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Analysis of land use and land cover change in the Sahel: a case study of Yobe State, Nigeria

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ABSTRACT

The study analyses the extent of land use and land cover change in the Sahel and the factors influencing the changes. To achieve this, a remote sensing technique was employed. The Landsat Thematic Mapper Image of 1986, Landsat Enhanced Thematic Mapper Image of 2002 and Landsat Enhanced Thematic Mapper Image of 2019 were collected and analysed. Six classes of land use and land cover were obtained using Earth Resource Development Assessment System Imagery 9.1 software. The result shows that there was a decrease in the land area occupied by wetland, shrub-land and water body, while there was an increase in the land area occupied by bare land/dune, settlement and scattered cultivation from the year 1986 to 2019. Increase in bare land/dune, scattered cultivation and settlement were mainly as a result of climate change, overgrazing, a southward movement of dunes from the Sahara desert, increasing farming activities and increasing demand for shelter by the increasing population. The decrease in shrub-land, water body, and wetland was mainly as a result of climate change, increasing deforestation, and increasing use of wetland for farming

activities. Based on the results of the analysis, it is recommended that measures should be taken to integrate sustainable land management and climate change adaptation options into the local government plans.

Keywords: Climate change, Land cover, Land use, Environmental sustainability, Land degradation

1. INTRODUCTION

Land use involves the management and modification of natural environment or wilderness into the built environment (Garba and Brewer, 2013). On the other hand, the land cover is the physical features of the earth surface, which include grasses, trees, bare ground, water, etc (Garba and Brewer, 2013). Change in land use/land cover is a very important driver of environmental change at the global level (Lambin et al, 2001; Lambin et al, 2006). Changes in the form and structure of land use/land cover may affect climate, flora and fauna, human livelihood, biogeochemical cycles and energy fluxes (Vitousek et al., 1997). Moreover, the changes in land use/land cover impacts negatively on the ecosystems at local, regional and global scales (Kasperson et al., 1995). Studies have shown that few landscapes on the earth are currently in their natural state, due to human activities and climate change (Cordonnier et al, 2017). Thus, the human use of land has a profound effect on the natural environment (Wijitkosum, 2016). The Increasing rate of the soil, air, and water pollution are the result of land use/land cover changes. Moreover, biodiversity is high on land that is relatively undisturbed, but low on land that is more intensively used such as, urban centre, farmland, deforested land, etc.(Ellis, 2011). According to United Nation Framework Convention on Climate Change report, land-use change due to deforestation in the tropics is the major contributing factor to carbon dioxide emissions in the 1990s, which averaged between 0.5 and 2.7 Giga tone of carbon (Gtc) per year (UNFCCC, 2009). Consequently, changes in landuse/land cover determine the vulnerability of people and their environment to socio-economic and political perturbations (Lambin and Geist, 2006). Furthermore, the changes result in land degradation, which alters ecosystem services and affect the ability of biological systems to support human needs (Lambin and Geist, 2006). Thus, land degradation is a major environmental problem in the Sahel region of Nigeria (Eze, 2018).

Studies (Odjugo, 2003; IPCC, 2014 Eze et al. 2020) have shown that climate change, land degradation and land use/land cover change remain inseparably linked through feedbacks between land degradation and precipitation. As severe weather events increase in frequency and severity due to climate change, dryland degradation tends to increase (IPCC, 2014). Odjugo, (2003) argues that climate change might worsenthe land use/land cover change through the modification of temperature, rainfall, solar insolation, and winds pattern in time and space. Conversely, land use/land cover change aggravates carbon dioxide (CO2)-induced climate change through the release of CO2 from cleared and dead vegetation and reduction of the carbon sequestration potential of bare land (Odjugo, 2003). The result is more greenhouse gases in the atmosphere, and a continuation of the vicious cycle involving climate change and land use/land cover change (IPCC, 2014).

In the Sahel, the demand for limited resources by the inhabitants, compounded by incidences of droughts and influx of migrants, particularly, herdsmen have resulted in continuous overexploitation of environmental resources in the region (Eze, 2018). The overexploitation of the environment has degenerated into land degradation (Yusuf, 2014). Land degradation has, in turn, aggravated the problem of desertification. The pressure of migrating human and livestock populations have led to intensive use of the fragile environment resulting in further degradation even during years of normal rainfall (Olagunju, 2015). Therefore, on the process of land-use practices, there is a need to minimize depletion of non-renewable resources, and use sustainable practices for managing renewable resources in the Sahel environment to achieve environmental sustainability. Environmental sustainability is defined in this study as the ability to maintain the rates of the harvest of renewable resources, waste generation, and depletion of a non-renewable resource without exceeding the rate of regeneration, and assimilation capacity of the environment.

