



# Assessment of Forest Reserve Deforestation in the Federal Capital Territory (FCT), Nigeria

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## Abstract

Forests provide a wide range of ecosystem services. Specifically, forests purify the air, filter water supplies, control floods and erosion, sustain biodiversity and genetic resources. In addition, they also provide recreation, cultural enrichment and educational services. Globally, there has been a significant decline in forest resources. The reduction of forest may involve individual trees of a given species at a given geographical coverage, site or specific species throughout its range or within an ecosystem. The causes of the reduction in forests are not evident due to complex interactions that need careful examination according to clear diagnostic criteria. This study evaluated deforestation in the Federal Capital Territory forest reserves and changes in land use/land cover changes over a 31-year period. The assessment of land use/land cover change using remote sensing data provides information for decision support systems. This information can support land conservation strategies, management of forest resources and enhance sustainable development. The purpose of the study was to identify changes in land use and land cover in the Federal Capital Territory forest reserves. To achieve this, satellite image processing techniques were employed to four epochs of 1990, 2001, 2013, and 2021 utilizing Landsat images. The results from this study revealed a significant reduction in forest reserves over the past 31 years, primarily due to anthropogenic activities. However, it was also observed that some forests areas have increased between 2013 and 2021 due to heightened insecurity in those locations. The results obtained from this study emphasized the necessity to enhance forest conservation mechanisms, as forests play a critical role in mitigating the impacts of climate change and providing various other ecosystem services.

## Subject Areas

Environmental Sciences

## Keywords

Deforestation, Land Use and Land Cover (LULC), Remote Sensing, Federal Capital Territory (FCT), Forest Reserves

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## 1. Introduction

Deforestation is one of the biggest challenges for people's livelihoods, the environment all around the world. Despite being mentioned in the Sustainable Development Goals under goal 15 "Life on Land" [1], the United Nation's Conference on Sustainable Development ("Rio + 20") has requested to set up the goal of forest Degradation Neutrality, calling for a compensation of degrading forest through land use and land cover improvement [2]. Furthermore, the sustainable development goals (SDGs) of the 2020 Agenda for Sustainable Development adopted by world leaders in September 2015 document the need to address the problem of deforestation. Similarly, sparse consideration has been given to how forest degradation on agricultural land could affect the ways in which forest is being managed and the implications it has for livelihoods and human development [3]. There is also an Economics of Deforestation (ELD) initiative, which is aimed at establishing a comprehensive framework for the evaluation of the economic losses due to forest degradation in order to assist the decision-making process [4].

The effective implementation of these international frameworks as well as well-informed planning and policy decisions, which are related to the sustainable forest management and the "zero net forest degradation" target requires credible and spatially explicit information on degraded forest [5]. A need to develop a standardized methodology for forest degradation assessment is also due to the necessity to support the sustainable development goal SDG 15.2. The SDG 15.2 aims "to protect, restore and promote sustainable use of forested land, to sustainably manage forests, as well as to halt and reverse land degradation" [1]. Deforestation of forest is caused by various factors, including climatic variations and human-induced activities. Human-induced deforestation occurs mainly due to overexploitation of forest resources for cropping and livestock farming, including irrigation practices, overgrazing of rangelands and fuel-wood exploitation [6].

Decision-making in ecosystem development and planning is becoming increasingly complex because of the interrelationship with various phenomena including local people, stakeholders, local culture and natural environment. Cost-benefit plays an important role in developing an ecosystem in a sustainable manner. GIS can be considered as a tool that provides techniques and technologies to achieve sustainable ecosystem development [7]. Remote sensing and GIS are considered as a set of powerful tools to process spatially referenced data and this spatial data

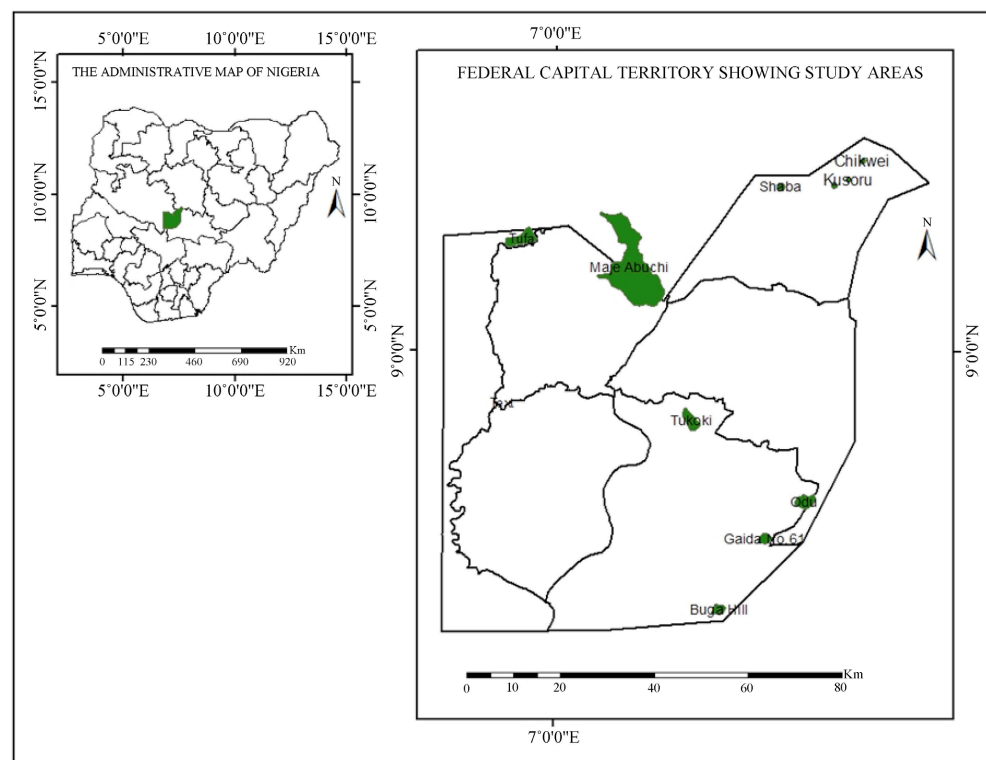
can be used to identify conflict, analyze impacts over time and find a suitable solution for a specific problem. Ecosystem activities generally can create various negative effects on surroundings. Impact assessment and simulation are increasingly important in ecosystem development and GIS can play a role in auditing environmental conditions, examining the suitability of locations for proposed developments site, identifying conflicting interests and modeling relationships.

The aim of the study is to monitor spatiotemporal forest reserve deforestation in the Federal Capital Territory with the following objectives: I. Assessment of land use and land cover change. II. Examination of land use and land cover change detection III. Examination of forest cover loss. IV. Identification of deforestation hotspot area.

## 2. Materials and Methods

### 2.1. Study Area

Federal Capital Territory is located within latitude Latitudes 8.25°N to 9.20°N and Longitudes 6.75°E to 7.60°E. and total Elevation of 536 m (**Figure 1**) with a total population of 1,402,201 (2006 population census) the (FCT) has a land area of 8000 square kilometres, this is about two and halftimes more than Lagos state land area, the former capital of Nigeria. The Federal Capital Territory is bounded on the north by Kaduna State, on the west by Niger State, on the east and south-east by Plateau State, and on the south-west by Kogi State. A scene that cannot be missed about Federal Capital Territory is coming together of the savannah grassland of the north and middle belt with the richness of the tropical rain forests of the south.



