



## Detection of Change in Forest and Trees Outside Forest Using Normalized Difference Vegetation Index Techniques in Adamawa Central, Adamawa State Nigeria

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**ABSTRACT:** The importance of trees in every environment is crucial given the fact that they make some provisional and supportive services such as food inform of fruits, shelter, shade, aesthetics, as well as carbon sequestration among others. Hence the objective of this paper is to use Normalized Difference Vegetation Index (NDVI) techniques to determine quantitatively the changes in forest and trees outside forest from 1990-2021 in Adamawa central. The result revealed that changes occurred in trees inside forest, between 2013 and 2021; Rocks and bare surface increased by 17.49%. Shrubs and grassland increased by 34.13% while healthy forest reduced to -48.38% within the same period. However, result of TOF shows similar trend between 2013 and 2021 in the study area. Rocks and bare surface increases to 58.15%, shrubs and grassland reduced to -37.46%, while dense forest decreased to -4.39%. The results revealed further a decline in the concentration of both trees inside forest and trees outside forest in the area. The study recommended a change of policy to mitigate the negative impact of degradation through various forest rehabilitation mechanisms such as afforestation and reforestation programs in the study area.

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Land cover is the bio-physical materials that cover the surface of the earth; these include grass, forest, bare groundwater bodies, etc (Maina *et al.*, 2020). Inversely, land cover defined as the “physical and biological cover over the land surface, which includes: vegetation, bare soil, water and artificial structure”. According to Pielke *et al.*, (2021), the forest ecosystem is a major component of the landscape that links the lands, biota, and human societies with several ecosystem services. The recent upsurge in human population has led to increased demand for ecosystem services; which attracts numerous human activities to modify the landscape through agricultural

practices, logging, firewood collection, deforestation, and building of houses among others. Such conversion and modification of land cover have significant effects on climate, forest ecosystem, and the environment. These interactions and conversions on the natural ecosystem have attracted the attention of several researchers from time immemorial to study the impacts of land-use/land-cover change on different environmental components (Pielke *et al.*, 2021). Deforestation causes habitat loss and biodiversity loss, influenced by human and natural factors like forest fires, droughts, invasive animals, floods, overpopulation, and climate change (Bodo *et*

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*al.*, 2021). Deforestation and forest destruction worldwide, especially in tropical regions, cause ecological problems such as Pollution and selective logging degrade local habitats, impacting soil and water quality, and potentially affecting biodiversity (Singh, 2021). The UN Food and Agriculture Organization reports that, 420 million hectares of global forest were lost due to deforestation between 1990 and 2020 (FAO, 2022). Unabated vegetation loss and degradation could trigger serious environmental problems that are linked to increased surface thermal response, reduced infiltration and increased surface runoff (Balogun, and Ishola, 2017). The NDVI is a standardized index that measures greenness or relative biomass by contrasting chlorophyll pigment absorption in the red band with the high reflectivity of plant material in the near-infrared band (Bush, 2022). The normalized difference vegetation index (NDVI) is developed for estimating vegetation cover from the reflective bands of satellite data (Sahebjalal and Dashtekian, 2013). NDVI is a widely used technique to detect land use land cover change, especially change of vegetation area and its pattern. Due to increase of both spatial (from km to cm) and spectral resolution (from wide band range to narrow band) of remote sensing data, it is possible to work in micro level. Satellite images are required to prepare NDVI by the GIS software. It is an indicator of vegetation health. Forest abolition is measured through the NDVI technique. It is also a powerful tool for the collection of data about vegetation from the satellite images. An important step in the utilization of satellite data to monitor change is the ability to compare images from different dates, for different plots on different scenes (Sahebjalal and Dashtekian, 2013). The Normalized Difference Vegetation Index (NDVI) is to detect different land cover changes considering the existence of varying phonologies, diverse topographic conditions, and areas with a high level of stand fragmentation (Alonso *et al.*, 2023). The technique can be applied with any land cover mapping methodology based on multitemporal analysis of satellite images. Remote Sensing data from Landsat Thematic Mapper (TM) image along with NDVI and Digital Elevation Model (DEM) data layers have been used to perform multi-source classification (Furusawa *et al.*, 2023). Changes in forest cover by the high-resolution satellite data with the help of Normalized Difference Vegetation Index (NDVI) based image processing technique is the most widely accepted method in land use land cover change detection (Giridharan, and Sivakumar, 2022). A change detection technique is used to quantify a temporary changes between two or more study periods based on NDVI for making an index of Floras for indicating the volume/amount of which area is highly vegetated and whether growing of vegetation

