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INTEGRATED REMOTE SENSING APPROACH TO DESERTIFICATION MONITORING IN THE CROP-RANGELAND AREA OF YOBE STATE, NIGERIA

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ABSTRACT

One of the most important recent issues facing Yobe State, North Eastern Nigeria, as well as Sub-Saharan Africa, is the threat of continued land degradation and desertification as a result of climatic factors and human activities. Remote sensing and satellites imageries with temporal and synoptic view, play a major role in developing a global and local operational capability for monitoring land degradation and desertification in dry lands, as well as in Yobe State. The process of desertification in Yobe State, especially in Yusufari, Nguru, Karasuwa, and Bade areas, has increased rapidly, and much effort has been devoted to define and study its causes and impacts. This study depicts the monitoring capability afforded by remote sensing to analyze and map the desertification processes in Yobe State by using supervised classification by maximum likelihood technique. Three cloud-free Landsat;Multispectral Scanner (MSS) sensor on board the Landsat-2, Thematic Mapper(TM)sensor on board the Landsat-5 satellite and Enhanced Thematic Mapper (ETM +) scenes covering the study area were selected for analysis. Imageries were acquired in January (the dry and rainy season in the study area) in years 1973, 1986, and 2006, respectively. Application of multi-temporal remote sensing data on this study demonstrated that it is possible to detect and map desertification processes in the study area, as well as in arid and semi-arid lands. The results emphasized the phenomena of sand encroachment from the northern part (Yusufari) to the southern part (Bade), following the wind direction. The increasing wind speed during the dry season is mainly attributed to the increase of sand encroachment in the study area. The study comes out with some valuable recommendations and comments, which could contribute positively in reducing sand encroachments, as well as land degradation and desertification processes in Yobe State.

Keywords: Environmental degradation, desertification, climate change, Remote & Sensing /GIS

INTRODUCTION

Nigeria is confronted with a number of serious environmental problems, which include drought, desertification (land degradation in dry-lands), sheet, gully, coastal erosion (land degradation in the humid and wetlands), and loss of bio-diversity. Others are poor environmental health and safety, urban waste pollution, climate change, and ozone depletion.

Drought and desertification have become major environmental problems in the northern part of the country. Desertification in Nigeria is overwhelmingly visible only in the extreme Northern states, which is why the federal government of Nigeria, in collaboration with Niger Republic, has initiated programs to combat desert encroachment. Their strategy was to establish shelter-belts for controlling land degradation and the development of environmentally sustainable model villages in Kano, Zamfara, Adamawa, Borno, Kaduna, Niger States, and Yobe State.

The level of ignorance suggests that the phenomenon of desert and desertification are not understood in our society. The picture that desertification or desert encroachment creates is one of sand dunes advancing over agricultural land and around the edges of the desert. This is, however, misleading as it implies a single process, instead of a constellation of processes. The desert edge does not advance exclusively; it is rather the combined effect of accelerated wind and water erosion, woodland destruction, water logging, and salinization of irrigated land. In other words, desertification is an embodiment of well-defined processes which operate singly, or in combination, on dry land regions to cause environmental degradation (natural processes under adverse climatic conditions by pressure).

Generally speaking, over cultivation, woodland destruction, poor irrigation practices, overgrazing, unsustainable development/public policy, alienated land ownership structure/ legislations, and wasteful energy policy all add to accelerate the processes already common in the dry land. These are the physical and biological degradation of soils, wind and water erosion, and soil salinization, even though the intensity and combination of causes and processes differ under different land uses. The areas that are mostly affected by desert encroachment include most parts of Katsina, Kano, Borno, Sokoto, Kebbi, Jigawa, Zamfara, Yobe, and Bauchi states of Nigeria.

In Northern Nigeria, widespread land degradation mainly attributed to deforestation, increasing agricultural intensity, and over-grazing livestock, combined with increasing demands for fuel wood, has led to a rate of deforestation estimated to be about 3.5 percent, which is one of the highest in the world (UNEP, 1993). Soils in the region are ferruginous tropical soils, generally of poor structure and low fertility. The hot and dry climate causes bare, unvegetated soils to easily heat up, especially during the dry season, resulting in soil baking. Coupled with high evaporation rates, the soil becomes powdery and easily blown away by the wind. Thus, in the absence of vegetation, wind and water erosion on exposed soils have had extremely detrimental effects, limiting plant growth and productivity. In the far northern areas, increasing sand dune formation is evident.

