



Estimating the Impact of Climate Change on Desertification in Northern Borno: A Geo-Spatial Approach

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General Note



Article is recommended to print as color version in recycled paper. *Save Trees, Save Climate.*

ABSTRACT

Nigeria is one of the most desert prone countries in Africa and the problem of desertification is expending southwards from 12° 30' to 10° 30'. In addition, rivers and lakes are being silted leading to rapid drying up of water bodies. A typical example is the case of the receding Lake Chad. This environmental problem has led many researchers to investigate the magnitude and monitor its spread, as a result, the geo-spatial approach has become the most widely used because of its efficiency. Majority of these studies are focused on the extent of the problem neglecting the fundamental causal factor of desertification. It is evident from available literature that few or no study has estimated the impact of climate change on desertification using a geo-spatial approach. Based on this, this paper investigates how climate change facilitates desertification in the north eastern part of Nigeria within the context of geo-spatial analysis and in addition, to map the magnitude of desertification in the region. The paper utilized climatic data and supervised classified remotely sensed data in Microsoft Excel and ILWIS environment respectively for detecting climate change and desert encroachment in the study region. The results showed that climate change facilitates desertification and that over 31 percent of the land surface of the region has become bare and the problem became worsened during the study period from 1986 to 2006. This problem was highly facilitated by extreme climatic conditions.

Keywords: Climate change; Desertification; Northern Borno; Geographic information system; Remote sensing.

1. INTRODUCTION

Desertification is a major environmental threat that plagues the earth and consequently affects human development. This global threat occurs when dry lands are exposed to extreme anthropogenic practices, such as; deforestation, overgrazing, over cropping, inappropriate irrigation methods and physical factors, such as; drought and climate change. Among these factors, climate change is the most devastating and wide spread cause of desertification. The most acceptable definition of climate change, was presented by IPCC (2007), it states that climate change is an alteration in the condition of the climate that can be identified (for example by using statistical tests) by changes in the mean and/or the variability of its properties and this, persists for an extended period (typically, for decades or longer).

The earth's constant warming and heating has affected many parts of Nigeria, especially those in the northern fringes (the Sahelian region) of the country, who are located far away from the cooling effect of the Atlantic Ocean along the coastline down the South. As a result of this, the region has been experiencing continuous climate change characterized by reduction in rainfall, increase in the rate of dryness and heat (Obioha, 2005). It has been reported that the north eastern Nigeria which was mainly a Sudan-Sahel Savannah is increasing aridity (Obioha, 2005). One-third of human population lives in the dry land including the poorest nations on earth. The poorest people within these areas are agriculturalists (including herders). They struggle valiantly and with great ingenuity to eke out a living from lands that are especially vulnerable to degradation (CGIAR, 2009).

Desertification is described as a process of land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climate variations and human activities (UNCED 1992). Desertification threatens the living condition of about 2.6 billion people (44 percent of the world's population) and 1.5 billion people depend directly on land that is being degraded for their livelihood (UNCCD 2009). About 40% (5.2 billion hectares) of the earth's land area is currently threatened by desertification (ADB, 2010). Desert encroachment threatens the livelihood of communities and the survival of a nation. 40 percent of African countries on the fringes of the Sahara Desert are under the threat of drought and desertification. This environmental menace has devastated lands and destroyed many homes. The drought that occurred in 1973 claimed more than 100,000 human lives and 12 million livestock (FAO, 2010). Desertification results in induced human migration and is exacerbated by climate change. Globally, the number of environmentally displaced people is between 17 and 24 million and under the current climate change scenario it is estimated that by 2030 water scarcity in some arid and semiarid places will displace up to 700 million people (ADB, 2010). Such forced migration has serious consequences, potentially leading to conflict over scarce resources and contributing to ethnic strife and political turmoil.

In general, uncontrolled human activities that take place in fragile ecological areas aggravate drought and desertification. Nigeria is one of the most desert prone countries in Africa (Nigeria Vision 20:2020, 2009). The problem of desertification is expending

southwards from 12° 30' to 10° 30' (Nigeria Vision 20:2020, 2009). In addition, rivers and lakes are being silted leading to rapid drying up of water bodies. A typical example is the case of the receding Lake Chad. Sand dunes formations or occurrence have equally increased by approximately 17 percent from 820 km² to 4,830 km² over the period (Nigeria Vision 20:2020, 2009). It has been estimated that between 50 and 75 percent of Bauchi, Borno, Gombe, Adamawa, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe and Zamfara states are being threatened by desertification (Nigeria Vision 20:2020, 2009). These states account for about 35 percent of the country's total land area. In addition, research has shown that 7 adjacent states to the south have about 10 to 15 percent of their land areas threatened by desertification (FADE, 2010).

However, a substantial amount of researchers that have modeled the problem of desert encroachment have focus attention strictly on estimating the magnitude and identifying the areas threatened by the menace (Musa and Shaib, 2010; Ahmed et al., 2010; Mohammad and Donald, 2008; Adjei, 2010; Gad and Shalaby, 2010; Deep Narayan Singh and Omprakash Madguni, 2017; Jaime Senabre, 2018). Many other studies have used geo-spatial techniques to map and model desertification worldwide. For instance, Sa'ad and Shariff (2011) employed geographic information system (GIS) and remote sensing (RS) techniques to study the status of desertification in 16 Arab countries. Gad and Lofty (2007, 2008) used GIS and remote sensing techniques in mapping desertification sensitivity in the north-western part of Egypt. Gad and Shalaby (2010) employed geo-spatial technology in the assessment and mapping of desertification sensitivity in Inland Sinai and Eastern Desert Wadies, Egypt. Adjei (2010) in assessing desertification in the upper East Region of Ghana adopted GIS and remote sensing techniques. Majority of these studies are focused on the extent of the problem neglecting the fundamental causal factor of desertification.