**Figure 1.** Study area map.

## 2.2. Methodology

### A. DATA ACQUISITION AND SOURCE

Remote Sensing Image: The Landsat data was acquired from the global land-cover website at the University of Maryland, USA (URL; <https://glad.umd.edu/ard/home>). The acquired images will be thematic mapper (TM) image of 1990, Enhance Thematic Mapper plus (ETM+) image of 2001 and 2013 and the Operational land Imager (OLI) of 2021 respectively as shown in **Table 1**. All the satellite images were obtained on 8<sup>th</sup> of November to follow weather consistence and climatic suitability of the work. The satellite data have 30 m spatial resolutions and the TM and ETM Plus images have spectral range of 0.45 - 2.35 micro meter with bands 1, 2, 3, 4, 5, 6, 7 and 8 while the Operational Land Imager (OLI) extends to band 12. All spatial datasets were projected to the WGS 84/UTM Zone 32 N coordinate system to ensure spatial consistency.

**Table 1.** Data use for the project.

S/N	Data Type	Year	Spatial Resolution
1	Landsat Thematic mapper (TM)	1990	30 meters
2	Landsat Enhanced Thematic mapper (ETM <sup>+</sup> )	2001	30 meters
3	Landsat Enhanced Thematic mapper (ETM <sup>+</sup> )	2013	30 meters
4	Landsat Operational Land Imager (OLI)	2021	30 meters
5	FCT Forests Shape file		

### B. SOFTWARE USED

The software used is as listed below:

a) ArcGIS 10.4:

The statistical analyst extensions of the ArcGIS 10.4 version was used to perform and create database, simple statistical analysis, and map.

b) Idrisi Selva:

Supervised classification was performed using Idrisi Selva and the land change modeler of the Idrisi was used to analyze the change detection between the years of observation.

Several systematic techniques were developed to perform vegetation dynamics analysis and change detection using as an input satellite images (time series or multitemporal images). The analysis of the spatiotemporal dynamics over the given observation period will be processed [8].

### C. DATA PRE-PROCESSING

The satellite imageries were preprocessed in order to correct the error during scanning, transmission and recording of the data. The pre-processing steps used were:

Radiometric correction to compensate the effects of atmosphere; this was carried out using Semi-Automatic classification plugin in Quantum Geographic Information System (QGIS). Geometric correction *i.e.* registration of the image to make it usable with other maps or images of the applied reference system was done by

georeferencing the image in Arc Map to register its spatial reference and noise removal to remove any type of unwanted noise due to the limitation of transmission and recording processes. This process was carried out in QGIS as explained in radiometric correction.

#### **i. Image Classification**

Image Processing Phase (Classification)

During the image-processing component of this study image pixels were grouped into land use types. The specific land use categories of interest to the study and the respective definitions were identified as

- Settlement Area: Land covered by buildings and other human made features.
- Bare surface: Rock outcrop, sand dunes, alluvial, gullies, mining areas
- Cropland: Grazing fields, Derived Savannah Agricultural Land: Farmlands including plantations.
- Forest: Areas dominated by woody vegetation
- Water Bodies: Natural water bodies including lakes, rivers, canals, and reservoir.

The specific processes followed to achieve the image classification into the identified land use classes are highlighted in this sub-section.

#### **ii. Unsupervised Classification**

Unsupervised classification using the ISODATA clustering criterion was used for the initial clustering of the pixels in the images. This method helped in the examination of the large number of unknown pixels and divided them into a number of classes based on the spectral characteristics present in the image values. This classification did not require analyst-specified training data. The number of desired classes at this stage was 15. These classes aided in developing the image training sites during the supervised classification process.

#### **iii. Field Work/Data Collection**

Field data collection was conducted to each forest on November 9<sup>th</sup> to 12<sup>th</sup>, 2021. During the field exercise, the coordinates of land use samples were collected. Some of these samples were used as training sites for the supervised classification and also used to interpret the clusters derived during the unsupervised classification. The second set of samples was used for conducting accuracy assessment (User's and Producer's accuracies) to test the consistency and reliability of the supervised classification. In addition to the collection of information on the location of land use classes, the field exercise provided an avenue to collect additional ancillary data on the deforestation sites. Some of the information collected on the field was used to estimate the volumes of forest loss at specific deforested sites.

#### **iv. Supervised Classification**

Supervised classification was used to cluster pixels in the satellite images into the identified six land use classes corresponding to user-defined training. The Maximum Likelihood classification algorithm was adopted because the approach is based on probability. In order to assign a pixel to a class, the probability of the pixel belonging to each of a predefined set of classes was calculated and the pixel assigned to the class for which the probability is highest. This approach is consistent and stable. Moreover, unless a probability threshold is selected, all pixels

in the image of interest are classified.

#### v. Accuracy Assessment

The accuracy assessment of the results from the supervised classification were conducted based on simple random sampling, and the results from the assessment were presented using error matrix that reports both user's and producer's accuracies in the result chapter of this report.

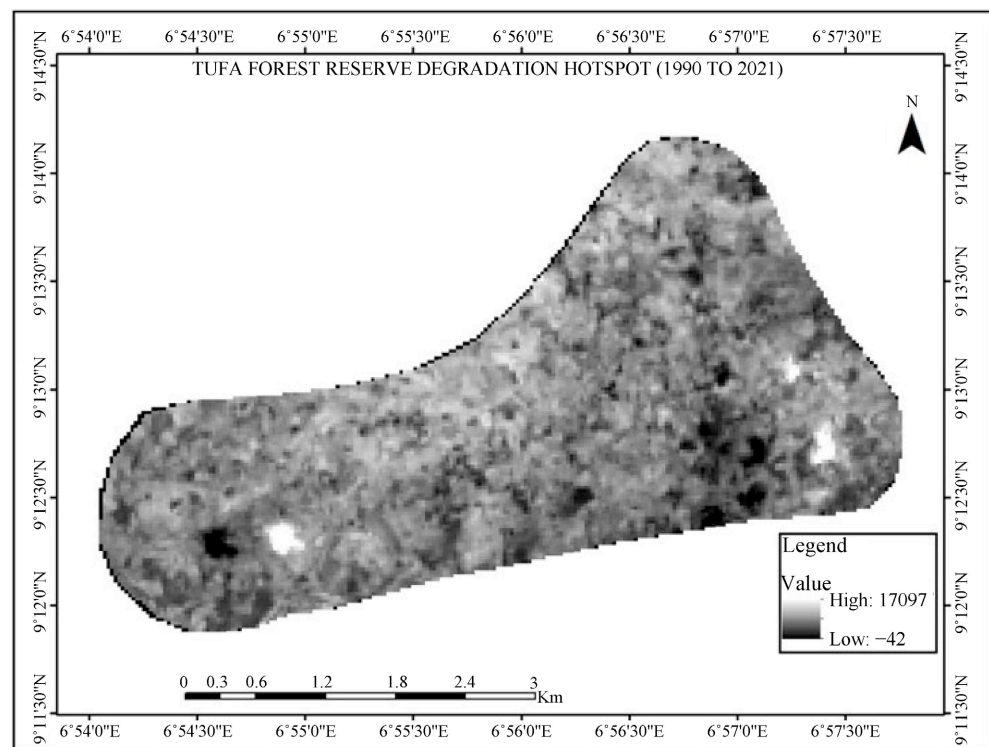
#### vi. Change Detection and Statistical Analysis of Change

A post-classification comparison change detection algorithm was used to determine changes in land use for the various epochs used in this study. The results are presented using transition matrix that indicates the transitions of the various land use during the various epochs.