At least 50,000 farmers in about 100 villages scattered along the desert fringes of the northern part of Yobe state are currently at risk of abandoning this year's (2008) farming season due to sand dunes. The dunes have covered a large expanse of agricultural farmlands (Toye, 2002)."The dunes are threatening life supporting oasis, burying water points, and, in some cases engulfing major roads in the affected areas. Trees planted by the government as shelter-belts to check the advancing dunes are withering, due to lack of attention," (Toye, 2002).

The document, compiled by the Ministry of Environment in Yobe State, reveals that aerial photographs taken have indicated that productive and mass land occupied by the dunes have increased from 25,000 hectares to more than 30,000 hectares, with its attendant negative impact on food and livestock production. "Considering a conservative production of five bags of 100 kg of grain of millet or sorghum per hectare in the area, it means the 30,000 hectares destroyed by the dunes is capable of producing over 1,500 bags of 100 kg of millet. With an average grain requirement of one bag of 100 kg of millet per family of four per month, it then follows that 150,000 bags can support 12,500 families of four or 50,000 people per year. The big question is how would these 50,000 people survive in this area?"(Yobe State Ministry of Environment, 2001).

The aim of the project is to model the extent of desert encroachment in the crop rangeland of northeastern Nigeria, Yobe area, with a view to providing accurate information on the increasing trend of desertification to support the decision in desert encroachment combating programs in Nigeria. The stated aim shall be achieved through the following specific objectives:

i. identify and map the boundary of desert encroachment in Yobe State, between 1973 and 2006.

ii. compute the extent of desert encroachment in this area.

iii. proffer a planning solution toward combating and abating this environmental menace in this region.

STUDY AREA

The area encompasses the semi-arid region of Yobe State, located on latitude 11°45' N to latitude 13°30'N and longitude 9°30' E and 12°30'E (figure 1). The eastern boundary is immediate to Borno State, to the west is Jigawa and Bauchi States, and to the north boundary is the international border with Niger Republic. Due to the aridity of the region, the federal government of Nigeria, in conjunction with the European Economic Community (E.E.C) in 1992, provided funds to address the problem of development and to reduce the social impacts of aridity on the population in the area. More than 90% of the population depends on rain fed agriculture, with millet and sorghum as the major grain crops and cowpea and groundnuts as the major legumes.

