, changing vegetation, soil, erosion, drought and urbanization. The results obtained conducted using this technique are applied in both environmental, political and social decisions (Albalawi and Kumar, 2013). Boitt and Odima (2007) pointed out that Remote Sensing has demonstrated to be an efficient tool which has been used globally for ecological studies. Accessibility of free and open satellite data from websites such as Landsat has made it efficient and cheap to conduct such studies. It is therefore important to carry out a research on desertification using the free and open cheap remote sensing data which is current and efficient and also covers a large area. There are various studies which have been carried out to monitor the process of desertification as well as detect land degradation by application of remote sensing techniques.

Hadeel *et.al* (2010) research utilized remote sensing and geographic information systems (GIS) to evaluate the ecologically sensitive area to desertification in the southern part of Iraq (Basrah Province). The thematic layers used were vegetation, soil, climate, and degree of sand movement which were the key data essential for approximating the desertification sensitivity index. The layers were obtained from the existing topographic map data, geologic map, satellite images (TM in 1990 and ETM+ in 2003), and field survey data analyses. The data was analyzed using the Spatial analyst tool in ArcGIS software and also to match the thematic layers and assess desertification index. The results obtained revealed an increment in the area of active sand movement 4,118.3 to 4,558.1 km^2, it also indicated that the areas most sensitive for sandy desertification were situated in the western–southern parts of Basrah Province, which represented 61.9% of the area. The other part of the southern area of the study site exhibited moderate sensitive areas for desertification, which represented 18.9% of the total area. On the other hand, the northern parts of the study site were categorized by a very low and low sensitivity for desertification, which was represented by 8.5% and 10.7% of the total area, correspondingly. The study suggested that there it was necessary to establish a specialized arid environment center, which could be harmonized with government sectors and various universities in the southern part of Iraq to solve numerous ecological problems.

Arnous et. al (2009) worked on application of Remote Sensing Technology in mapping desertification: A Case Study, Oudia Area, Tunisia. Their specific objective was to evaluate the disparity of the decertified land and the marshlands so as to assess the climatic and anthropogenic influences on desertification. The research approaches applied were digital image processing of high-resolution satellite data as well as field verification. The results obtained indicated that the wetlands were bigger in Oudia area. It also showed that the disparity of the extension of mobile dunes was in inverse proportion to that of wetlands. The main process of desertification was the reactivation of dormant sand dunes. The variations in marshlands and decertified lands interrelated significantly well with the changes in local rainfall as well as temperature, indicating that climate might have been the main aspect triggering desertification in the Oudia area. The other sandy parts of Oudia area, however, indicated that anthropogenic activities could have been the major factor that contributed to desertification and land degradation. The advancement of remote sensing technology enabled the analysis and the interaction of various elements of the environment in relation with the dynamics of soil and the anthropogenic activity. The study attempted the application of high-resolution Quick Bird imagery to map desertification in Oudia. The procedure adopted was the simultaneous approach of geomorphological and digital analysis of high-resolution satellite data for defining and mapping the desertification landscape. For an accurate and precise identification of the desertification sensitivity, visual interpretation coupled with supervised classification with the use of training sites. The results showed that Oudia was under the risk of encroachment by the sand dunes besides a substantial wind activity. The study concluded by strongly recommending the application of the modern techniques of remote sensing in mapping and assessment of desertification.

Shalaby *et. al (*2004) studied the assessment and impacts of desertification in Egypt using Remote sensing and GIS. the study analyzed desertification processes and their impacts on land cover changes between the year 1992 to 2000 using low resolution satellite data. The study employed the use of two satellite imagery that is NOAA-AVHRR and SPOT vegetation which were acquired in November 1992 and 2000 respectively to assess desertification and changes of agricultural lands. Using the technique of maximum likelihood, a supervised classification was carried out whereby Change image was obtained by use of classified images. The module of cross-tabulation Geographic Information Systems (GIS) was employed to assess the trend and form of land cover changes. The study established that farm land rose by 14.3% during the study period, especially, around the Nile River Delta and near the Northern Lakes of Egypt. The study excluded the newly cultivated lands from the desert as well as the salt marshes, some of the agricultural lands were also turned into degraded areas as a result of urban expansion and desertification.

Boitt and Odima (2007) Assessed Desertification Dynamics in Machakos County, Kenya. The study adopted the use of various parameters such as DVI (Normalized Difference Vegetation Index, TGSI (Topsoil Grain Size Index) and Albedo. The study focused on assessing desertification dynamics in Machakos County between 1990 and 2010. The study concluded that desertification can be mapped through the application of NDVI, TGSI and Albedo.

2.9 Conceptual framework

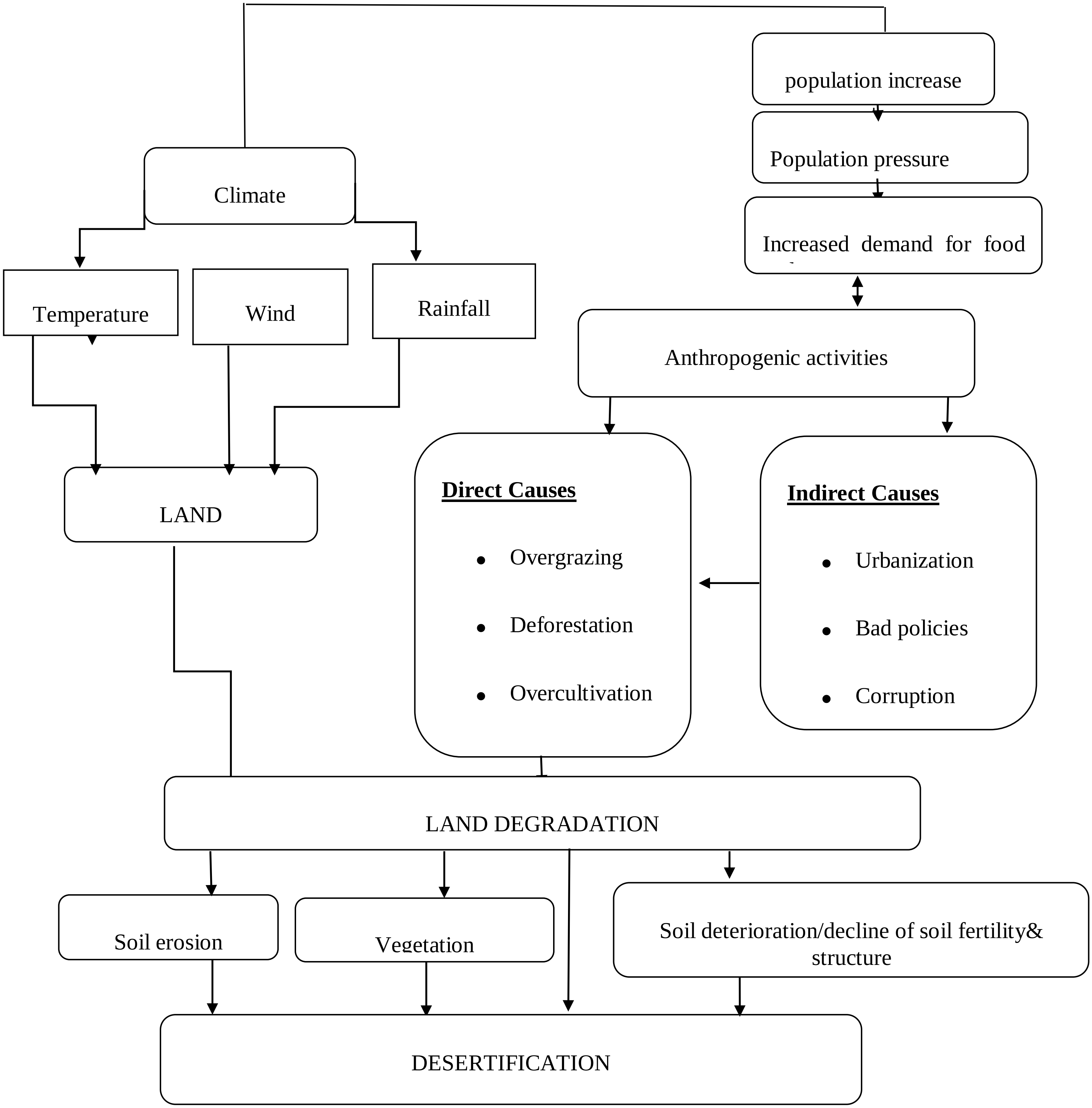

Figure 2. 2 Conceptual model

The desertification framework model (figure 2.3) illustrates the linkage between desertification and various causes both natural and human based. This was developed from the literature review on the major causes of desertification with desertification being the dependent variable and the causes of desertification being the independent variables.

Population increase exerts pressure on the land due to the increased demand for both food and energy. Man is a major trigger to desertification through various anthropogenic activities which are direct or indirect causes, these various causes coupled with the natural factors like wind, temperature and rainfall lead to land degradation. The land degradation could be soil erosion (removal of the top soil by agents of erosion) which causes a decline in soil fertility and vegetation degradation or loss which leaves the land bare leading to desertification.

