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Geospatial Assessment of Desert Encroachment in Dukku Local Government Area of Gombe State, Nigeria

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Abstract

Desertification is a major environmental hazard that the world is facing today and is a major threat in the arid and semi-arid regions. This research was carried out in Dukku Local Government Area, Gombe State to assess the rate of desert encroachment in the study area. The study was based on satellite imagery using GIS analysis. Multi temporal satellite was acquired from Land Sat images of 2000TM, Landsat image ETM 2010 and Landsat images 2020 OLI of Dukku vegetation cover. The NDVI (Normalised Differential Vegetation Index) shows changes in vegetation growth rate, the NDVI value ranges from -0.722 low to 0.806 high in (2000); -0.150 low to 0.665 high in (2010); and very thin of-0.133 low to 0.307 high in (2020). The NDVI indicates that forest cover decreases through of the three epochs while open space and bare surface increase. This indicates the rate of desert encroachment on the vegetation cover of the study area. The study recommended the modern farming techniques that emphasise conservation tillage as well as plantation forest in response to deforestation and desertification.

Keywords: Desertification, Encroachment, NDVI, Dukku, Gombe State

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Évaluation géospatiale de l'empiètement du désert dans la zone d'administration locale de Dukku de l'État de Gombe, au Nigéria

Résume

La désertification est un danger environnemental majeur auquel le monde est confronté aujourd'hui et constitue une menace majeure dans les régions arides et semi-arides. Cette recherche a été menée dans la zone d'administration locale de Dukku, dans l'État de Gombe, afin d'évaluer le taux d'empiètement du désert dans la zone d'étude. L'étude était basée sur l'imagerie satellitaire utilisant l'analyse SIG. Le satellite multitemporel a été acquis à partir d'images Land Sat de 2000TM, d'images Landsat ETM 2010 et d'images Landsat 2020 OLI de la couverture végétale de Dukku. Le NDVI (Normalised Differential Vegetation Index) montre des changements dans le taux de croissance de la végétation, la valeur NDVI varie de -0,722 bas à 0,806 élevé en (2000); -0,150 bas à 0,665 haut en (2010); et très mince de -0,133 bas à 0,307 plus haut en (2020). Le NDVI indique que le couvert forestier diminue à travers les trois époques tandis que l'espace ouvert et la surface nue augmentent. Cela indique le taux d'empiètement du désert sur la couverture végétale de la zone d'étude. L'étude a recommandé les techniques agricoles modernes qui mettent l'accent sur le travail du sol de conservation ainsi que sur la forêt de plantation en réponse à la déforestation et à la désertification.

Mots-clés: Désertification, Empiètement, NDVI, Dukku, État de Gombe.

INTRODUCTION

Desertification means the decline in the ability of the land to carry out ecosystem main functions and services that maintain the well-being of the society and its development specifically in the drylands (Adeel et al. 2005; Muhammad, Mohd, Azani, and Alias, 2021). Safriel (2009) refers to desertification to mean land degradation (LD) in the drylands (arid, semi-arid, humid, and sub-humid), as manifested by a determined decrease of biological productivity of the land. LD as defined by Raul and Koohafkan (2004) is the process of gradual or permanent loss of land productivity mainly due to anthropogenic activities, or from the disparity between land quality and the intensity of land use. LD may include such changes in the land as a decline in crop yield or a drastic reduction in the existing vegetative density in a particular area. LD as a prelude to desertification is the term that ascribes the lands affected by the reduction of primary productivity of the earth.

Drought and desertification have become major environmental problems in northern parts of Nigeria. Desertification in Nigeria is overwhelmingly visible only in the extreme northern states (Musa and Sahib, 2010). The visible sign of this phenomenon is the gradual shift in vegetation from grasses, bushes and occasional trees, to grass and bushes; and in the final stages, expansive areas of desert-like sand. It has been estimated that between 50% and 75% of Bauchi, Borno, Gombe, Jigawa, Kano, Katsina, Kebbi, Sokoto, Yobe, and Zamfara States in Nigeria are being affected by desertification (Audu and Adie, 2018).