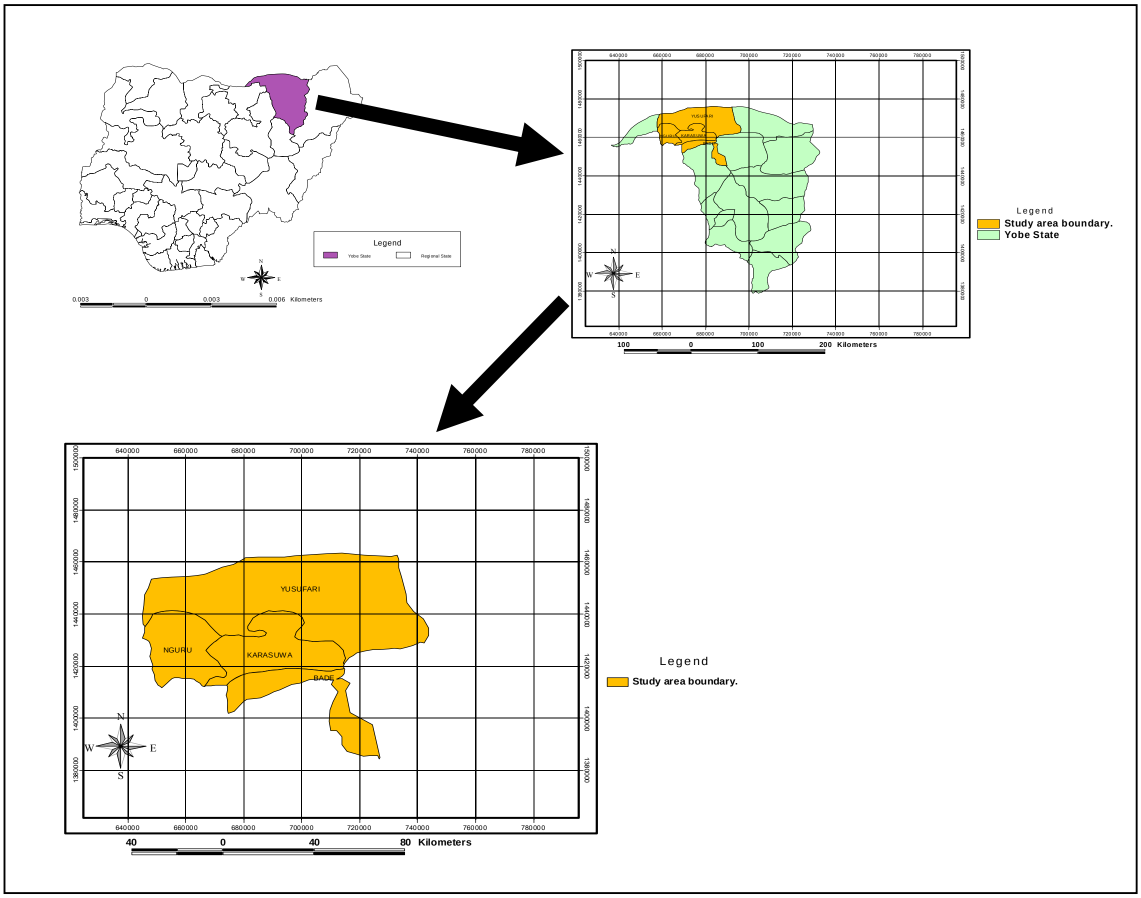

Fig 1: The Location of Yobe State and the Study Area.

Source: Author, 2008

In general, the landscape of the area ranges from flat to gently undulating plain, with the river system dissecting the dune fields. In the northern part of the area, there are extensive rolling sand plains with superimposed relict dunes. In the southern part of the area, the relict dunes are more pronounced, partly due to a change in climatic conditions with increased drought. The dunes have started to move in some places, encroaching against villages. Associated with rivers are the ‘Fadamas’ on flood plains, which are depressions connected to the rivers by shallow channels. In the wetland areas, the river flow is divided up between numerous small channels. The precise drainage (Fig.2) is probably changing all the time as some channels silt up, while others assume new importance (Diyam 1996). A notable example is the Burum Gana, which was formerly a major drainage channel parallel to Komadugu Gana and to the north. Now, virtually all of its flow is captured by the Marma channel, which flows into Nguru Lake.

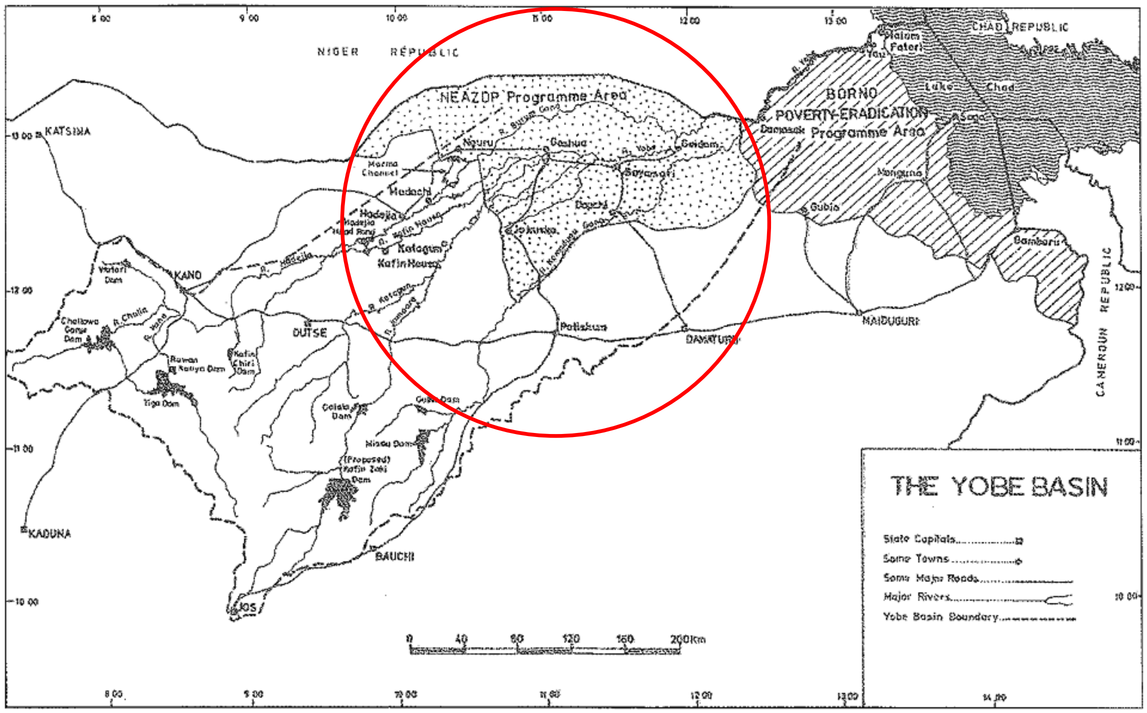

Fig. 2: Drainage pattern in the Study Area enclosed in Red Circle

Source: Federal Ministry of Water Resources, 2000.

