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An Assessment of Land Cover Change in Gashaka-Gumti National Park, Nigeria

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Abstract

The paper assessed the land cover change in Gashaka-Gumti National Park between 1991 and 2021. To achieve this, LandSat data of years 1991, 2001, 2011 and 2021 were obtained from the United States Geological Survey online resource. The findings of the study revealed that there is decrease in the different land cover types over time as a result of anthropogenic activities of the enclave dwellers. The study observed that the continuous existence of enclaves within and around the Park constitutes a serious threat to the survival of the Park. The study recommended that the federal government should consider resettlement of the enclave dwellers to give way for the development of the Park.

Keywords

Wildlife, Ecosystem, Forest Cover, Grass Land, Water Body and Anthropogenic Activities

1. Introduction

Over the years, the human population has increased significantly, and it is still increasing rapidly. This indicates that the billions of people that inhabit the planet are consuming natural resources more quickly than before. Additionally, growth and development threatens the habitats and continued survival of numerous species of wildlife around the world, especially those that could be uprooted for land development, consumed as food, or employed for other human uses.

According to the Millennium Ecosystem Assessment (MEA, 2015), more than 60% of the world's ecosystems have already undergone significant degradation as a result of human activities in recent years. Numerous economic benefits have resulted from these developments, but they have come at an increasing environmental cost, including biodiversity loss and land degradation, which has led to numerous economic, social, and cultural losses. The greatest dangers to global biodiversity have long been acknowledged to be habitat loss, fragmentation, overexploitation of natural resources, pollution, and the spread of invasive alien species. According to the Global Biodiversity Outlook (GBO) report from 2010, the majority of threats to biodiversity were substantially growing.

Landcover originally referred to the kind and state of vegetation, such as forest and grass cover, but it has broadened in subsequent usage to include other aspects of the natural environment such as soil type, biodiversity as well as surface and groundwater (Turner, 2002). Landcover change has been described as the most hit by anthropogenic disturbance in the environment (Umar, 2019). In essence both land use and landcover changes are products of prevailing interacting natural and anthropogenic processes by human activities. Land use and landcover change and land degradation are driven by the same set of proximate and underlying factors central to environmental processes (Tiwari & Saxena, 2011). The growing concern for natural resource management in recent times has been necessitated by increasing demographic pressures and their associated man-made activities, which have resulted in serious environmental stress and ecological instability. Over the last 300 years, the effects of land use and landcover change have grown from significant to dangerous proportions (Briassoulis, 1999). Humans, not natural agents, are expected to cause these changes and to be responsible for their magnitude and severity. Of course, because of the high propensity of population growth and subsequent resource over-exploitation, these changes have been found to be more profound in developing countries (Umar, 2019). The consequences of these environmental issues are severe, both in the short and long term. Food security, human and wildlife vulnerability, health and safety are all at risk in the short term, while the earth's viability is jeopardized in the long term (Sagan et al., 1999). Concerns about landcover change emerged on the global environmental change research agenda several decades ago, with the realization that land surface processes influence climate (Wolters et al., 2000). A much broader range of effects of land use and landcover change on ecosystem goods and services were discovered.

Land use and landcover dynamics must be studied in order to investigate the various ecological and developmental consequences of land use change over time. This makes land use and landcover mapping, as well as change detection relevant inputs into decision-making for implementing appropriate policy responses. Change detection, as defined by Singh (1999), is the process of identifying differences in the state of an object or phenomenon by observing it at different times. Land use and landcover change detection allows for the identification of major change processes and, by extension, the characterization of land use dynamics.

The establishment of the Gashaka-Gumti National Park was part of government's efforts aimed at enhancing ecosystem stability. After about 30 years of establishment, there is need to examine how well the Park has fared considering the numerous enclaves within the Park whose inhabitants depend mostly on the Park's resources for their survival. Although a lot of related researches have been undertaken by different researchers in different areas of the National Park, only very few are known to have been carried out to assess the extent of land cover change due to anthropogenic activities of the enclave dwellers in Gashaka-Gumti National Park in the most recent time. It is against this background that this study assesses the extent of land cover change in the area and how it impacts on the ecosystem stability of which the Park is meant to achieve.

