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Assessment of Status and Distribution of Trees Inside Forest and Trees Outside Forest between 1990-2021 in Adamawa Central, Adamawa State, Nigeria

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ABSTRACT: Forests significantly aid the stabilization of the global ecology by solving environmental concerns such as climate change and carbon sequestering. Therefore, the objective of this paper was to evaluate the status and distribution of Trees Inside Forest (TIF) and Trees Outside Forests (TOF) between 1990 and 2021in Adamawa Central, Adamawa State Nigeria, using standard methods of the Normalized Different Vegetation Index (NDVI), through the use of satellite imagery from 1990, 2000, 2013, and 2021 respectively. The findings showed that, the TOF decreased from 12.9 km^2 in 1990 to just 3.6 km^2 in 2021, the number of TIF decreased from 549.2 km^2 in 1990 to 174.8 km^2 in 2021. A shift in policy is necessary to mitigate the negative effects of changing land cover, boosting agricultural production, and restoring urban and forest trees by various means like afforestation and replanting.

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Nigeria is blessed with large areas of forest land by nature, including tropical rainforests in the southwest, swamp forests in the southernmost section of the nation, and wooded savannah in the central belt (Mfon *et al.*, 2014). According to the authors' further report, Nigeria is one of the nations in the world with an abundance of forest resources, where by forests is made up of roughly 110, 890 km^2 of Nigeria's 910,770 km2 total land area. Although the rate of net global deforestation has slowed down by more than 50% over the past 25 years due to improvements in forest management practices worldwide. The world's forests are still disappearing as a result of population growth and the conversion of forested land to agriculture and other uses, according to FAO (2015).According to Smeets and Faaij's (2007) assessment, TOF's provide almost two thirds of the wood fuel consumed in developing countries. People will become less in touch with natural forests (Nowak*et al.*,2001), and non-forest trees in urban and peri-urban settings will become more significant as a substitute for nature in the daily lives of a growing proportion of the global population. Studies have indicated that trees are an important resource, and they are produced outside of forests as part of agricultural and urban landscapes, as well as in natural tree formations with low crown cover (Smeets and Faaij 2007). The urban forest, which is made up of the trespass in urban gardens, parks, and streets, offers numerous ecosystem services to cities. These services include buffering carbon emissions

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through sequestration and carbon storage (Nowak and Crane, 2001) and eliminating air-borne pollutants, which lessens the effects of urban heat islands (Akbari *et al.,* 2001).As stated in various ways, trees serve as a significant sink for carbon dioxide (CO_2), absorbing carbon from the atmosphere and storing it as fixed biomass while they develop. When it comes to reducing atmospheric carbon emissions, urban trees provide two advantages: they directly store carbon and stabilize natural ecosystems by increasing nutrient, recycling and allowing biogeochemical processes to maintain climate conditions (Sadeli, 2013).Plant greenness or photosynthetic activity is measured by the Normalized Difference Vegetation Index (NDVI). The proxy for vegetation productivity that is most frequently used and simple to calculate is based on satellite images (Scanlon, 2002). Based on the concept of Photo synthetically Active Radiation (PAR) and a straightforward numerical indicator, the Normalized Difference Vegetative Index (NDVI) provides a broad estimate of the amount of vegetative cover on the land surface (Malo *et al.,* 1990). Through spatial and temporal analysis tools, change detection is effective in detecting cumulative changes in land use and land cover, species extinction, rate of deforestation, rate of change on trees outside forests (TOF), afforestation effect, and other changes. Therefore, the objective of this paper was to evaluate the status and distribution of Trees Inside Forest (TIF) and Trees Outside Forests (TOF) between 1990 and 2021in Adamawa Central, Adamawa State, Nigeria.

MATERIALS AND METHOD

Study Area: With a total land area of about 6,419.69 km², the research area is situated between latitudes 8^0 38' 47'' and 9^0 50' 17'' North and longitudes 11° 58' 54'' and 13° 18' 31'' East. The research geographic 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).