RESEARCH METHODOLOGY

Data acquisition and pre-processing

Three cloud-free Landsat, MSS, TM, and ETM+, scenes covering the study area were obtained for analysis. The images were acquired in January and August, the dry and rainy seasons of the study area in 1973, 1986, and 2006, respectively. The MSS image consists of four bands; the characteristic of this image, compared to the others, is low in terms of spatial ground resolution and band widths (Table 1). Multispectral sensors collect data in a few spectral bands, which cover important regions of the reflected solar spectrum (about 350 to 2500 µm). Because these sensors provide data in multiple bands, the ground resolution is degraded and the total number of pixels per line for these sensors is less than that of panchromatic sensors. This is due to both the decreased light energy available in each band, as well as bandwidths. Therefore, the spectral resolution for space borne multispectral sensors is usually poorer than for panchromatic sensors. Multispectral sensors have been used, effectively, in studies of land degradation in arid and semi-arid lands.

TM and ETM+ imagery were acquired in seven and nine bands, respectively, covering the visible, near, and mid infrared regions of the electromagnetic spectrum. The utility of Landsat imagery for studying environmental changes in arid regions has long been suggested as a time and cost-efficient method. There are several justifications for the use of MSS and TM imagery in studies concerning human dimensions of environmental change.

Table 1: The main characteristics of the imagery used in the study

Instrument	MSS	TM	ETM+
Landsat	Landsat 2	Landsat 4	Landsat 7
Acquisition date	14 Jan 1973	20 Jan 1986	13 August 2006
Path / row no	188/50	175/50	175/50
Spectral bands((μm)	4 bands 1. 0.5-0.6 (green) 2. 0.6-0.7 (red) 3. 0.7-0-0.8 (near-infrared) 4. 0.8-1.1 (near-infrared)	7 bands 1. 0.45-0.52 (blue) 2. 0.52.0.60 (green) 3. 0.63-0.69 (red) 4. 0.76-0.90 (near-infrared) 5. 1.55-1.75 (mid-infrared) 6.10-4-12.5 (thermal) 7. 2.08- 2.35 (mid-infrared)	9 bands same as TM , except : - Optical bands - Thermal - Panchromatic
Ground resolution	79m*79m	30m*30m	30m*30m
Dynamic range(bit)	7 bit	8 bit	8 bit

Source: Jain, A.K. (1989)

Field Work and Representative Training Sites

The field work, as one of the most important steps, was carried out in order to: choose representative training sites and to overcome the problems of time and season differences between the fieldworks and when the remotely sensed data were collected. The desertification conditions were carefully studied with attention being paid to various forms of sand dunes, sand covered areas, areas subject to erosion and sand dunes around bushes. Because of the dynamic nature of vegetation and due to the fact that desertified areas varying in the time and space, we used the data corresponding to the remotely sensed data for the training classes.

Techniques of Image Processing:

Spectral signature evaluation

In this study, the training samples were taken on the conventional False Color Composite (FCC) where field observations were made. A large enough sample is often needed because the distributions of the sample mean approached normality as the size of the sample increased. The sampling was performed by displaying the conventional FCC on the color monitor and, then, the training samples were carefully assigned.

Image Classification and Accuracy Assessment

The training samples used to estimate the statistical characteristics of the spectral classes were typical and represent the norm for each class. The MSS, TM, and ETM band combinations were examined for classification of MSS, TM, and ETM imagery with the same method. The accuracy per category was computed by the number of correctly classified pixels by the total number of pixels that were classified in each category (row total). The overall accuracy was also computed by dividing the total number of the correctly classified pixels of each class to the total number of classes.

RESULTS AND DISCUSSION

Extent of Desertification for the of period 1973 to 1986

The classified image of magnitude and direction, with reference to the years 1973 and 1986 (Figure 3 a&b), highlights intensive dynamics related to the different classes during these periods, characterized by the increase of sand and decrease in vegetation cover(Fig. 4) in the study area. The change image, as presented in Table 2, shows that the sand (desertification) class covers about 40.16% of the total area. Meanwhile, the vegetation and shrubs classes cover only 23.99% and 7.06%, respectively. Wetland/water and riparian vegetation constitute 11.82% and 16.97%. This indicates the trend of increasing sand encroachment in the study area during this period. Sand, in 1973 to 1986, covers 40.16% of the total area and it is dominant in Yusufari and Karasuwa areas in the northern and north-central part of the study area (Fig.5). The excessive sand encroachment might be due incessant rainfall, wind, and human impacts in the study area, such as farming and grazing (Figure 6a &b).