Nigeria is one of the countries south of the Sahara faced with a rapid desert encroachment, with notable effects on the northern part of the country. Desertification phenomenon has been reported in northern Nigeria since 1920s, but the impact has been more glaring since the famine of 1971 to 1973 in this part of the country (Olagunju, 2015). Desertification affects fifteen northern states of the country (Jaiyeoba, 2002) and almost one-fifth of the total Nigeria land area is becoming desertified. These states supply most of the country's agricultural products such as beans, soya beans, tomato, melon, pepper, onion, cows, rams and many more. Though climatic variability contributes to desertification phenomenon, but this is aggravated by the unsustainable activities of human beings in the environment. Such activities include deforestation for industrial purpose and fuel wood, urbanization, bush burning, agro-activities on marginal lands and other unsustainable agricultural activities (Climate Change Challenge, 2012).

Nigeria is faced with a desertification problem accounting for about 68.38% of the country's total land area. However, the extent and severity

of desertification in Nigeria have not been fully established, neither is the rate of progression documented (Olagunju2015; Idris Medugu et al. 2011). The extent to which desertification is encroaching needs tobe measured and mapped to make proper planning for sustainable management planning (Muhammad, Mohd, Azani, and Alias, 2021).

According to Oladipo (1993), about 140,000km^2 of Nigeria is prone to severe desertification, particularly areas of latitude 12^{o}N. These desertification frontline States have a total landmass of 393,000km square and form a grazing area for about 90% of cattle population in the country. Brown (2006), the Nigerian livestock population grew from 6million to 66million between 1950 and 2006, an eleven (11) fold increase while her human population grew from 33million in 1950 to 140 million in 2006, and a four-fold expansion which has forced farmers to plough marginal land under the pressure to meet food needs. As a result, the country is slowly turning into a desert. The survival of humans and livestock are being threatened by desertification in these frontline States. These areas in the desert frontline States are characterized by a short erratic or uncertain rainfall period and long dry season. The annual precipitation in these areas could be as low as 200mm while the peak is about 600mm (Otegbeye, 2004).

A number of studies have been undertaking in the study area to assess desertification incidence on socio-economic development in varying degrees in Gombe State and other parts of the country. For Example, Blessing (2015) assessed the incidence of desertification in the Northern parts of Katsina State Nigeria, and found that desertification in the study area was exacerbated through anthropogenic activities like fuel wood exploitation which is their main source of energy for cooking, over cultivation and over grazing. Hadiza, Mohammed and Benedine (2018) studied assessment of desertification sensitivity in Jibiya Local Government Area, Katsina State, Nigeria, their studies found out that the study area was subjected to indiscriminate cutting down of trees and cultivation of average farmlands have caused frequent drought in the study area. Audu and Adie (2018) examined desertification in Northern Nigeria: causes and consequences, and found out that climatic variability, deforestation, extensive cultivation, overgrazing, cultivation of marginal land, bush burning, fuel wood extraction, faulty irrigation system and urbanization were identified as the major causes of desertification. However, none of the researches undertaken has used the Normalized Vegetation Index (NDVI) methodology to assess the incidence of desertification within the study area. This study thus applied NDVI technique to model desertification in Dukku Local Government area

by mapping out and assessing the changes in vegetation cover from 2000-2020. This study aimed to assess the geospatial rate of desert encroachment in Dukku Local Government Area of Gombe State. Hence, the specific objectives are: to map out the changes in vegetation cover of the study area from (2000-2020), and to assess the rate of desert encroachment in the study area from (2000-2020).

The Study Area

Dukku Local Government is located between Latitude 10^0 47'N and 10^0 49'N; and Longitude 10^0 41'E and 10^0 48'E. It is situated at a distance of about 78km from Gombe, the capital city of Gombe State. Dukku L.G.A is bounded with Bauchi State to the west and north-west, to the north-east by Nafada L.G.A, Funakaye L.G.A to the east and Kwami L.G.A to the south, and Akko L.G.A, to the south-west. In terms of size, Dukku L.G.A occupies a total land area of about 3,815sq km. It is characterized by the northern guinea savanna vegetation type. The area is intensively cultivated to an array of crops such as millet, maize, guinea corn and beans (Ahmad, 2019).