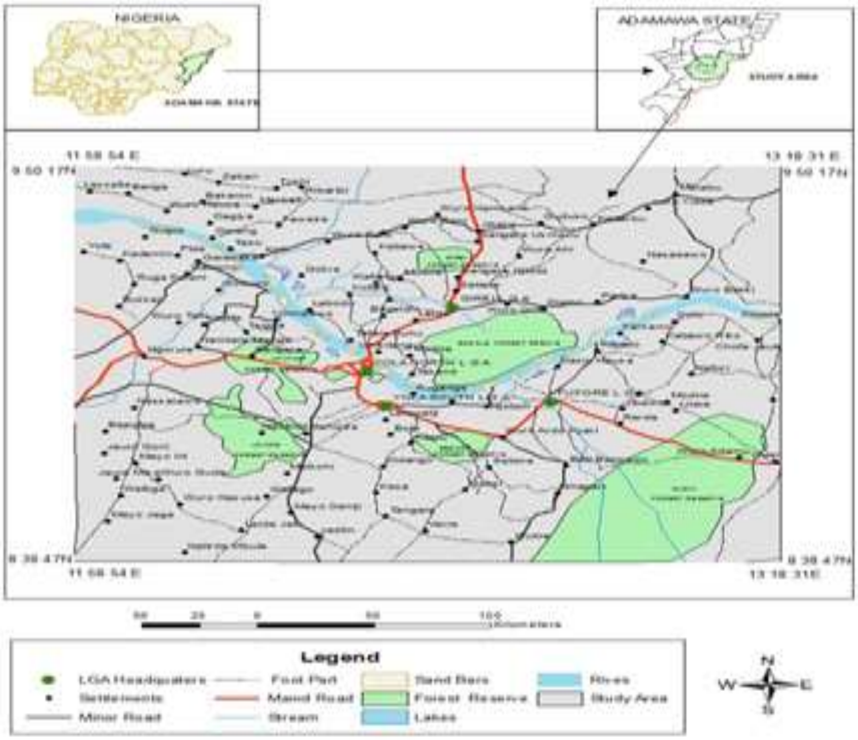

Fig 1: Map of the study area
Adopted from Adamawa State Land and Survey

*Methods:*Four historical Landsat imagery encompassing the study region over the previous 32 years (1990–2021) are the source of 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).

The formula for NDVI images was NDVI = NIR – RED/NIR + RED, where RED stands for red band and NIR for near-infrared band (Kriegler *et al.,* 1969). 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^2), images were cropped to fit the study area's boundaries. For trimming the TOF research location, ArcGIS Pro 2.9 was utilized. Next, using the following formula, the Normalized Difference Vegetation Index (NDVI) was applied to the imagery for each period:

i. Band 4 - Band 3 / Band 4 + Band 3 is the NDVI for Landsat 4-7.

ii. Band 5 in addition to Band 4 / Band 5 is the NDVI.

iii. According to Table 1, Landsat 8 OLI of 2013 and 2021 used bands 4 and 5, which represent red and infra-red bands, respectively, while Landsat TM of 1990 and 2000 used bands 3 and 4.

iv. 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 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 values as any values above 0.3. The area for Trees Outside Forest was excised (Clipped), and examined, and maps for trees inside the forest and TOF were created using the NDVI technique for data analysis. The Erdas Imagine 2015, ArcGIS Pro2.9 program was utilized to analyze the data.

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

Status and Distribution of TIF and TOF: Using the NDVI classification approach, Table 2 shows the findings of the distribution of trees inside forest and trees outside forest of the study area from 1990 to 2021, covering a total land area of 6,419.69 km^2.