Studies on land use/land cover have been conducted in different parts of the world (Lambin et al, 2001; Islam & Weil, 2002; Wu & Tiessen, 2002; Lambin et al, 2006; Cotler & Ortega-Larrocea 2006; Vera et al 2007; García-Ruiz, 2010;Liu et al 2010; Musa & Shuaib, 2010;Wijitkosum, 2012; Wang et al, 2012).Majority of the studies concentrated on the impacts of land use/land cover change on soil erosion, soil degradation, soil quality, biodiversity. Little or no work has been done on the extent of land use/land cover change and the factors driving the changes in the Sahel region. Food and Agricultural Organization (FAO) states that there is a need to understand the relationship between land degradation land use and land cover change. It will help in developing a policy that will enhance sustainable forms of land use (FAO, 2017). Moreover, the knowledge of key drivers of land use and land cover change is essential for land use planning (Kleemann et al 2017). Against this background, this research assesses the extent of land use/land cover change and the drivers of these changes, to come up with the strategies to conserve land resources in the Sahel region.

2. MATERIALS AND METHODS

The Study Area

Yobe State is located in North-eastern Nigeria. It is situated on latitudes 10°30'N to 13°25'N and longitudes 9°35'E and 12°30'E. The study area is surrounded bythe Niger Republic to the North, Bauchi State to the west, Gombe State to the southwest, Jigawa State to the northwest, and Borno State to the east, (Figure 1). The landmass of the study area is 47,153 square kilometres with a population of 2,532,395 as at 2006 population census. It has a population density of 29.92 persons per square kilometre.

The climate of the study area is classified as a semi-arid climate. It is characterized by two major seasons, namely, the dry and wet seasons. The dry season lasts for about 9 to 10 months; while the wet season lasts for only 2 to 3 months. The mean annual rainfall is less than 500mm (Ayoade, 1988; Anyadike, 1993; Eze, 2018). The mean annual temperature is about 28°C. Evapotranspiration exceeds the rainfall amount in the study area. The vegetation of the study area is predominantly Sahel savanna, with few areas in the southern part under Sudan savanna. The vegetation consists of shrubs and other trees adapted to semi-arid regions of Africa (Nwaka, 1991). Farming is the predominant economic activities of the people in the study area. However, the study area is prone to drought and desertification. Consequently, the inhabitants and their livelihood are vulnerable to drought and desertification (Musa and Shaib 2010).