CHAPTER 3: MATERIALS AND METHODS

3.1 Introduction

This chapter gives the details of the study area, datasets used and their sources. It also elaborates how the data was cleaned, processed before the analysis was carried out.

3.2 Study Area

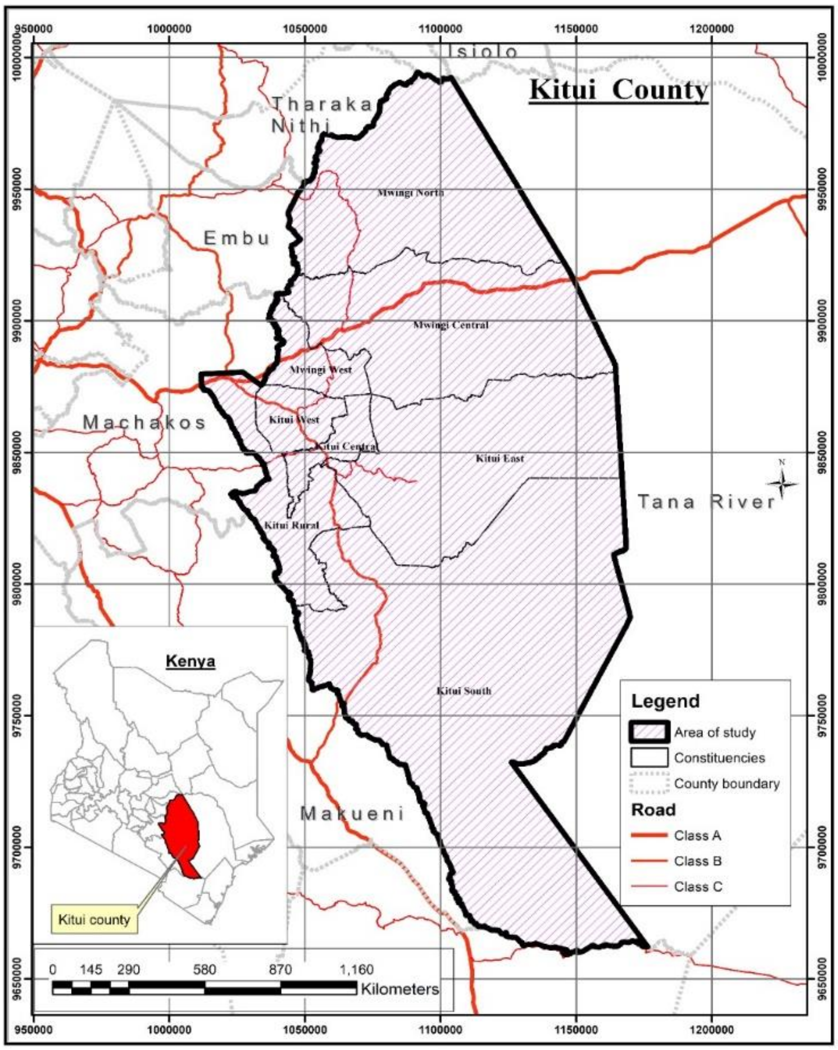

Figure 3. 1 study area

The research focused on Kitui County which is one of the 47 counties in Kenya. Kitui is the sixth biggest county in Kenya. It covers an area of around 30,496.4 KM^2. The county borders seven other counties, namely, Makueni, Tana River, Taita Taveta, Embu, Tharaka Nithi and Meru Taita Taveta County to the south, Embu to the north-west, and Tharaka-Nithi and Meru counties as shown in figure 3.1. Kitui county is situated between latitudes 0°10 South and 3°0 South and longitudes 37°50 East and 39°0 East. The county has eight sub counties lies and in the arid and semi-arid regions. Forty-six percent of the Tsavo East National Park lies in Kitui County. The county has a huge heritage with numerous unexploited tourism potential. Proximity of the county to Nairobi as well as Standard Gauge Railway provides countless openings for economic growth and transformation. Two Permanent rivers, namely, Tana and Athi flow through the County.

The county generally has a flat landscape which gently rolls down towards the east and northeast with altitudes are as low as 400 meters. The altitude of the Kitui County ranges between 400m and 1800m above sea level. The Yatta Plateau is found in the western part of the County and stretches from the north to the southern part of the County between Rivers Athi and Tiva. The County has 7 agro-ecological zones which include Upper-Midland 3-4; Upper-Midland 4; Lower-Midland 3; Lower-Midland 4; Lower-Midland 5; Inner Lowland 5; and Inner Lowland 6

Population

Kitui had a population of 819,250 in 1999 which rapidly increased to 1,136,187in 2019 with a population density of 37.34/km^2 according to Kenya bureau of statistics. Majority of the population live in the rural areas with a small people living in the urban areas according to a report by county integrated plan 2018/2022.(Dynamics & In, n.d.).

3.3 Research methodology

The methodology adopted for the project was as shown in figure 3.2.

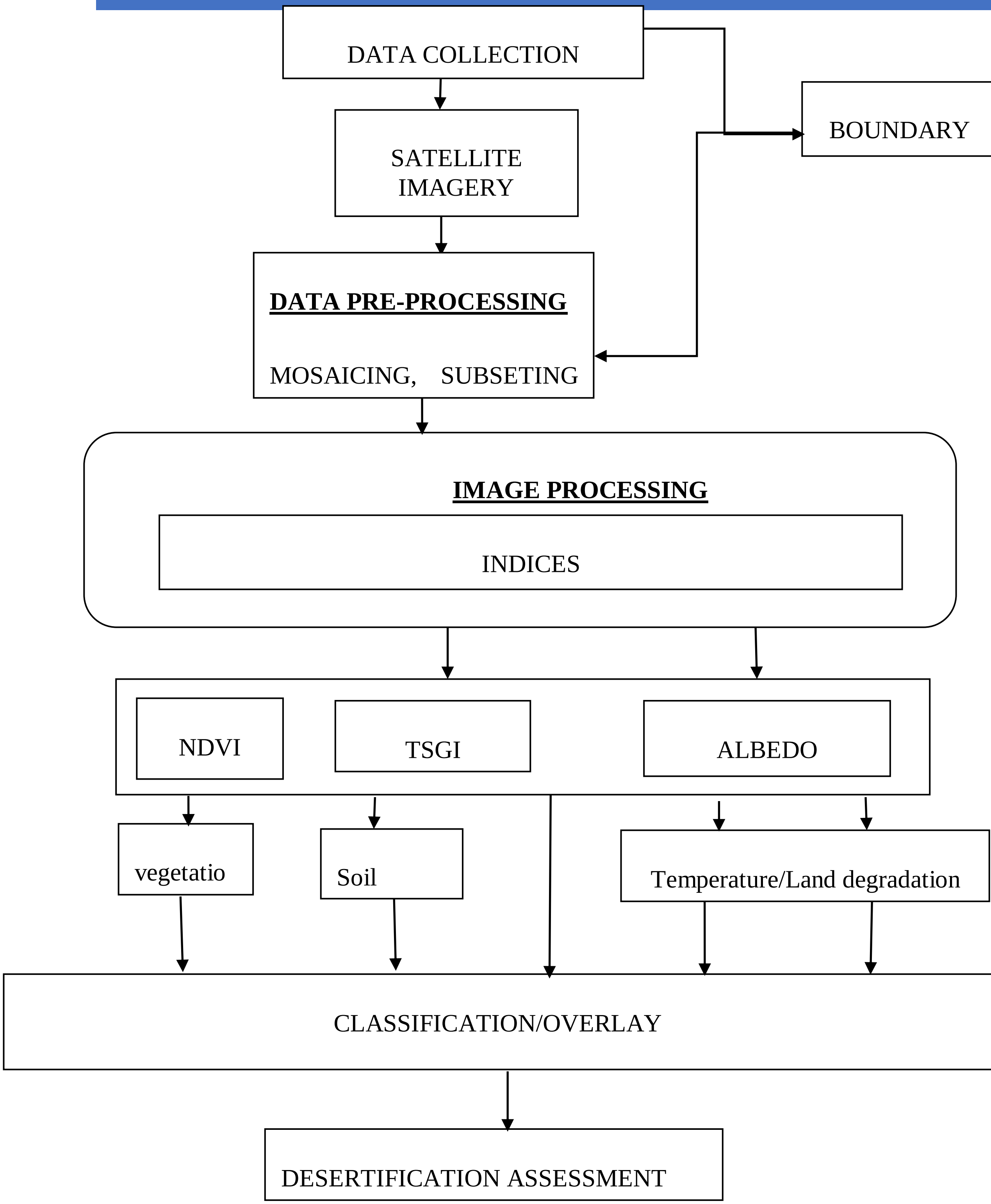

Figure 3.2 Methodology Flowchart

3.4 Research Instruments

The instruments used to carry out the research were as indicated below;

- Esri software; this is an ESRI GIS software that was used to process, analyse and visualize the spatial data.