Table2: Status and Distribution of TIF and TOF between 1990-2021

Trend of Trees Distribution for TIF (1990- 2021)				
Year	1990 Area (km^2)	2000 Area (km^2)	2013 Area (km^2)	2021 Area (km^2)
Low NDVI value (< 0.14)	4088.8	1241.4	1603.0	1755.1
Medium NDVI value (0.14 -0.3)	1737.5	3198.0	3874.4	4171.2
High NDVI value (>0.3)	549.2	779.4	595.5	174.8
Trend of Trees Distribution for TOF (1990-2021)				
Year	1990 Area (km^2)	2000 Area (km^2)	2013 Area (km^2)	2021 Area (km^2)
Low NDVI value (< 0.14)	152.6	40.2	8.8	45.9
Medium NDVI value (0.14 -0.3)	17.1	86.1	178.3	154.4
High NDVI value (>0.3)	12.9	10.9	6.4	3.6

Source: Landsat Data Analysis, (2021)

With four study periods spanning from 1990 to 2021, the trend of tree distribution illustrates how each specific class varies over time. Within the research region, Table 2 and Figures 2–9 showed how the NDVI value of the trees changed over time. A total of 4088.8 square kilometres were covered by the low NDVI value for trees inside forest in 1990; this number dropped to 1241.4 sq km in 2000; it increased to 1603.0 sq km in 2013, and it reached 1755.1 sq km in 2021. The medium NDVI values increased from 1737.5 sq km in 1990 to 3198.0 sq km in 2000, 3874.4 sq km in 2013, and to 4171.2 sq km in 2021. As aforementioned, the high NDVI values for trees within forests were 549.2 sq km in 1990 and increased to 779.4 sq km in 2000, dropped to 595.5 sq km in 2013 and then decreased to 174.8 in 2021.The result in Table 2also revealed the trees distribution for TOF (trees outside forest) in the research area from 1990 to 2021. The low NDVI values were 152.6 sq km in 1990, 40.2 sq km in 2000, 8.8 sq km in 2013, and 45.9 sq km in 2021. The medium NDVI readings for TOF were 17.1 sq km in 1990, 86.1 sq km in 2000, 178.3 sq km in 2013, and 154.4 sq km by 2021.