Geo-spatial approach has been widely accepted and adopted by empirical researchers in the field of disaster and environmental management because of its efficiency and reliability. It is evident from available literature that few or no study have estimated the impact that climate change exhibit on desertification using a geo-spatial methodology. Based on this background, the substantive objective of this paper is to investigate how climate change facilitates desertification in the north eastern part of Nigeria (northern Borno) within the context of geo-spatial analysis and in addition, to map the magnitude of desertification in the region.

2. MATERIALS AND METHODS

2.1. Study region

The study region, located in the north eastern corner of Nigeria, lies within latitude 11° 15' N to 13° 45' N and longitude 13° 45' E to 14° 45' E with a total area of about 46,053 km². It is composed of the following local government areas: Abadam, Bama, Dikwa, Gubio, Guzemala, Jere, Kaga, Kalabalge, Konduga, Kukawa, Mafa, Magumeri, Maiduguri, Marte, Mobbor, Monguno, Ngala, Nganzai (Fig. 1). It has a total population of over 3 million people and majority of this population are farmers and nomadic herdsman. The area features a variety of fluvial and Aeolian landforms like fossil sand dunes, beach ridges and inter-dunes and ridge depressions. These features are said to be a combined effect of endogenic and exogenic processes, traceable to the Pleistocene and the Holocene climatic periods respectively.

The major seasons of the country (rainy season and dry season) are found in the region. Temperature is high all year round; with hot daily mean temperature ranging from 35° C to 40° C and an annual mean of 30° C. In the southern part of the state, the weather is relatively milder. The rainy season last for less than 80 days in the extreme north, but in the extreme south, it last up to 140 days. The mean annual rainfall is over 800mm on the Biu Plateau but less than 500 mm in the extreme north around Lake Chad. Rainfall tends to have been declining since the 1960s (DMS, 1992). Relative humidity is generally low throughout the state, ranging from as low as 15 percent in the driest months of February and March to the highest values of 70 to 80 percent in the months of July and August. Two vegetation zones are identified in the region, Sudan and Sahel savannah. The semi-arid nature of the Sahel and Sudan savannah makes the vegetation consist mainly of open acacia tree savannah. In the south, shrub vegetation is interspersed with tall trees and woodland. Vegetation has been greatly modified in most places as a result of over-cultivation and over-grazing, land degradation and desertification which have been on the increase causing the desert to advance southwards.

2.2. Methodology

2.2.1. Data

The study used two classes of data: the first is climatic data for a period of 70 years (1941-2010), obtained from Maiduguri synoptic stations. This data was collected from the Nigerian Meteorological Agency (NIMET); the second category of data is remotely sensed data obtained from the National Center for Remote Sensing (NCRS) Jos. Two sets of satellite imageries for three different years, Land-Sat TM, 1986 and Land-Sat ETM, 2001 and 2006 covering the study area were assembled and analyzed for change detection. The two imageries for the three years are multi spectral images with spatial resolutions of 32 m (Land-sat TM 1986) and 28.5 m (Land-sat ETM 2001 and 2006).