- QGIS- free and open source software- used for image correction

- Ms word This is a Microsoft application that was used to document the report

3.5 Data acquisition

This study used Landsat satellite imagery which are multi temporal. The images were acquired from the USGS geoportal website. The imagery data were acquired for the year 2000 and 2020. The county is covered by five images. A composite was made from the various band and mosaiced and clipped using the county administrative boundary data. In order to be able to derive the indices, the respective bands which included Near Infrared (NIR), Red, blue, green band, Short Wave infrared(SWIR I&2) were extracted from the mosaiced clipped image using the make raster layer tool in the data management toolbox/layers and table view/make raster layer as shown in figure 3.3 below Three indices were extracted from the satellite imagery which were derived from the various band combination of the Landsat 7 image. Three indices derived were ALBEDO/land surface temperature, NDVI and TSGI.

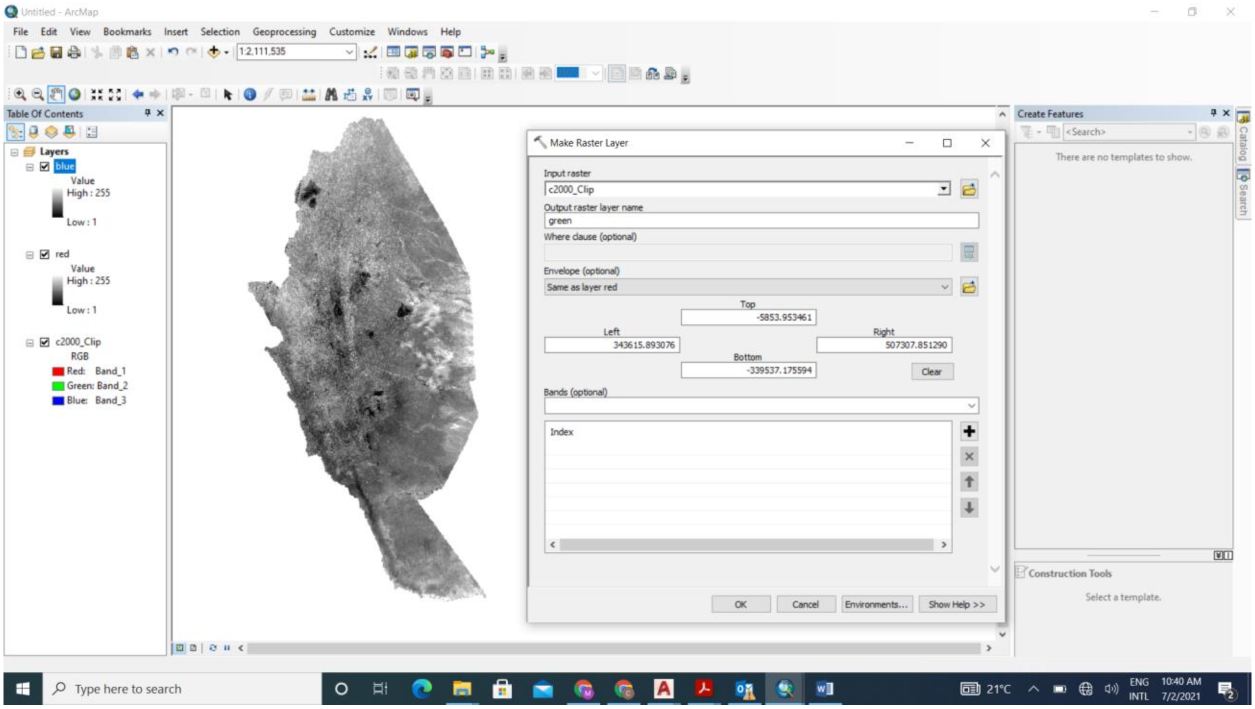

Figure 3. 3 Extraction of bands

3.6 Indices derivation

3.6.1 Albedo

This is an index which is used to quantify the portion of the sunlight reflected by the earth surface, an increase in land surface temperature implies degraded land quality (Robinove et al). The calculation done through application of several equations through raster calculator using USGS formulas. According to (M. Lamchin et al., 2016) albedo is calculated as shown below

$$\textbf{Albedo} = 0.356\ \text{blue} + 0.130\ \text{red} + 0.373\ \text{NIR} + 0.085\ \text{SWIR} + 0.072\ \text{SWIR 2} - 0.018/1.016 \qquad (3.1)$$

The first process was to convert the image digital numbers (DN) to Top of Atmosphere (TOA) reflectance values. This was achieved through the use of the semi classification plugin in QGIS software.

To derive the Albedo maps, a raster calculator in ArcMap was used whereby the formula above was entered.

The albedo maps generated for the two epochs are as shown in figure 3.3

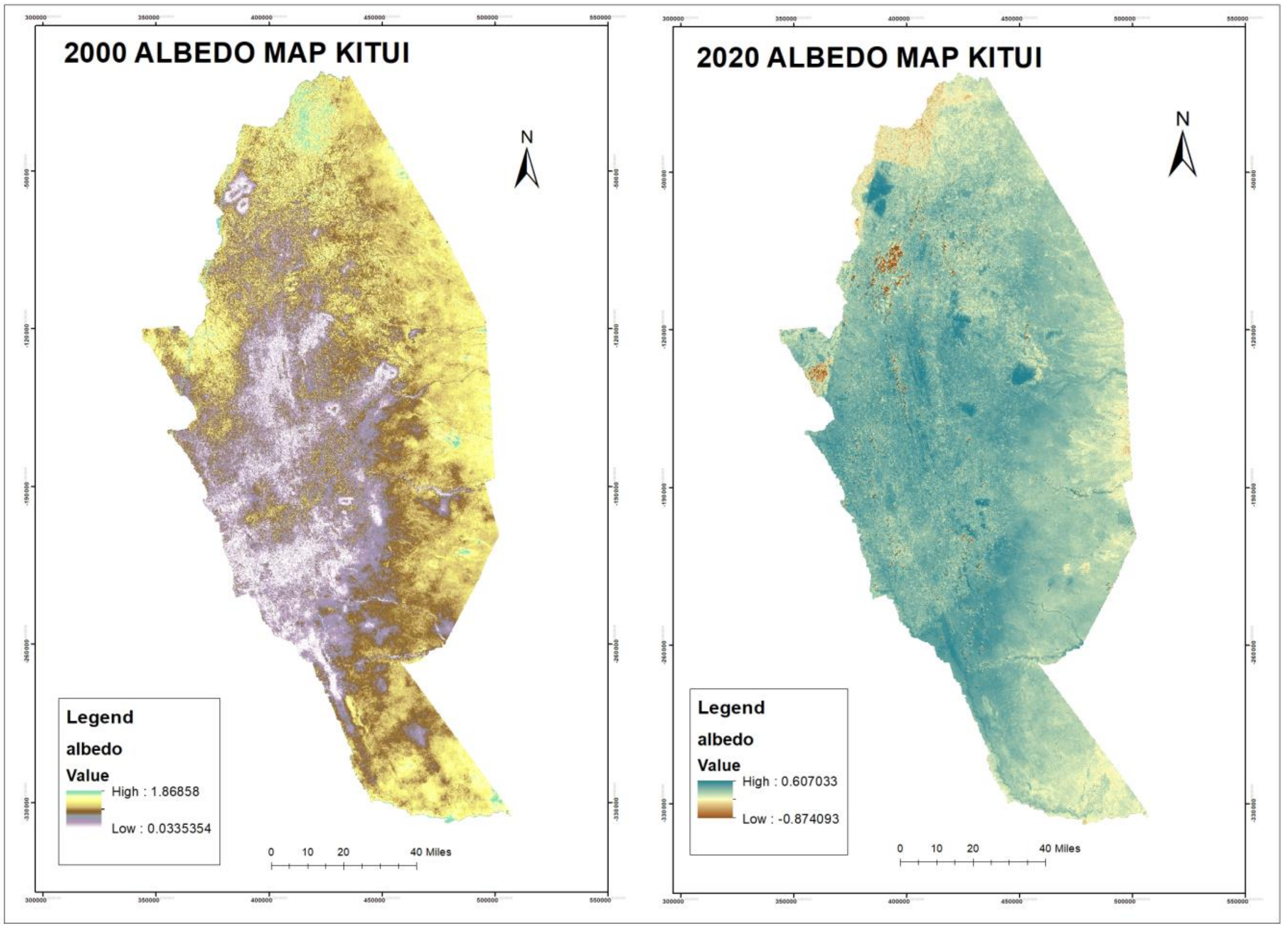

Figure 3. 4 Albedo maps

The areas with high albedo depict the areas with bare soil which reflect most of the sun while areas with vegetation had low albedo since they absorb most radiation. From the results areas around the central part of Kitui in the year 2000 had low albedo as compared to other areas in the county contrary to the year 2020 where only a few areas had low albedo.