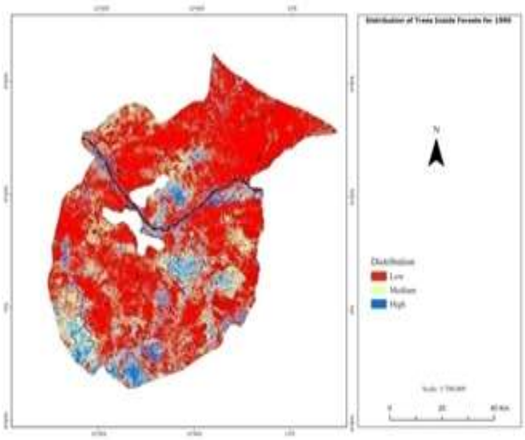

Fig 2: NDVI Map showing Trees Inside Forest in 1990

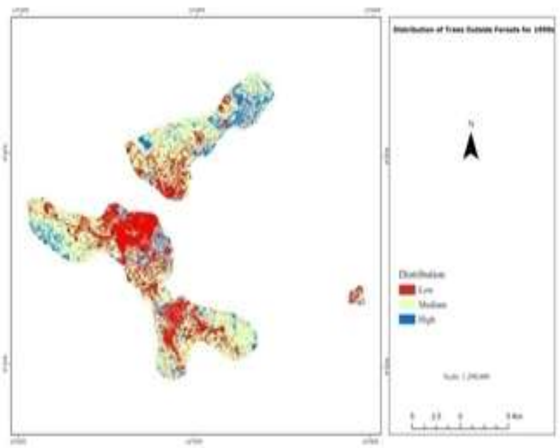

Fig 3: NDVI Map showing Trees Outside Forest in 1990

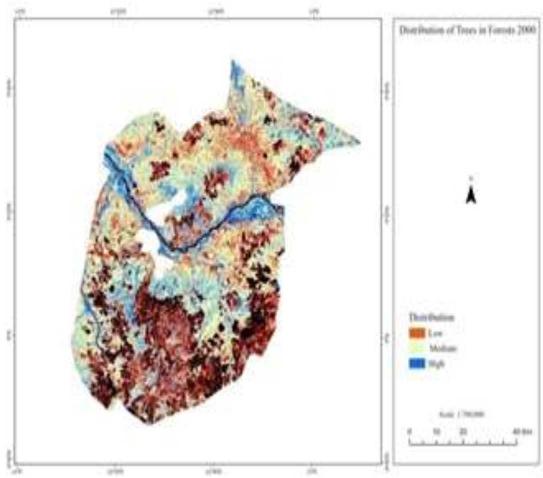

Fig 4: NDVI Map showing Trees Inside Forest in 2000

However, the high NDVI values for TOF in 1990 covered an area of roughly 12.9 square kilometres in 1990. This area decreased to 10.9 square kilometres in 2000, then decreases further to 6.4 square kilometres in 2013, and finally decreased significantly to 3.6 square kilometres in the year 2021.The NDVI results generally imply that the forest and TOF were generally reduced and depleted, indicating a highly substantial alteration. High rates of deforestation and population pressure are the main causes of the depletion of the forests and TOF. Similar findings were noted in a Zeleke and Hurni (2001) study, it was reported from the findings that, the primary cause of Ethiopia's declining vegetation cover is the country's high rate of deforestation, which is higher than the rates of afforestation and replanting. In another study by Gashaw *et al.* (2014) that used GIS approaches to detect vegetation change in the Hulet Wegedamea area of Northern Ethiopia between 1985 and 2011 produced similar results.

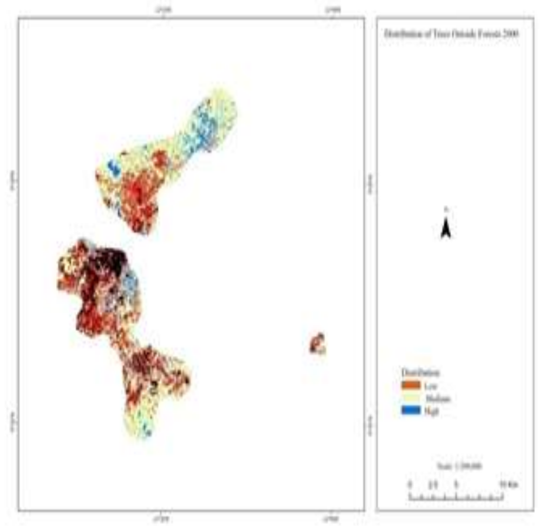

Fig 5: NDVI Map showing Trees outside Forest in 2000

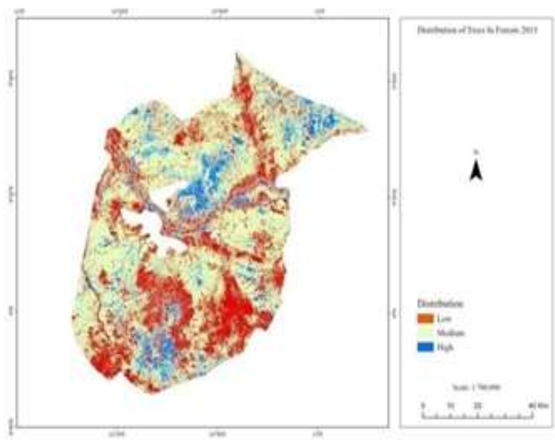

Fig 6: NDVI Map showing Trees Inside forest in 2013

The study conducted indicates that between the two periods, there is a degradation of vegetation. To lessen the issue, various restoration strategies for degraded areas ought to be encouraged. Different governmental and non-governmental organizations need to be the driving forces behind the reforestation and afforestation of various species.