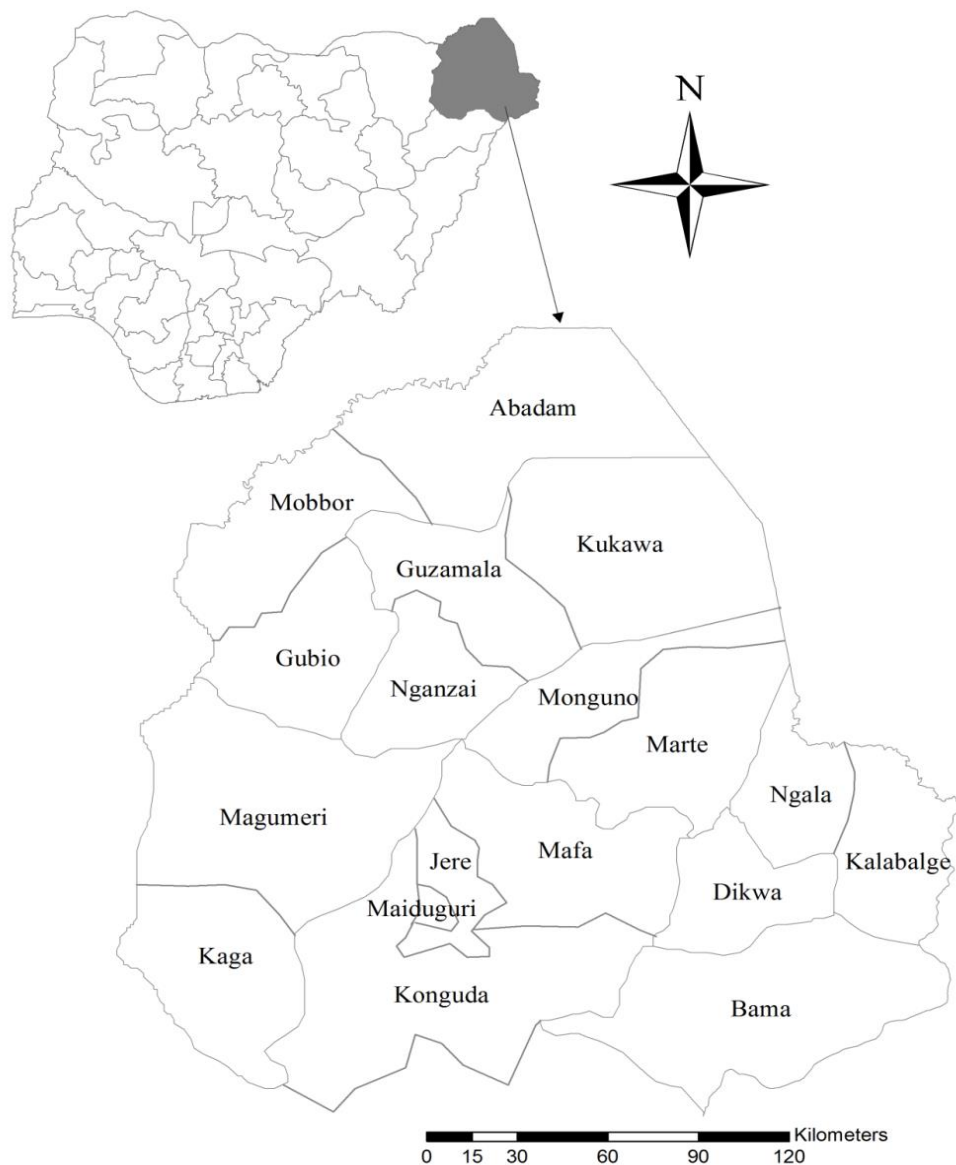


Figure 1 The location of the study area (northern Borno) in the north eastern edge of Nigeria

2.2.2. Data, image preparation and classification

Supervised classification using GIS software and Integrated Land and Water Information System (ILWIS) were employed for image visual enhancement and classification. The imageries were filtered and stretched to enhance visualization. The visually enhanced imageries were classified based on sample set that was created according to training pixel (Fig. 2). The classification was done using false colour composite image with class domain of eight categories to detect the following land uses; agricultural land (yellow), settlement (Red), water bodies (blue), bare land (brown), burnt surface (black), marsh land (pink), shrub land (pitch green) and wood land (green). The classification was carried out based on the eight classes, on assigned value to each pixel; which is referred to as pixel training. Each pixel represents one of the defined classes, which is represented by colours in the created domain. The imageries were classified using maximum likelihood algorithm. The classified imageries were converted to represent the classes with true colour from the class domain linked to representation object in the ILWIS environment. The climatic data were rainfall and temperature of the study area. Also the Microsoft excel statistical package was used to perform the statistical analysis of the climatic trend of temperature and rainfall for 70 years. This provides the necessary tools upon which the basic information on the climatic pattern are drawn and examined.

