GIS and Remote sensing Analysis of the impact of land use land cover change on forest degradation: Evidence from the Central Part of Taraba State, Nigeria

ABSTRACT

Forest is a fundamental, significant, and valuable component of a sustainable environment. Ecosystem services, biodiversity development, and economic growth in any nation depend on the proficient use of forests and their resources. However, deforestation has remained the single most important environmental phenomenon threatening the existence of the forest environment in Nigeria. This study was carried out to assess the exploitation of forestland in the central zone of Taraba state using GIS and remote sensing techniques. The satellite imageries used are Landsat imageries of 2006, 2012, and 2018. Ground Control points (GCPs) were obtained from Google earth to validate the coordinates of the classified imageries. The result obtained from 2006 classification showed that thick forest occupied the total of 1685448.99 ha equivalent to 80.38% and was the highest land cover suffering a decline in the area amounting to 694696 ha which equals to 33.13% in 2018. The pattern of land cover changes at the early stage was restricted to dissection and perforation in 2006. A remarkable expansion of bare land patches accompanied by total attrition of thick forest was identified due North in Bali local government area as compared to Gashaka and Kurmi local governments that have fragmented and little shrinking pattern of changes from 6.87% in 2006 to 37.65% in 2018. This shows that; as bare land increases, thick forests keep on decreasing within thirteen (13) years. It was recommended that increased reforestation efforts, sensitization and periodical campaigns against deforestation, and redesign of the existing forestry laws by the state government to curtail incessant incidents of deforestation in the study area be undertaken.

Keywords: *Forest;* Forest degradation; GIS and Remote sensing; Land use land cover change; *Taraba State, Nigeria*

1. INTRODUCTION

Forest is a fundamental, significant and valuable component of the ecosystem that support sustainable agriculture; stabilize soils and climate [1, 2]. It regulates water flows, gives shade and shelter, and provides a habitat for pollinators and the natural predators for agricultural pest [3]. Forest has been and is contributing to the food security and income for hundreds of millions of people, especially in developing countries such as Africa and Nigeria inclusive [4]. A huge portion of Africa's total population (2.5 billion people) are highly dependent on natural forest resources for varieties of services, while in Nigeria, approximately 60 million indigenous people are almost wholly dependent on the forest, while 350 million people depend on the forest for a high degree for subsistence and income [5-7].

However, despite the important roles forest play in the life of mankind and the environment, man continues to destroy them through diverse anthropogenic activities [8, 9]. Disturbances created by these activities influence forest dynamics and tree density with resultant consequences of accelerated deforestation. According to [10], deforestation refers to the process of clearing, removing forest trees where the land is converted to other types of activities for non-forest use, like conversion of forest reserves areas to residential or industrial areas, removing of forest trees as a result of road or rail construction, conversion for agricultural purposes and cutting down of forest trees for domestic and industrial use like firewood, timbers, paper production and charcoal production [4, 6, 11] .

Globally, about 31% of the world land surface, that is, more than four billion hectares, was covered by forest. The global land area with forests in developed nations stands for 42% and 58% in developing nations [9, 12]. However, Per capita forest area had fallen globally from an average of nearly1.2 ha in 2000 to 0.6 ha in 2010—some scholars including [4, 6, 7, 13] projected that without sufficient reforestation, it would be less than 0.2 ha by 2025, with most occurring in developing nations. Nigeria is the largest loser of annual natural forests in Africa and has the highest deforestation rate of an average of 409 700 hectares every year, which is equivalent to an annual deforestation rate of 2.38% that is higher than the world average of 0.2% [1, 14]. At 2.38%, Nigeria's average annual deforestation rate of natural forest is the highest in the world and puts it on the place to lose virtually all its primary forest within few years [15].

Although deforestation occurred in many parts of the country, the most adversely affected state is the less endowed Taraba state and particularly its central zone [16, 17]. The apparent increase of uncontrolled degradation of forests in the last decade in the zone has increased with increased problems relating to human survival, welfare, and development. Yet, little or no attention has not been paid by the government of the state, as there are no new laws enacted to curtail the incident nor any program of afforestation embarked upon over the years.

Still, most of the previous studies, including those of [4, 9, 17-19] have focused mainly on land use/land cover trends, loss of arable lands, and exploitation of rosewood trees through the use of questionnaires and interviews without considering the spatial pattern of land-use change, types and causative activity in the study area. While the information on the spatially explicit and thematically detailed quantitative analyses of forest land cover change over long periods and at a regional scale like this remains a significant guide for implementing effective forestland use policy in Nigeria. Besides, the use of GIS and remote sensing techniques as a tool allows for better tracking of deforestation and forest degradation events, types, and causative activity with a high degree of accuracy than any other methods [5, 8, 12]. Therefore, it is on this premise that this study seeks to assess the exploitation of forestland in the central zone of Taraba state using GIS and remote sensing techniques. The vision was to provide information on the events, types, and how unhealthy forestland use change is being accelerated and to serve as a baseline data for further similar research work in the study area and to complement existing similar studies in other parts of the country.

2. MATERIAL AND METHODS

2.1 The Study Area

Taraba state lies roughly between latitude 6°30" and 9°36" North and longitude 9°10" and 5°0" East. It is bounded on the North by Bauchi State, Northeast by Gombe, West by Nasarawa and Plateau states, and Adamawa state on the East; Southwest is bordered with Benue State. An international boundary on the South and southeast separates the state from the Republic of Cameroon (Figure 1). Taraba State has a total landmass of approximately 54 473km^2 while the study area (comprising of Bali, Gashaka, and Kurmi local government areas) covers 20, 968 km^2 of a total landmass. The study area has an undulating topography consisting of flat, isolated, and chains of a mountain with elevation ranges of between 264 to 934 m above sea level and a total population of about 555,294 persons. Most of the people living within the area are predominantly engaged in farming, fishing, and lumbering, hunting, and carving as well as cutting trees for sale in towns as firewood.

Climate

The study area has climatic characteristics typical of a tropical climatic condition characterized by a wet and dry climate. The wet season lasts on average from March to October. Mean annual rainfall varies between 1158 mm in Bali to over 1500 mm in Gashaka Local government area [20]. The wettest months are August and September. The dry season lasts from November to February; the driest months are December and January, with relative humidity dropping to about 15percent. The mean annual temperature is about 28°C with maximum temperature varying between 30 to 34.4°C. The minimum temperatures range between 15to 23°C.