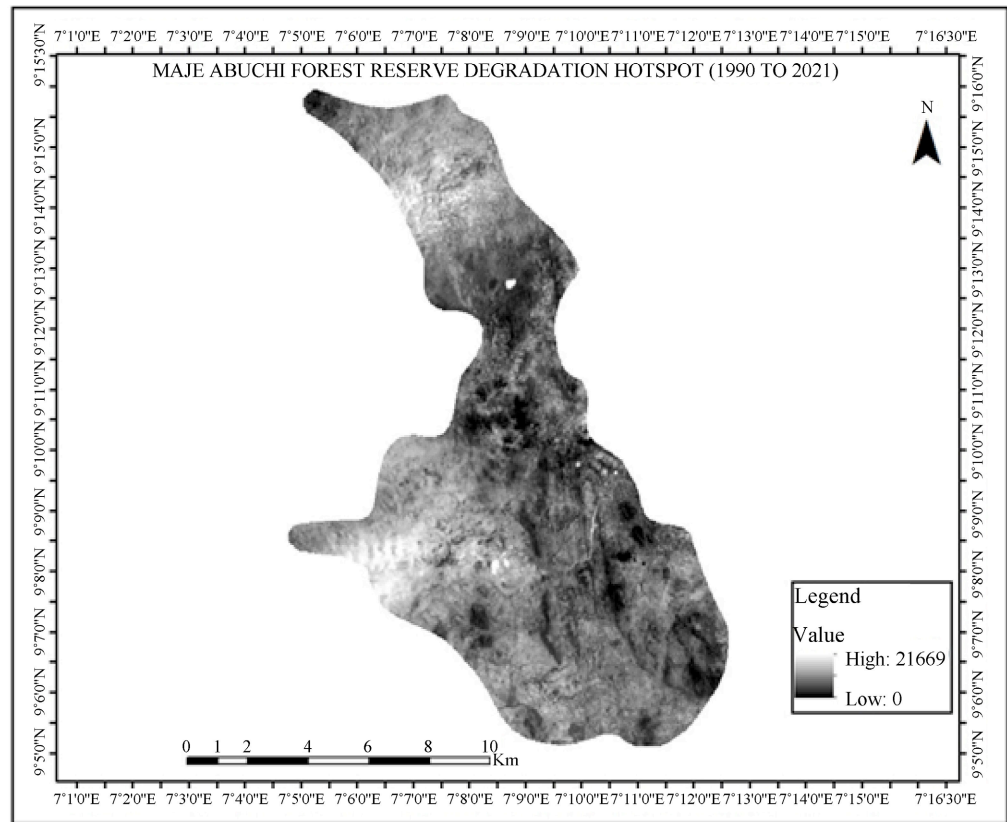
### 3. Results and Discussion

The terms Land Use and Land Cover (LULC) is often used interchangeably, but each term has its own unique meaning. Land cover refers to the surface cover on the ground like vegetation, urban infrastructure, water, bare soil etc. Identification of land cover establishes the baseline information for activities like thematic mapping and change detection analysis. Land use refers to the purpose the land serves, for example, recreation, wildlife habitat, or agriculture.

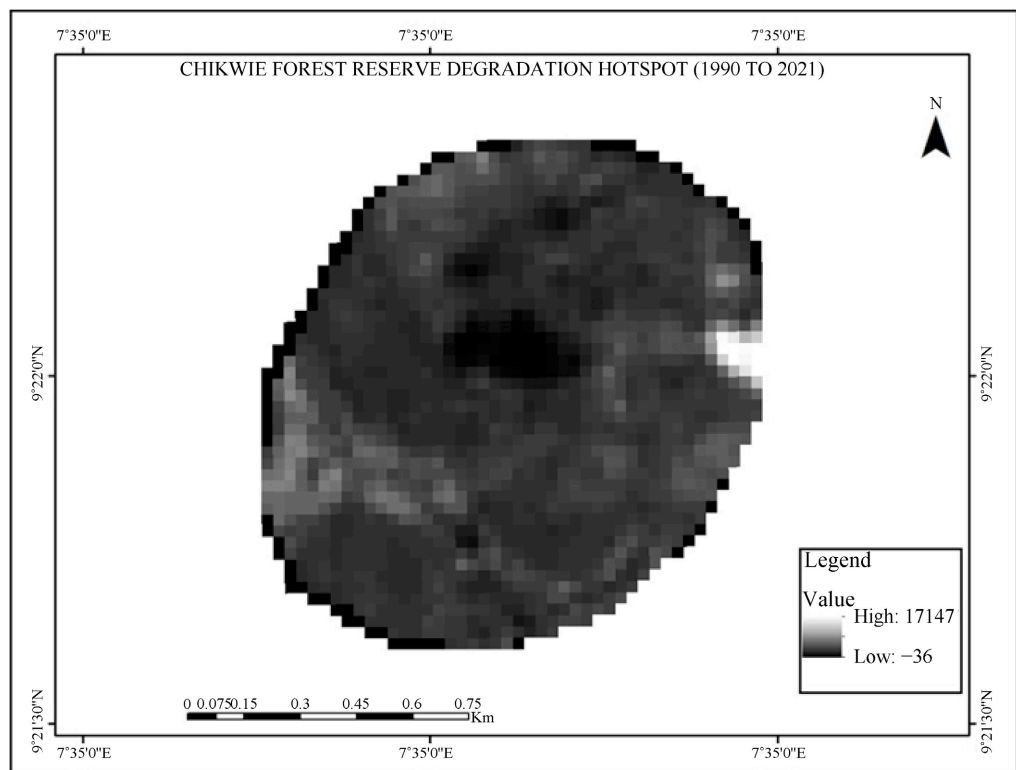
**Figures 2-11** show results of image differencing of hotspot areas of deforestation in Federal Capital Territory Forest Reserve. The grey white colour indicates the spot areas that are being seriously deforested (deforestation hotspot).