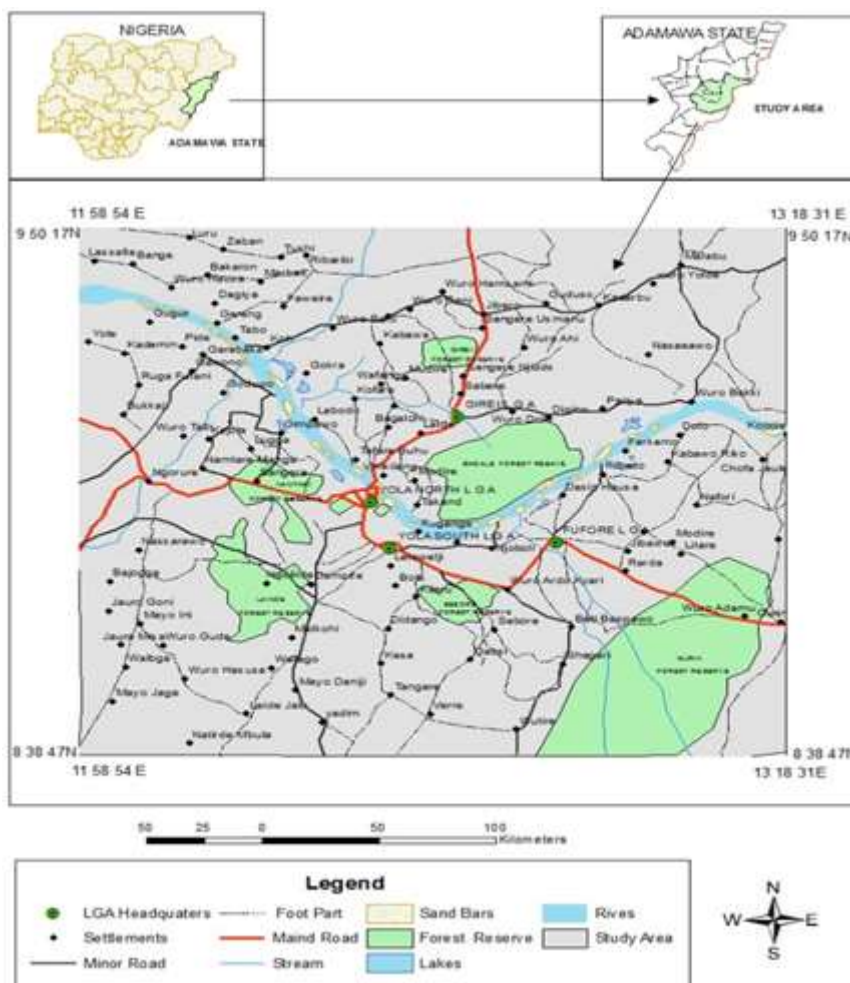
is possible or not (Sumona *et al.*, 2019). Wani *et al.* (2021) attempted to bridge the huge variability that exists in the definition, classification, assessment techniques, monitoring methodology, and assessment approach of Trees Outside Forest (TOF) across different countries with a view to provide a uniformity across the globe. They used integrated techniques of assessing TOF using field methods complimented by robust remote sensing techniques. The result revealed that field inventory methods are irreplaceable owing to their importance in establishing relationships with such advanced remote sensing and GIS techniques. It further indicates that remote sensing applications have shown promising results in deciphering TOF resources by adopting multiple satellite data and classification techniques. They conclude that carbon inventory assessment programs at national and international levels desire for adoption of latest methods including remote sensing and geographic information system (GIS) integrated with field inventory and advanced algorithms for better qualitative and quantitative assessment of TOF resources.

The objective of this paper is to assess the changes in forest and trees outside forest from 1990 - 2021 in Adamawa central, Adamawa State, Nigeria.

## MATERIALS AND METHOD

**Study Area:** With a total land area of about 6,419.69 km<sup>2</sup>, Adamawa Central is located between latitudes 80 38' 47'' and 90 50' 17'' North and longitudes 11° 58' 54'' and 13° 18' 31'' East. The study area borders the Cameroon Republic to the east, the Local Governments of Mayo-Belwa and Jada to the southwest, Song to the north, and Demsa to the west in Adamawa State. Like all of Guinea Savannah, this region has distinct rainy and dry seasons, and the humidity and temperature change with the season. With 750 to 1000 mm of yearly rainfall on average, the rainy season lasts from April to October (Adebayo, 1999).