Vegetation

The vegetation of the study area is chiefly of the guinea Savannah vegetation dominated by Daniella Daniella and providing a limited amount of shade [21]. Rainfall distribution and topography are the most important factors influencing the pattern of vegetation in the study area with vigorous vegetation during the wet seasons but their foliage wilt in dry seasons. A wide variety of shrubs and trees are also present. The dominant shrubs and grasses are the Hymenocardia and *Andropogon* communities, respectively. The economic trees commonly found include Shea-butter (*Vitellaria paradoxa*), LocustLocust Bean (*Parkia biglobosa*), Sapele (*Entandrophragma cylindricum*), Mahogany (*Khaya spp*), Afra (*Nectophryne afra*) and Iroko (*Millicia excels*). Some cultivated plants include Mango (*Mangifera indica*), Guava (Psidium), Date palm (*Phoenix dactylifera*), PawpawPawpaw (*Asimina tribola*), Orange (*Citrus spp*), and Cashew nut (*Anacardium accidentale*) [4, 17, 22]. The grasses are used for grazing not only by goats but also traditional browsers, while trees and shrubs for firewood, timber, woodcarving, palm products, fruit gathering, and various construction purposes. The study area is witnessing a fast increasing number of sawmills and an explosion in indiscriminate felling of forest trees. Rising poverty, unemployment has forced more people to rely directly on forest resources at an unprecedented rate [4, 17, 22]. Consequently, forest in the study area is under threat from the progressive reduction in number and size.

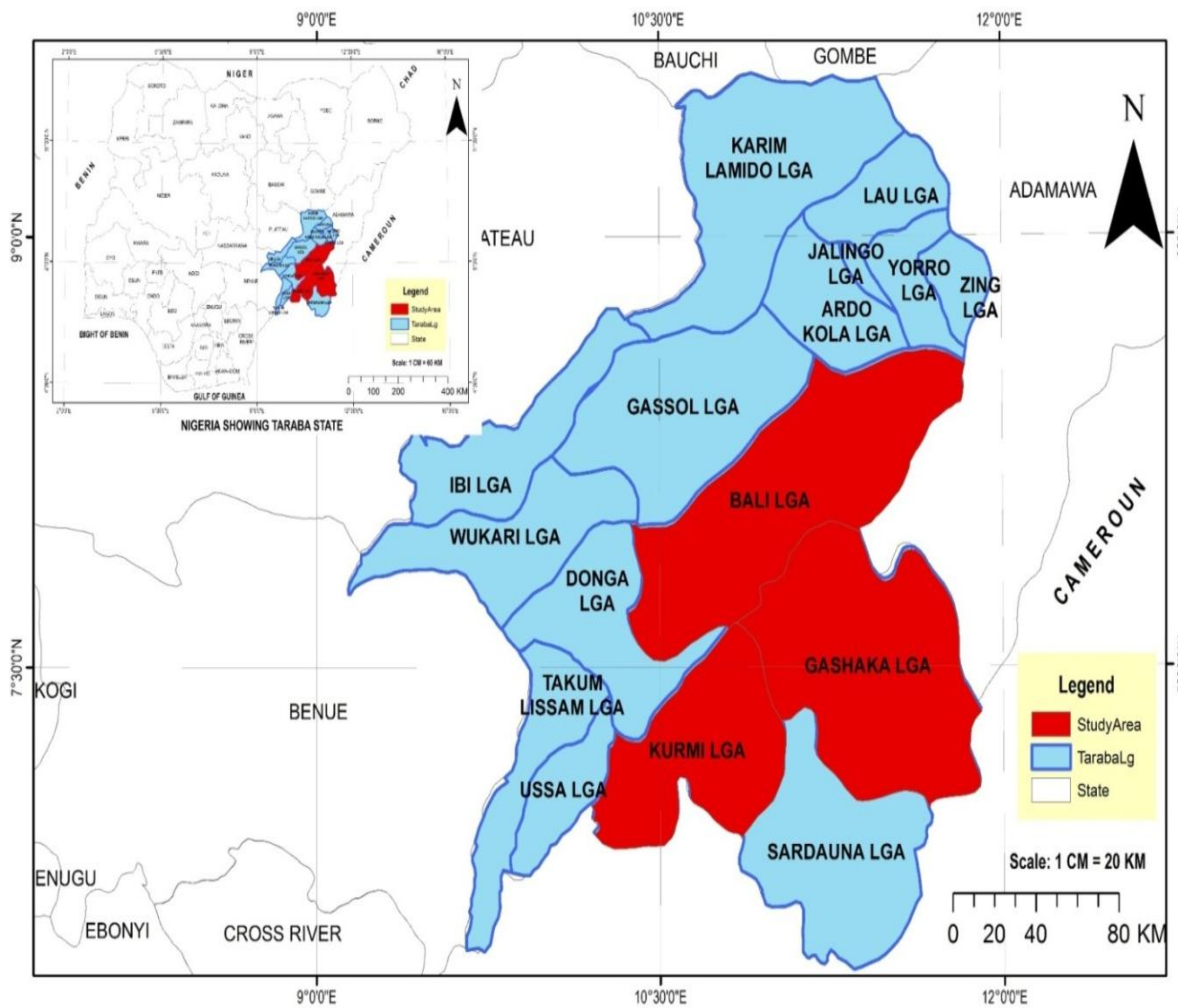

Figure 1: The Study Area within Taraba State.
Source: Department of Geography Taraba State University

2.2 Methods

Satellite imageries of the study area were obtained from the United State Geological Survey (USGS). The satellite imageries used are Landsat imageries of 2006, 2012, and 2018. Ground Control points (GCPs) were obtained from Google earth to validate the coordinates of the classified imageries.

Landsat 7 ETM+ (Enhanced Thematic Mapper) image of 10th January 2006 with 30 m spatial resolution and 15 m spatial resolution (panchromatic), which in total has nine bands, was used to determine the extent of land use land cover coverage of the area of 2006. To examine the extent of land use land cover coverage of 2012, Landsat 7 ETM+ (Enhanced Thematic Mapper) image of 3rd January 2012 with 30 m spatial resolution and 15-meter spatial resolution (panchromatic), which in total has nine bands was used. While Landsat 8 OLI & TIRS (Operational Land Imager and Thermal Infrared Sensor) image of 27th January 2018 with 30meter spatial resolution and 15 m spatial resolution (panchromatic) has 11 bands were used to determine the area extent of land use land cover coverage of 2018.