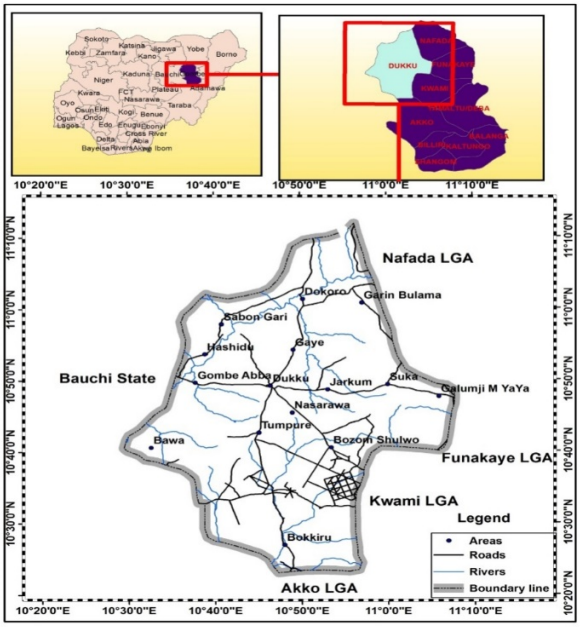

Fig.1. Map of the area
Source: Modified from Administrative Map of Gombe State

The climate of Dukku Local Government Area is the same with most part of Sudan savanna. According to Koppen's climate Classification Sudan savanna and particularly Gombe State is within the AW types of climate. It is seasonally wet and dry having an average annual rainfall ranging from 850mm to 1000mm. The rainfall is concentrated between May and October with single maximum in June and August, and it is associated with storms of high intensity. The mean maximum monthly temperature is 37^0C occurring in March to May. The minimum monthly temperature is 18^0C occurring in December to February. Relative humanity has the same pattern being 95% in august and dropped to less than 10% during the Harmattan in December /January (Ati.et al. 2009). The study area developed on basement complex and sedimentary formation,

such that the soil development here are vertisol which are very fertile and good for agricultural purpose. The soil of the area is ferruginous developed on sandy parent materials. The sandy surface horizons are underline by weekly developed clay. They are dark green in colour and have pH values ranging from 4.7 to 6.6. The soil contains this grained potential which is easily eroded. This might be due to either parent materials that developed or due to man's effort to satisfy his needs which could lead to exposure of soils to climatic factors such rainfall, which drain out the valuable mineral that might build the soil (Uto, 1999). The vegetation of Dukku Local Government Area comprises of light closed canopy with sprinkling of under shrubs growth of grasses to a more open grass of lesser height, more spreading and stunted shrubs and dense growth of grasses. The vegetation here is a mixture of trees and grasses. Most of the trees range between 3.5-5 meters height. The vegetation is typically Sudan type and it is the by the tick leave thorny trees, especially acacias of Sahalian fingers. Other trees found include *Adansonia Digitata (baobob, Mangiferaindica (mango tree), and arzadrichataindica (Neam)*among others. However most of the land is covered with grasses (Ahmad, 2019)

MATERIALS AND METHODS

Data on vegetation cover of 2000, 2010 and 2020 were derived from the satellite images that cover the period, the summary of the spatial data characteristics collected images are presented in Table1. Changes in land surface conditions caused by desertification are mainly characterized by alteration of biomass or vegetation, landscape pattern and subtle meteorological conditions. Therefore, indices that reflect these changes can be selected to assess desertification (Al-Bakri, Saoub, Nickling, Suleiman, Salahat, Khresat et al, 2012; Ebtihal, 2020). In this research, NDVI spectral indices were used. Several studies adopted the ability of NDVI to study desertification due to its ability to determine the presence or absence of vegetation and seasonal vegetation changes in arid and semi-arid regions of the world (Afrasinei, *et al*, 2017; Ebtihal, 2020).

NDVI can be calculated using the formula:

$$\text{NDVI} = \frac{\text{NIR}-\text{RED}}{\text{NIR}+\text{RED}} \text{----------1}$$

Where: ρ NIR and ρ RED are the spectral reflectance in the (NIR) and(RED) bands, respectively.The NDVI values range from -1 to +1 (Lillesand, Kiefer and chipman, 2004). For this study, the classification scheme in Table 2 was used to classify and analyse the images. The range of values used in Table 2 was obtained from the NDVI imageries used for this work.