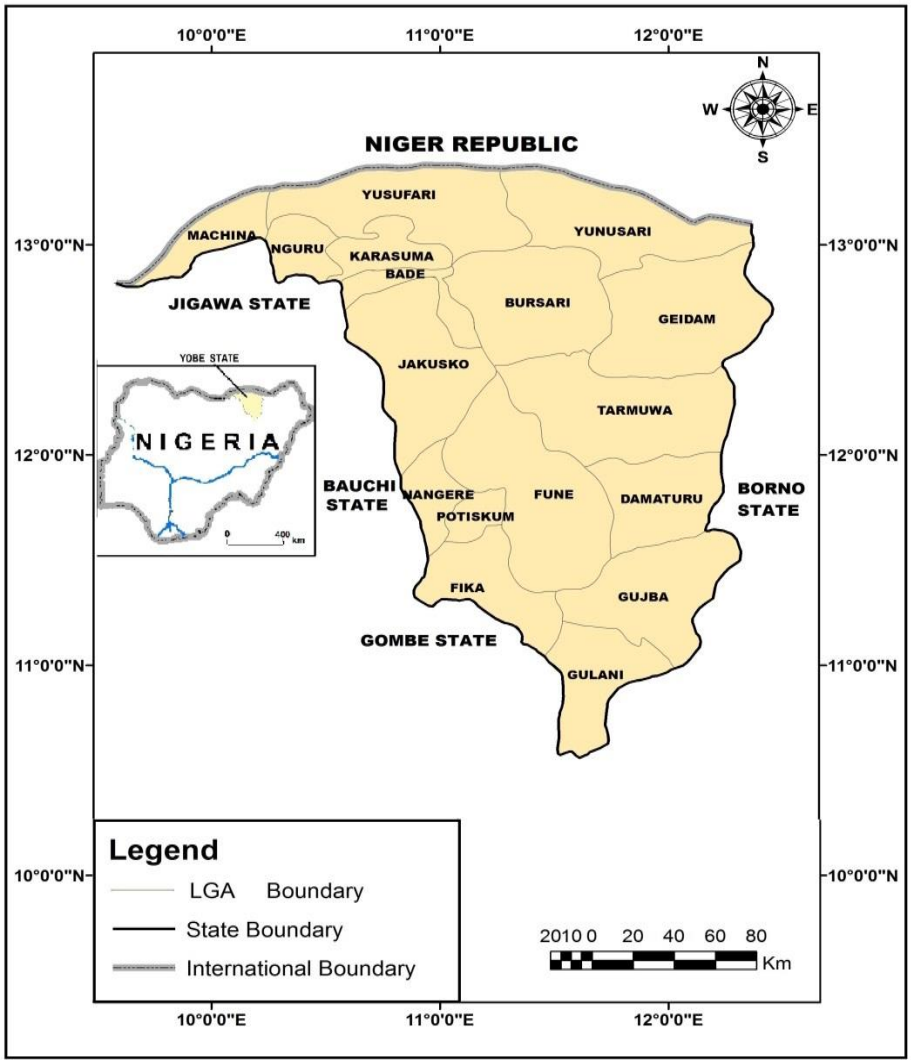

Figure 1 The study area

Data Collection

The satellite data (Landsat Thematic Mapper (TM) Image of 1986, Landsat Enhanced Thematic Mapper (ETM) Image of 2002 and. Landsat Enhanced Thematic Mapper (ETM) Image of 2019) were utilized for the assessment of the extent of changes that have occurred and the drivers of these changes in the study area.

Data Analysis

Image Processing and Classification

Image processing was performed to derive land use and land cover classes using Earth Resource Development Assessment System (ERDAS) Imagery 9.1 software. A geometric correction was carried out to reduce the distortions necessary for image matching in the case of the multi-date images used. False-colour composites of all the satellite images were created. All the images used were imported from ERDAS format into the Integrated Land and Water Information System (ILWIS) format for image classification. Supervised image classification using the Maximum Likelihood method was carried out to produce the six distinct land use and land cover classes or themes namely; bare surface/dunes, settlement, wetland, cultivation, shrub-land and water body (Figure 2). A supervised classification foremost depends on the spectral values of the pixels that were selected to serve as training pixels in the sample. For each set of spectral input values, the distance towards each of the classes is calculated using Mahalanobis distance. The Mahalanobis distance was introduced by P. C. Mahalanobis in 1936 as a tool used in measuring a distance between a point (P) and a distribution (D), It is used to determine how many standard deviations away P is from the mean of D.