**Methods:** Four historical Landsat images encompassing the study area over the previous 32 years (1990–2021) constituted the data for this study. The United States Geological Survey provided the images, which have a 30 m spatial resolution (USGS, 2018). WRS 2 path/row 185/53, 185/54 was utilized in all of these data sets, which were collected during the research years by Landsat 4 and 5 Thematic Mapper (TM) and landsat8, Operational Land Imager (OLI) as presented in Table 1. Images from December, February, and March were chosen because of lower phonological stability and spectral separability, as documented by Ayuba, (2006).



**Fig 1:** The study area  
*Adopted from Adamawa State Ministry of Land and Survey.*

The formula for NDVI images was  $NDVI = \frac{NIR - RED}{NIR + RED}$ , where RED stands for red band and NIR for near-infrared band (Giridharan, and Sivakumar, 2022). After the images were retrieved, a four-band dataset (Band 1, Band 2, Band 3, and Band 4) in RGB colors was created using the Layer Stack or Composite function.

Using the study area boundary (6419.69 km<sup>2</sup>), images were cropped to fit the study area's boundaries. For trimming the TOF research location, ArcGIS Pro 2.9 was utilized.

The Normalized Difference Vegetation Index NDVI was then applied to the images for each Time period using the formula:

$$NDVI = \frac{Band\ 4 - Band\ 3}{Band\ 4 + Band\ 3} \text{ Landsat 4-7} \quad \text{equation 1}$$

$$NDVI = \frac{Band\ 5 - Band\ 4}{Band\ 5 + Band\ 4} \text{ Landsat 8-9} \quad \text{equation 2}$$

Band 3 and 4 were used in creating the NDVI for Landsat TM of 1990 and 2000, for Landsat 8 OLI of 2013 and 2021, band 4 and 5 were used, which represent red and infra-red bands respectively.

The created NDVI classes were loaded into ArcGIS Pro2.9, where they were categorized as High, Medium, and Low NDVI using an Equal Interval Classification Method based on these three classes. The following NDVI value classification was based on the ecological zone (North Eastern Nigeria), which is mostly characterized by sparse vegetation: Low NDVI values were defined as less than 0.14, medium NDVI values as between 0.14 and 0.3, and high NDVI as values above 0.3. The area for Trees Outside Forest was excised (Clipped), and examined, and maps for trees inside forest and TOF were created using the NDVI technique for data analysis ,through Erdas Imagine 2015and ArcGIS Pro2.9 program.

**Table 1:** Features of Satellite Data

Time Period	Satellite Image	Path/ Row	Acquisition Date	Bands Used in Analysis	Sensor or Resolution
1990	Landsat 4-5 Thematic Mapper	185/53, 185/54	December 17th, 1990	1, 2, 3, and 4	TM 30m
2000	Landsat 4-5 Thematic Mapper	185/53, 185/54	February, 1st, 2000	1, 2, 3, and 4	TM 30m
2013	Landsat 8 Operational Land Imager	185/53, 185/54	March 28th, 2013	2, 3, 4, and 5	OLI 30m
2021	Landsat 8 Operational Land Imager	185/53, 185/54	December 14th, 2021	2, 3, 4, and 5	OLI 30m

Source: USGS, 2021

## RESULTS AND DISCUSSIONS

*Changes in Forest Trees and TOF from 1990 - 2021:* The three classes of NDVI values of low, medium, and high are represented with red, green, and blue (RGB) colors as shown in the maps in the image's basic cognitive process, figures 2, 3, 4, 5, 6, 7, 8, and 9 (for both trees inside forest and trees outside forest). Green represents medium density with an NDVI value of 0.14 - 0.3 representing shrubs and grassland, blue represents high-density forest/trees with an NDVI value of > 0.3 representing healthy and dense forest, and red represents low density with an NDVI value of < 0.14 representing rocks, sands, and bare surface.