2. Materials and Methods

2.1. Description of the Study Area

Gashaka-Gumti National Park, Nigeria's largest park, covers 6731 square kilometers of wilderness (Akinsoji et al., 2016). The name of the park was inspired by two (2) of the region's most historic settlements: Gashaka village in Taraba State and Gumti village in Adamawa State. The Federal Government of Nigeria established the Gashaka-Gumti National Park in 1991 by merging the Gashaka Game Reserve and the Gumti Game Reserve. The park, like any other park in Nigeria, was established as a protected area for the purposes of nature conservation, recreation, ecotourism, scientific and medical research, and promoting the art, craft, and cultural value of the indigenous people who live in the park's vicinity.

2.1.1. Location

Gashska Gumti National Park is located between latitude 7˚56' to 7˚59'N and longitude 11˚48' to 11˚54'E. The total area of the park covers about 6731 km^2. The park is located in Adamawa and Taraba States (**Figure 1**). The Gumti section of the park is in Adamawa State while the Gashaka section is in Taraba State (Akinsoji et al., 2016).

2.1.2. Relief and Drainage

The Park's Northern, Gumti sector is relatively flat, whereas the southern, Gashaka sector is more mountainous. This rugged terrain is characterized by steep, densely forested slopes, deep plunging valleys, precipitous escarpments, and fast-flowing rivers. The elevation ranges from 450 meters above sea level in the plains of the Northern sector to the peaks and pinnacles of Mount Gangirwal (Mountain of Death) in the Southern Park sector, which, at 2400 meters above sea level, is Nigeria's highest mountain (Mubi, 2010).

There is a good drainage system in Gashaka-Gumti National Park as seen in Akinsoji et al. (2016) and Oruonye et al. (2017). The park is transversed by rivers such as Mayo Kam, Mayo Yim, Mayo Kpa, Mayo Gamgam, Mayo Beriji and Mayo Burtali which serve as a home to some aquatic animals and a good source of water to the surrounding settlements.

2.1.3. Data Needs/Source

This research work requires only secondary data to achieve the expected objectives. Temporal and spatial data are required to achieve the objective of this study. These were acquired through Landsat images of 1991, 2001, 2011 and 2021. They were all obtained from the United States Geological Survey online resources. The images were subjected to the different satellite image processing methods before usage.

2.1.4. Instrument for Data Collection

Landsat images of Gashaka Gumti National Park for years 1991, 2001, 2011 and 2021 were used to obtain spatial and temporal information on the study area. Remote sensing data is preferred because it is the most reliable and widely used method of acquiring spatial information on a given location. It is also the most effective instrument for environmental change detection and monitoring (Islam et al., 2011). To acquire the data on the major fauna (mammals) found in the park, archival records of the Park were used.