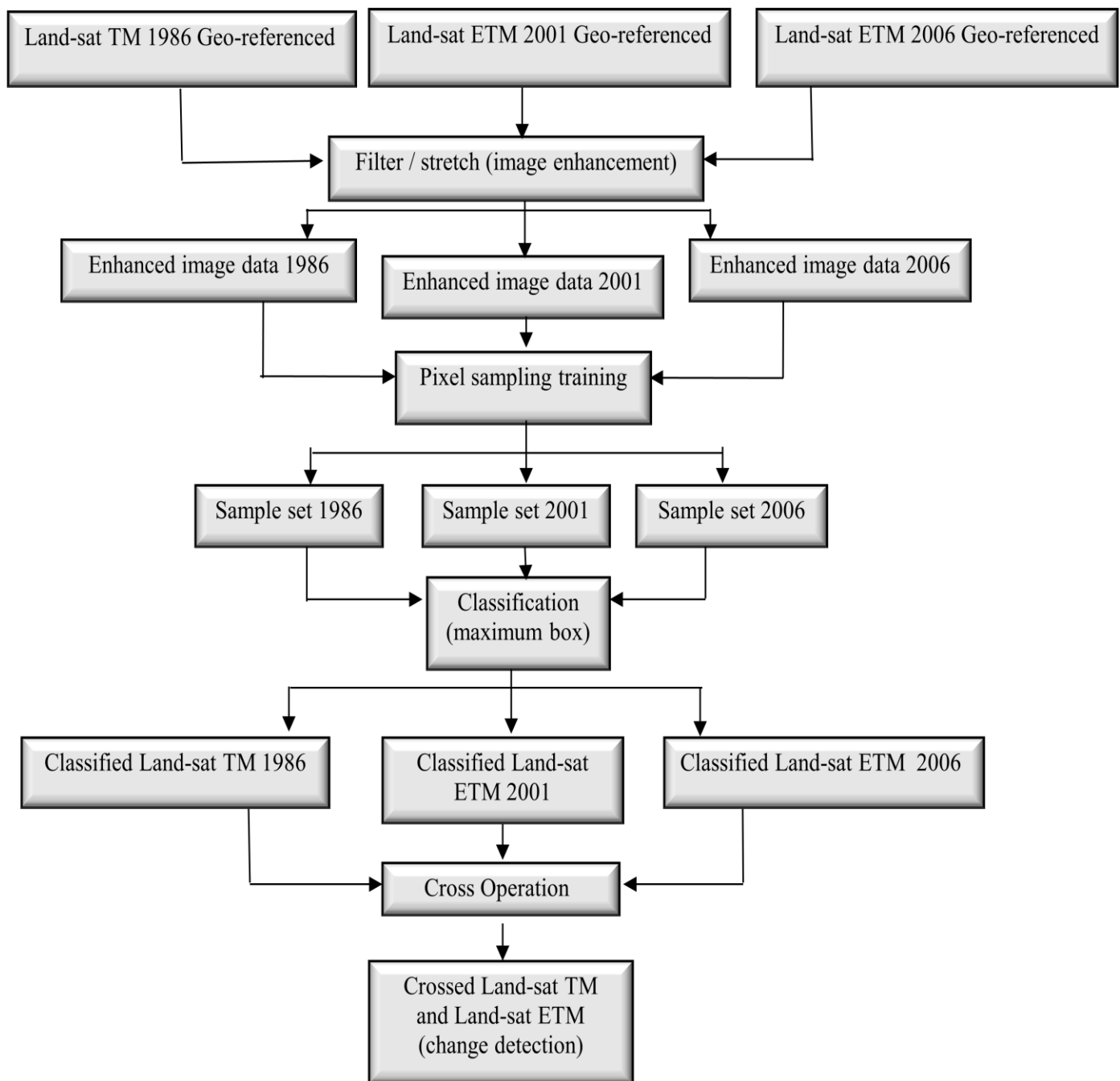


Figure 2 Flow chart of methodology

Source: Modified from (Idoko and Bisong, 2010)

3. RESULTS AND DISCUSSION

3.1. Climate change detection

The results of this paper are broken into two parts-those relating to climate change which is represented with temperature and rainfall and those relating to remote sensing which involves well processed satellite images for geo-visualization. A detailed observation of the climatic data presented in Fig. 3 to 4 shows that there is a steady increase in temperature in the study region.

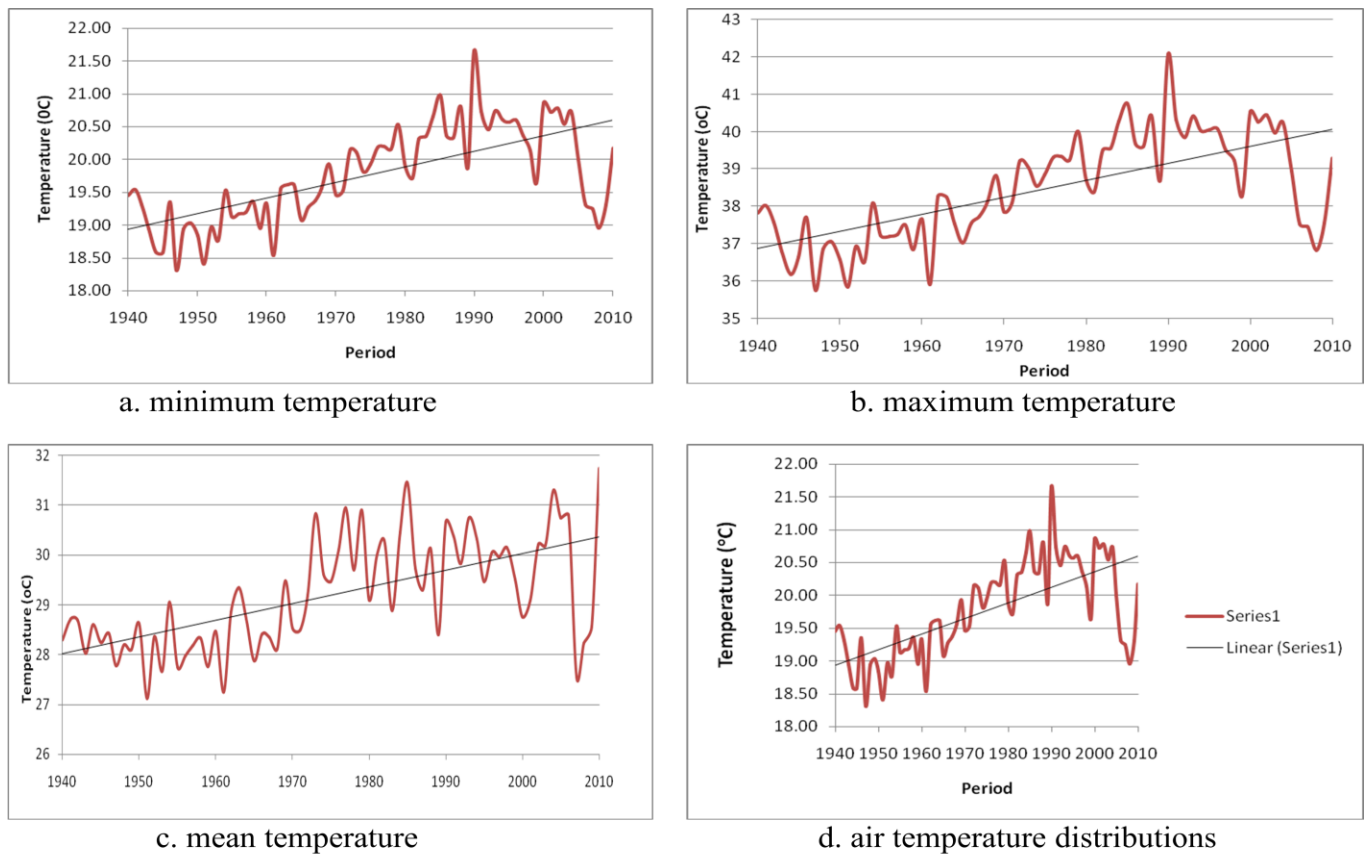


Figure 3 Annual temperature for 7 decades (1940-2010) for the study area

Fig. 3 shows that from 1940 to 1960 the temperature was relatively stable until the 1970s that initiated a consistent rise. The result shows that temperatures have continued to rise, with a minimum of 20.0° C i.e. 18.4° C (low), 21.6° C (high), and a maximum of 38.9° C i.e. 35.8° C (low), 42.0° C (high), and mean temperatures of 29.4° C i.e. 27.0° C (low), 31.8° C (high). This result is in conformity with the global trend (IPCC, 2001 and Odjugo, 2010).