The result of cross tabular analysis on percentage changes on trees inside forest of the study area are presented in table 2 for 1990 and 2000. The result revealed that rock, sand and bare surface presented as low density in the image classification occupied a total land area of 4,088.8km<sup>2</sup> in 1990 and decreased to 1241.4km<sup>2</sup> in the year 2000 indicating a decreased of -62.61%. Shrubs and grassland presented as medium density in image classification occupied a total land area of 1,737.5km<sup>2</sup> in 1990 and increased to 3,198.0km<sup>2</sup> in the year 2000, indicating an increase of 32.18% in 2000. Healthy trees presented as high density forest in the image classification occupied a total land area of 549.2km<sup>2</sup> in 1990 increases to 779.4km<sup>2</sup> in the year 2000, indicating an increased of about 5.07% in the year 2000. This means that rocks and baresurface give way to shrubs and grassland with slide burst in forest which might be because of increase in plantation and slower rate logging. Similar trend with slide variations also occurred on the trees density between year 2000 and 2013. Rocks, sands and bare surface presented as low density occupied a total land area of 1241.4km<sup>2</sup> in year 2000 increased to 1,603.0km<sup>2</sup> in 2013, indicating an increase of 29.59%. Shrubs and grassland presented as medium density in year 2000 occupied a total land area of 3198km<sup>2</sup>, increased to 3,874.4km<sup>2</sup> in 2013, indicating an increase of 55.36%. Healthy forest presented as high

density in year 2000 occupied a total land area of 779.4km<sup>2</sup> then decreased to 595.5km<sup>2</sup> in 2013, indicating a decreased of -15.05%. The results showed an increase both in rocks, baresurface and in shrubs, grassland with larger increase in later class while a drastic decline occurred in healthy forest and might be because of rise in population in the area as a result of insurgency within that period who depends solely on forest resource.

The scenario continued however, between 2013 and 2021 showing similar transitions across the three classes of NDVI value range. In 2013, rocks, sands and bare surface (low density) occupied a total land area of 1,603.0km<sup>2</sup> then increases to 1,755.1km<sup>2</sup> in the year 2021, indicating increased of 17.49%. Shrubs and grassland (medium density) in 2013 occupied a total land area of 3,874.4km<sup>2</sup> increased to 4171.2km<sup>2</sup> in 2021, indicated an increase of 34.13%. Healthy forest (high density) in 2013 occupied a total land area of 595.5km<sup>2</sup> then decreased to 174.8km<sup>2</sup> in 2021 which indicated a decreased of -48.38% that year.

The changes in forest is similar to that of between 2000 and 213 only that here the reduction in healthy forest is more Sevier than the previous. The healthy forests have lost to rocks, bare surface and grassland and shrubs within the study period. This means that the forest was highly tempered with in the area as a result of population growth coupled with the said insurgency activity, agriculture, firewood, overgrazing and construction.

The result is in line with that of Mohammed and Abubakar (2019) in a study conducted on vegetation of Adamawa State, attested that immigrant farmers, herdsmen and internally displaced persons IDP's influenced loss of vegetation of the State. However, an increase of about 5.07% was recorded within the period (1990 -2000). This might be because the protected forests in the study area were less tempered with, especially Girei, Bagale, and Gurin Forests Reserves.

**Table 2:**Change Detection of Trees inside Forest in percentages between 1990- 2021

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NDVI Class/Year	1990 AreaKm <sup>2</sup> (a)	2000 AreaKm <sup>2</sup> (b)	Changes between 1990 and 2000 Area km <sup>2</sup> (b-a)	% Change (km <sup>2</sup> )	Remark
Low (< 0.14)	4088.8	1241.4	-2847.4	-62.61	Decreased
Medium(0.14-0.3)	1737.5	3198.0	1460.5	32.18	Increased
High(> 0.3)	549.2	779.4	230.2	5.07	Increased
Total	6375.5	5218.8	4538.1	100	
NDVI Class/Year	2000 AreaKm <sup>2</sup> (a)	2013 AreaKm <sup>2</sup> (b)	Changes between 2000 and 2013 Area km <sup>2</sup> (b-a)	% Change (km <sup>2</sup> )	Remark
Low (< 0.14)	1241.4	1603.0	361.6	29.59	Increased
Medium (0.14-0.3)	3198.0	3874.4	676.4	55.36	Increased
High(> 0.3)	779.4	595.5	-183.9	-15.05	Decreased
Total	5218.8	6072.9	1221.9	100	
NDVI Class/Year	2013 AreaKm <sup>2</sup> (a)	2021 AreaKm <sup>2</sup> (b)	Changes between 2013 and 2021 Area km <sup>2</sup> (b-a)	% Change (km <sup>2</sup> )	Remark
Low (< 0.14)	1603.0	1755.1	152.1	17.49	Increased
Medium (0.14-0.3)	3874.4	4171.2	296.8	34.13	Increased
High(>0.3)	595.5	174.8	- 420.7	- 48.38	Decreased
Total	6072.9	6101.1	869.6	100	