Data Pre-processing

All the six images of 2006, 2012, and 2018 were pre-processed using Adobe photo-shop for image enhancement. While geometric and radiometric corrections are made using Erdas imagine.

Image Layer stacked, Mosaic, and Sub-setting.

The Satellite imageries were imported into Arcmap 10.3environment. The images collected from USGS in Path 186, Row 55 were layer stacked using the “composite band tool” in ArcGIS and merged as one image to have the information covered by bands in a single combine image of all bands (layer stacked). This process was repeated for all the images. Using the “mosaic to new raster tool” in ArcGIS, the image of the scene Path 186, Row 55 and Path 186, Row 54 of 2006, 2012, and 2018 were then merged into one mosaic image to overlap the edges of the images (that of Path 186, Row 55 and Path 186, Row 54), Figure 2. A subset covering the area of interest was extracted from the larger mosaic scene of the three mosaic images using the “Clip tool” in ArcGIS and awaits the classification.

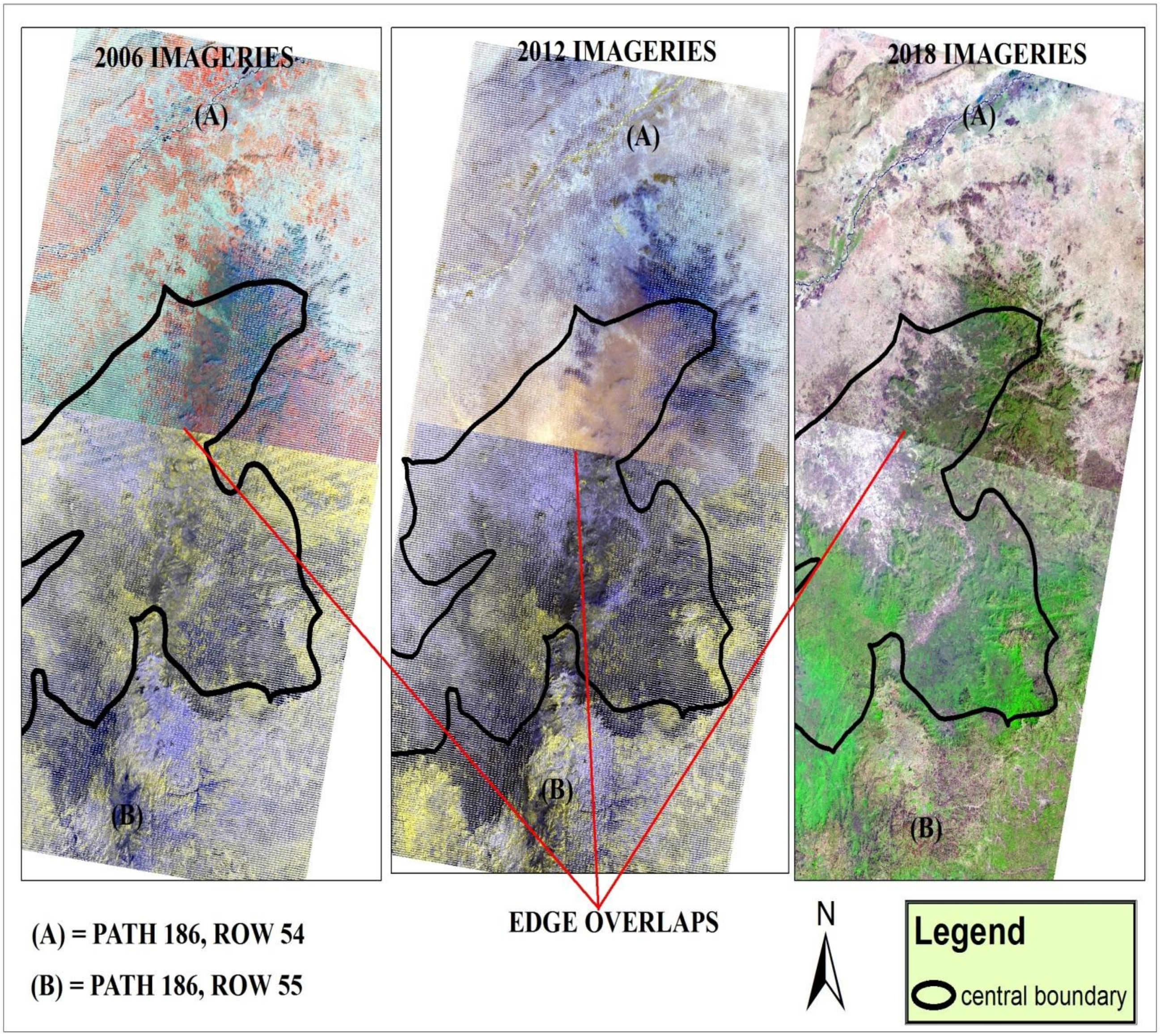

Figure 2: Image Layer-stacking, Mosaic and Sub-setting

Source: USGS Landsat imageries (2018)

Image Classification

Maximum likelihood Supervised classification technique was employed in classifying the images into various classes. This method is preferable due to the prior knowledge of the environment for over thirty years which enables guiding the training data for the classification. Training data was generated to guide the classification based on the land use/land cover themes present in the area. The known land cover types (training sites) were coded with the names of the corresponding thematic features. Based on Jensen (2005) land use/cover classification scheme, the various land use land cover types within the area of this study were classified into five: thick forest, bare land, shrubs, water body, and built-up areas(Table 1).

Table 1. Land Use Land cover classification Scheme

Land use-Land cover classes	Description
Thick forest	A land dominated by trees with a per cent of greater than 60% and a height of more than two meters. Thick forest, evergreen forest, mixed forest with a higher density of trees
Bare Land	Lands with exposed soil, rocks, sand and never have more than 10% vegetation. Bare ground, barely exposed rocks.
Shrubs	Land with woody vegetation not more than 2 meters tall. The shrub can be either evergreen or deciduous, cropland/arable land, or agricultural land.
Water Body	Lakes, reservoirs, streams, rivers, and swamps. The area is covered by open water such as a river, waterlogged area.
Built-Up Area	The land is covered by buildings and other man-made structures. Residential, industrial area mixed urban and built-up land.