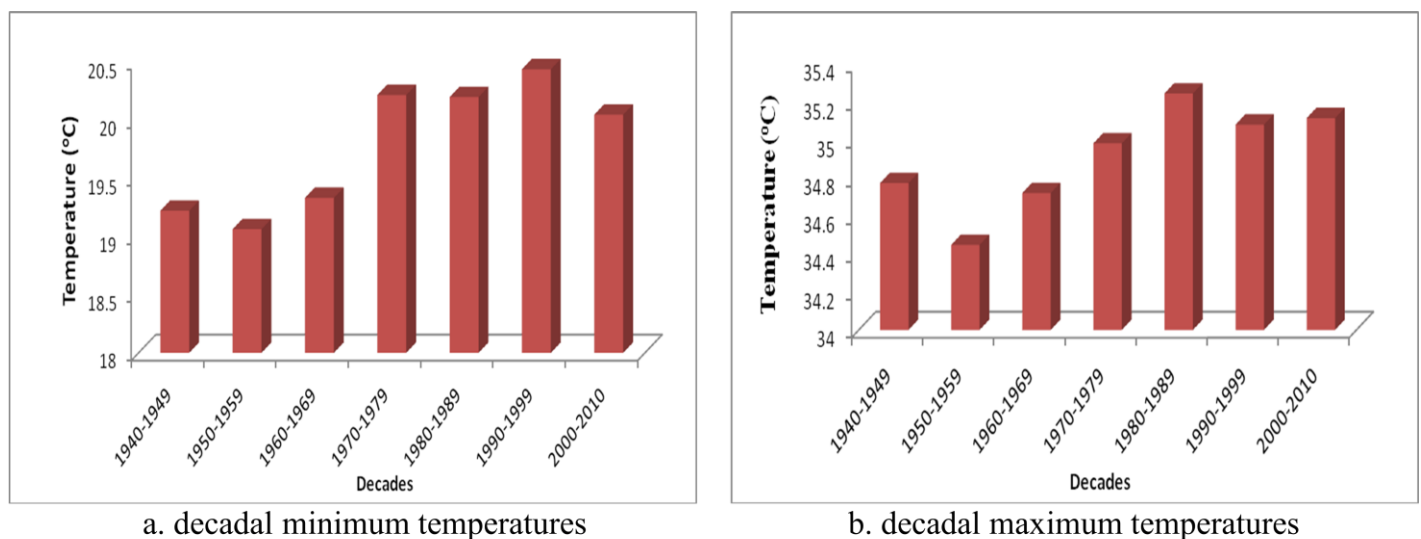


Figure 4 Decadal temperature trends of the study region

Fig. 4a reveals that the decadal minimum temperature has been fluctuating; it has decreased from 19.3°C in the 1940s and 1950s decades to 19.1°C in the 1950s to 1960s. Sharp minimum temperature rise is noticed from the 1970s, with a slight drop in 2000 to 2010. The mean minimum temperature is 19.8°C with 19.3°C (low) and 20.6°C (high) and a difference of 1.3°C for the decades. Fig. 4b shows the same pattern observed in Fig. 4a. A gradual increase from the 1940s to the 1960s is also noticed and a sharp rise from the 1970s. Basically, the mean temperature range have remained high, 35.5°C (high) and 34.1°C (low) with a difference of 1.4°C and an average of 34.8°C .