Low = rocks, sands, bare surface. Medium = shrubs and grassland. High=dense forest/trees  
 Source: Field work, 2021

Table 3 also presents the result of cross tabular analysis in percentage changes on trees outside forest TOF of the study area from 1990 to 2000. The result revealed that rocks, sands and bare surface presented as low density in the image classification occupied a total land area of 152.6km<sup>2</sup> in 1990 and then dropped to 40.2km<sup>2</sup> in the year 2000 indicating a decreased of -61.29%. Shrubs and grassland represented as medium density in image classification occupied a total land area of 17.1km<sup>2</sup> in 1990 and then increased to 86.1km<sup>2</sup> in the year 2000, indicating an increase of 37.62%. Healthy trees presented as high density forest in the image classification occupied a total land area of 12.9km<sup>2</sup> in 1990 then decreases to 10.9km<sup>2</sup> in the year 2000, indicating a decreased of about -1.09%. This means that decrease in rocksand baresurface correspond with decline in dense trees, resulting to increase in shrubs and grassland in the area within the period.Similar trend with slide variations also occurred on the trees density between year 2000 and 2013. Rocks, sands and bare surface presented as low density occupied a total land area of 40.2km<sup>2</sup> in year 2000 then decreased to 8.8km<sup>2</sup> in 2013, indicating a decreased of -24.51%. Shrubs and grassland presented as medium density in year 2000 occupied a total land area of 86.1km<sup>2</sup>, and then increased to 178.3km<sup>2</sup> in 2013, indicating an increase of 71.98%. Healthy forest presented as high density in year 2000 occupied a total land area of 10.9km<sup>2</sup> then decreased to 6.4km<sup>2</sup> in 2013, indicating a decreased of -3.51%. The result is similar to that of 1990 to 2000 i.e decrease in rocks, bare

surface and dense trees and might be attributed to the modern construction of houses, roads and pavement in the urban areas that led to the decline in the number TOF. Rocks and baresurface plus dense trees have lost to grassland an shrubs within the period.

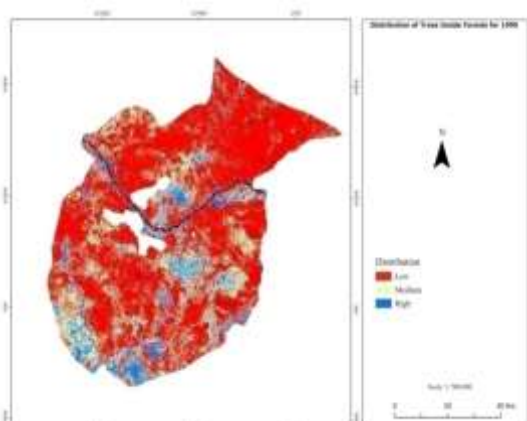
The scenario continued however, between 2013 and 2021 showsa similar transition across the three classes of NDVI value. In 2013, rocks, sands and bare surfaces (low density) occupied a total land area of 8.8km<sup>2</sup> then increases to 45.9km<sup>2</sup> in the year 2021, indicating an increase of 58.15%. Shrubs and grassland (medium density) in 2013 occupied a total land area of 178.3km<sup>2</sup> and then decreased to 154.4km<sup>2</sup> in 2021, indicating a decrease of -37.46%. Healthy forest (high density) in 2013 occupied a total land area of 6.4km<sup>2</sup> then decreased to 3.6km<sup>2</sup> in 2021 which indicated a decreased of - 4.39% .

The result shows a tremendous increase in rocks and bare surface with alarming decline in shrubs, grassland and dense trees. It means that dense trees plus shrubs and grassland have lost to rocks and bare surface in the area. The finding was in line with the findings of HeadBoy (2021) who reported that in Jimeta Metropolitan area, the area covered by trees has been reduced from 74.47km<sup>2</sup> in 1991 to 45.42km<sup>2</sup> in 2007. He argued that increased in urbanization and population growth influences the way land is used, which consequently contributed to urban forest depletion.