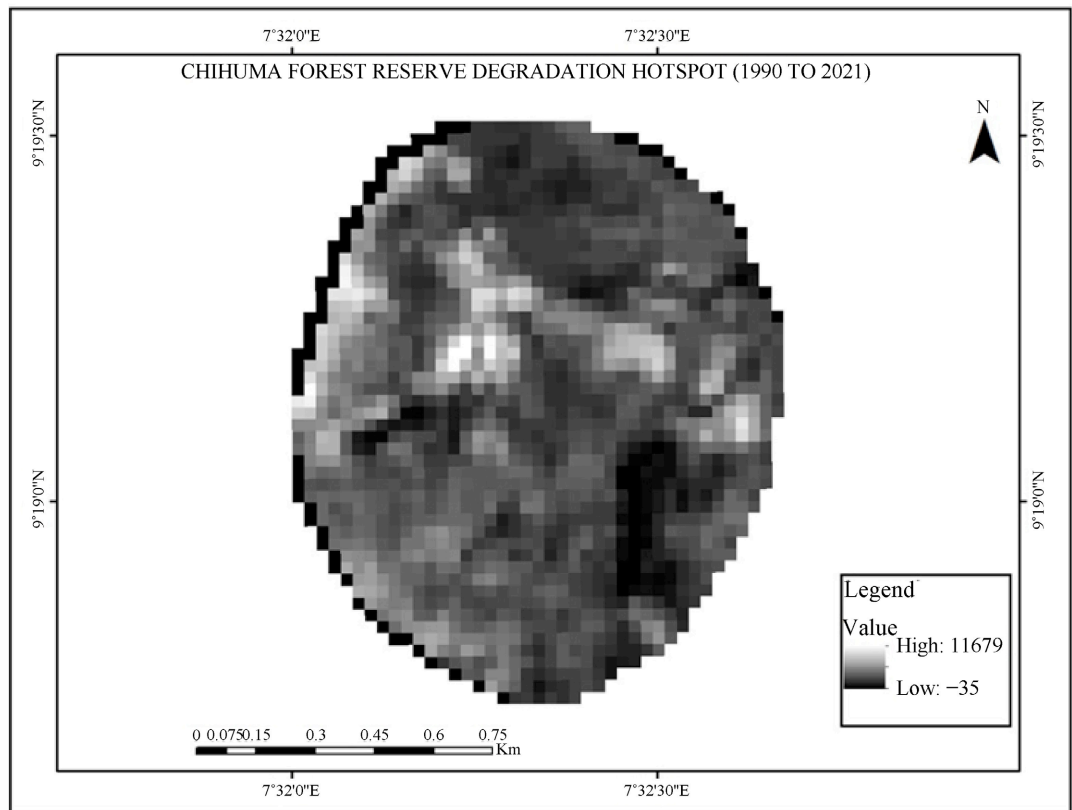
**Figure 2.** Tufa forest reserve hotspot area.



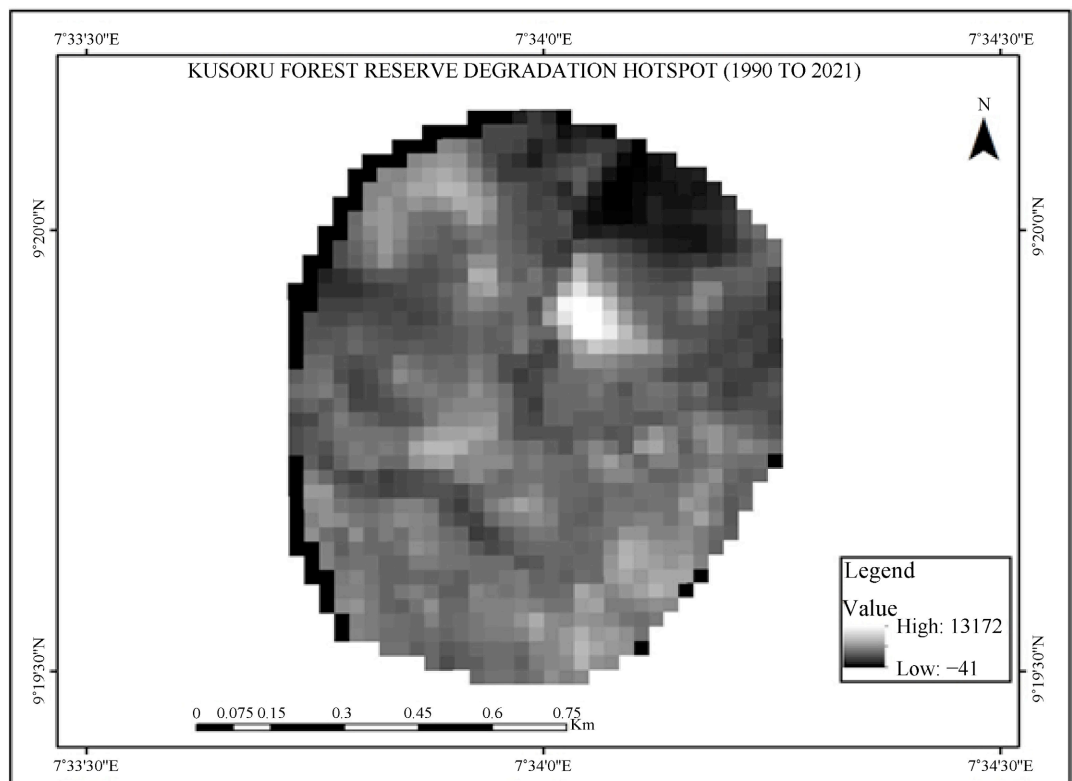
**Figure 3.** Maje-Abuchi forest reserve hotspot area.



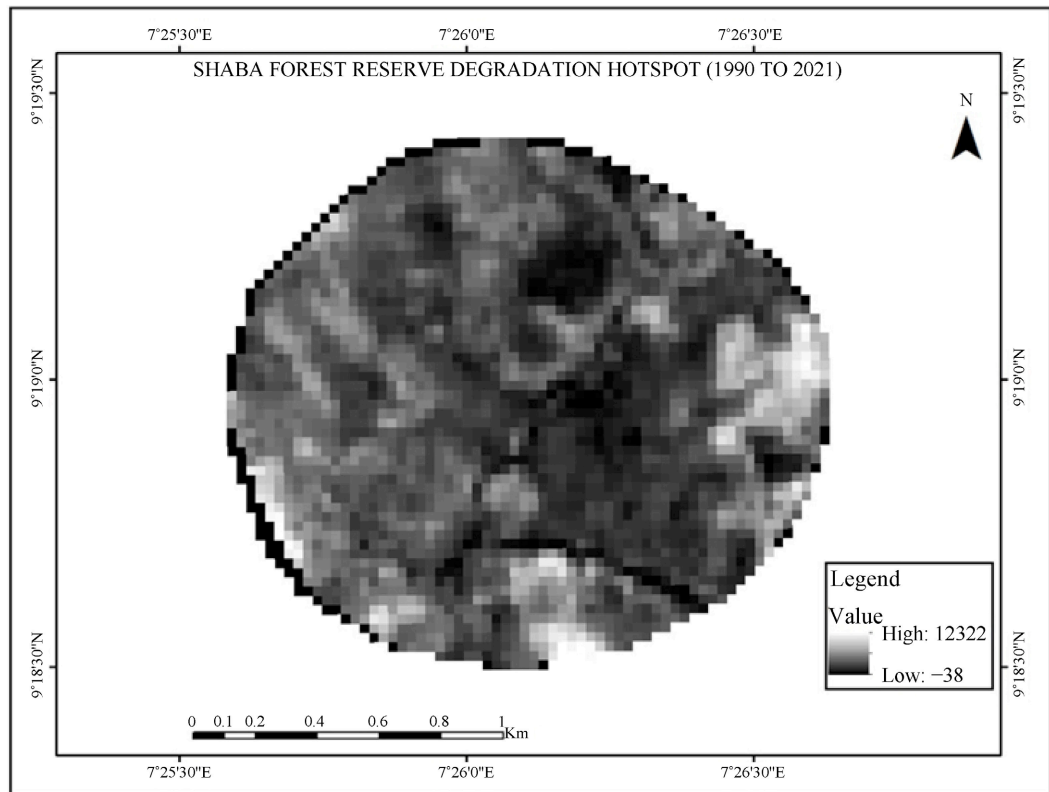
**Figure 4.** Chikwei forest reserve hotspot area.