Source: Jensen (2005)

Ground-truthing and Accuracy Assessment

Ground control points were obtained from Google earth to ascertain the accuracy of the classified images. It was done in locations related to the classes of the study. This was plotted on the images to verify the training sites as regards the success of the classification, Figure 2. As such, ten (10) ground control points were taken for each class, making a total of fifty (50) points of truth data for each Landsat image (2006, 2012, and 2018) and a total of one hundred and fifty (150) points for all the three images.

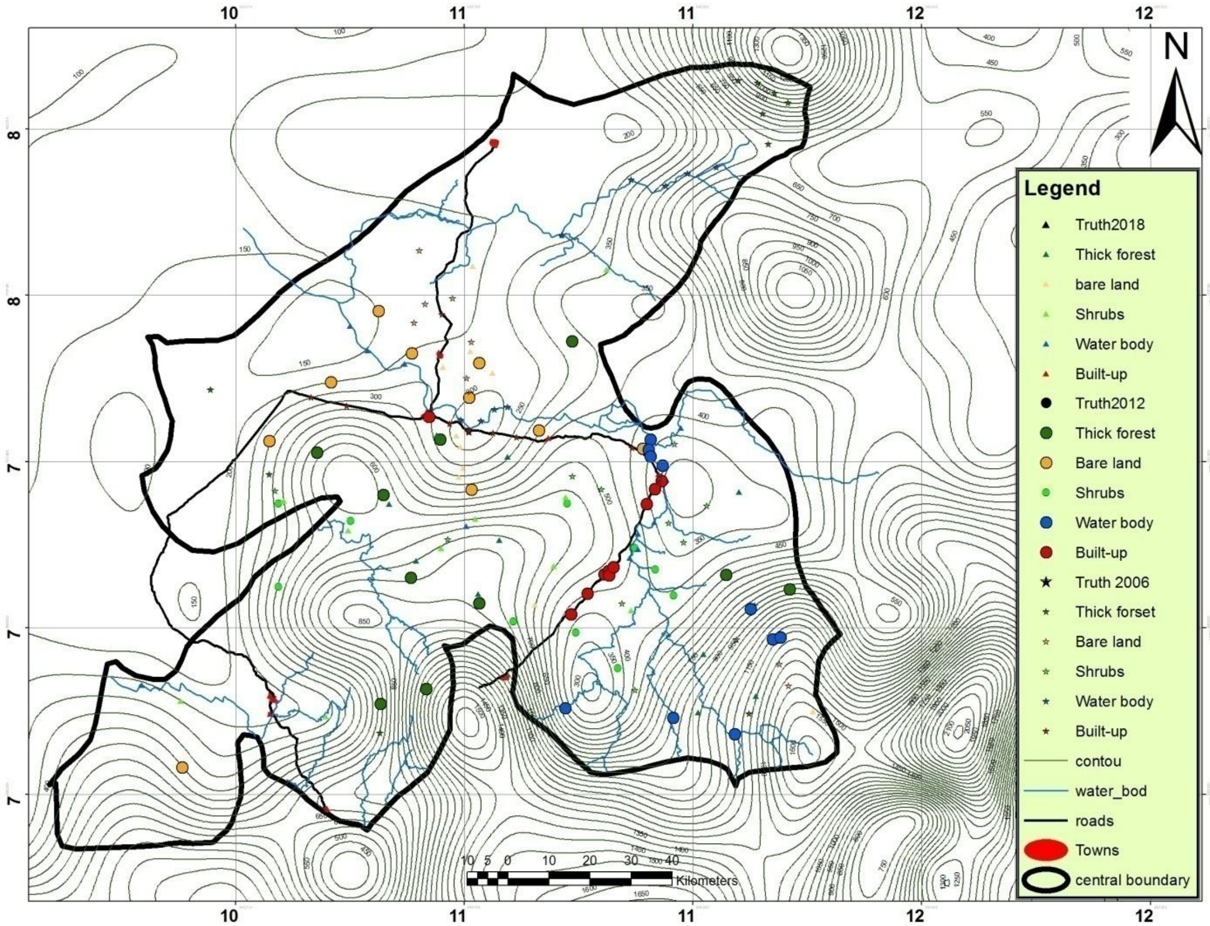

Figure 3: Base map of central Taraba

Source: Google earth and field survey (2018)

Data Analysis, Presentation, and Display

To analyze the extent, type, and pattern of land cover from 2006 to 2018, images of the study area were overlaid in ArcGIS to detect changes that have resulted from the land cover classification. The extent of the change in the area of the land cover classes was extracted and calculated. The resulting values were converted into percentages and used as absolute data for the presentation of land use land cover changes and to also determine the rate of land use land cover changes in the area between 2006 and 2018. The findings were presented using charts, plates, maps, and figures.

RESULTS AND DISCUSSIONS

This section was segmented into two sub-sections. The first examines the Land Cover Distribution of the Central Zone of Taraba State in 2006, 2012, and 2018. The second section examines changes that occurred in Thick forest cover in the Central zone of Taraba from 2006 to 2018.

Section A: Land Cover distribution of Central Zone of Taraba State in 2006, 2012, and 2018.

a. **Land Cover Distribution of Central Zone of Taraba State in 2006**

The land cover class of the area in 2006 was characterized into five classes, namely, Thick forest, Shrub, Bare land, Waterbody and Built-up (Figure 4). The pattern of land cover alteration was restricted to perforation and dissection of lands. Both shrub and thick forest classes have remained in a matrix formation with little or no alterations. Also, easily identifiable matrices of thick forest that covered the entire study area with less dissected corridor pattern of bare lands and patch formation of built-up area (Bali town) towards Northern part of the study area was observed. This suggests that the thick forest was intact with little or no interference by rural farmers that uses crude implements and the migrant nomads. Based on the GIS analysis image classification, river Taraba cut through the matrixes of thick forest in a corridor formation due North.