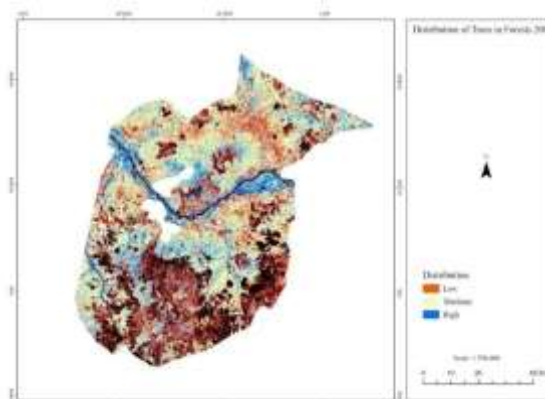
**Table 3:** Change Detection for TOF in percentages between 1990- 2021

NDVI Class/Year	1990 AreaKm <sup>2</sup> (a)	2000 AreaKm <sup>2</sup> (b)	Changes between 1990 and 2000 Area km <sup>2</sup> (b-a)	% Change (km <sup>2</sup> )	Remark
Low (< 0.14)	152.6	40.2	-112.4	- 61.29	Decreased
Medium(0.14-0.3)	17.1	86.1	69	37.62	Increased
High(> 0.3)	12.9	10.9	- 2	- 1.09	Decreased
Total	182.6	137.2	183.4	100	
NDVI Class/Year	2000 AreaKm <sup>2</sup> (a)	2013 AreaKm <sup>2</sup> (b)	Changes between 2000 and 2013 Area km <sup>2</sup> (b-a)	% Change (km <sup>2</sup> )	Remark
Low (< 0.14)	40.2	8.8	- 31.4	- 24.51	Decreased
Medium (0.14-0.3)	86.1	178.3	92.2	71.98	Increased
High(> 0.3)	10.9	6.4	- 4.5	- 3.51	Decreased
Total	137.2	193.5	128.1	100	
NDVI Class/Year	2013 AreaKm <sup>2</sup> (a)	2021 AreaKm <sup>2</sup> (b)	Changes between 2013 and 2021 Area km <sup>2</sup> (b-a)	% Change (km <sup>2</sup> )	Remark
Low (< 0.14)	8.8	45.9	37.1	58.15	Increased
Medium (0.14-0.3)	178.3	154.4	- 23.9	-37.46	Decreased
High(>0.3)	6.4	3.6	- 2.8	- 4.39	Decreased
Total	193.5	203.9	63.8	100	

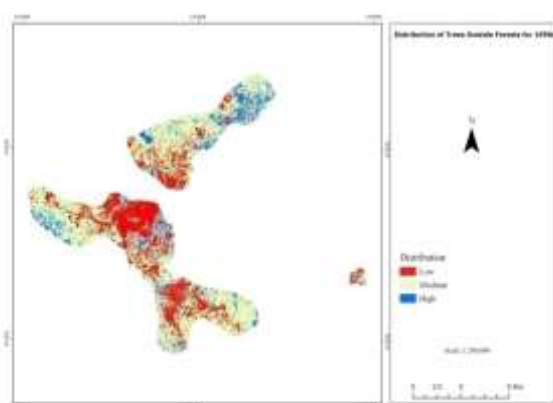
*Low = rocks, sands, bare surface. Medium = shrubs and grassland. High=dense forest/trees*  
 Source: Field work, 2021



**Fig 2:** NDVI Map showing Trees Inside Forest in 1990



**Fig 4:** NDVI Map showing Trees Inside Forest in 2000



**Fig 3:** NDVI Map showing Trees Outside Forest in 1990

The finding also is consistent with Zemba (2010) who study the Land use/Land cover Change and Development of Urban Head Island in Jimeta Metropolis, Adamawa State. In his findings he stressed that the continuous degradation of urban trees in the area will lead to higher concentration of carbon in atmosphere consequently resulting in temperature increase. Thus trees as a major component of the terrestrial ecosystem plays an important role in the global carbon cycle acting as both sources and sinks of carbon depending on the specific regime and activities. Luigard and Heil (2014) who studied Carbon accumulation by Native Trees and Soils in an Urban Park, Auckland, New Zealand conformed this finding that increased in urbanization is destroying natural

ecosystems and degrading the environment of urban areas.