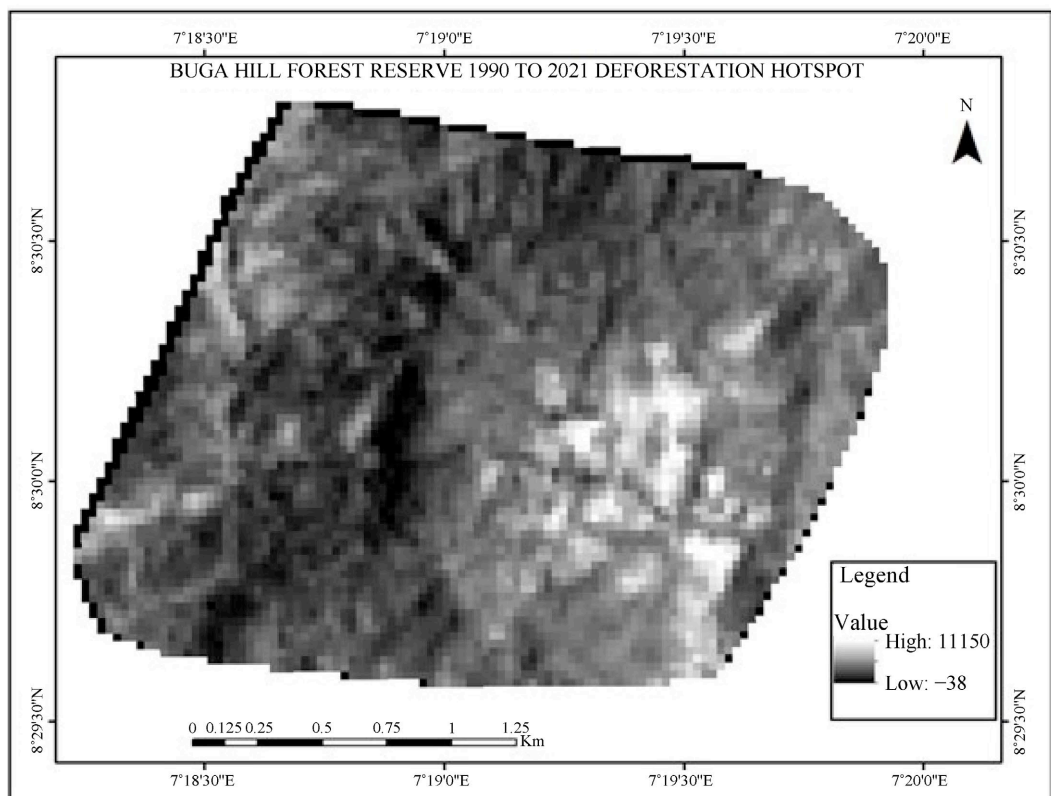
**Figure 5.** Chihuma forest reserve hotspot area.



**Figure 6.** Kusoru forest reserve hotspot area.



**Figure 7.** Shaba forest reserve hotspot area.



**Figure 8.** Buga forest reserve hotspot.

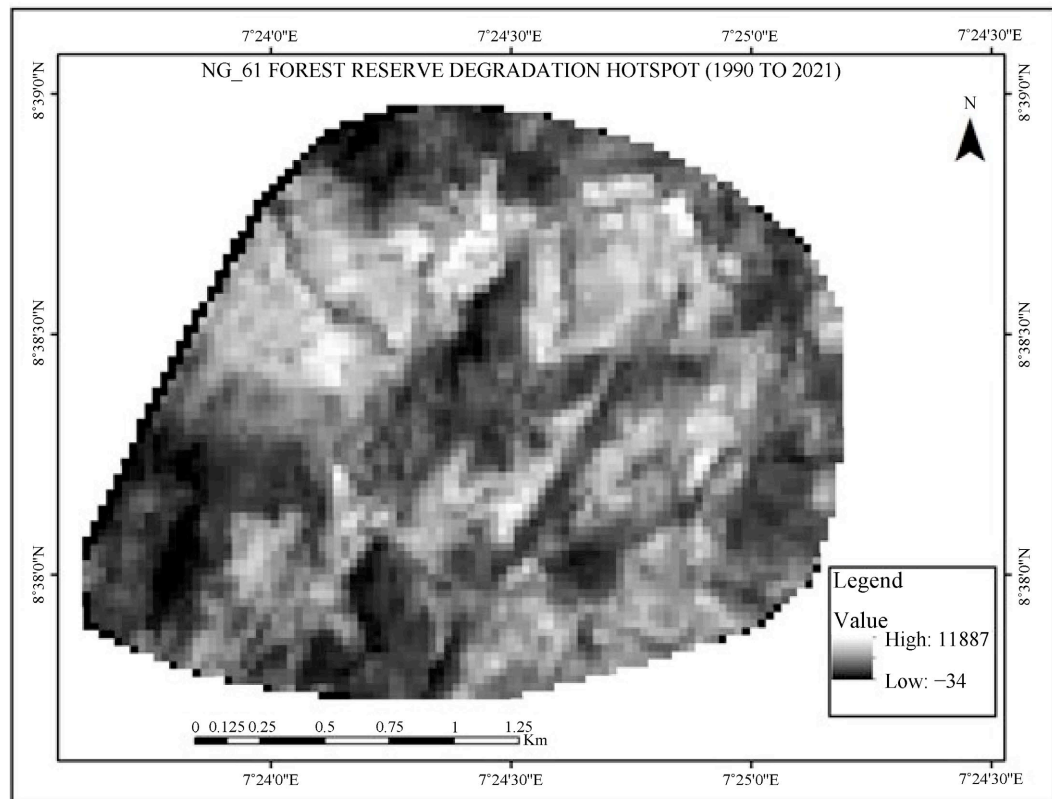


Figure 9. NG\_61 forest reserve hotspot.