Table 1: Characteristics of Spatial Data

Type of Satellite Image	Date of acquisition	Row/Path	Spatial Resolution (m)	Source
Landsat 05 TM	29/11/2000	p186/r53	30m	Google Earth Engine
Landsat 07 ETM	23/11/2010	p186/r53	30m	
Landsat 08 OLI	24/11/2020	p186/r53	30m	
Training Sites Locations				GPS field record
Topographic				Ministry of Lands Gombe State

Source: Authors compilation (2021)

Table 2: NDVI Classification Scheme Adopted

SN	Class Type	Range of Value	Interpretation
1	Low density (non-vegetated areas)	-0.1 – 0.30	These are basically the water bodies, built-up areas, rock outcrops and bare surface
2	High density (vegetated areas)	0.31 – 0.806	Areas that are vegetated, with thick or light forest, shrubs and grasses

Source: Authors compilation (2021)

RESULTS AND DISCUSSION

Rate of Desertification in the study area

NDVI values for the study area ranges from-0.722 low to 0.806 high in the year 2000 (Figure 2), It is observed that the more NDVI value increases the more the vegetation/forest cover is healthy. These findings contradict (Ebtihal, 2020) that higher value of the NDVI range refers to (0.777) which represents water bodies, dense vegetation and wetlands. On the other hand; the low value of (-1.693) represents dunes, soil being bare and devoid of vegetation in the study area. For 2010, Figure 3 reveals that the NDVI values forthe year 2010 were decreased from -0.150 low to 0.665 high compared to that of 2000. This shows that the forest density rapidly decreased. This is similar to the findings of (Hussaini, 2019) that thick forest decreases throughout the year while open spaces or barren land increases subsequently in progressive period. These indicate the negative impact of desertification on vegetation cover in the study area.

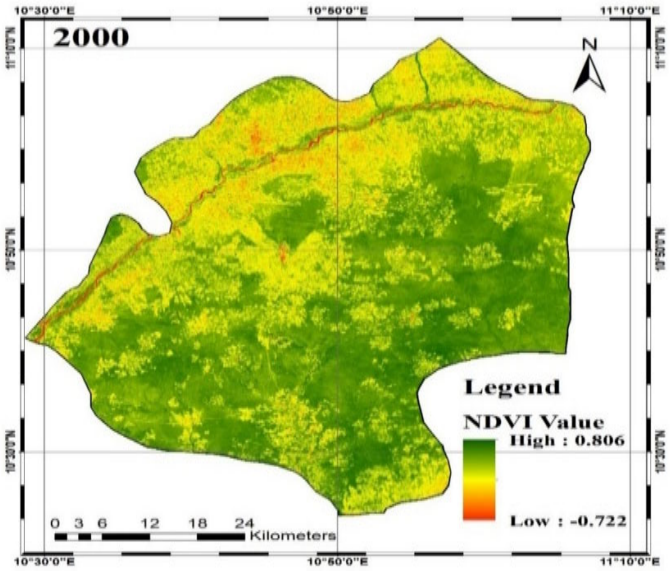

Figure 2: Dukku NDVI Map of Year 2000

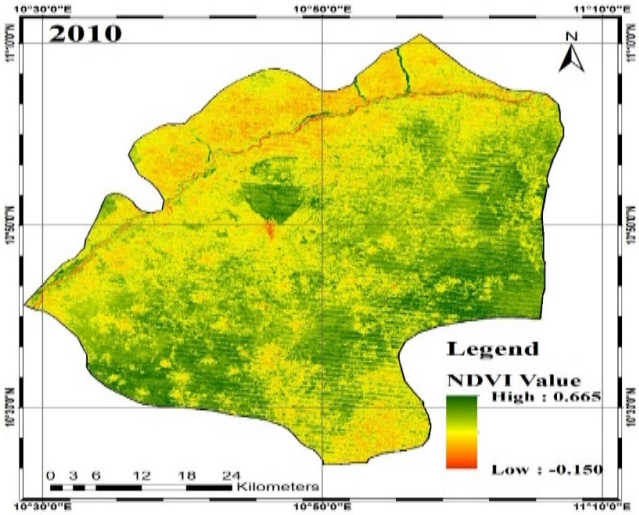

Figure 3: Dukku NDVI Map of Year 2010

The NDVI values for the year 2020 show very thin decrease in forest/vegetation ranging from -0.133 low to high value of 0.307 (Figure 4). The lowest values were found on the less vegetated soils presumably because reflection from the soil was high, and produce low values in NIR band and high values in the RED band; hence the NDVI values are low. The high NDVI values were identified as the forested/vegetated area while low values are the other land uses that included build up, water bodies and barren land. This results was not concomitant with findings of Cecilia (2019) that high rate of NDVI of 0.0972603 which indicated rich or dense vegetation cover and water bodies while -0.5954023 depicts areas without vegetation