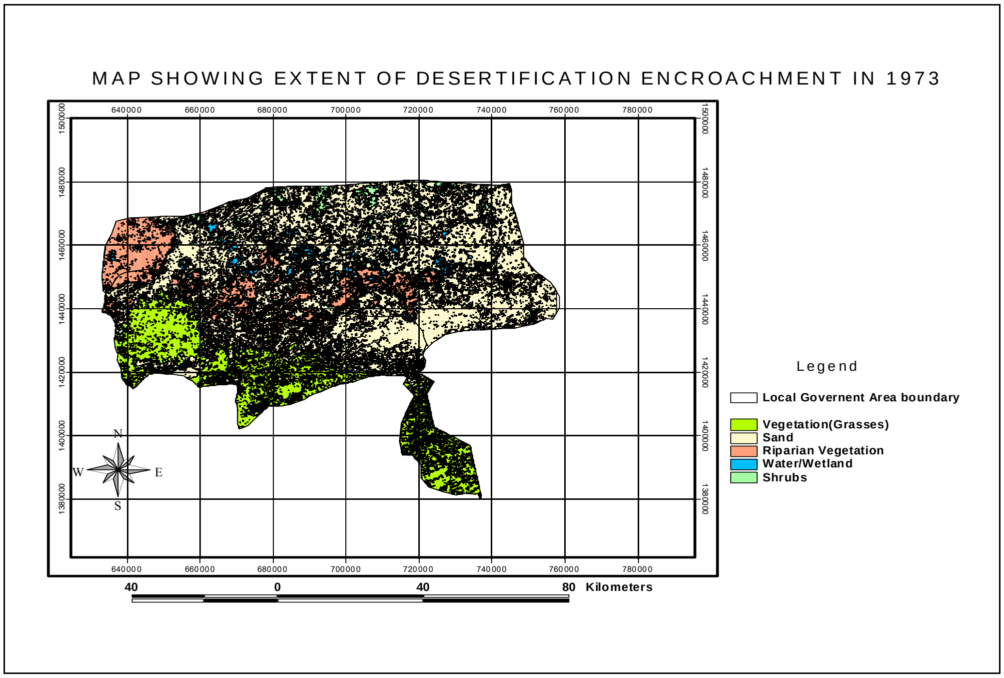

Fig.3a: Classified image of Desertification Extent for periods 1973

Source: Author, 2008.

Table 2: Landuse change Distribution between 1973 and 1986

Class name	Area (Sq.m)	Area (%)
Vegetation(Grasses)	384613	23.99
Sand(Desertified)	643801	40.16
Riparian Vegetation	189433	11.82
Water/Wetland	272089	16.97
Shrubs	113179	7.06
Total	**1603115**	**100.00**

Source: Author, 2008.