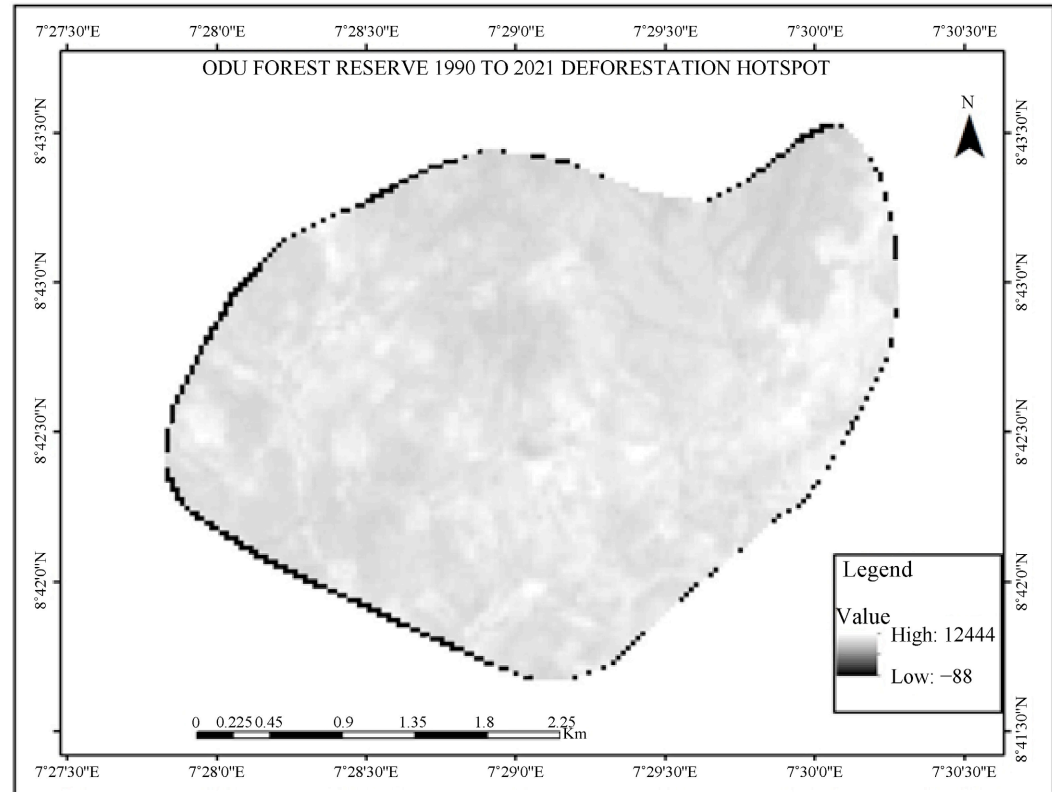
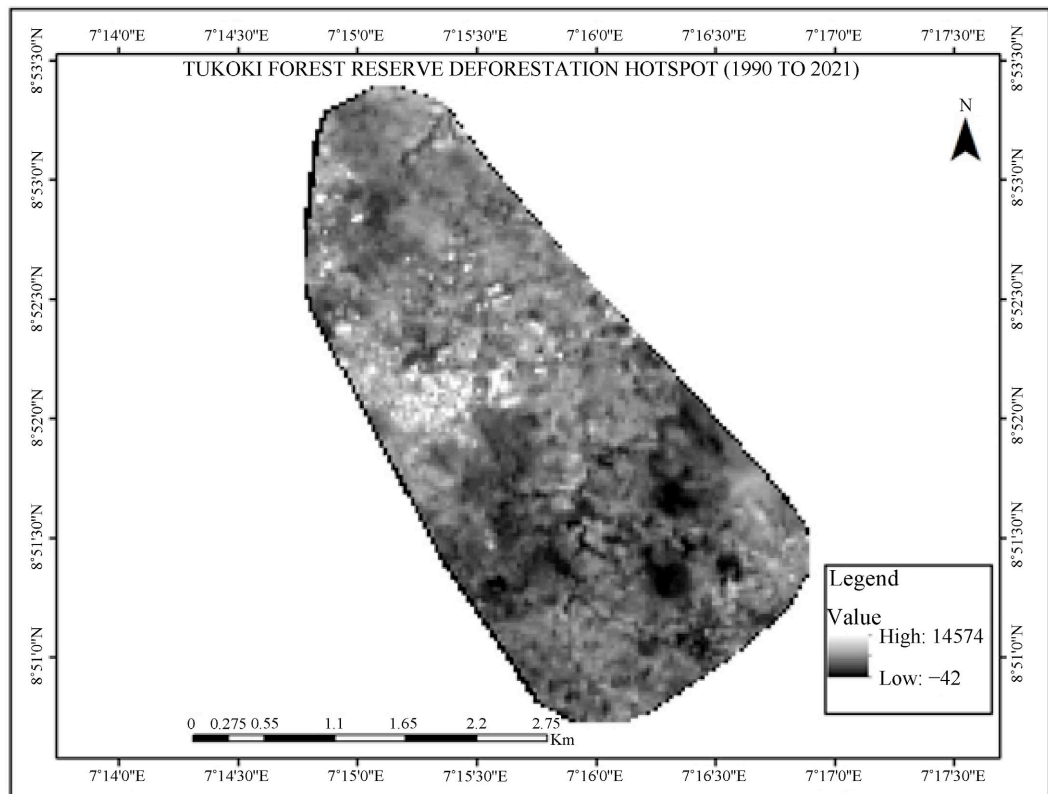


Figure 10. Odu forest reserve hotspot.