3.6.2 NDVI

The Normalized difference Vegetation Index (NDVI) is mainly applied in monitoring drought and desertification. According to (Aburas et al., 2015; Ahmad and Sharif, 2016), NDVI is mainly used to detect any changes in land cover changes occasioned by human-induced actions like construction and other developmental works. It can also be widely applied to analyze the spatio-temporal variations of vegetation coverage (Statistic Malaysia, 2014). NDVI was derived from image analysis window as shown in the figure 3.4 below. The formula used for calculating NDVI is

$$NDVI = (NIR - RED)/(NIR + RED) \quad (3.2)$$

Where;

NIR= Reflection in the near infrared spectrum

Red= Reflection in the red range of the spectrum

This formula categorises the density of the vegetation (NDVI) at a given area of the image by equating the variance in the intensity of reflectance light in the red and near infrared bands of the satellite image.

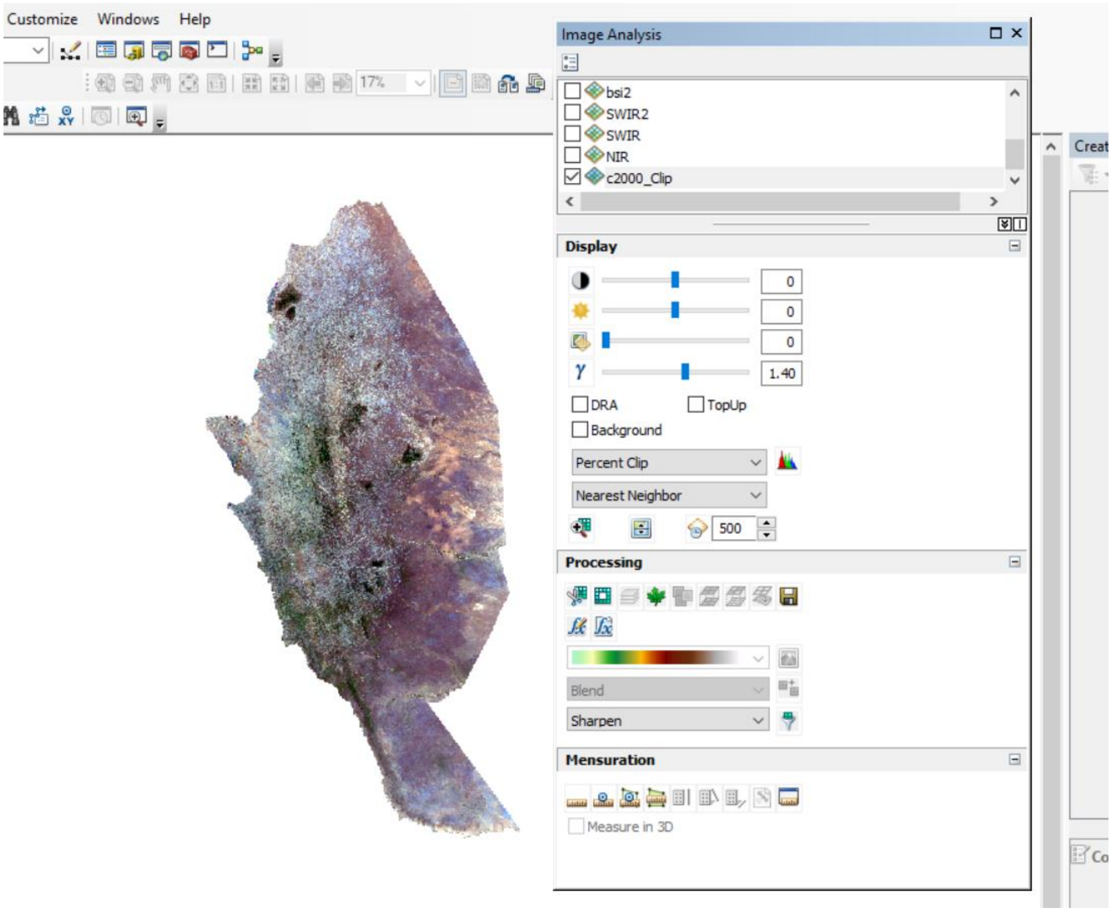

Figure 3. 5 NDVI derivation

This index defined values in the range of -1.0 to 1.0. The areas of high NDVI depicts areas with dense vegetation, wetlands and water bodies, while the areas of low NDVI depicts areas without vegetation in the study area. With areas with more vegetation are racked closer to 1 while the areas with no vegetation are closer to -1. The maps generated were as shown below generated were as indicated in figure 3.5.

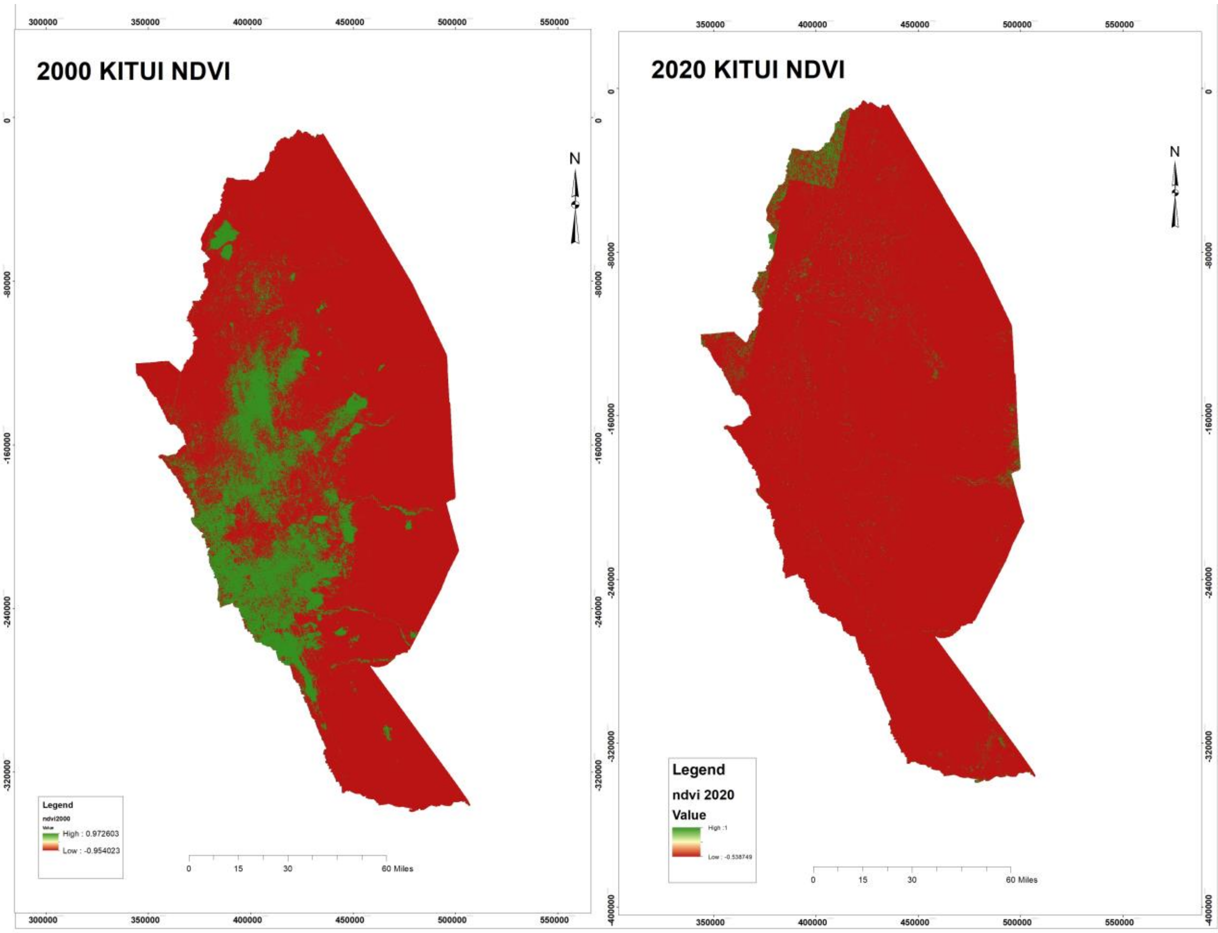

Figure 3. 6 NDVI maps

3.6.3 TSGI

To overcome the challenge associated with the NDVI whereby even a single rainfall occurrence could change the vegetation reflectance which could then lead to misinterpretation of the real level of desertification (Xiao et al, 2006), TSGI was proposed to alleviate this drawback by providing the top soil grain size. It shows the coursing of top soil grain size of sand particles. The severity of desertification can be directly linked with the coarseness of the top soil. The coarser the top soil, the severe the desertification and vice vasa. A high TSGI value relates to the area with content of fine sand in the top soil.

Using the raster calculator, TSGI was calculated using the formula:

TSGI= (Red-Blue) - (Red +Blue +Green). (3.3)

The results obtained were as shown in figure 3.5 below.