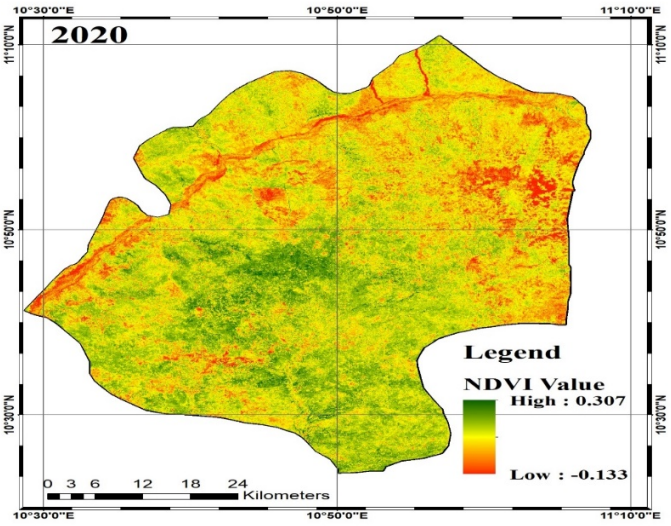

Figure 4: Dukku NDVI Map of Year 2020

Table 3 shows the summary and changes in forest cover in the study area between 2000 to 2020, and indicates the total area covered by each feature in kilometre squares and their respective proportion (in percentage). The summary shows the various classification levels and changes in forest cover between 2000, 2010 and 2020. In 2000 over 1029.23sqkm area was none vegetated with

27.87%, while 2199.53sqkm cover about 59.56% in 2010. In 2020 about 75.97% with area of 2805.56sq km was none-vegetated. For the dense vegetation forest in 2000, about 72.13% was covered by forest with the area of 2663.90sq km. In 2010 forest vegetation dense was reduced with 40.44% with area of 1493.60sqkm, 24.03% vegetation dense decreased in 2020, with 887.57sqkm. It could be observed from table that thick forest decreases throughout the three periods while open spaces also increases subsequently in progressive period this correspond with the study of Hussaini (2019) and Cecilia (2019). However, the result of the analysis of indicates that; about 86% of the inhabitants in the study area are using fuel wood as a means of energy; this is mainly because larger percentages of the population in the rural areas are living under endemic poverty (FGN 2015; Muhammad, Mohd, Azani, and Alias, 2021), with less access to infrastructure

Table 3: Forest Cover Change 2000 to 2020

	2000		2010		2020	
Classes	Area(sqkm)	%	Area(sqkm)	%	Area(sqkm)	%
Non-Vegetated	1029.23	27.87	2199.53	59.56	2805.56	75.97
Dense Vegetation/Forest	2663.90	72.13	1493.60	40.44	887.57	24.03
Total	3693.13	100.00	3693.13	100.00	3693.13	100.00

Source: Authors compilation (2021)

Table 4 Shows the rate of changes discovered in two decades, in first decade changes from 2000-2010 indicates that non vegetated area is 1170.31sqkm with 113.71%. Rate of changes in 2010-2020 indicates that 27.55% is non vegetated with area of 606.03sqkm. The annual rate from 2000-2020 is 3.531498. Dense vegetation/forest lost -43.93% in 2000-2010 with -1170.30sqkm, likewise the lost -40.58% in 2010-2020 with -606.03sqkm. The result shows that -2.11267 is the annual rate of vegetation lost from 2000-2020. This also contradict the findings of Cecilia, (2019) that the 2020 NDVI analysis showed a major decline in the vegetation index of the county with a bigger portion had little vegetation index. It can be observed that the NDVI values for the year 2000 shows a very low albedo compared to 2020. The areas with high albedo depict the areas with bare soil which reflects most of the sun while areas with vegetation had low albedo since they absorb most radiation. In other word between 2000 and 2010; 113.71% of the study area has become desert, while these areas increased to 27.55% between 2010 and 2020. The annual rate of desertification from 2000 to 2020 was 3.531498%. Similar result was found by (Elhag and Fadoel, 2012; Elhag, Abubaker and Almaleeh, 2014) in the semi desert area of ElGitaina Area, in the White Nile State