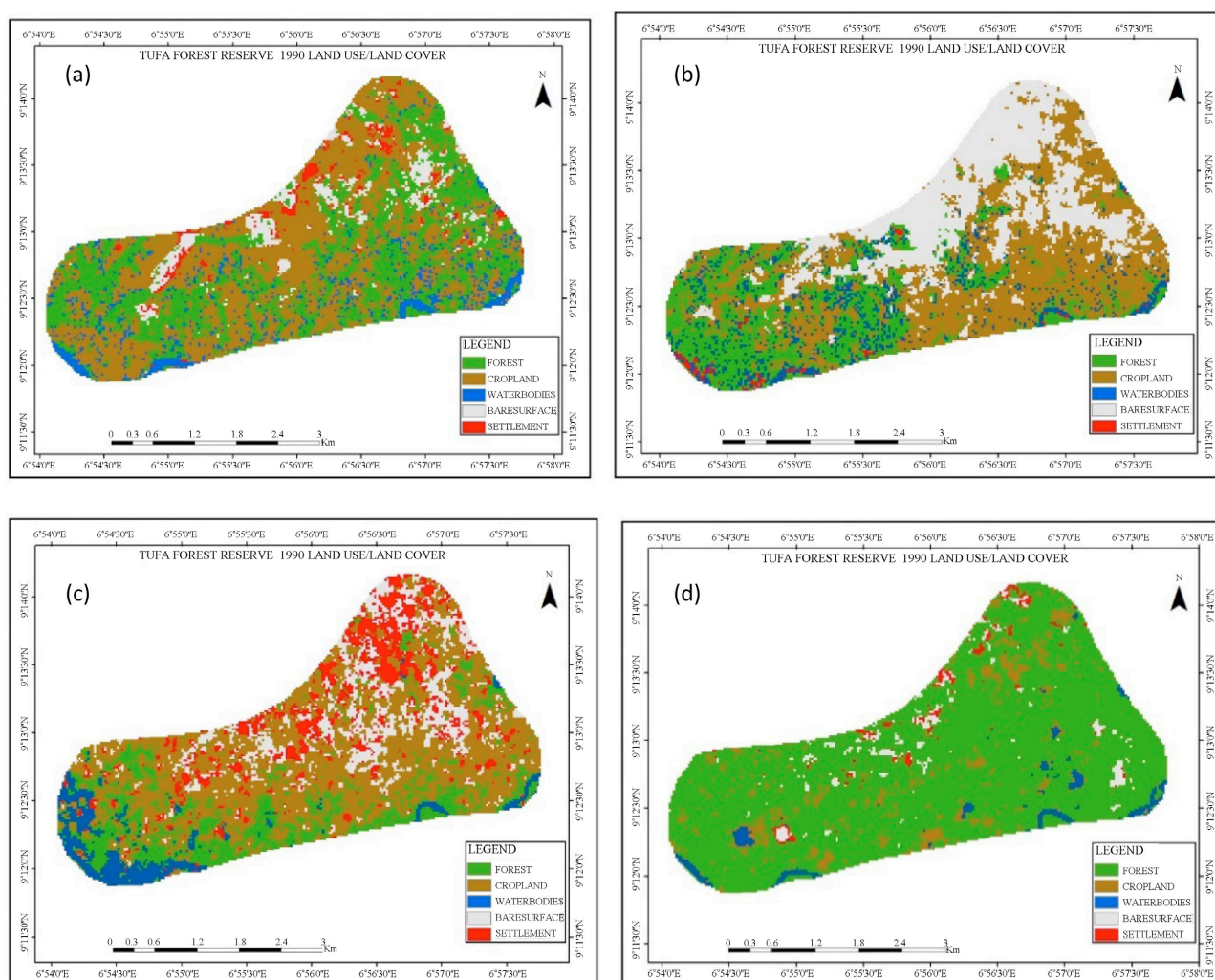


**Figure 11.** Tukoki forest reserve hotspot area.

**Figures 12-14** are the land use/land cover maps of existing forest reserves in the FCT, namely; Tufa in Abaji, Chihuma, Chikwei, Kusuru and Shaba in Bwari, Maje Abuchi in Gwagwalada, then, Buga Hill, NG61, Odu and Tukoki in Kuje Area Council.

**Figure 12** shows land use/land cover Maps, and the percentage land cover by each class showed area cover in hectares for each class from 1990 to 2021. The results of the classified image in showed that the total land area of Tufa forest was 254.598982 hectares (ha). Individual class area and statistics for Tufa forest are summarized in **Tables 2-5**. The percentage area of each class is represented as follows; forest 37%, cropland 46%, water bodies 8%, bare surface 7% and settlement 2%. The result also showed that the cropland area had the largest share of land mass of (692.284099 ha) and the settlement had the least land mass of (38.748951 ha) of the total land use and land cover categories assigned. The resulting land use/land cover maps of the Tufa 2001 shown had an overall map accuracy of 87.00% for the image by using error matrix/accuracy tools. This is the commonly employed approach for evaluating per-pixel classification. Kappa statistics/index was also computed for each classified map to measure the accuracy of the results. The resulting classification of land use/cover maps of the two periods had a Kappa statistics was 0.8625. This was reasonably good overall accuracy and accepted for the subsequent analysis and change detection. Forest covers an area of 516.22 ha (35%), cropland covers an area of 417.74 ha (28%), Water body

covers an area of 50.88 ha (3%), while Bare surface and Settlement cover an area of 363.94 ha (24%) and 143.94 ha (10%). In Tufa 2013, cropland constitutes the larger area at 48% while water body constitutes the least area at 6%. Tufa forest of 2021 has transitioned into an Agriculture hub over the years with 48.94% of its coverage being croplands, and Bare surfaces being the next dominant class at 24.79%; this could be a result of deforestation and urbanization within and surrounding the forest. 14.35% of the total coverage are settlements, 2% are water bodies and a low coverage of 9.64% is the only forest class remaining. **Tables 6-9** further show the accuracy assessment of Tufa forest reserve.



**Figure 12.** Tufa forest reserve LU/LC 1990 to 2021.

**Table 2.** Showing area in hectares and percentage of Tufa forest reserve 1990.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	548.055915	37%
2	CROPLAND	692.284099	46%
3	WATER BODY	114.560906	8%

**Continued**

4	BARE SURFACE	99.134525	7%
5	SETTLEMENT	38.748951	2%
6	TOTAL	254.598982	100%

**Table 3.** Showing area in hectares and percentage of Tufa forest reserve 2001.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	516.22	35%
2	CROPLAND	417.74	28%
3	WATER BODY	50.88	3%
4	BARE SURFACE	363.94	24%
5	SETTLEMENT	143.94	10%
6	TOTAL	1492.72	100%

**Table 4.** Showing area in hectares and percentage of Tufa forest reserve 2013.

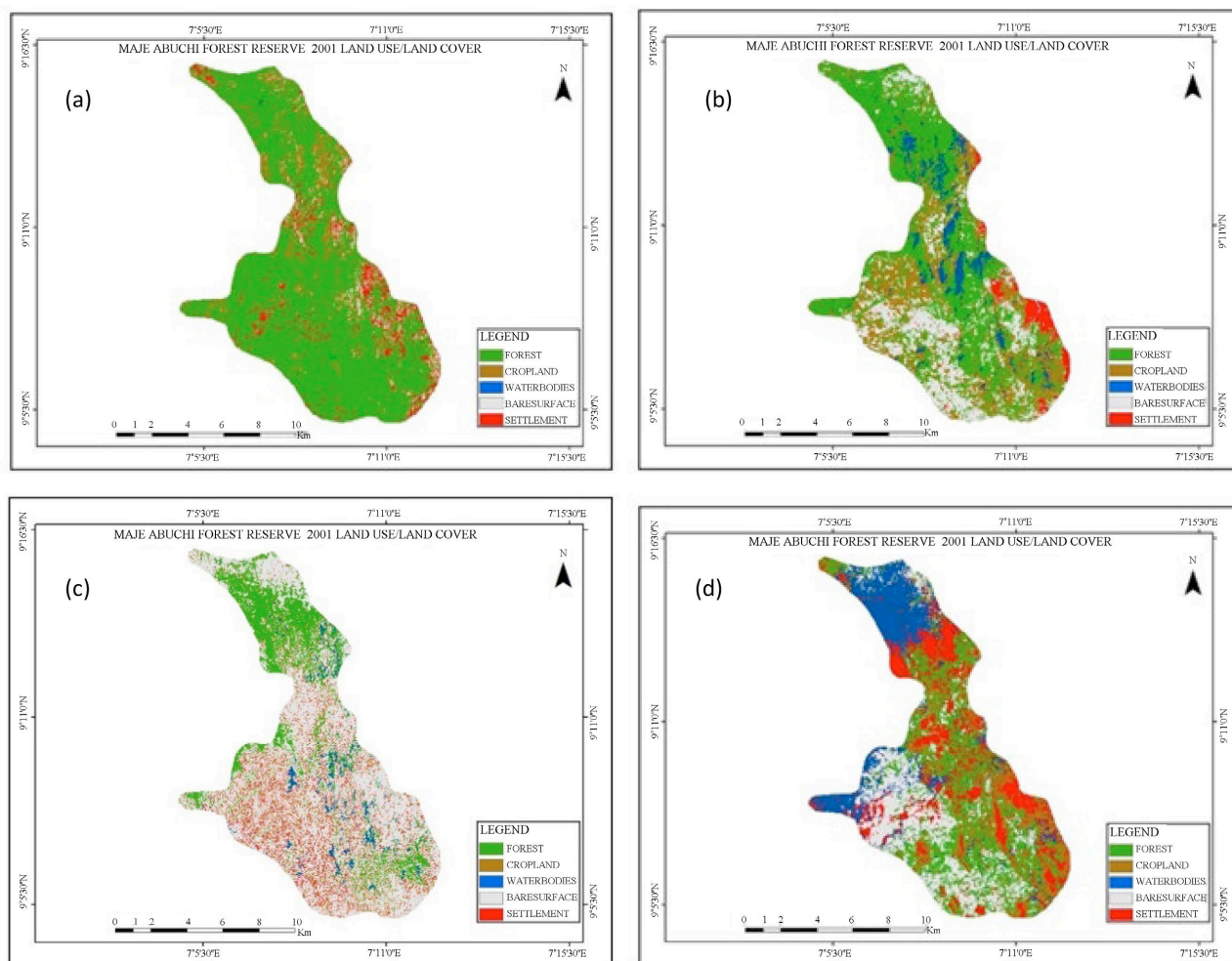
S/N	CLASSES	AREA (Hectare)	Area (%)
1	FOREST	276.2022	19%
2	CROPLAND	720.0283	48%
3	WATER BODY	94.00133	6%
4	BARE SURFACE	220.1121	15%
5	SETTLEMENT	182.0827	12%
6	TOTAL	1492.427	100.00%