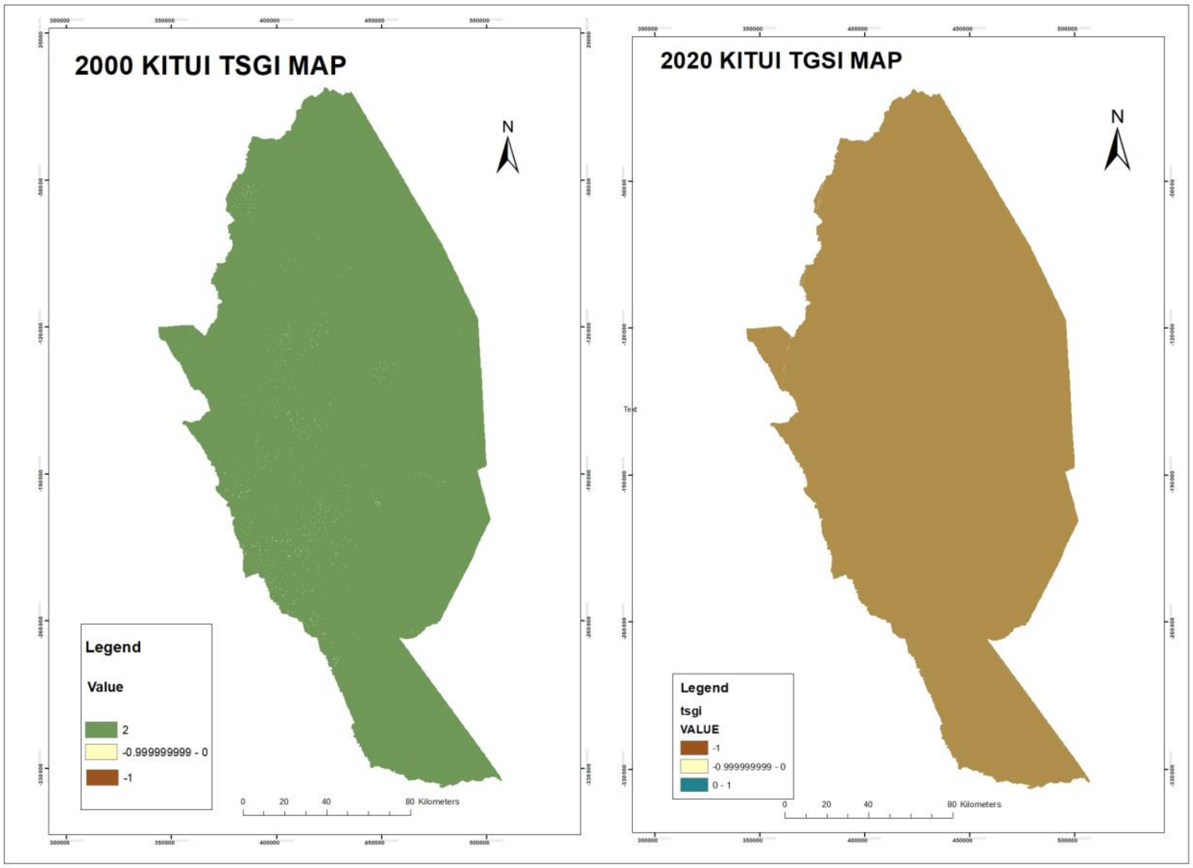

Figure 3. 7 maps showing TSGI in Kitui county

The areas with vegetation had low TGSI in 2000 as compared to areas without vegetation which had a higher TSGI. In the year 2020, the county had higher TGSI as depicted in both the NDVI and the Albedo where a bigger portion of the county was exposed to reflectance.

3.7 TGSI, NDVI AND ALBEDO overlay

The indices were reclassified in two classes of high and low. The high classes were assigned 2 and the low classes 1. The three were then combined to achieve the various levels of desertification as below;

High albedo +High TSGI +low NDVI= high desertification value 3 **(3.4)**

High albedo +low TSGI +Low NDVI Medium desertification value 2

(3.5)

Low albedo +High TSGI +Low albedo =medium desertification value 2

(3.6)

Else Low desertification was assigned 1

(3.7)

from the reclassified indices, a raster calculator was used to calculate the desertification maps using the formula below.

Con (("NDVI" == 1) & ("Albedo" == 2) & ("TGSI" == 2),3, Con (("NDVI" == 1) & ("Albedo" == 2) & ("TGSI" == 1),2, Con (("NDVI" == 1) & ("Albedo" == 1) & ("TGSI" == 2),2,1))) **(3.8)**

The formula was input in the raster calculator from the ArcMap toolbox as shown in figure 3.8

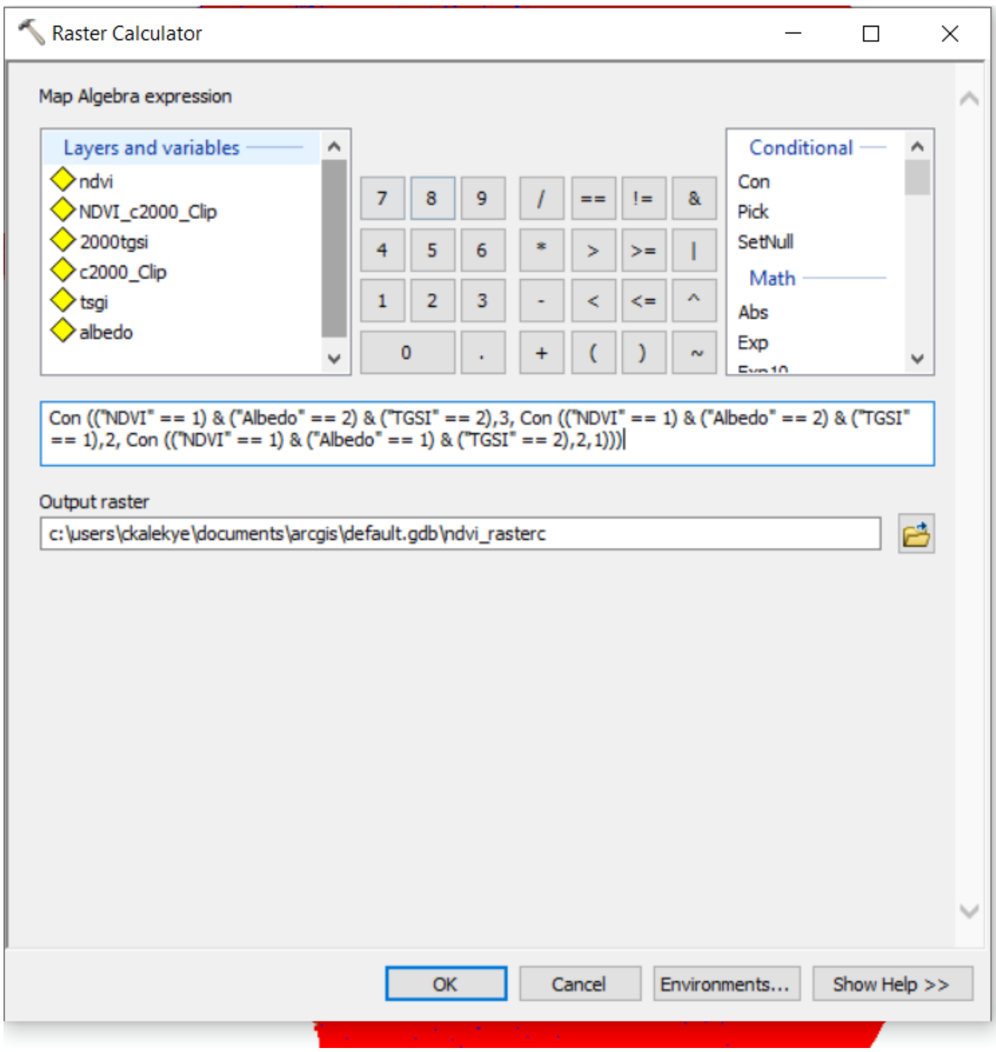

Figure 3.8 Raster calculation of desertification

3.8Validation of the results

To ascertain whether population growth and anthropogenic activities had an impact on desertification, Population density maps for the year 1999 and 2019 were also developed from the 1999 and 2019 population census data which was obtained from the Kenya bureau of statistic website. The results obtained were as indicated in figure 3.9