On the proportion of the total area occupied by each land cover class and an accurate assessment of the classified image Table 2, and 3 shows that thick forest has the highest proportion of the total land accounting for 1685448.99 ha representing (80.38%) of the total land. This is followed by shrubs with 227819.07ha (10.87%) bare land has 144172.44ha representing (6.87%) while water body and built-up area amounted to 37448.01ha (1.78%) and 1874.16 (0.09%) respectively.

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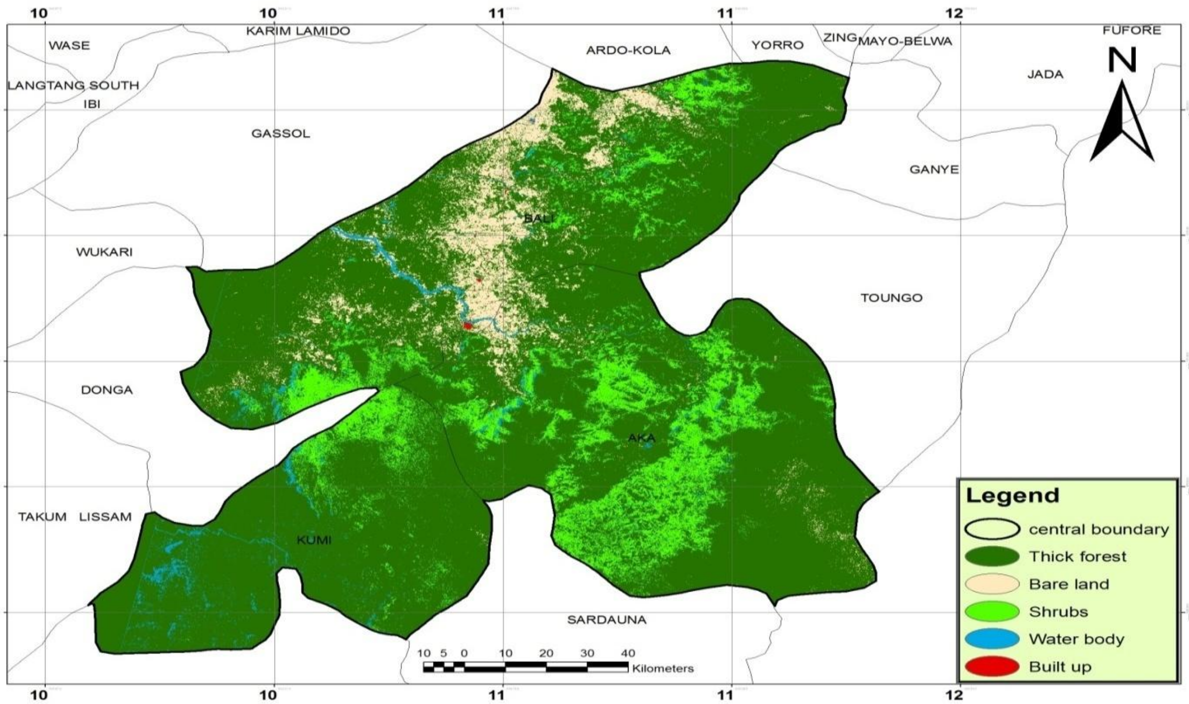

Figure 4: Extend of Thick Forest in 2006
Source: author GIS analysis

Table 2: Land Cover Distribution in 2006

Land cover	Area cover	Percentages %
Thick forest	1685448.99	80.38
Bare land	144172.44	6.88
Shrubs	227819.07	10.87
Waterbody	37448.01	1.78
Built-up	1874.16	0.09
Total	**209 6762.65**	**100**

Source: Author GIS analysis (2018)

Table 3: Accuracy Assessment of the Classified Image in 2006

Parameters	Thick forest	Bare land	shrubs	Waterbody	Built-up
Thick forest	9	2	2	1	4
Bare land	0	6	0	1	6
Shrubs	1	0	7	1	0
Waterbody	0	0	0	6	0
Built-up	0	2	1	1	6
Overallaccuracy	**68%**				

Source: Author GIS analysis (2018)

b. **Land Cover distribution of Central Taraba in 2012**

The image classification showed a marked significant decrease in the thick forest class with scattered matrixes that have undergone massive deforestation. Fragmented patterns of the thick forest matrix were observed to the extreme southeast and southern part of the study area. To the Southwest and northeast part, the thick forest fragmented matrixes continue to shrinkage, while in the north-central part, a massive shrinkage that moved towards an attrition pattern was recorded. This means that shrubs dissected by bare lands are gradually reclaiming the thickness of the forest. The tremendous decreases in the thick forest could be a result of massive deforestation caused by increased lumbering activities in the recent few decades in the area.

Similarly, the findings in Table 4 shows that the thick forest has reduced in size from 1685448.99 ha (80.38%) in 2006 to 990753.03 ha (47.25%) in 2012 while an increase in bare land patches from144172.44 ha (6.87%) to 652246.38 ha (31.11%), shrubs from 227819.09 ha (10.89%) to 390229.56 ha (18.61%), and water body from 37448.01 ha (1.78%) to 61812.54 ha (2.94%) was observed. The increased in bare land to shrubs was due to the clearing of shrubs by farmers for cultivation, while the increase in water bodies was due to accelerated deforestation of the thick forest that was shielding the water initially.