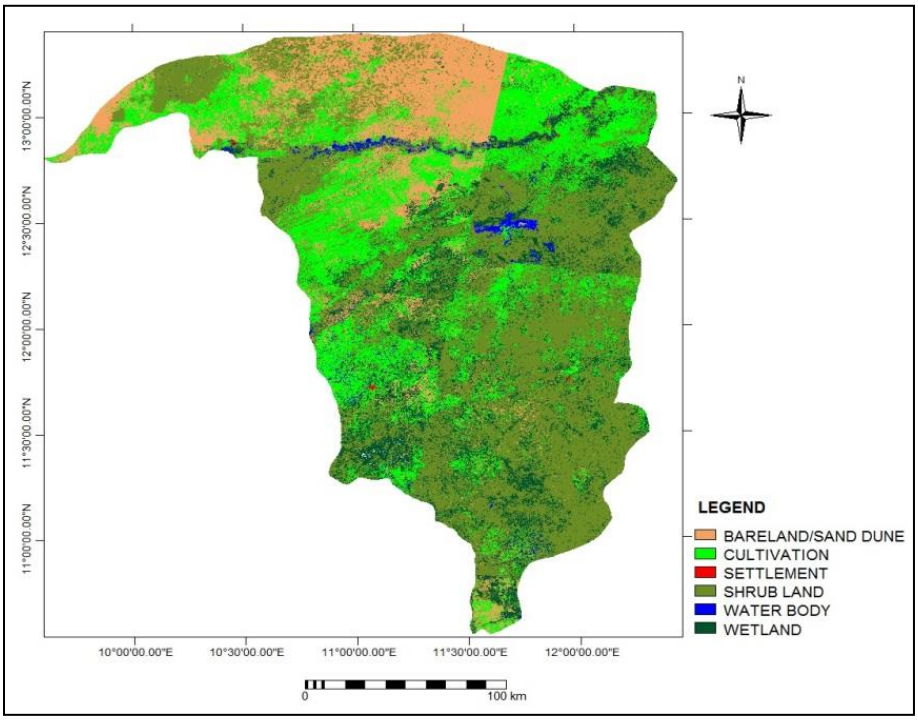

Figure 2 land use and land cover of the study area in 1986 *(Source: National Centre for Remote Sensing, Jos, Nigeria)*

3. RESULTS

Figures 2, 3 and 4 are maps showing6 classes of Land use and Land cover changes in the study area for the year 1986, 2002 and 2019 respectively. However, Table 1 shows the land use and land cover statistics (areas occupied in km^2 and in percentages). In 1986, shrub land occupied 20538.5km^2 (45.14 %), scattered cultivation 9736.4km^2 (21.40%), bare land/dune 7060.6km^2 (15.52%), wetland 5362.6km^2 (11.78 %), water body 1609.9km^2 (3.54%) and settlement 1194.3km^2 (2.62%), (Table 1-Figure 2). In 2002, shrub land occupied 17305.2km^2 (38.1%), scattered cultivation 12654.6km^2 (27.8%), bare land/dune 8417.5km^2 (18.5%), wetland4055.4km^2 (8.9%), water body 1336.4km^2 (2.9%), and settlement 1733.2km^2 (3.8%), (Table 1-Figure 3). In 2019, shrub land occupied 10471.6km^2 (23.01%), scattered cultivation17108.1km^2 (37.6%), bare land/dune10861.9km^2 (23.9%), wetland3153.5km^2 (6.9%), water body 1114.5km^2 (2.4%) and settlement 2792.7km^2 (6.1%) (Table 1, Figure 4).

Table 1 Land use and Land cover Statistics (in Km^2) of the Study Area in 1986, 2002 and 2019

Rank	LULC CLASS	1986	2002	2019	% change 1986/2002	% change 2002/2019	% Change 1986/2019
1	SHRUB-LAND	20538.5 (45.14%)	17305.2 (38.1%)	10471.6 (23.01%)	-7.1%	-15%	-22.1%
2	CULTIVATION	9736.4	12654.6	17108.1	6.4%	9.9%	16.2%

		(21.40%)	(27.8%)	(37.6%)			
3	BARE LAND / SAND DUNE	7060.6 (15.52%)	8417.5 (18.5%)	10861.9 (23.9%)	3.0%	5.3%	8.4%
4	WETLAND	5362.6 (11.78%)	4055.4 (8.9%)	3153.5 (6.9%)	-2.9%	-2.0%	-4.9%
5	WATER BODY	1609.9 (3.54%)	1336.4 (2.9%)	1114.5 (2.4%)	-0.6%	-0.5%	-1.1%
6	SETTLEMENT	1194.3 (2.62%)	1733.2 (3.8%)	2792.7 (6.1%)	1.2%	2.3%	3.5%
	TOTAL	45502.2 (100%)	45502.2 (100%)	45502.2 (100%)			