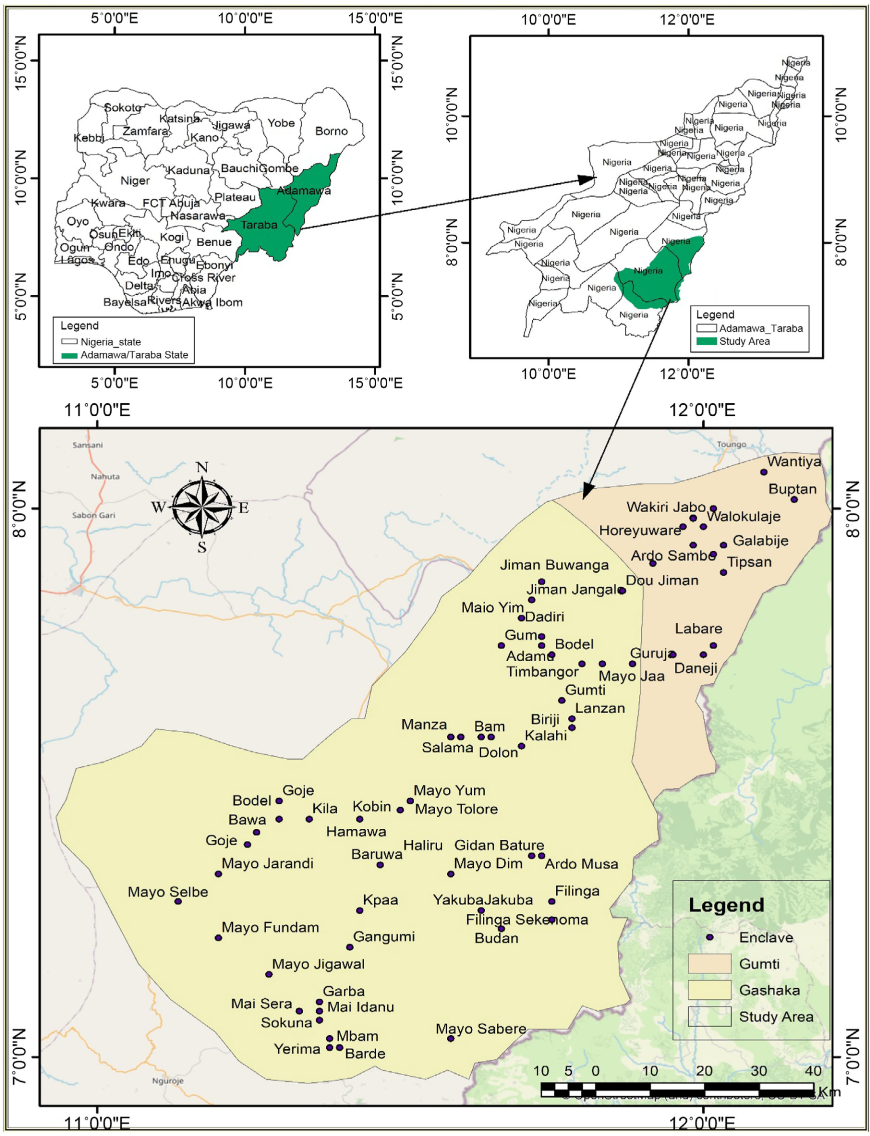

Figure 1. Map of Nigeria showing the Gashaka Gumti National Park. Source: Tarraba State Geographic Information System (2023).

3. Methods of Data Analysis

3.1. Satellite Image Preprocessing

Due to the instrumental errors associated with the ache sensor, noise from multiple sources, and uncertainty in scale and geometric conditions, comparative studies using different Landsat data can be difficult. Preprocessing satellite imagery before image classification and change detection is thus critical to minimizing errors and building a more thorough association between the obtained data and biophysical features on the ground (Coppin et al., 2004). The raw data collected were preprocessed in ERDAS imagine for band combination and image sub-setting based on Area of Interest (AOI).

3.2. Image Classification

This study depended on RS and other different tools. The study area was classified into different types or classes of land uses. The land classification was prepared for different periods. The images were classified in order to assign different spectral signatures from the LANDSAT datasets to different land uses and land covers. This was done based on the reflectance characteristics of the different land uses. The different colors were used for improving visualization of different objects on the imagery. The IR color composite NIR (4), SWIR (5), and Red (3) were applied to identify different levels of vegetation growth and to separate different shades of vegetation.

The images were classified in order to assign different spectral signatures from the LANDSAT datasets to different land use and land cover. This was done based on the reflectance characteristics of the various land use land cover types. To improve visualization of various objects on the imagery, various color composites were used. The infrared color composite NIR (4), SWIR (5), and Red (3) were used to identify different levels of vegetation growth and to separate different shades of vegetation.

Other color composites that are sensitive to variations in moisture content, such as Short Wave Infra-red (7), Far Infra-red (3), and Red (3), were used to identify built-up areas and bare soils. This was supplemented by a number of field visits and the use of Google Earth software, which allowed the main land use land cover types to be identified.

Training samples were chosen for each of the predetermined land use land cover types by delineating polygons around representative sites. Using the pixels enclosed by these polygons, spectral signatures for the respective land use land cover types derived from satellite imagery were recorded. A good spectral signature ensures that there is "minimal confusion" among the land covers to be mapped (Gao et al., 2010).

For supervised classification, the Maximum Likelihood classifier algorithm with decision rule was used with 300 training sites for four major land use land cover classes in the study area. The Maximum Likelihood Classification is the most widely used perpixel method that takes spectral information from land cover classes into account (Qian, Zhou, & Hou, 2007).

3.3. Accuracy Assessment

This study adopted the Error Matrix approach (ERRMAT in ArcGIS) to assess the accuracy of the classification. The error matrix assesses accuracy using four parameters which include overall accuracy, user's accuracy, producer's accuracy and the Kappa Index of Agreement (KIA).

3.3.1. Individual Class Accuracy

Individual Class Accuracy is calculated by dividing the number of correctly classified pixels in each category by either the total number of pixels in the corresponding column; Producer's accuracy, or row; User's accuracy.