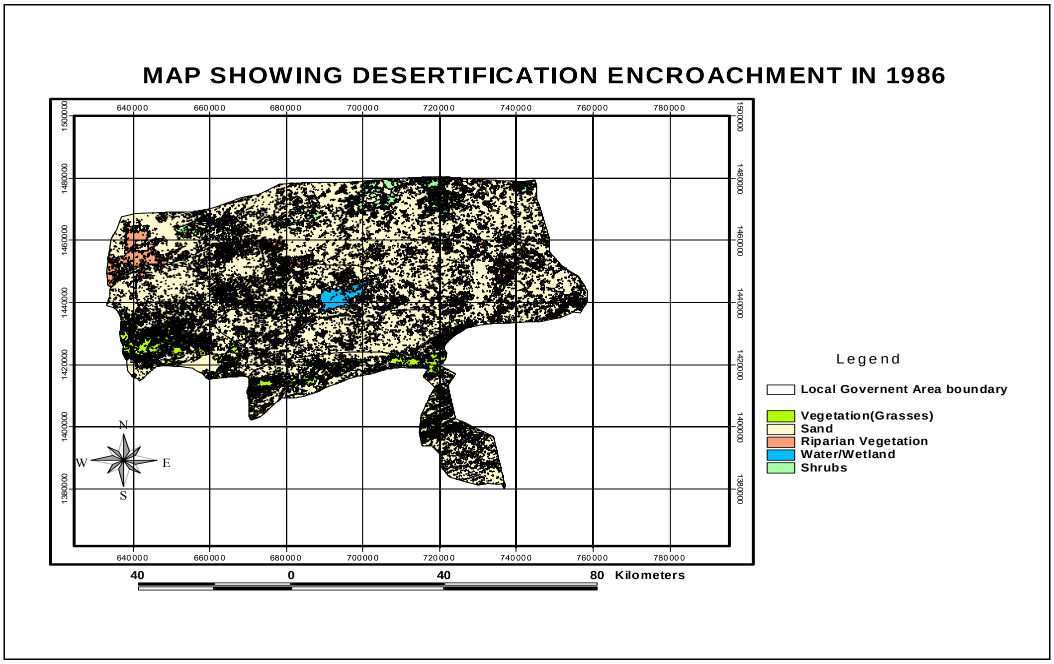

Fig.3b: Classified image of Desertification Extent for periods 1986

Source: Author, 2008.

Fig.4**: Vegetation cover in Bade,** vegetation is denser and dominated by Acacia tortilis (Photograph by the author, southern part of Bade, July 2007, rainy season).

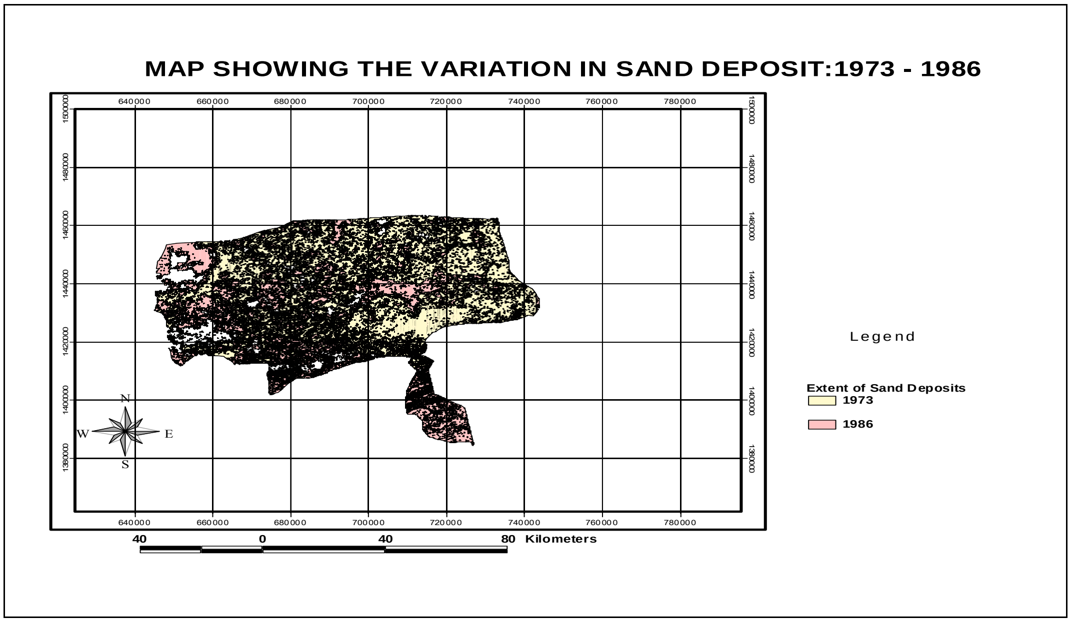

Fig.5: Variation of Desertification Extent for periods 1973-1986

Source: Author, 2008.

Fig.6a**:** clearance of trees for cultivation during dry Season around Bade area (Photograph by the author, Jan2007)

Extent of Desertification for the of period 1986 to 2006

The change image referring to the years 1986 and 2006 (Fig. 7), reflects different patterns of change in desertified (sand) and vegetation classes. The desertified class appears to have a very high intensity in the northern part of the study area. The vegetation (re-growth) class dominated in the southwestern part of the study area. Contrasting this with the changes in 1973 and 1986 revealed an increase in the vegetation (re-growth class) in the study area in the addressed period. Table 3 shows that the vegetation class covers 32.72% in the period of 1986 and 2006, compared to only 23.99% in period of 1973 and 1986. Nevertheless, the sand (desertified) class is decreased to 38.27%, during the periods 1986-2006, from 40.16%, during the period 1973-1986. The period 1986 to 2006, in comparison with the period 1973-1986, witnessed a decrease in the desertified areas and increase in the vegetation (re-growth) areas (Fig. 8). The vegetation cover in 2006 revealed relatively good coverage, compared to 1986.