Source: Computed by the author

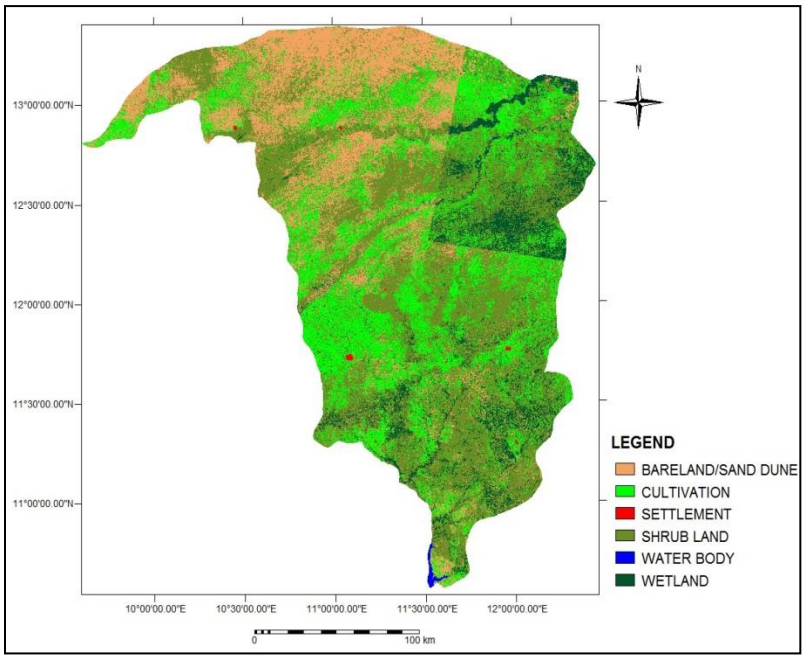

Figure 3 land use and land cover of the study area in 2002 *(Source: National Centre for Remote Sensing, Jos, Nigeria)*

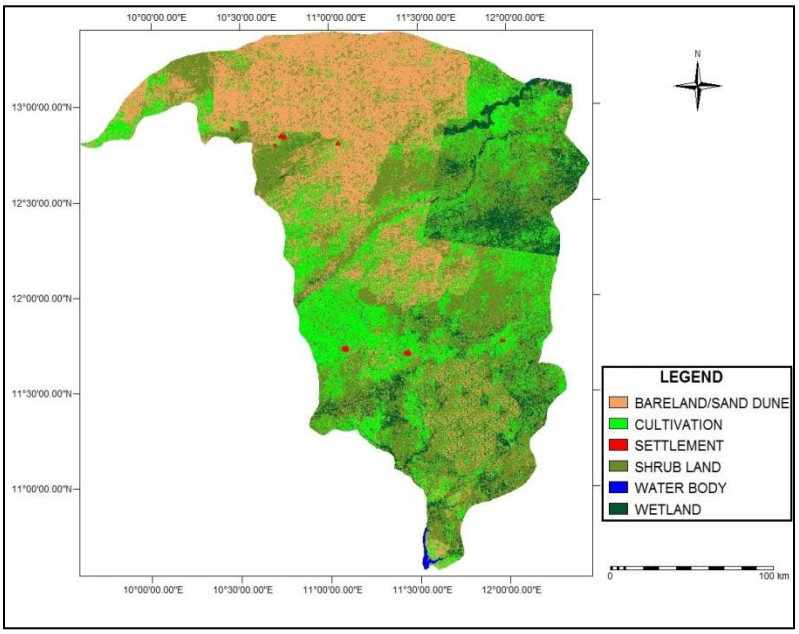

Figure 4 land use and land cover of the study area in 2019 *(Source: National Centre for Remote Sensing, Jos, Nigeria)*

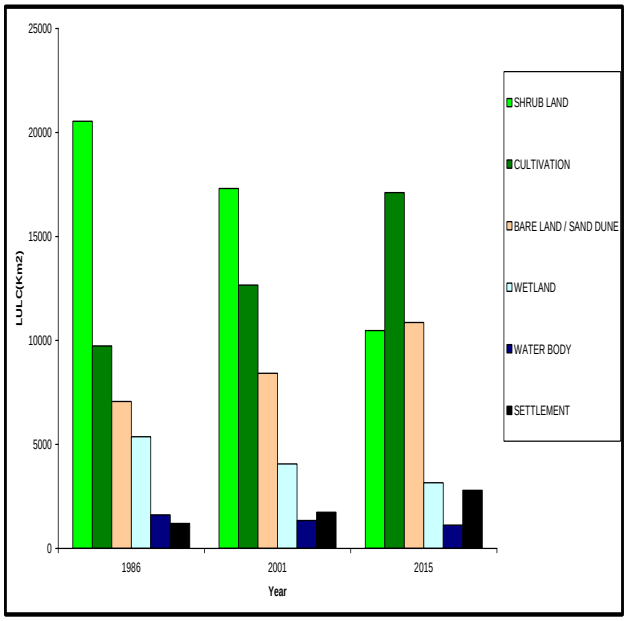

Figure 5 Summary of land use and land cover (in km^2) for the study area in 1986, 2002 and 2019 *(Source: Fieldwork 2019)*