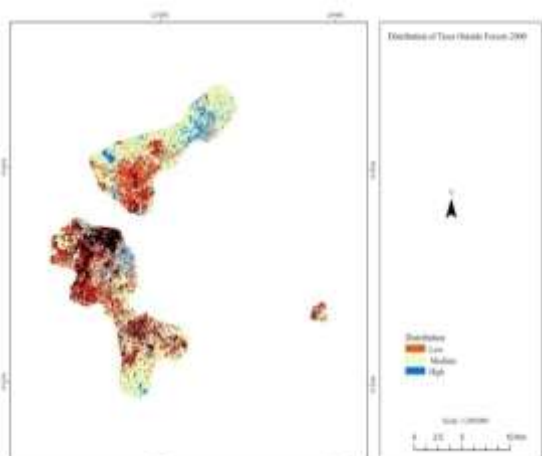


Fig 5: NDVI Map showing Trees outside Forest in 2000

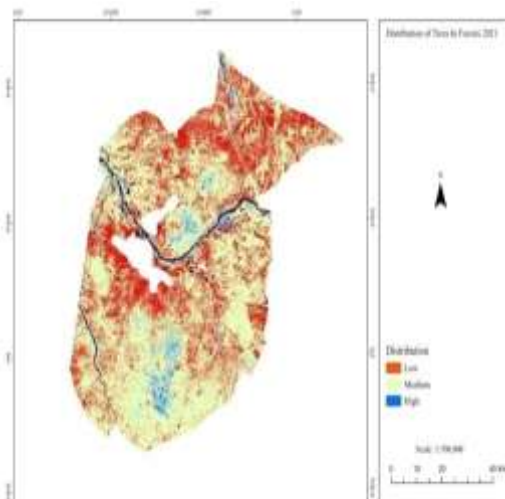


Fig 8: NDVI Map showing Trees Inside Forest in 2021

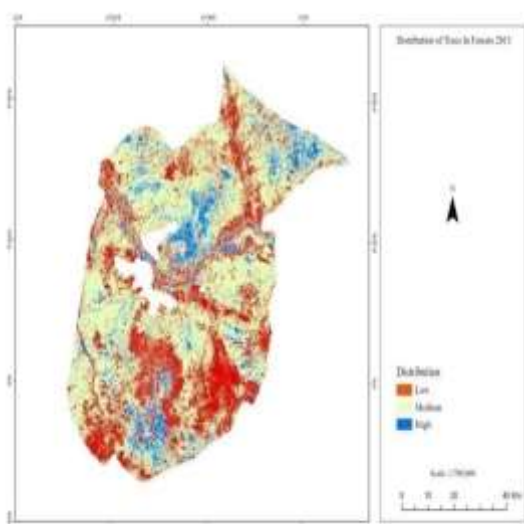


Fig 6: NDVI Map showing Trees Inside forest in 2013

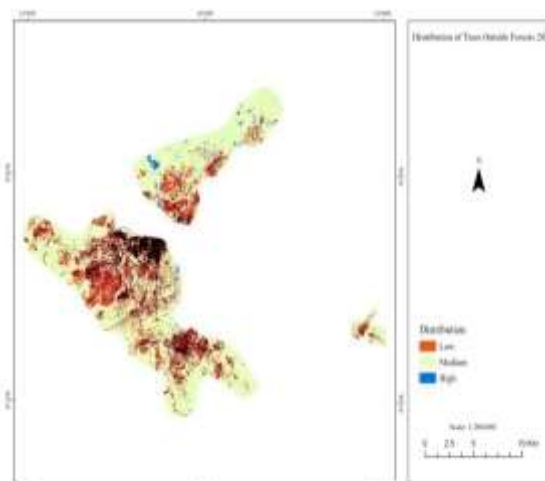


Fig 9: NDVI Map showing Trees Outside Forest in 2021

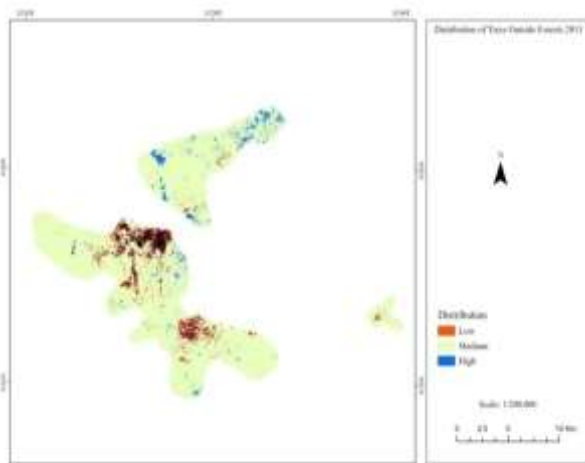


Fig 7: NDVI Map showing Trees Outside Forest in 2013

*Accuracy Assessment:* Without evaluating the image's correctness, the categorization process is not finished. On the classified images, a sample for testing pixels was selected and their class identification was compared with the reference data to ascertain the classification accuracy. The classification accuracy was evaluated using the Kappa coefficient which is an index that compares the categorization results to values determined by chance. As shown in Table 4, the NDVI results' kappa degree of accuracy was 85% in 1990, 92% in 2000, 97% in 2013, and 94% in 2021. The degree of accuracy that is above 60% shows the reliability performance of the NDVI images classification indicating an agreement between the two data sets (Pavel, 2016). It determines how well a specific classification method performed. In either case the land cover types are in reality very similar.

**Table 4:** Accuracy Assessment for NDIV 1990, 2000, 2013 and 2021

Accuracy Assessment for NDVI 1990								
Class	No NDVI	Low	Medium	High	Total	U_Accuracy	Kappa	
No NDVI	10	0	0	0	10	1	0	
Low	12	294	10	1	317	0.927444795	0	
Medium	2	0	133	0	135	0.985185185	0	
High	0	0	17	26	43	0.604651163	0	
Total	24	294	160	27	505	0	0	
P_Accuracy	0.416667	1	0.83125	0.962962	0	0.914563107	0	
Kappa	0	0	0	0	0	0	0.847682	

Accuracy Assessment for NDVI 2000								
Class	NoNDVI	Low	Medium	High	Total	U_Accuracy	Kappa	
No NDVI	83	0	0	0	83	1	0	
Low	0	99	0	0	99	1	0	
Medium	0	1	254	0	255	0.996078	0	