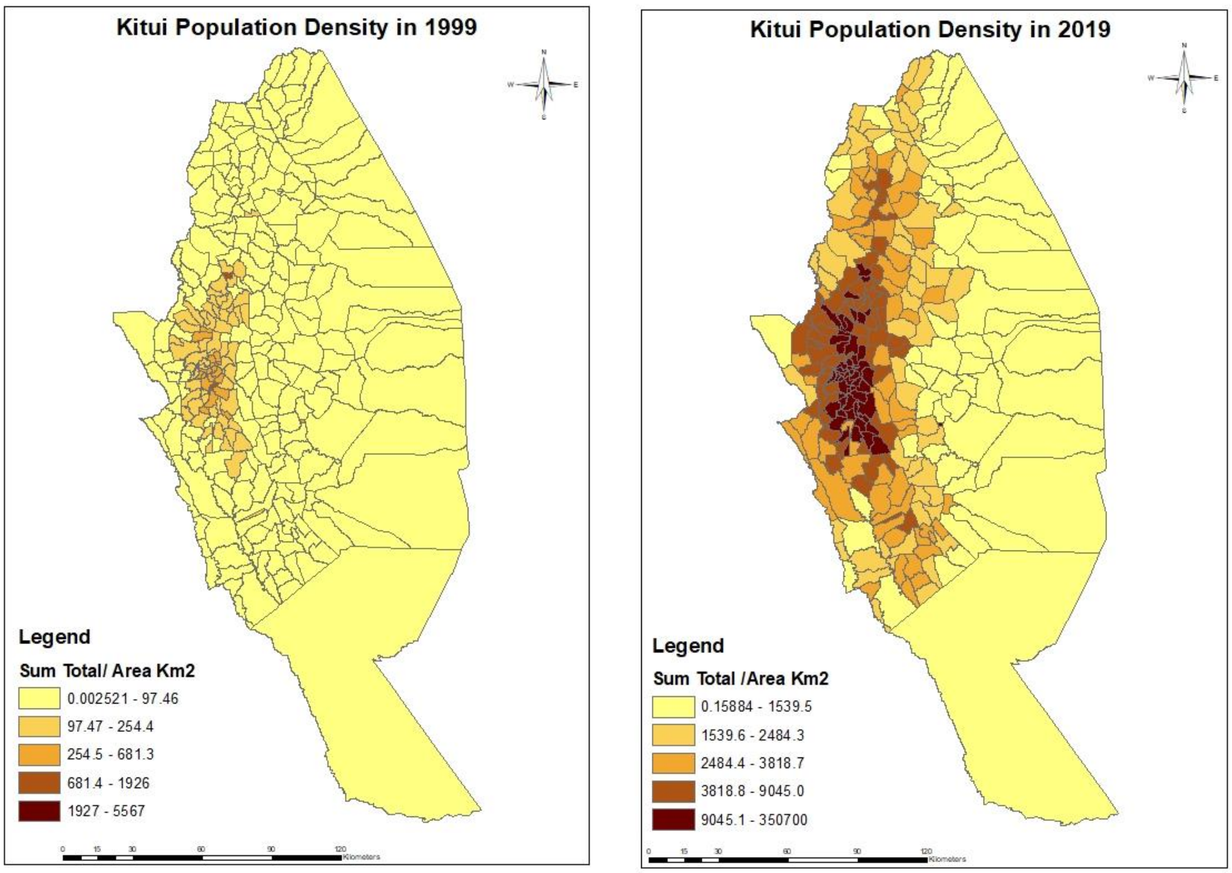

Figure 3. 9 Population Density Maps

It is evident from the results obtained that the population increased from 819,250 in 19999 to1,136,187 in 2019 as shown in the population density maps in figure 3.9. The rise in population density in the western part of the county is believed to have resulted in increased human induced activities which led to more land degradation leading to an increase in desertification.

Field visits and verification

A random field visit to the county was also carried to assess the situation on the ground. as shown in figure 4.0, some dry and bare land was captured in Mwingi west. The picture clearly indicate that the area is under threat of desertification. Areas along the river were observed to be badly eroded due to uncontrolled sand harvesting as shown in figure 4.0. In other areas the land was left bear with huge rocks being exposed due to soil erosion leading to land degradation, only a few shrubs were found with most of the indigenous trees having been cut down for charcoal burning or to pave way for cultivation.

Figure 3.10 Mwingi west showing medium and high desertification.

Figure 3.11 sand harvesting leaving the riverbanks exposed and bare rocks

A visit to the southern part of the county showed a mixture of medium and high desertification with some areas being totally bear with little or no vegetation as shown on figure 4.2

Figure 3.12 Medium desertification in southern parts of the county

CHAPTER 4: RESULTS AND DISCUSSION

4.1 NDVI 2000 AND 2020

The Normalized Difference Vegetation Index obtained for the County indicated that the areas around the central part of the county had high rates of NDVI of 0.972603 which indicated rich or dense vegetation cover and water bodies around the central part. Other areas especially the northern, some parts in the south and the western side had low NDVI of -0.5954023 which depicts areas without vegetation. The areas with vegetation racked closer to 1 while those without vegetation racked closer to -1 as shown in figure 4.3

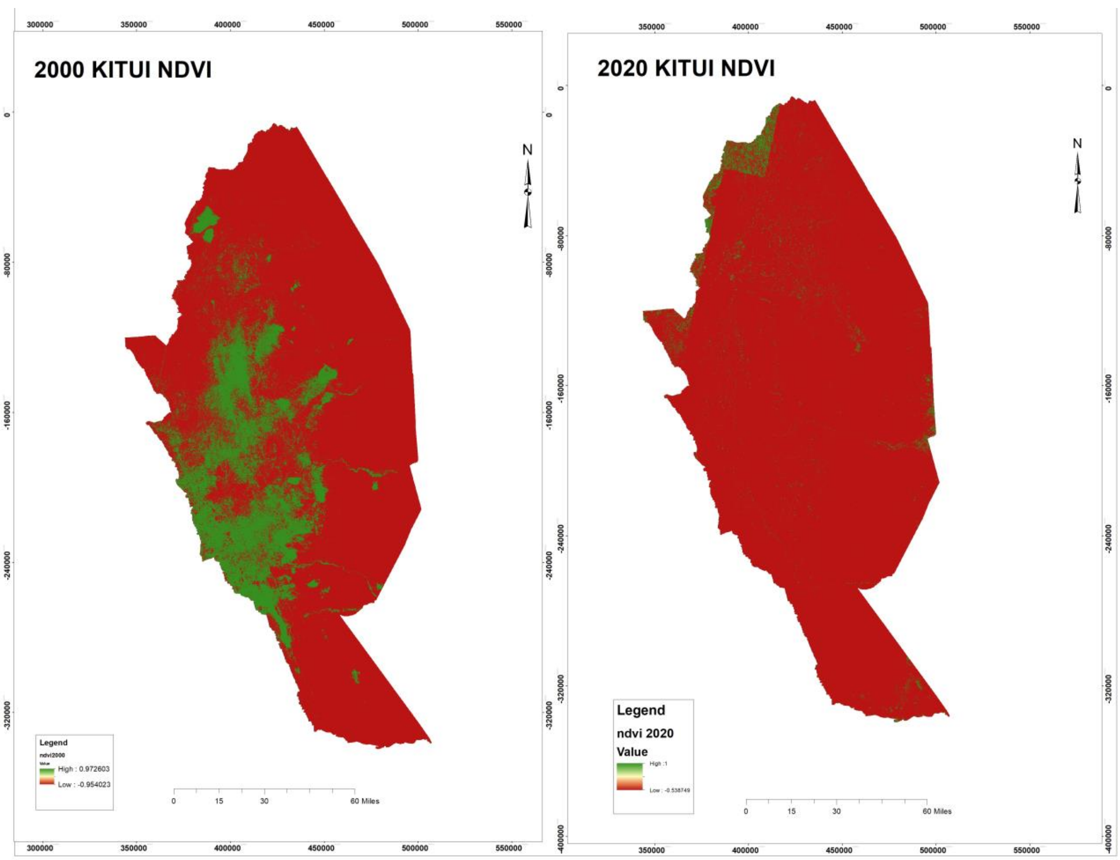

Figure 4. 1 NDVI maps

The 2020 NDVI analysis showed a major decline in the vegetation index whereby the high depicted 1 and the low NDVI depicted -0.538749. a bigger portion of the county had little vegetation index apart from areas around the northern part of the county where there was some high vegetation index.

4.2 2000 AND 2020 ALBEDO

The results obtained for the year 2000 showed that just like the NDVI, the central and western part of the county had low albedo while the southern and the western parts of the county had high albedo as shown in figure 4.4 below. The areas with high albedo depict the areas with bare soil which reflect most of the sun while areas with vegetation had low albedo since they absorb most radiation. From the results areas around the central part of Kitui in the year 2000 had low albedo as compared to other areas in the county contrary to the year 2020 where only a few areas had low albedo which is as a result of the area being bare.