Individual class accuracy can be expressed as

$$\hat{c} = \frac{p}{c} \; \textit{for Producer's accuracy} \tag{1}$$

$$\hat{c} = \frac{p}{r} \; \textit{for User's accuracy} \tag{2}$$

where

p = number of correctly classified pixels;

c = total number of pixels in the corresponding column;

r = total number of pixels in the corresponding row.

3.3.2. Overall Accuracy

Overall accuracy is computed by dividing the total number of correctly classified pixels (i.e., the sum of the elements along the major diagonal) by the total number of reference pixels.

Overall accuracy can be expressed as:

$$\bar{A} = \frac{\sum p}{N}$$

where

p = number of correctly classified pixels;

N = Total number of points.

3.3.3. Kappa Coefficient Estimation

Cohen's kappa statistic measures interrater reliability (sometimes called interobserver agreement). Interrater reliability, or precision, happens when your data raters (or collectors) give the same score to the same data item. The Kappa statistic varies from 0 to 1 as in **Table 1**.

Theoretically, Kappa can be express as

$$\check{K} = \frac{\text{Observed accuracy} - \text{Chance agreement}}{1 - \text{Chance agreement}}$$

- Observed accuracy determine by sum of diagonals (points correctly mapped) in the error matrix.
- Chance agreement determine by sum of product of row and column totals of each class.

Table 1. Kappa statistics.

Interpretation of Kappa Statistic	
Kappa	**Agreement**
<0.20	Poor classification
0.21 - 0.40	Fair classification
0.41 - 0.60	Moderate classification
0.61 - 0.80	Good classification
0.81 - 100	Very Good classification

(Alawamy et al., 2020).

Kappa coefficient can therefore be statistically expressed as

$$\check{K} = \frac{N \sum p - \rho}{N^2 - \rho}$$

where

N = Total number of points;

p = Sum of correctly classified pixels;

ρ = Sum of product row and column totals of each class.

4. Result and Discussion

4.1. Results

4.1.1. Flora Richness and Abundance in GGNP

Figure 2 and Table 2 show the land use land cover change of GGNP in 1991. Out of the 6731 square kilometer (Km^2) land area of the Park, the forest cover took 3269.78 Km^2 with 48.58%, followed by Grassland/Shrub 3269.04 Km^2, representing 48.57%, then Built-up/bare surface covered 137.82 Km^2 representing 2.05%, while water body/wetland on the other hand, had 54.36 Km^2 with 0.81%.

4.1.2. Land Cover Classification in GGNP (2001)

In 2001, Grassland/Shrub (3312.90 Km^2; 49.22%) took the lead, followed by Forest cover (3212.63 Km^2; 47.73%) while Water body/Wetland covered (7.85 Km^2; 0.12%) (Table 3 and Figure 3).

4.1.3. Land Cover Classification in GGNP (2011)

In 2011, Forest cover (3444.60 Km^2; 51.18%) took the lead, followed by Grassland/Shrub (3158.40 Km^2; 46.92%), while Water body/Wetland covered (33.66 Km^2; 0.50%) (Table 4. and Figure 4).

4.1.4. Land Cover Classification in GGNP (2021)

Table 5 and Figure 5 show that in 2021, forest cover (3647.61 Km^2; 54.19%) took the lead, followed by Grassland/Shrub (2674.96 Km^2; 39.74%), while Water body/Wetland (17.50 Km^2; 0.26%) recorded the least.