High	0	3	23	36	62	0.580645	0	
Total	83	103	277	36	499	0	0	
P_Accuracy		0.9611						
Kappa	1	65	0.916968	1	0	0.946955	0	
	0	0	0	0	0	0	0.918694	

Accuracy Assessment for NDVI 2013								
Class	No NDVI	Low	Medium	High	Total	U_Accuracy	Kappa	
No NDVI	12	0	0	0	12	1	0	
Low	0	128	1	0	129	0.9922481	0	
Medium	0	6	304	1	311	0.977492	0	
High	0	1	0	47	48	0.9791667	0	
Total	12	135	305	48	500	0	0	
P_Accuracy		0.94814						
Kappa	1	8	0.996721	0.979167	0	0.982	0	
	0	0	0	0	0	0	0.966736	

Accuracy Assessment for NDVI 2021								
Class	No NDVI	Low	Medium	High	Total	U_Accuracy	Kappa	
No NDVI	10	0	0	0	10	1	0	
Low	0	141	0	1	142	0.992957746	0	
Medium	0	0	326	11	337	0.96735905	0	
High	0	0	0	14	14	1	0	
Total	10	141	326	26	503	0	0	
P_Accuracy	1	1	1	0.466667	0	0.968810916	0	
Kappa	0	0	0	0	0	0	0.938149	

Source: Data Analysis (2021)

**Conclusions:** This study highlights the significant of NDVI technique in forest studies. The results from this study shows that, the high NDVI values of Forest and TOF total area are fast disappearing, while the low and medium values which are match to rocks and bare ground, grassland and shrubs are increasing. The Forest total area was reduced to -48.38% in 2021, while deforestation caused a substantial decrease in the number of TOF to -4.39% in 2021. Trees in urban environments TOF and trees inside forest both have a better ability to absorb carbon from the atmosphere and lessen the effects of climate change; food inform of fruits, shelter, shade, as well as aesthetics. There should be a sound afforestation and reforestation programs in the area by the government, Non-governmental organizations, World Bank, partners and individual land owners to enable forests perform their services to man and the micro organism.

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**Data Availability Statement:** Data are available upon request from the corresponding author.

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