In addition, shrub areas relatively increased from 7.06% during the period of 1976-1988, to 7.88% during the next period of 1986-2006, while the **riparian vegetation** and **water/wetlands** class decreases to 6.66% and 14.46% respectively between 1986-2006, from 11.82% and 16.97% respectively recorded during the period 1973-1986.

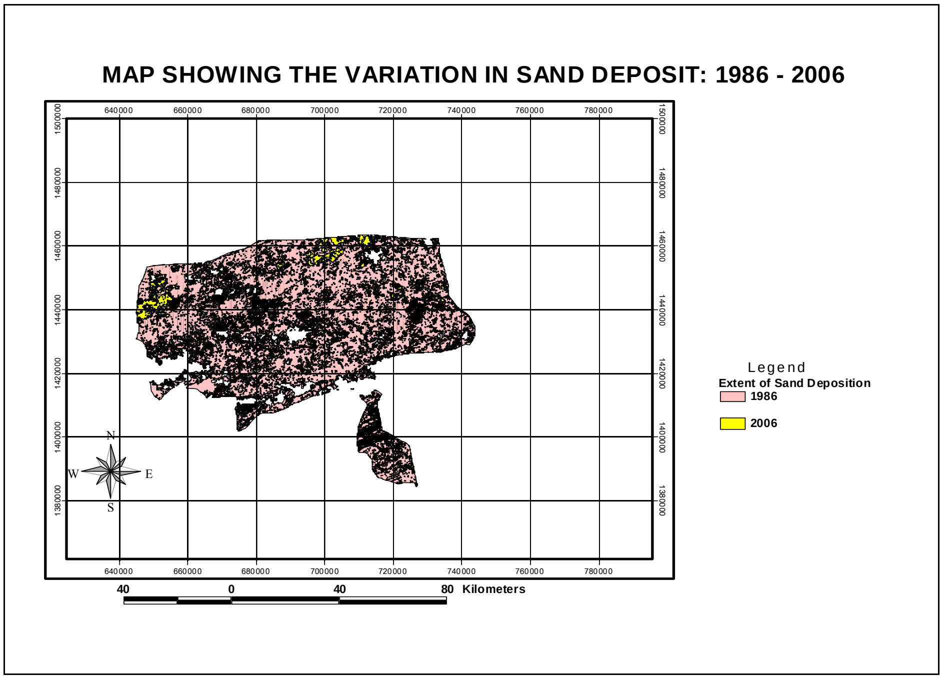

Fig.7: Variation of Desertification Extent in 1986 and 2006.

Source: Author, 2008.

Class name	Area (M^2)	Area (%)
Vegetation(Grasses)	524529	32.72
Sand(Desertified)	613583	38.27
Riparian Vegetation	106756	6.66
Water/Wetland	231859	14.46
Shrubs	126388	7.88
Total	**1603115**	**100.00**

Table 3: Distributions of classes of change image 1986 and 2006

Source: Author, 2008.