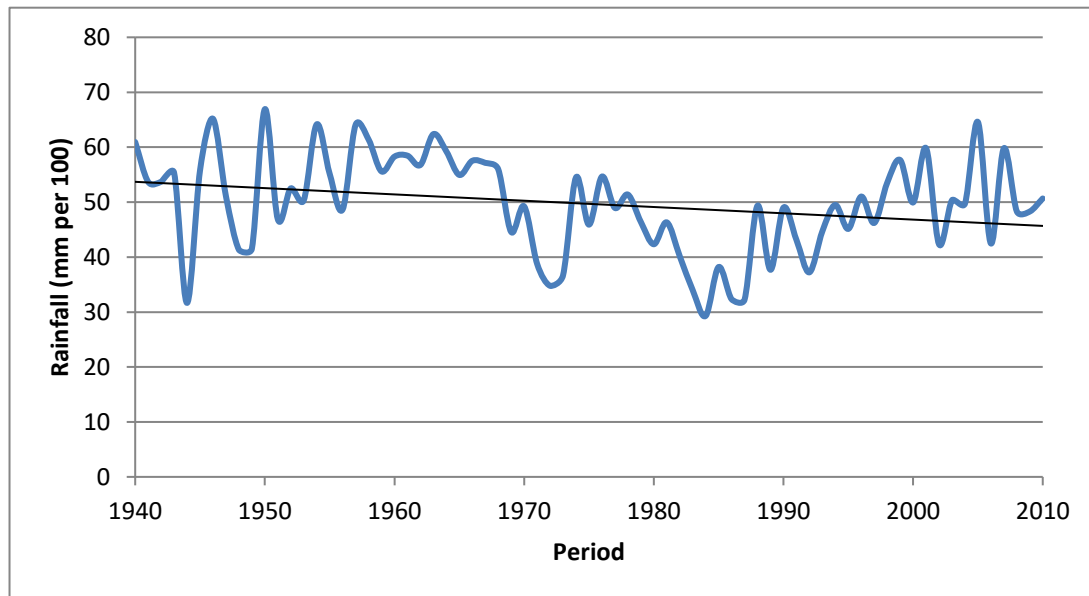
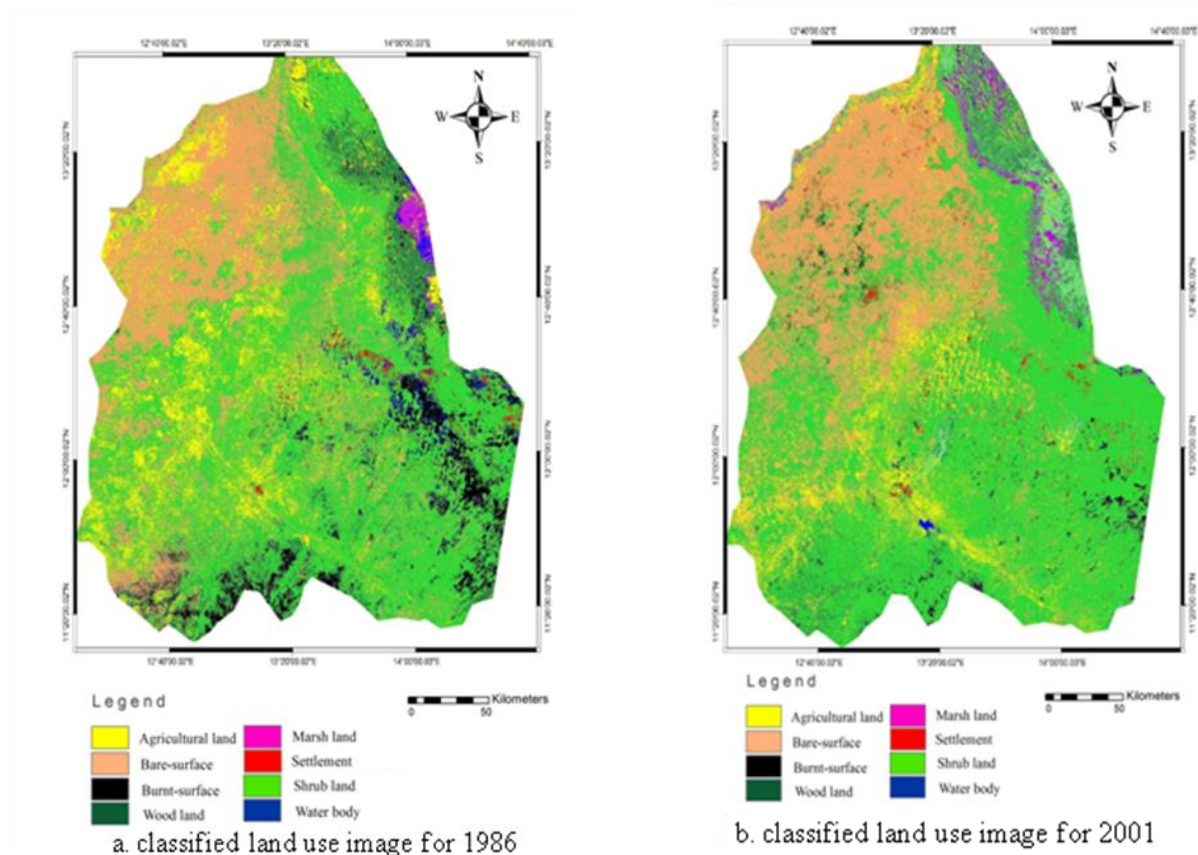


Figure 5 Annual rainfall of the study area for 7 decades (1940 to 2010)