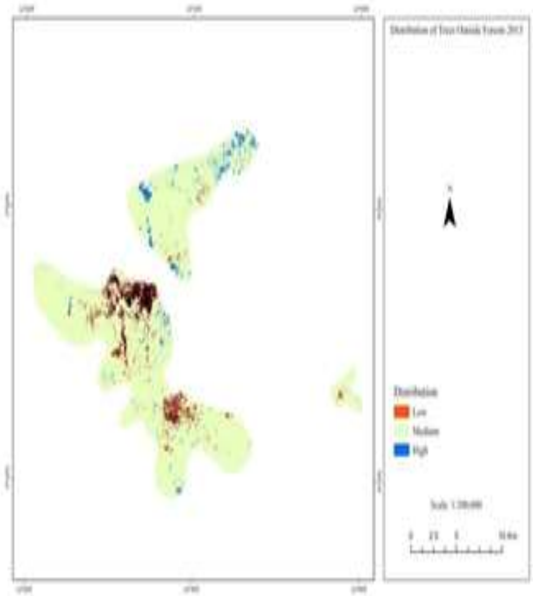

Fig 7: NDVI Map showing Trees Outside Forest in 2013

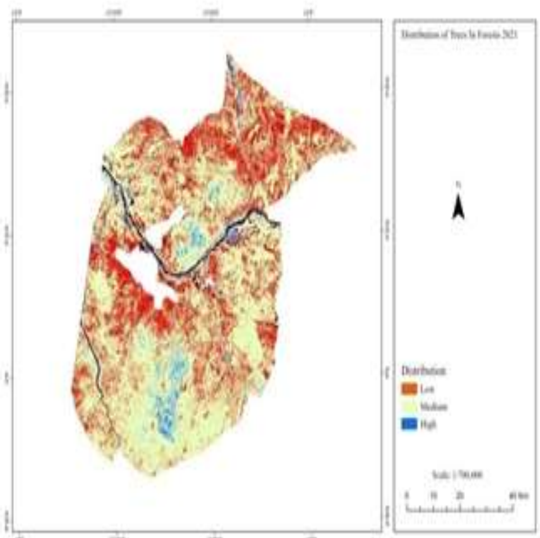

Fig 8: NDVI Map showing Trees Inside Forest in 2021

The three classed NDVI values of low, medium, and high are represented with red, green, and blue (RGB) colours 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 the forest and trees outside the 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.

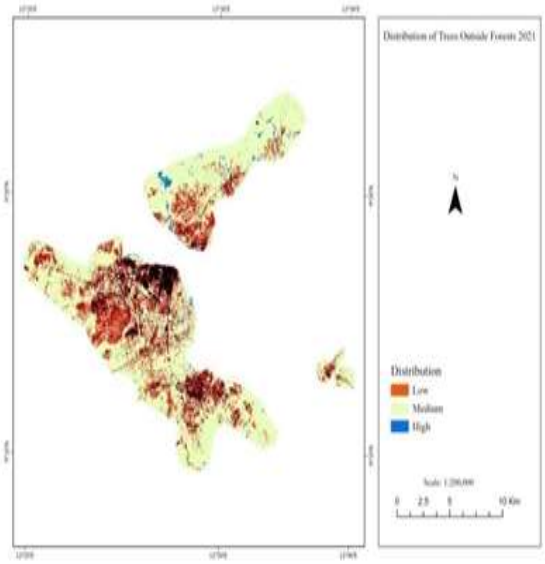

Fig 9: NDVI Map showing Trees Outside Forest in 2021

*Accuracy Assessment:*Without evaluating the image's correctness, the categorization process is not finished. On the classified images, a sample of testing pixels is selected and their class identification is 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 3, the NDVI results' kappa degree of accuracy was 85% in 1990, 92% in 2000, 97% in 2013, and 94% in 2021.

*Conclusions:*This study highlights the significant of NDVI technique in forest studies. The results from this study showed that, the NDVI values of TIF and TOF total area are fast disappearing, while the low and medium values which correspond to rocks and bare ground, grassland and shrubs are increasing.

The TIF total area was reduced to 174.8 km^2 in 2021, while deforestation caused a substantial decrease in the number of TOF to 3.6 km^2 in 2021. Trees in urban environments TOF and trees inside forest TIF both have a better ability to absorb carbon from the atmosphere and lessen the effects of climate change.

Table 3: 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	**No NDVI**	**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	1	0.961165	0.916968	1	0	0.946955	0
Kappa	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	1	0.948148	0.996721	0.979167	0	0.982	0
Kappa	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)

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