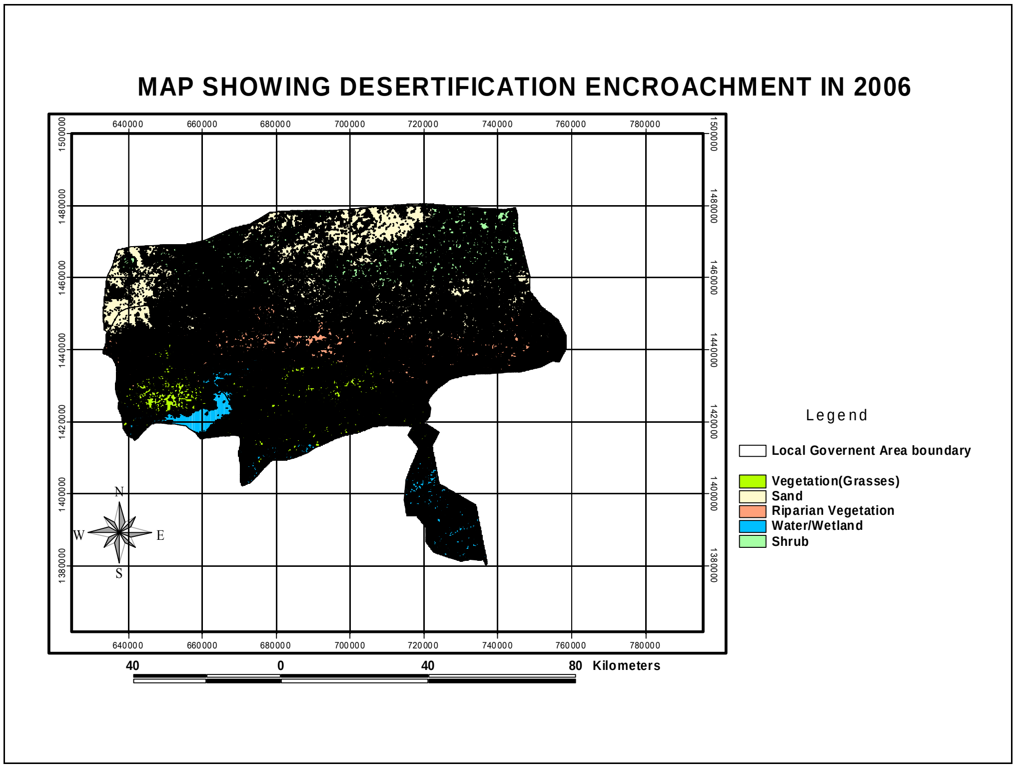

Fig.8: Classified image of Desertification Extent for period 2006

Source: Author, 2008.

Discussion of dynamics of change

Dynamics of change during the period 1973-1986

Based on the visual interpretation of the changed map for the period 1973-1986, in addition to information obtained during field surveys, secondary data, and relevant literature, it can be indicated that a rapid encroachment of sand and high decrease of vegetation cover in the study area is evident. Figure 5 includes a subset of the change map of 1973-1986, showing the most affected areas with desertification in the northern part of the study area. In this regards, findings have illustrated that the sand encroachment has been rapidly increased during the period of 1973-1986. In the northern part of the study area, the pattern of change evidently highlights the pressure of human interferences and its negative effects on fragile natural resources. These pressures are related to overgrazing by livestock and rain fed agriculture (Figure 6a &b). Continuous over grazing of rangelands in Karasuwa area, during the wet seasons, result in degradation of vegetation cover and exposed the soil to wind erosion. Rangelands degradation is further aggravated by the expansion of the areas under shifting cultivation and, thus, leading to the destruction of vegetation cover in these areas. In arid conditions vegetation provides protection against degradation processes such as wind and water erosion.

RECOMMENDATIONS

Intensive land-use in fragile ecosystems, such as in Yobe State, obviously accelerates desertification and the land degradation processes. The decrease in vegetation cover, simultaneously with increasing exposure of soil surface, will certainly increase the wind erosion and sand encroachment in the study area. Despite this severe problem, efforts should be exerted to study and assess the desertification processes in Yobe, as well as in arid and semi-arid regions, in order to mitigate this problem. Based on the findings, the following recommendations were made:

1. Application of remote sensing as accurate, low-cost, and safe techniques to assess and monitor the desertification processes in semi-arid areas provides valuable information on suitable land-use/land-cover management to conserve the natural resources in the study area.

2. Application of remote sensing with extensive focus (in situ) on desertified areas is more effective than a widespread global one.

3. Use of high resolution and more advanced remote sensing data (such as hyperspectral imagery) for monitoring desertification and land degradation.

4. Establishment of more extensive regional monitoring networks to collect baseline data relevant to all aspects of desertification, specifically in the study area and Sahel region of the country, in general.

5. Establishment of shelterbelts and windbreaks by cultivating suitable species, such as Maerua crassifolia, Leptadena pyrotechnica, and Acacia tortilis, to avoid wind erosion and to protect the study area from desert encroachment.

6. Enhancement of rehabilitation programs by forest administration and agricultural sector to protect the natural forest in the area with more emphasis on community participation.

CONCLUSIONS

Spatial data and multi-temporal analysis of remote sensing data were allocated to understand the phenomena of the desertification processes in Yobe State. Supervised classification by maximum likelihood technique was adopted to map and analyze the desertification processes using the above mentioned data. Combinations of multispectral mixture analysis of Landsat imagery and field observations enlightened the nature and causes of the desertification processes in the study area in the years 1973, 1986, and 2006. Dynamics of desertification, in the relationship between man, animal, and vegetation, as determinant factors of desertification in the study area were analyzed and discussed. The results showed a noticeable significant decrease in vegetation fraction in 1973, 1986, and 2006, respectively, while sand fraction was rapidly increasing during the same periods. This concludes that desertification can be recognized by the reduction of total vegetation cover and exposure of bare sand soils.

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