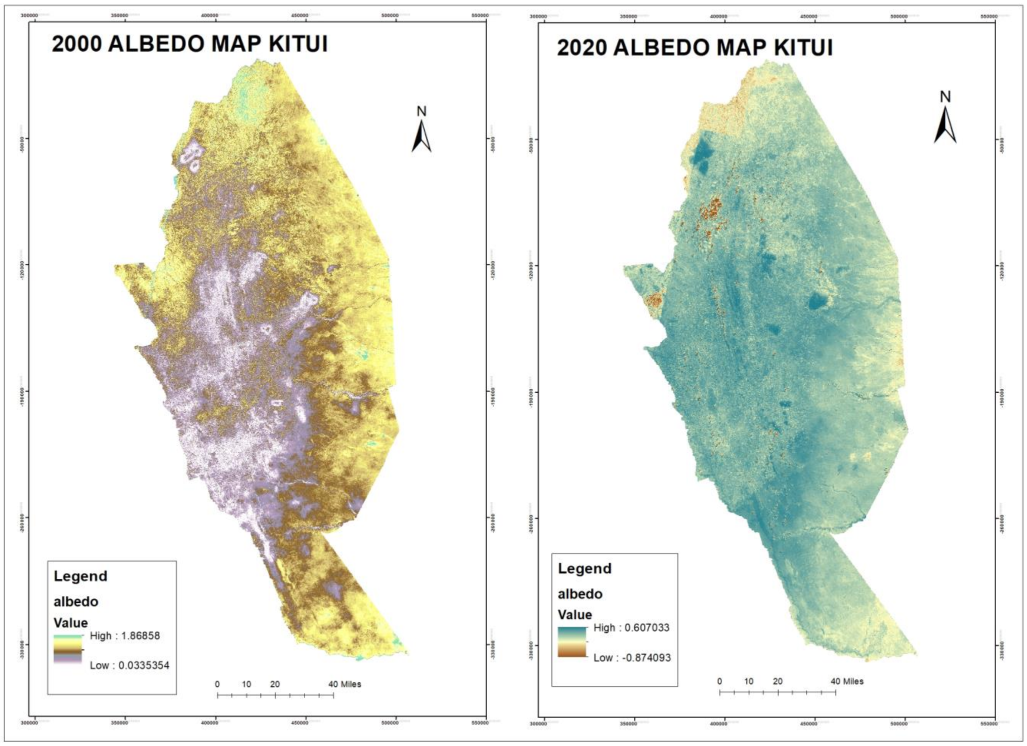

Figure 4.2 maps showing albedo

The Albedo results obtained showed that there was a low Albedo in the central and the southwest parts of the County for the year 2000, this was attributed to the high vegetation cover in the area which was depicted by the High NDVI 2000 results.

4.3 2000 and 2020 TSGI

For the year 2000 the county had high TSGI value of 2 and a low TSGI value of around -1. The low TSGI values were recorded in areas which had high NDVI and Low Albedo as shown in figure 4.5 below. for the year 2020, the whole county recorded high TSGI values which are attributed to the areas being bare and thus exposed to agents of erosion which made the soil texture coarse.

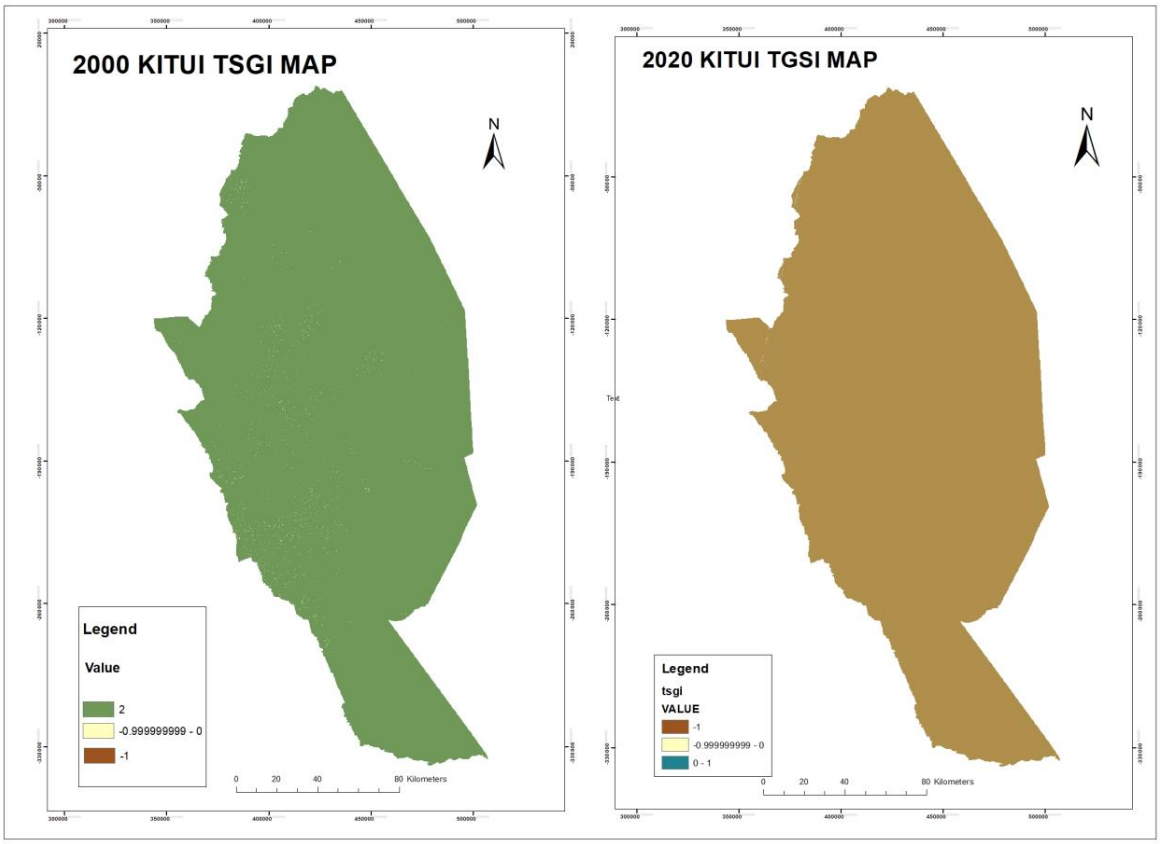

Figure 4.3 maps showing TGSI

For the years 2000 the TSGI value was observed to be low in the western areas of the county, this are the same areas that had high vegetation coverage. This means that the areas with low TSGI had their soils intact and were not exposed to soil degradation. On the other hand, for the year 2020, the high TSGI are distributed all over the county this are the areas which had low NDVI which indicated an exposure of the soil to degradation which is an indication of desertification.

4.4 Population density

To determine whether the population increase had any impact on the growth and increase of desertification, a population density map for the year 1999 and 2019 was derived as shown in figure 4.6 The results obtained indicated that the county's population has increased from 819,250 -in 19999 to1,136,187 in 2019. It is evident that the continued increase in population over the years coupled with various anthropogenic activities has either directly or indirectly contribute to desertification.

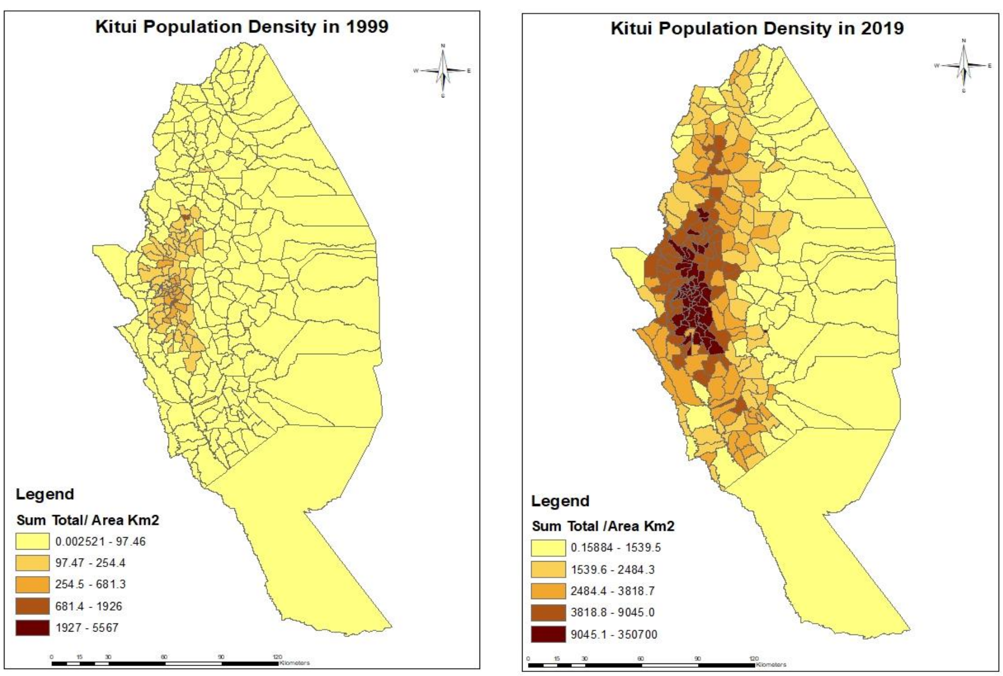

Figure 4. 4 population density maps.

The county population rose from 819,250 in 19999 to1,136,187 in 2019, this was a clear indication that the increase in population brought in pressure on the land which lead to an increase in land degradation resulting to desertification in the county.