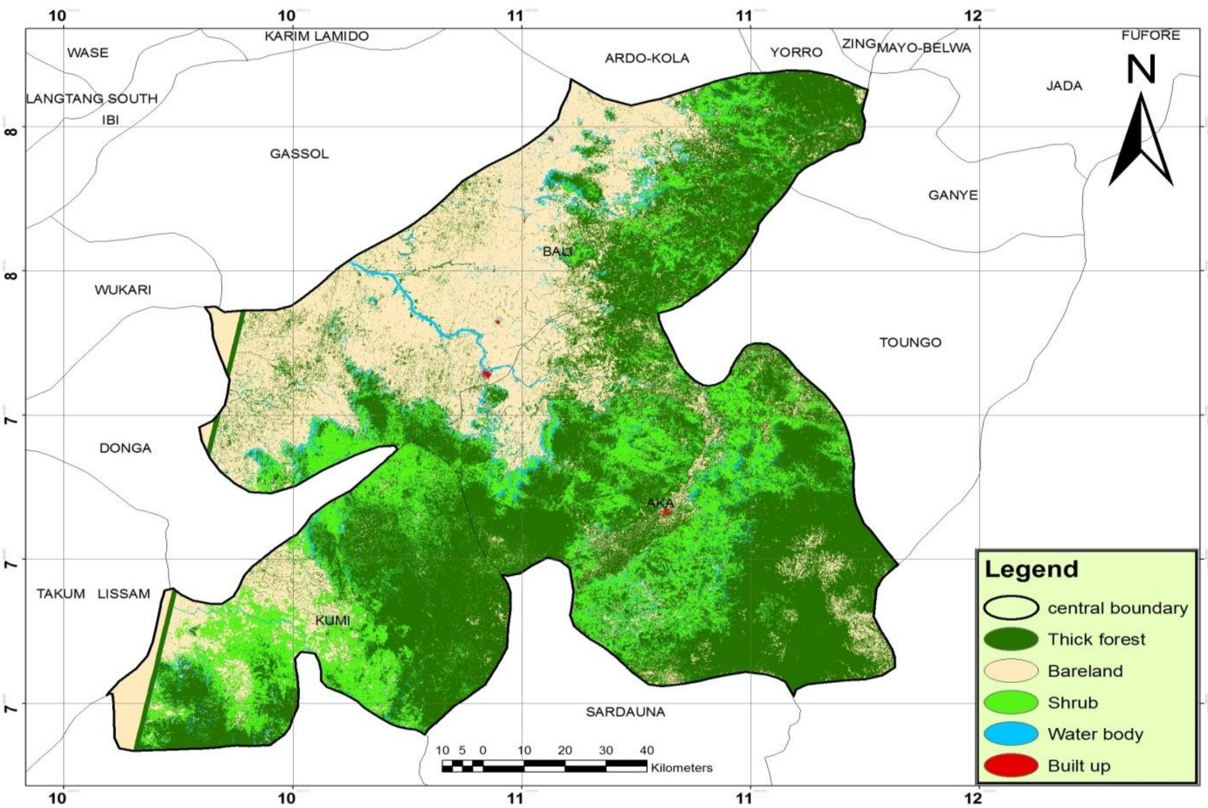

Figure 5: Extend of Thick Forest in 2012
Source: Author GIS analysis (2018)

Table 4. Land Cover Distribution of Central Taraba in 2012

Land cover	Area cover ha	Percentage %
Thick forest	990753.03	47.25
Bare land	652246.38	31.11
Shrubs	390229.56	18.61
Waterbody	61812.54	2.95
built-up	1721.16	0.08
Total	**2096762.63**	**100**

Source: Author GIS analysis 2018

Table 5. Accuracy Assessment of the Classified Image in 2012

Parameters	Thick forest	Bare land	Shrubs	Waterbody	Built-up
Thick forest	10	0	0	2	3
Bare land	0	9	0	4	2
Shrubs	0	1	10	1	0
Waterbody	0	0	0	3	1
Built-up	0	0	0	0	4
accuracy	**72%**				

Source: Author GIS analysis (2018)

c. Land Cover Distribution of Central Taraba in 2018

The major pattern of land covers at this epoch was characterized by attrition and shrinkage. Attrition pattern has fully developed in a complete disappearance of the thick forest giving rise to bare land patch formation at the Northeast and central part of the study area and a little shrinking fragments of thick forest and shrub classes to the Northeast. To the South, Southeast, and Southwest is the fragmented pattern of thick forest and shrub matrixes with perforated patches of bare lands in isolation, while a dissected pattern of bare land decreases along Gembu road in an attempt to protect the Gashaka Gumti National Park by the state Ministry of Environment and Rural Development. This means that there is a continued dispersal and decrease in thick forest cover, which adds to the existing loss of lands within the class involving all the characterized patterns of land cover changes.

Similarly, the findings in Table 6 depicts a decrease in thick forest cover from 990753.03ha (47.25%) in 2012 to 841993.83ha (37.65%) in 2018. Also, an increase in bare land from 652246.38ha (31.11%) to 849218.49ha (37.65%), and water body from 61812.54 ha (2.94%) to 176678.88 ha (7.83%), As well as a slight increased in built-up area from 1721.16 ha (0.08%) to 1895.22 ha (0.08%) was recorded. The thick forest keeps on decreasing as a result of massive deforestation going on in the area. Bare land keeps increasing due to the springing up of more farms from the remnants of the forest that were cleared. Water bodies keep on rising due to exposure of some streams and ponds that were hidden beneath the foliage of the thick forest that was cut down, and a negligible increase in built-up areas was recorded due to new built-up farmsteads. Table 7 shows the accuracy assessment of the classified image.