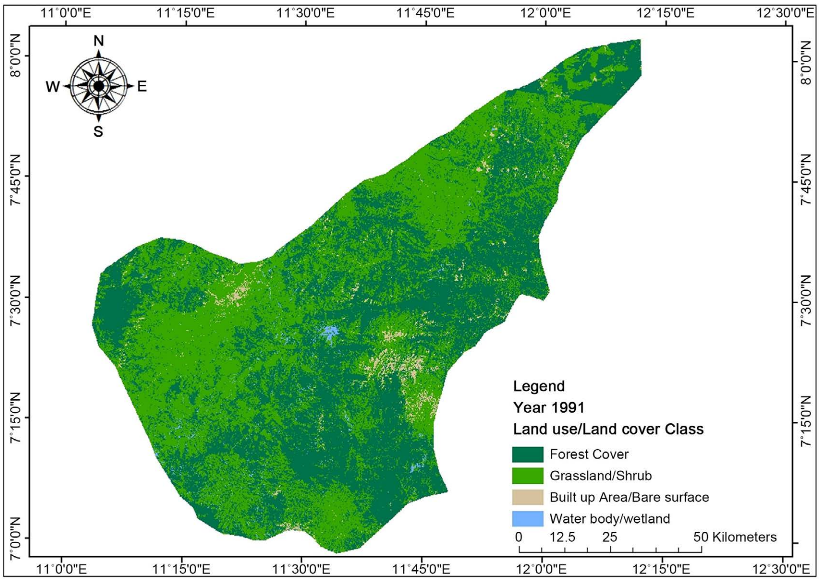

Figure 2. Land cover classification of GGNP-1991. Source: United States Geological Survey (1991).

Table 2. Land cover classification-1991.

	YEAR 1991	
LULC_Class	Area (Square Km)	Percentage (%)
Forest Cover	3269.78	48.58
Grassland/Shrub	3269.04	48.57
Built-up Area/Bare surface	137.82	2.05
Water body/wetland	54.36	0.81
Total	**6731.00**	**100**

Source: United States Geological Survey (1991).

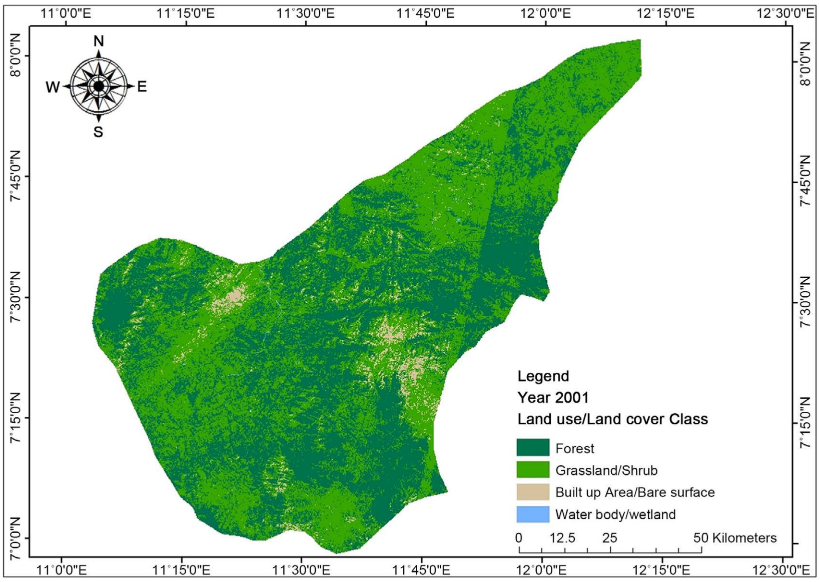

Figure 3. Land cover classification of GGNP-2001. Source: United States Geological Survey (2001).

Table 3. Land use land cover Classification-2001.

	YEAR 2001	
LULC_Class	Area (Square Km)	Percentage (%)
Forest cover	3212.63	47.73
Grassland/Shrub	3312.90	49.22
Built-up Area/ Bare surface	197.62	2.94
Water body/Wet land	7.85	0.12
Total	**6731.00**	**100**

Source: United States Geological Survey (2001).

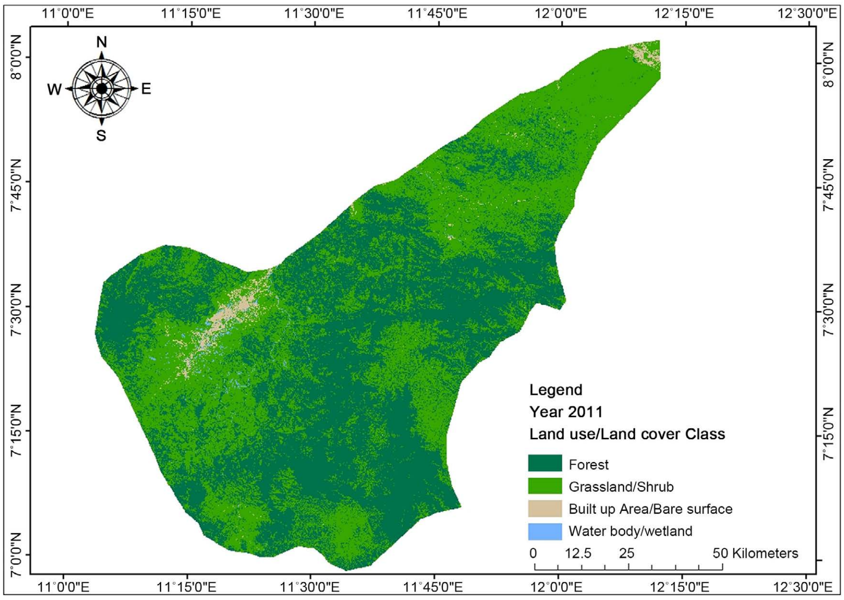

Figure 4. Land cover classification of GGNP-2011. Source: United States Geological Survey (2011).