4.5 Desertification spatio temporal maps

An analysis of the results of the desertification maps as shown in Figure 4.7 below indicate that Kitui County is under a threat of desertification especially most areas that were under low desertification have all moved to the medium zone. The areas that are prone to desertification include areas like Kitui south, Central, Kitui East, Kitui rural, Mwingi west, east and Kitui Rural. An analysis made for the area change in the high, low and medium desertification at the various epochs showed an increase of high desertification as well as an increase in medium desertification area coverage in meters squared, on the contrary, the low desertification area was observed to decrease which means an increase of desertification in Kitui county. The various desertification area was tabulated as shown in table 4.7 below.

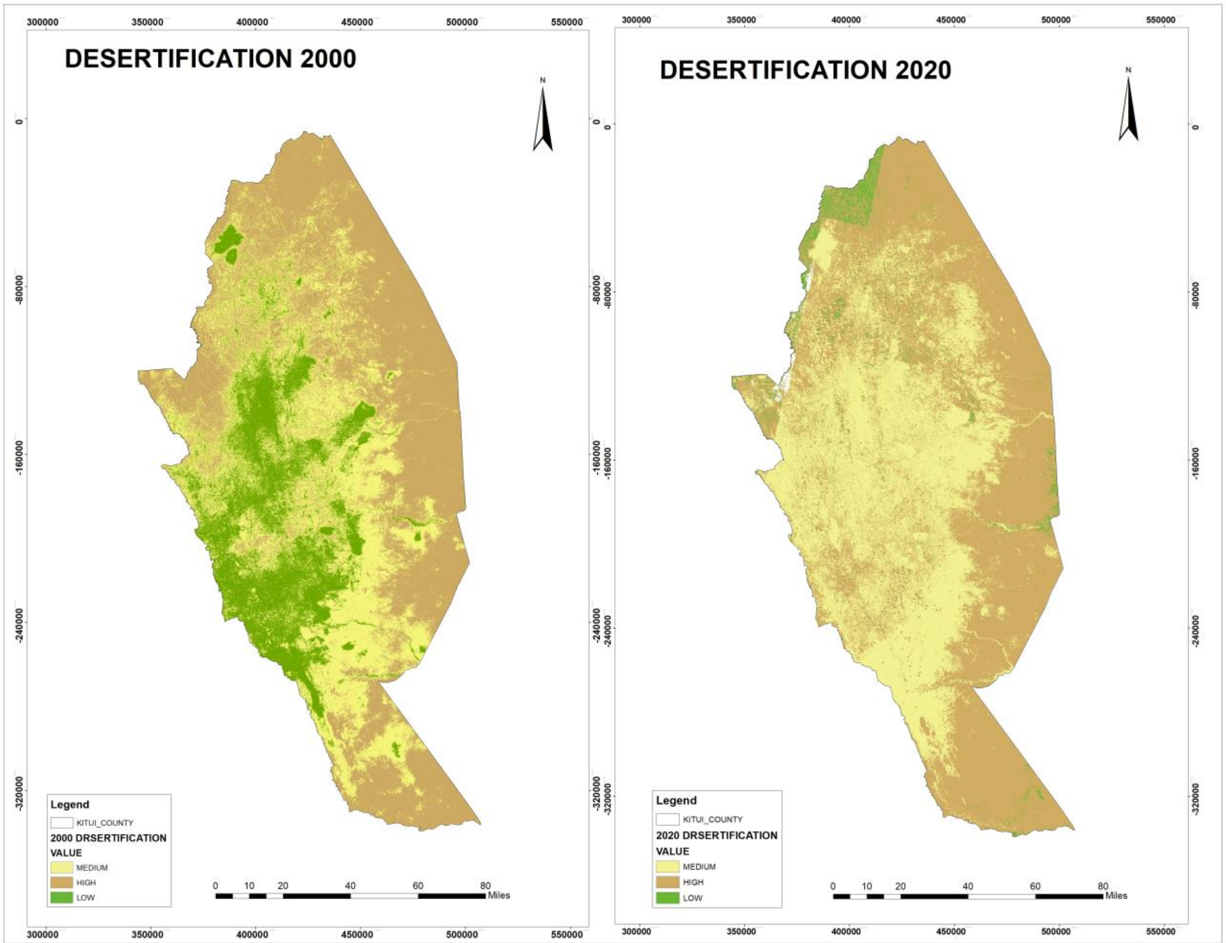

Figure 4. 5 Desertification maps

Table 4. 1 Desertification area coverage

2000 rate of Desertification		**2020 rate of Desertification**	**Unit**	
Desertification	**Area M^2**	**Desertification**	**Area M^2**	**% change**
Low	587,319,210	Low	93,053,880	620%
Medium	1042467480	Medium	1,279,643,760	8%
High	1420251030	High	1,668,462,570	85%

From the results obtained low desertification decreased at a rate of 620% percentage from 2000 to 2020 which is a clear indication that the county is facing desertification at an alarming rate. The medium

4.6 **Discussions of the results**

The 2000 Normalized Difference Vegetation Index obtained for the County indicated that the areas around the western and central part of the county had high rates of NDVI of 0.972603 which indicated rich or dense vegetation cover and water bodies around the central part. Other areas especially the northern, some parts in the south and the western side had low NDVI of -0.5954023 which depicts areas without vegetation. The areas with vegetation racked closer to 1 while those without vegetation racked closer to -1 as shown in figure 4.1. The 2020 NDVI results were very low as compared to 2000 results. There were only a few small areas in the northern part of the county with high NDVI.

On the other hand, the Albedo results obtained for the year 2000 showed that just like the NDVI, the central and western part of the county had low albedo while the southern and the western parts of the county had high albedo as shown in figure 4.2 below. The areas with high albedo depict the areas with bare soil which reflect most of the sun while areas with vegetation had low albedo since they absorb most radiation. From the results areas around the central part of Kitui in the year 2000 had low albedo as compared to other areas in the county contrary to the year 2020 where only a few areas had low albedo which is as a result of the area being bare, this was also observed from the TSGI results whereby the 2000 results had low reflected ability for the areas which had high vegetation cover and high on areas with low vegetation coverage.

From the results obtained, the low desertification in the county was observed to have drastically reduced by 620%, this was attributed to the increase in population as was observed in the density population maps. The growth in population led to an increase in various anthropogenic activities which led to land degradation thus an increase in desertification. The medium desertification reduced by 8% while the high desertification rate increased by 85%. A bigger part of the county is in the medium desertification category with only a small area around the northern part which is in the low category, and the other areas under high desertification threat.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS.

5.1 Conclusions

The research found out that the major causes of desertification in the county include natural factors like drought, climate change and population pressure. The other major causes are human induced activities like deforestation particularly charcoal burning which is more prevalent in the county as the residents look for an alternative source of income, sand harvesting is also rampant in the county which lead to soil degradation, this coupled with overgrazing, poor farming methods among other activities contribute to desertification.

The spatial temporal maps developed showed a great increase in desertification from the year 2000 to 2020. From the results obtained, it is evident that there has been an increase in both high and low desertification area coverage, this is also depicted by the decrease of the NDVI values in 2020, the low desertification coverage has also been decreasing in area coverage. The increase in both high and medium desertification with the decrease in low desertification is an urgent call which the County government should address with immediate concern. The increase in desertification is attributed to pressure of human activities like charcoal burning, overgrazing, deforestation and cultivation due to an increase in population density.

The research also found out that the increasing population pressure exerted pressure on the county leading to land degradation which eventually causes desertification. Due to the high poverty levels in the county, the people are forced to look for alternative sources to supplement their income like charcoal burning, deforestation, poor farming practices and sand harvesting which are slowly but surely exposing the county to desertification. Most areas in the county like Kitui south, Mwingi North, Mwingi west, Mwingi East and Kitui east the areas identified to be most susceptible to desertification.

In conclusion, remote sensing provides a large amount of data for analysis, monitoring and change detection on the earth surface. Remote sensing can be a vital source of information on land cover and land use which is crucial to appreciate ecological matters and changes in arid and semi-arid regions, especially in monitoring desertification as has been applied in this study.

5.2 Recommendations

to curb the major causes of desertification in the county the county government should engage on an afforestation exercise to educated the residents in restoring the forest coverage. The county government together with the relevant NGOS should embark on afforestation and re-afforestation projects in the county especially areas that are in the high desertification category like Kitui south, Mwingi North, Mwingi west, Mwingi east and Kitui east in order to increase the forest coverage since deforestation is also a major factor that contribute to desertification in the county. The Ministry of education can come up with programs that teach the pupils on tree planting and environmental management.

The county government to employ the residents as forest rangers to protect the forest.

There is need for the county government and other relevant entities to improvised alternative sources of energy other than charcoal.

There is need for the county government to put strict measures to curb charcoal burning which is still rampant in the county despite the ban on charcoal and sand harvesting. The county residents should resist and discourage sand harvesting which renders the riverbanks bare leading to soil erosion and land degradation.

There is also need for the county government to educate the residents on better farming practices which prevent soil erosion and bring maximum yields.

5.3 Areas for Further Research

A further study can be carried out to monitor desertification in the county and incorporated with rainfall data and Land use land cover data of the area to assess the impacts of desertification in the county.

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