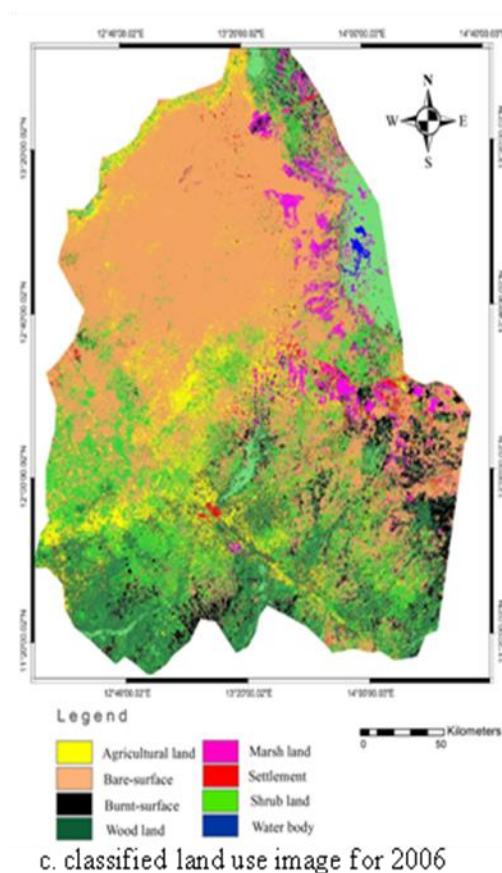


Figure 6 Land use maps of 1986, 2001 and 2006 of the study region

Rainfall totals were relatively high in the 1940s to 1960s and very low in the 1970s and 1980s (Fig. 5). In the 1990s, a gradual increase is noticed and this continues till 2010. This result shows that there is a decline in the amount of rainfall for the region when comparing the first three decades (1940s, 1950s and 1960s decades) with the last set of decades. Available researches shows not only increasing temperatures and decreasing rainfall amount as confirmed by this paper but also pointed out that these climatic changes have started reducing water resources (Chindo and Nyelong 2005; Odjugo 2007), biodiversity (NEST 2003) and coastal mudation (IPCC 2007).

3.2. The magnitude of desertification and change detection

Classified images of land use change of Northern Borno for the three years (1986, 2001 and 2006) were generated (Fig. 6) and the individual class area in percentage and change statistic for the three periods are summarized in Table 1. From 1986 to 2006 the result shows that a substantial change in the land cover and desert encroachment has occurred in the study region. From 1986 to 2001 and 2001 to 2006 agricultural land area decreased by 3.25 percent and increased a little by 0.57 percent respectively. The total percentage change for this land use from 1986 to 2006 is 3.08 percent decrease. Bare surface which represents desert area in this paper, increased by 1.91 percent from 1986 to 2001 and between 2001 and 2006, it increased by 14.2 percent.

Overall, from 1986 to 2006 desertification has increased by 16.11 percent (Table 1). A careful observation of Table 1 reveals that in 1986 and 2001 the area covered by shrub vegetation is approximately 35 and 37 percent respectively, while the desert area coverage for these periods were as low as approximately 15 and 16 percent respectively. In 2006, the area covered by shrub drastically reduced (to 11.35 percent of the overall area), while desertification rapidly increased and covered the larger percentage of the total region (31.19 percent).

Table 1 Summary of land use maps classification area statistics for 1986, 2001 and 2006

S/N	Land uses	1986 (%)	2001 (%)	2006 (%)	% change between 1986 -2001	% change between 2001 - 2006	% change between 1986 - 2006
1	Agricultural land	8.78	5.13	5.70	- 3.25	+ 0.57	- 3.08
2	Bare surface	15.08	16.99	31.19	+ 1.91	+ 14.2	+ 16.11
3	Burnt surface	4.05	1.03	5.56	- 3.02	+ 4.53	+ 1.51
4	Marsh land	0.39	1.01	2.04	+ 0.62	+ 1.03	+ 1.65
5	Settlement	0.57	0.77	0.98	+ 0.2	+ 0.21	+ 0.41
6	Shrub land	35.09	37.37	11.35	+ 2.28	- 26.02	- 23.74
7	Water body	0.71	0.16	0.14	- 0.55	- 0.02	- 0.57
8	Wood land	2.82	2.35	4.13	- 0.47	+ 1.78	+ 1.31

(+) Percentage increase; (-) Percentage decrease

Substantial differences in terms of reduction in vegetation cover and other land use changes, such as, water bodies, burnt surface and wetlands or marsh lands could be observed when the three set of images (in Fig. 6) are compared. Fig. 6a represents the base year and Fig 6b and c represent the years for comparison and platforms for change detection.

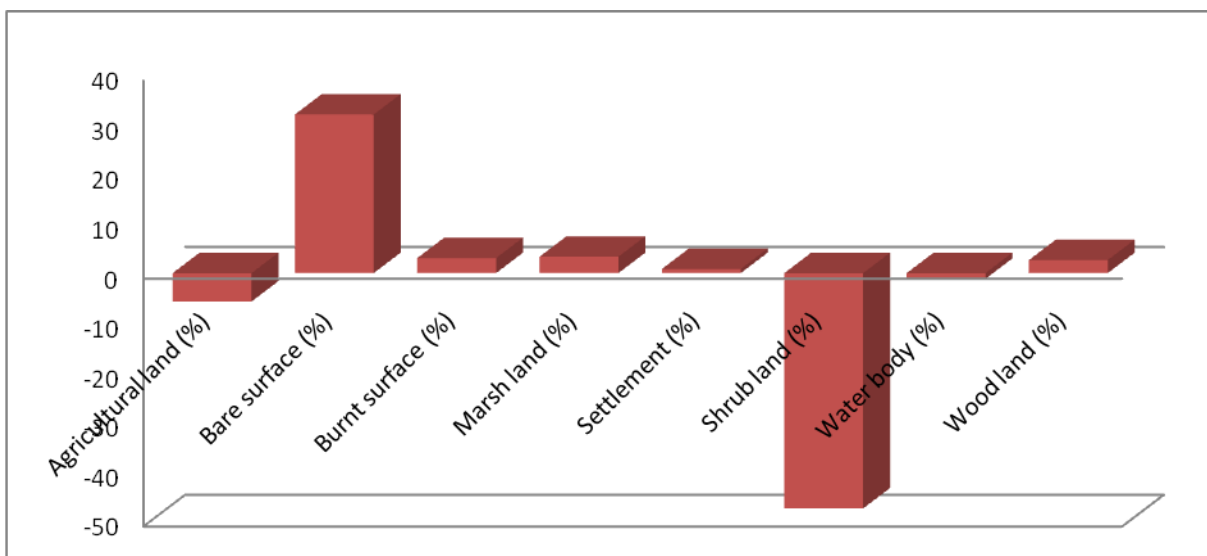
**Figure 7** Percentage change in the various land uses for the region