Table 4. Land cover change-2011.

	YEAR 2011	
LULC_Class	Area (Square Km)	Percentage (%)
Forest cover	3444.60	51.18
Grassland/Shrub	3158.40	46.92
Built-up Area/ Bare Surface	94.35	1.40
Water body	33.66	0.50
Total	6731.00	100

Source: United States Geological Survey (2011).

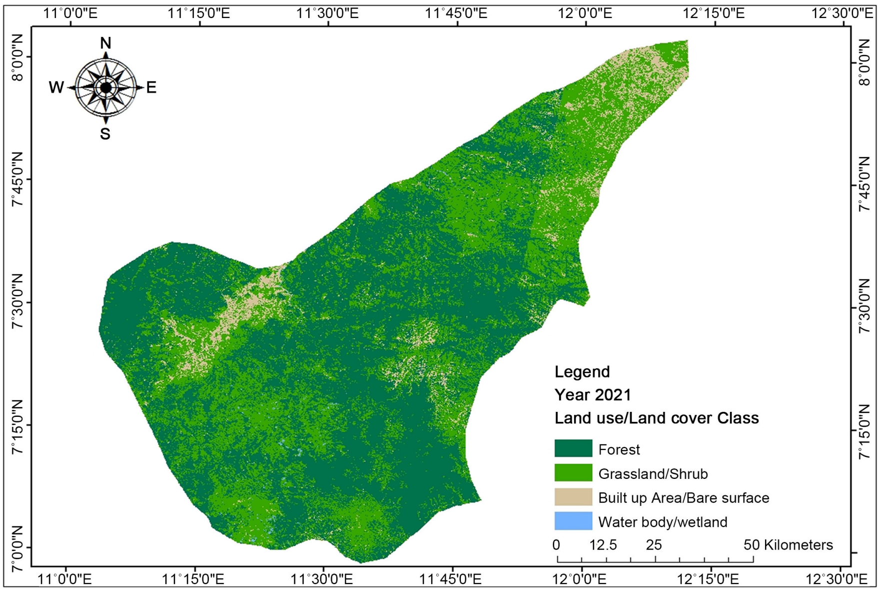

Figure 5. Land cover classification of GGNP-2021. Source: United States Geological Survey (2021).

Table 5. Land cover Classification-2021.

	YEAR 2021	
LULC_Class	Area (Square Km)	Percentage (%)
Forest cover	3647.61	54.19
Grassland/Shrub	2674.96	39.74
Built up Area/Bare surface	390.93	5.81
Water body/wetland	17.50	0.26
Total	**6731.00**	**100**

Source: United States Geological Survey (2021).

4.1.5. Change in Land Cover between 1991 and 2021 (30 Years)

The results in Table 6 depict the rate of change in land cover for a period of 30 years (1991-2021). Forest cover witnessed 5.61% increase from 1991 to 2021. Grassland/shrub on the other hand, witnessed a decrease of 8.83% between 1991 and 2021. Built-up/bare surface increased by 3.76% between 1991 and 2021 while Water body decreased by 0.55% within the same period.

Table 6. Change in Land Cover in GGNP between 1991 and 2021.

YEAR 1991			YEAR 2021		
LULC_Class	**Area (Sq/Km)**	**(%) inc/dec**	**LULC_Class**	**Area (Sq/Km)**	**(%) inc/dec**
Forest Cover	3269.78	48.58	Forest cover	3647.61	54.19
Grassland/Shrub	3269.04	48.57	Grassland/Shrub	2674.96	39.74
Built-up/Bare surface	137.82	2.05	Built up/Bare surface	390.93	5.81
Water body	54.36	0.81	Water body	17.50	0.26
Total	**6731.00**	**100**	**Total**	**6731.00**	**100**

Source: United States Geological Survey (1991 and 2021).