Consequently, Figure 5 which is also explained in Table 1 shows the summary of changes that have occurred on land use and land cover in the study area for the year 1986, 2002 and 2019. The rate of increase/decrease between 1986 and 2002 were -7.10% (shrub land), 6.40% (cultivation), 3.00% (bare land/sand dune), -2.90% (wetland), -0.60% (water body) and 1.20% (settlement). The rate of increase/decrease between 2002 and 2019 were -15% (shrub land), 9.90% (cultivation), 5.30% (bare land/sand dune), -2.0% (wetland), -0.50% (water body) and 2.30% (settlement). Also the rate of increase/decrease between 1986 and 2019 were -22.1% (shrub land), 16.2% (cultivation), 8.4% (bare land/sand dune), -4.9% (wetland), -1.1% (water body) and 3.5% (settlement). Moreover, both increase and decrease occurred on land use and land cover in the study area Figure 5. Thus, the highest increase occurred on scattered cultivation while the highest decrease occurred on shrub land in 1986/2002, 2002/2019 and 1986/2019. On the other hand, the lowest increase occurred on settlement and the lowest decrease occurred on water body in 1986/2002, 2002/2019 and 1986/2019 (Figure 5).

4. DISCUSSION

There have been significant changes in the land-use and land cover in the study area. The changes between the year 1986 and 2019, particularly in bare land/dunes, show that the rate of increase is very high. In 1986, bare land/dunes covered 15.52% of the total land area. In 2002, bare land/dunes have increased from 15.52 to 18.5% and in 2019, it has increased to 23.9% which has covered about one-third of the total landmass. Thus, indicating a high rate of desertification in the study area. Moreover, shrub-land which occupied the largest part of the total land area in 1986 has reduced drastically to become the 3rd largest after cultivated land and bare surfaces in 2019. The area occupied by settlement in 1986 was more than doubled in 2019. The total areas occupied by cultivated land and bare surfaces almost doubled from 1986 to 2019. Also, the total areas occupied by wetland and water body from 1986 to 2019 have shown a gradual and steady decrease. These changes that have occurred in the study area between 1986 and 2019 could be attributed to different factors. These include climate change, overgrazing, increase in farming activities, increasing demand for shelter by the increasing population, increasing deforestation, increasing use of wetland for farming and a southward movement of dunes from the Sahara desert. IPCC, (2014) states that, as severe weather events increase in frequency and severity due to climate change, bare land/ dunes (dryland degradation) tends to increase. Also, Odjugo, (2003) argues that climate change might exacerbate land cover change (land degradation) through alteration of spatial and temporal patterns in temperature, rainfall, solar insolation, and winds. Conversely, land use and land cover change aggravate carbon dioxide (CO_2)-induced climate change through the release of CO_2 from cleared and dead vegetation and reduction of the carbon sequestration potential of degraded land (FAO, 2017). Moreover, more than 650 million people living in Africa are predominantly farmers and are dependent on rain-fed agriculture. The Africa continent is already affected by water scarcity and land degradation, which will be further exacerbated by overgrazing, deforestation, over-cultivation etc(FAO, 2017). Thus, changes in the natural environment are as a result of socio-economic and cultural forces such as overgrazing, poverty, high population growth, deforestation, migration and weak tenure

system (Agyemang, 2012). Moreover, increasing farming activities, bush fires, and climate variability contribute to land use and land cover changes (Eze et al, 2020). Also, Lambin et al (2001) argue that households' responses to financial opportunities, as facilitated by institutional factors, enhance land use and land cover changes. These changes are indications of increasing human pressure on dry land resources, unsustainable agricultural practices and the effect of physical factors on the environment, resulting from climate change, increasing dunes, increasing droughts occurrences, increasing farming activities, overgrazing, over-cultivation and deforestation (Eze, 2018). Consequently, the increase in bare land/dune, scattered cultivation, and decrease in shrub-land, water body, and wetland has exacerbated environmental unsustainability, leading to desertification in Yobe State, Nigeria.

5. RECOMMENDATIONS

Land use and land cover change can undermine environmental health. Moreover, land use and land cover dynamics are widespread, accelerating, and its processes driven by physical factors and human actions produce changes that impact negatively on the environment (Agarwal et al., 2002). Achieving environmental sustainability requires both local management and macro policy approaches that promote the sustainability of land resources and climate change adaptation (Eze et al, 2020). In this regards, the following measures should be followed to reduce the impact of climate change and achieve environmental sustainability on the face of land use and land cover change.