Table 2 and Fig. 7 show various levels of change (in percentage) of the land use that have occurred in the study region for the 20 years period. Table 2 shows that agricultural land cover increased by + 0.57 and decreased by – 6.33, desert area increased by + 32.22 and decreased by 0.00, burnt surface increased by + 6.04 and decreased by – 3.02, marsh land increased + 3.3 and decreased by 0.00, settlement increased by + 0.82 and decreased by 0.00, shrub land increased by + 2.28 and decreased by – 49.76, water body increased by 0.00 and decreased by – 1.14, wood land increased by + 3.09 and decreased by – 0.47. Overall, agricultural land, shrub land and water bodies show decrease in it areal extent, while bare surface, marsh land, settlement and wood land show increase in areal size throughout the periods under study. The reason for the observed increase in marsh land maybe attributable to

the drying up of water bodies. The observed increase in bare surface and settlement maybe responsible for the observed decrease in the shrub and agricultural lands.

Table 2 Summary statistics of the degree of land use changes in the region

S/N	Change	Agricultural land (%)	Bare surface (%)	Burnt surface (%)	Marsh land (%)	Settlement (%)	Shrub land (%)	Water body (%)	Wood land (%)
1	Increase	+ 0.57	+ 32.22	+ 6.04	+ 3.3	+ 0.82	+2.28	0.00	+ 3.09
2	Decrease	- 6.33	0.00	- 3.02	0.00	0.00	- 49.76	- 1.14	- 0.47
3	Total Change	-5.73	+ 32	+3.02	+3.3	+0.82	-47.48	-1.14	+2.62

(+) Percentage increase; (-) Percentage decrease

3.3. Climate change and desertification

There is gradual change in the climatic parameters used in this study and this change has initiated a substantial increase in desertification. The trend of changing shrub land to bare land is rapidly increasing. The climatic parameters revealed that climate change in the study area became intense in the 1970s and has since shown continuous increase. Annual mean temperature (Fig. 3c) shows consistent rise for about 40 years-from the 1970s to 2010 with a slight drop in the 2000s decade. The rainfall trend line of Fig. 4 shows a gradual decline in the amount of annual rainfall for the region. The result of this change in climate within this time frame can be linked to the magnitude and growth of bare land in the region. Drawing from the results of the analysis and conclusions from other researchers, that consistent increase in the temperature of an area and a decrease in the amount of rainfall leads to desertification (Giuseppe et. al., 2008; Verbist et. al., 2008; Odjugo 2005; 2010), this paper concludes that the observed climate change account for the desert encroachment in the region.

4. CONCLUSION

Climatic data and multi temporal remote sensing data were employed to estimate the impact of climate change on desertification in Northern Borno. The use of these two categories of data has provided an understanding of the level of contribution that climate change exert on desertification. Although, anthropogenic factors play a vital role in influencing the rate of desert encroachment but climate change is more wide spread and severe because it introduces excess heating and water shortage and these are prerequisite to the depletion of vegetation cover and consequently leading to drought. Results of this paper showed that the overall severity of the land surface which became bare in the study region worsened during the study period from 1986 to 2006 and this was highly facilitated by extreme climatic condition. Overall bare land which is an indicator of desertification is currently occupying over 31 percent of the total land mass of Northern Borno. The degree of desert encroachment over time is becoming alarming and worrisome. For instance, the study revealed that in the first decade under study, desertification increased by less than 2 percent and in the subsequent decade, the desert coverage increased from approximately 17 percent to over 31 percent (i.e. it doubled within this period). The study region, in general, is exposed to a high risk of environmental degradation.

This study recommends that modern knowledge base institutions should be put in place to properly handle information pertaining to climate change and desertification. Such institutions should be able to monitor and predict changes that are taking place or about to take place using modern technologies like geographic information systems and remote sensing. Intensified soil conservation mechanisms should be in place and existing ones strengthen; afforestation and reforestation programmes should go beyond the annual "rituals" of tree planting taking place in the month of June/July every year to more proactive measures. It is also necessary to compare the case of Northern Borno with other northern states in the country that are experiencing similar environmental menace. It is hoped that the application of geo-spatial technology to desertification study as it relate to climate change as demonstrated in this paper will open up a new frontier of comparative researches in the country and globally so as to reveal hidden patterns of land degradation and other environmental degradation processes.

SUMMARY OF RESEARCH

1. Nigeria is prone to desertification and this has been exacerbated by climate change
2. Many studies in the existent literatures on desertification in Nigeria have not adequately covered what the causal factors to desertification in Nigeria are and this is the area of relevance of the current study
3. Geospatial techniques in combination with archival observations of climate data are veritable tool to address the impact of climate vagaries to desertification which is desertification is expending southwards from latitude 12° 30' to 10° 30'

FUTURE ISSUES

Just as the IPCC has predicted that the African continent is most vulnerable to climate change as a result of weak infrastructural development for resilience against climate shocks, it is imperative that the effects and impacts of climate change research remains on the front burner of studies from the African continent in view of putting the government on their tools for sustainable development and genuine climate governance. This will help to measure the impacts of climate change and the adaptation approaches to be adopted in a sustainable manner.

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