5. Discussion

Out of the three (3) land cover types in this study, Forest cover had the highest land cover (3269.78 km^2; 48.58%) in 1991, followed by Grassland/Shrub (3269.04 Km^2; 48.57%) while Water body/Wetland had (54.36 km^2; 0.81%). 1991 was the year the National Park was established. Naturally it is expected that as time went on, the vegetation cover should increase. This, however was not the case as a result of different anthropogenic activities in the area. In 2001, 10 years after the establishment of the National Park, Forest cover and Water body/wetland lost some percentages to the other land use land cover types with the Forest land decreasing to 3212.63 km^2 (47.73%) and Water body/wetland decreasing to 7.85 km^2 (0.12%). On the other hand, Grassland/shrub increased to 197.62 km^2, representing 2.94%. The loss in forest cover may be due to clearance by the enclaves for different agricultural activities or for shelter purpose. Once forest is cleared and crops planted, it reflects as grass or shrub surface on the satellite image thereby giving rise to increase in Grass land/shrub area. On the other hand, where the forest is cleared to give way for building, it reflects as built up on the satellite image. The loss in Water body/wetland may either be due to drought or activities of the enclaves. It may be possible that the wetland were taken over as farmlands for the cultivation of crops such as rice or sugarcane which does better in wetland or encroached into for settlement/residential purposes.

In 2011, there was a dramatic turnaround in the land use land cover types in GGNP. The vegetation/forest cover received a boost compared to what it was in 2001. In 2011, forest land extended up to 3444.60 Km^2 (51.18%) of the total land area in GGNP. Water body/wetland also received a boost of 33.66 Km^2 (0.50%). Grassland/shrub however, witnessed a drop in land area with 3158.40 Km^2 (46.92%). Built up area/bare surface dropped to 94.35 Km^2 (1.40%). The gain in forest cover could be as a result of regeneration of the cleared forest or development of some shrub areas into forest. It could also be as a result of stability in the forest cover without much disturbance/interference. The increase in water body/wetland may be due to the high amount of rainfall received that year which resulted in increase in the sizes of the rivers/streams within the Park. The restriction of access and other activities around the wetland area may also be a reason for the increase. The loss in grassland/shrub could be regeneration and development of shrubs into forest as stressed above. This development reduces grass land/shrub land to the advantage of forest land.

There was further increase in Forest cover in 2021 to 3647.61 Km^2 (54.19%), while Grassland/shrub further decreased to 2674.96 Km^2 (39.74%). Water body/wetland decreased to (17.50 Km^2; 0.26%). The gain and loss on the part of Forest cover and Grassland/shrub may still be attributed to regeneration of the harvested forest products and development of shrubs into forest land. It may also be attributed to increase in the population of the enclave dwellers which in turn, requires more land area for living and cultivation. The recovery in built up/bare surface may result from the return of the people to the flooded areas in the previous years which may also be the reason for the decrease in the size of water body/wetland.

Between 1991 and 2021, Forest cover gained a total of 377.83 km^2 (5.61%); the gain in forest cover could be as a result of regeneration of the cleared forest or development of some shrub areas into forest. It could also be as a result of stability in the forest cover due to effective management and control by the Park managers. With this positive result, it shows the Park is achieving its mandate in this regard. Grassland/Shrubs on the other hand, lost about 594.08 km^2, (8.83%) to either forest or Built-up/Bare surface. The loss in Grassland/Shrub could be attributed to regeneration and development of shrubs into forest as earlier observed. This development reduces Grass land/Shrub to the advantage of Forest land. The loss to forest land may be regarded as a positive development as against the one lost to Built-up/bare surface which gained 253.11 km^2 (3.76%). The gain in built-up/bare surface could be as a result of settlement expansion or economic activities of the enclaves. Water body/Wetland also suffered loss between 1991 and 2021. The reason for this is as a result of settlement expansion and other anthropogenic activities of the enclave dwellers

6. Conclusion

This study assessed the land cover change in Gashaka-Gumti National Park from 1991 to 2021. The study employed remote sensing/GIS data to determine the changes in land cover types over time. The findings of the study revealed that there is decrease in the different land cover types over time as a result of anthropogenic of the enclave dwellers. The study recommended that the Federal Government should do everything possible to resettle the enclave dweller to give way for the Park to fully develop.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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