Table 4: Rate of changes of forest/desertification cover

Classes	Changes 2000-2010		Changes 2010-2020		Annual Rate % 2000-2020
	Area(sqkm)	%	Area(sqkm)	%	
Non-Vegetated	1170.31	113.71	606.03	27.55	3.531498
Dense Vegetation/Forest	-1170.30	-43.93	-606.03	-40.58	-2.11267

Source: Authors compilation (2021)

Dukku Local Government Area witnesses some changes through the years 2000, 2010 and 2020. In 2000, more than 27.87% of the total area has become sand sheet and sand dunes, while this area increased to 59.56% in 2010, and further increased to 75.97% in 2020. (See Fig. 5). The finding of this study shows that the sensitivity towards desertification decreases from north to south. The identification of the relationship between desertification and effective predictive factors can help in quantifying the desertification process. The northern part of the study area is identified as more sensitive to desertification; this agreed with the finding of Ayuba (2016); Idris Medugu et al. (2011) and Ester et al, (2022); however, the southern part appears to be less sensitive. This study identifies that the north part of the study area is more vulnerable to desertification and therefore deserves special attention.

The results obtained for the year 2000 showed that just like the NDVI, the southern part of the study area had low albedo while the northern part had high albedo as shown in Figure 5 below. 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 southern part in the year 2000 had low albedo as compared to other areas of the study area contrary to the year 2020 where only a few had low albedo which is as a result of the area being bare. The albedo results obtained showed that there was a low albedo in the southern parts of the study area for the year 2000; this was attributed to high vegetation cover in the area which was depicted by the high NDVI 2000 results. This finding is in agreement with that obtained by Cecelia, (2019) who reported that areas around central part of Kuiti County in the year 2000 had low albedo as compared to other areas in the county contrary to the year 2020 where only few areas had low albedo which is as a result of the area being bar.

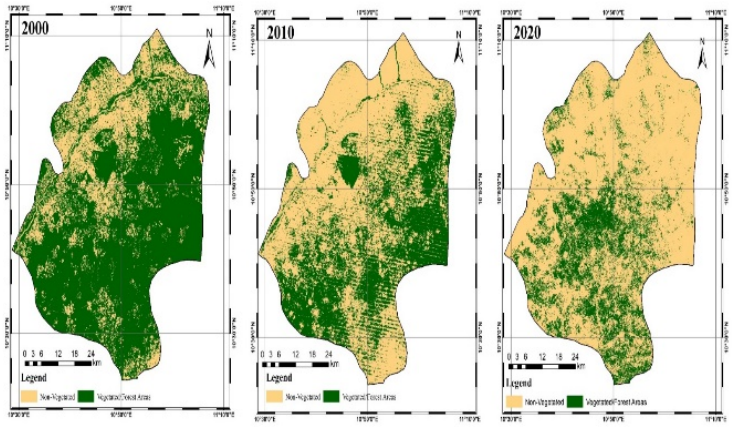

Figure 5: Rate of Desertification

CONCLUSION

The study assessed the rate of desert encroachment in Dukku L.G.A of Gombe from 2000 to 2020. It assessed the changes in the forest cover features in the study area from 2000 to 2020. The materials and methods used included Landsat images of 2000TM; Land Sat image ETM 2010 and Land Sat images 2020 OLI. Satellite Images were used to address the main objective of which is to map and assess the changes occurred in the land cover features in the study area from 2000 to 2020. The study found out that in 2000, thick vegetation had 2663.90sq. km with 72.13% while in 2010, 1493.60sq. km of 40.44% followed by 2020 with 24.03%. Non-vegetation areas in 2020 also had the highest percentage of 75.95% followed by 59.56% in 2010 and 27.87% in 2000 respectively. The rate forest cover changed between 2000 and 2020 shows that none vegetated has the highest percentage of 3.531498% annual rate followed by densely vegetation with -2.11267 annually. Degradation of the environment as a result of deforestation leads to desertification which in turn affects the physical, chemical and biological conditions of soil. Therefore, protection of forests from deforestation helps to prevent desertification. To curb deforestation in the study area, the policy makers should begin to see the need for new conservation strategies; and government should enlighten the rural farmers through agricultural extension services on sustainable utilization of land. Government should also establish a plantation and maintain shelter belts to combat desertification, by incorporating the rural dwellers in establishment and management aspect. Government should ensure rehabilitation of the environment through planting of trees to restore the degraded areas. The local people should be encouraged to engage in tree planting campaigns and leguminous crops including other cover crops for preventing erosion leading to desertification.

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