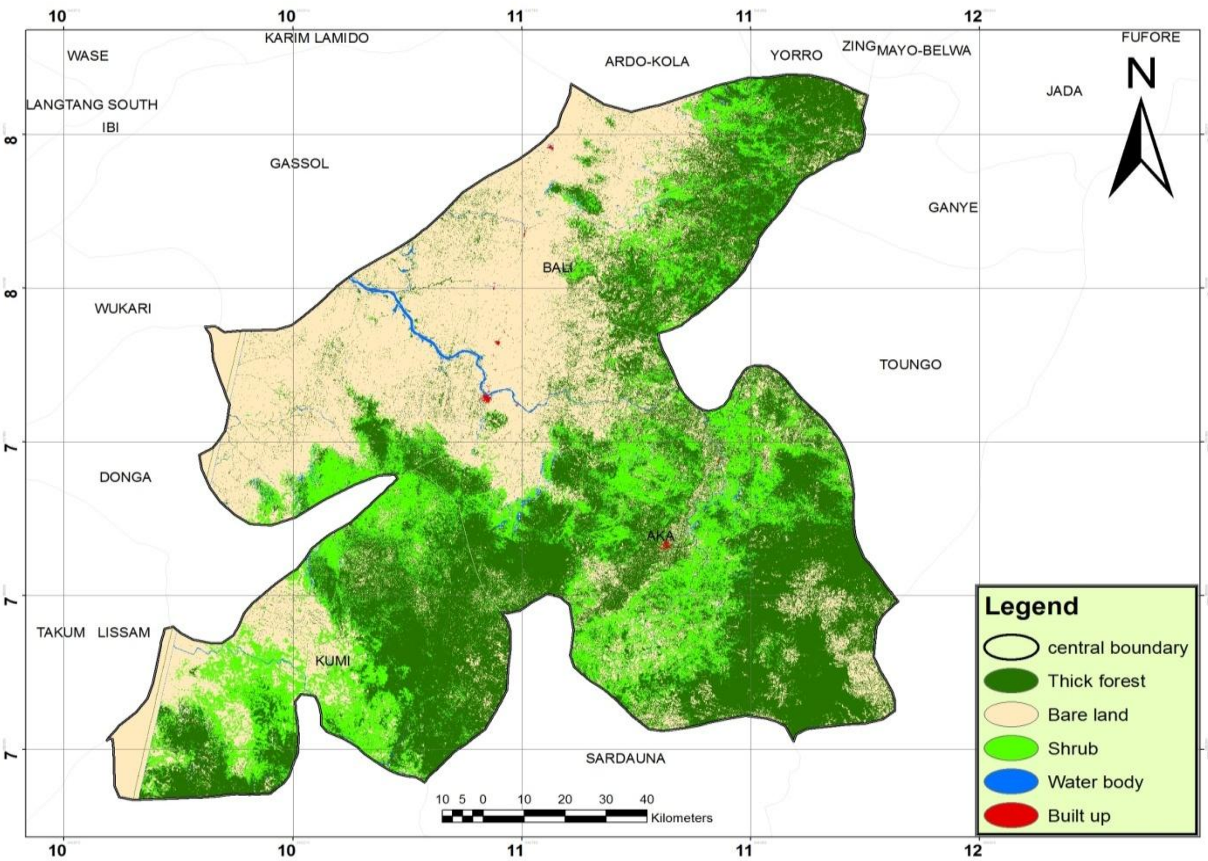

Figure 6: Extend of thick forest in 2018.
Source: author GIS analysis

Table 6. Land Cover Distribution in 2018

Land cover	**Area cover (ha)**	**Percentage (%)**
Thick forest	682993.66	37.33
Bare land	849218.49	37.65
Shrubs	385976.35	17.11
Waterbody	176678.88	7.83
Built-up	1895.22	0.08
Total	**2255762.75**	**100**

Source: Author GIS analysis (2018)

Table 7. Accuracy Assessment of the Classified Image in 2018

Parameters	**Thick forest**	**Bare land**	**Shrubs**	**Waterbody**	**Built-up**
Thick forest	10	0	1	0	3
Bare land	0	10	0	0	5
Shrubs	0	0	9	0	0
Waterbody	0	0	0	10	0
Built-up	0	0	0	0	2
Overall accuracy	**82%**				

Source: Author GIS analysis (2018)

SECTION B: Changes that occurred in Thick forest Cover in Central Taraba from 2006 to 2018

Through a careful understanding of the processes and the metamorphosis that occurred within the land cover classes from one epoch to another, the result obtained from 2006 classification showed that thick forest occupied the total of 1685448.99 ha equivalent to 80.38% and was the highest land cover suffering a decline in the area amounting to 694696 ha which equals to 33.13% in 2018. The pattern of land cover changes at the early stage was restricted to dissection and perforation in 2006. A remarkable expansion of bare land patches accompanied by total attrition of thick forest was identified due North in Bali local government area as compared to Gashaka and Kurmi local governments that have fragmented and little shrinking pattern of changes from 6.87% in 2006 to 37.65% in 2018. This shows that; as bare land increases, thick forests keep on decreasing within thirteen (13) years depicted in Table 8.

From the GIS analysis, Bali local government area suffers the worst deforestation due to its accessibility by roads linking its nooks and crannies from Dakka, Mayo-KamKam, Garba-Chede, Maihula, and Sabon-Gida areas in corridor formation. This makes it vulnerable because of the easy transportation of logs from any place. Gashaka local government houses the Gumti national park at the South-Eastern part of central Taraba, with villages like Mayo-Jamtari, Serti, Mayo-jarandi, and Mayo-SelbeSelbe situated within the Gembu road linking Mambilla plateau, is also a bit accessible, which makes it suffered less deforestation than other areas. Logs were carried from Gashaka forest to the main road for onward transportation to the South. However, due to severe penalties imposed on loggers by the park's management, the local government does not witness much deforestation. However, Kurmi local Government is not accessible, but due to restrictions imposed by the Gumti national park, it suffers a higher deforestation level than Gashaka but lower than Bali because of the freight cost associated with bad roads, which make it expensive to transport logs from the local government area to major roads.

From the GIS-based image classification, a trend analysis is displayed in figure 8 to show the trend of change in thick forest cover and bare lands. All these factors contribute a lot to the arithmetic rate of increase in bare land patches with a decrease in the thick forest matrix.