Poverty Reduction

Reduction of rural poverty, through livelihood diversification by creating economic activities that will generate employment for the households. These can be achieved through finance and technical assistance like loans and capacity building. When finance and technical assistance are given to the households, it will encourage them in going into small and medium scale businesses such as poultry farming, fish farming, production of local briquettes (to solve the immediate household problems of unaffordable fuel and dependency on firewood), trades and services, which on its own will generate employment.

Alternative Sources of Energy

Promotion of alternative sources of energy (use of coal stoves, local briquettes, gas cookers, biogas digesters, box-solar cookers, off-grid solar power plant) to reduce human impact on the remaining woody biodiversity resources is needed. Therefore promotion of alternative sources of energy will contribute towards development aspirations of the study area in many important ways. 1. An alternative source of energy will enhance protection of trees that can be cut down for firewood or charcoal production. 2. Use of briquettes will protect the state's forest, savanna and dryland habitats. 3. Use of renewable energy technology will ease the energy demand from fossil fuels and grid electricity.

Environmental Education and Awareness Creation at the Grass-Root Level

There is need to enlighten the communities on the sustainable agricultural practices, use of woody resources and abandon the environmentally unfriendly activities such as persistent cutting down of trees for firewood/charcoal production, overgrazing, over-cultivation etc. Education and awareness creation will help the households adopt improved approaches for environmental sustainability.

Adoption of Ranching System

In the study area, the predominant grazing type is continuous. This is a grazing type where cattle graze freely from one place to the other. This continuous grazing has contributed to over-grazing and has also caused a lot of communal clashes not only in the study area but in the country as a whole. Therefore, adoption of the ranching system particularly silvopasture is necessary. Silvopasture is a type of ranching system whereby the farmer combines forestry practice and grazing of animals conjointly in a particular area. This type of ranching system maintains the biodiversity, soil fertility and increase animal production and income. The development of cattle ranches will also remove the problems of overgrazing and communal clashes in the study area and Nigeria in general.

6. CONCLUSION

In the study area, land use and land cover have recorded significant changes between the year 1986 and 2019 on bare land/dunes, shrub-land, scattered cultivation, wetland, water body and settlement. Generally, shrub-land, wetland and water body showed a decrease in the landmass between 1986 and 2019 while scattered cultivation, bare land/dune and settlement showed an increase in the landmass between 1986 and 2019. Thus, the highest increase in land use/land cover occurred on scattered cultivation while the highest decrease in land use/land cover occurred on shrub-land. Increase in bare land/dune, scattered cultivation and settlement

were mainly as a result of overgrazing, a southward movement of dunes from the Sahara desert, increasing farming activities and increasing demand for shelter by the increasing population. The decrease in shrub-land, water body, and wetland was mainly as a result of increasing deforestation, increasing use of wetland for farming activities, climate change, and also the southward movement of dunes from Sahara desert.

Thus, the changes in land use and land cover in the study area were indications of increasing human pressure on dry land resources, unsustainable agricultural practices and the effect of physical factors on the environment, especially increasing dunes, increasing droughts, increasing farming activities, overgrazing, over-cultivation and deforestation. Consequently, these changes have exacerbated environmental unsustainability, leading to desertification in Yobe State, Nigeria.

The study has successfully used a remote sensing technique (satellite image processing and classification approach) to determine the extent of land use and land cover change in the Sahel and the factors influencing the changes. However, the degree of land use and land cover change and the factors influencing the changes have much to offer in terms of policy decisions. The study has also produced the spatial maps of land use and land cover change, which can be used for the reduction of the potential damage of desertification by integrating its outputs into spatial planning and emergency planning on combating desertification in the study area.

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Author's Contributions

Jude Nwafor Eze is the principal investigator. His contributions were encompassing (study design, data collection, also involved in the analysis, and the general compilations).

Patience Chinyelu Onokala is a co-investigator. Her contributions were mainly on the aspect of statistical analysis and literature review.

Conflict of Interest

We, write to attest that the article submitted to Discovery Journal for consideration has not been published previously. It is not under consideration for publication elsewhere and that its publication is approved by us (Jude Nwafor Eze and Patience Chinyelu Onokala) and openly by the authorities in charge where the research work was conducted. However, if the article is accepted for publication in your journal, it will not be published elsewhere in any other form in English or any other language, including electronically without the written consent of the copyright holder.

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