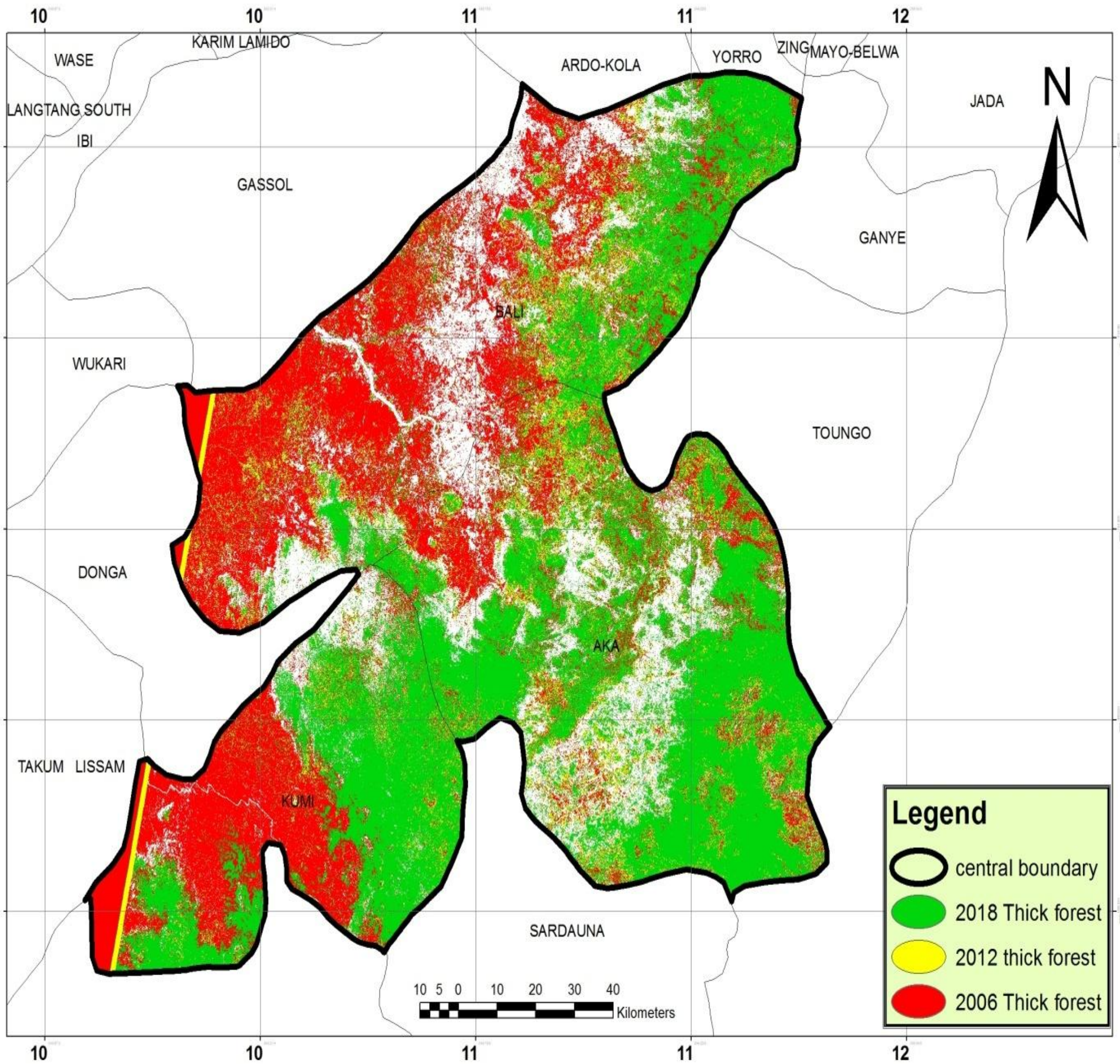

Figure 7: Collective Analysis of Thick Forest from 2006 to 2018
Source: Author GIS analysis (2018)

Table 8: Changes in land cover class (Thick Forest and Bare Land) from2006 to 2018

Years	Thick Forest	Bare Land	Change in Thick Forest	Change in Bare land
2006	1685448.99	144172.4	-	-
2012	990753.03	652246.38	694695.87	-508073.94
2018	682993.66	849218.59	307759.37	-196972.21

Source: Author GIS analysis (2018)

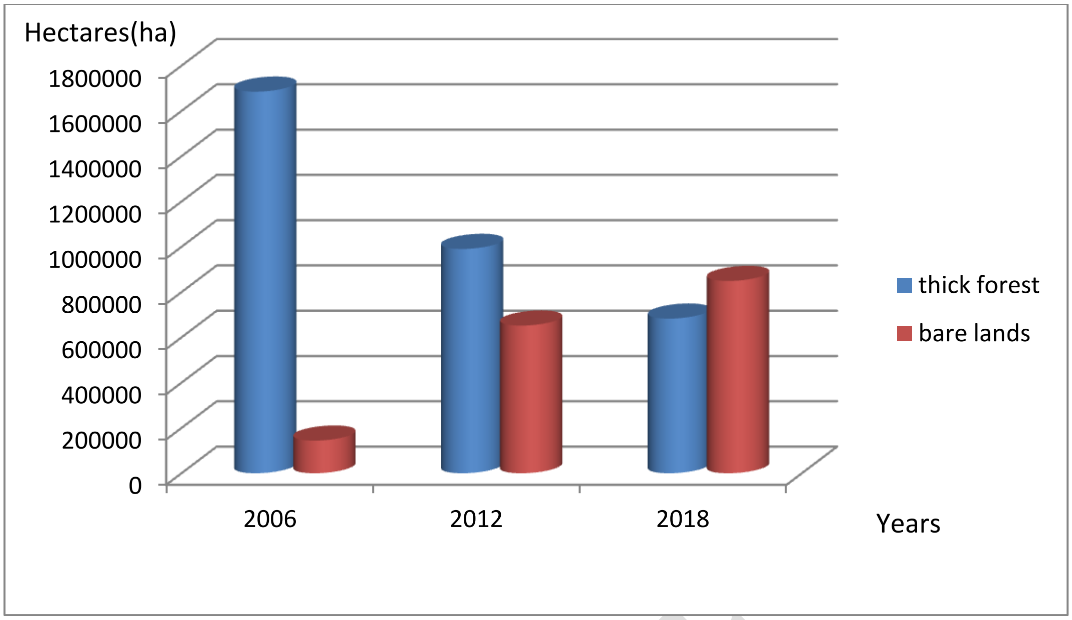

Figure 8: The trend of thick forest and bare lands between 2006 and 2018

Source: Authors fieldwork (2018)

CONCLUSION

This study assesses the exploitation of forestland in the central zone of Taraba state using GIS and remote sensing techniques. Landsat imageries of 2006, 2012, and 2018 was used. Ground Control points (GCPs) were obtained from Google earth to validate the coordinates of the classified imageries. The result obtained from 2006 classification showed that thick forest occupied the total of 1685448.99 ha equivalent to 80.38% and was, the highest land cover suffering a decline in the area amounting to 694696 ha which equals to 33.13% in 2018. The pattern of land cover changes at the early stage was restricted to dissection and perforation in 2006. A remarkable expansion of bare land patches accompanied by total attrition of thick forest was identified due North in Bali local government area as compared to Gashaka and Kurmi local governments that have fragmented and little shrinking pattern of changes from 6.87% in 2006 to 37.65% in 2018. This shows that; as bare land increases, thick forests keep on decreasing within thirteen (13) years. The study recommended that increased reforestation efforts, sensitization and periodical campaigns against deforestation, and redesign of the existing forestry laws by the state government to curtail incessant incidents of deforestation in the study area be undertaken.

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