**Table 5.** Showing area in hectares and percentage of Tufa forest reserve 2021.

S/N	CLASSES	AREA (HECTARE)	AREA (%)
1	FOREST	723.573128	49.00%
2	CROPLAND	366.525462	25.00%
3	WATERBODIES	33.672707	2.00%
4	BARESURFACES	212.149614	14.00%
5	SETTLEMENT	142.593532	10.00%
	TOTAL	1478.514443	100.00%

**Table 6.** Shows accuracy assessment of the Tufa forest reserve of 1990 LU/LC.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	18	20	18	100.00%	90.00%
Cropland	19	20	17	89.47%	85.00%
Water bodies	21	20	17	80.95%	85.00%
Bare surface	21	20	18	85.71%	90.00%
Settlement	21	20	19	90.48%	95.00%
Totals	100	100	89	Over all total accuracy = 87.00%	



**Figure 13.** Maje-Abuchi forest reserve LU/LC from 1990 to 2021.

**Table 7.** Shows accuracy assessment of the Tufa forest reserve of 2001 LU/LC.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	19	20	17	89.57%	85.00%
Cropland	20	20	18	85.71%	90.00%
Water bodies	22	20	18	84.51%	87.00%
Bare surface	20	20	17	90.00%	90.00%
Settlement	19	20	19	94.74%	90.00%
Totals	100	100	89	Over all total accuracy = 88.76%	

**Table 8.** Shows accuracy assessment of the Tufa forest reserve of 2013 LU/LC.

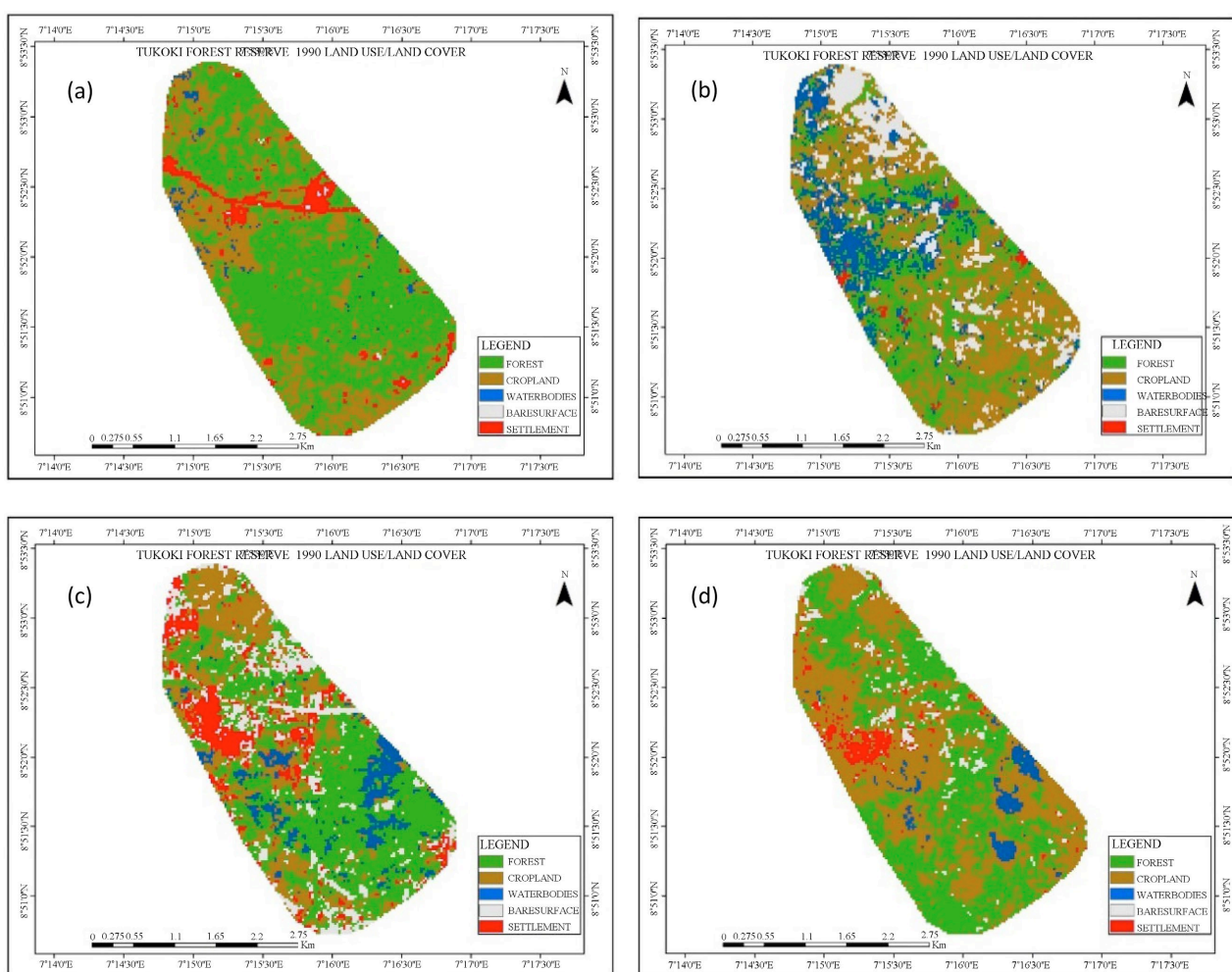
Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	29	33	28	96.55%	84.85%
Cropland	44	33	28	63.64%	84.85%

**Continued**

Water bodies	28	33	23	82.14%	69.70%
Bare surface	35	33	30	85.71%	90.91%
Settlement	29	33	28	96.55%	84.85%
Totals	165	165	137	Overall total accuracy = 83.03%	

**Table 9.** Shows accuracy assessment of the Tufa forest reserve of 2021 LU/LC.

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Forest	8	7	6	75.00%	85.71%
Cropland	37	41	36	97.30%	87.80%
Water bodies	3	3	3	100.00%	100.00%
Bare surface	23	20	20	86.96%	100.00%
Settlement	8	8	8	100.00%	100.00%
Totals	79	79	73	Over all total accuracy = 92.41%	



**Figure 14.** Tukoki forest reserve LU/LC from 1990 to 2021.

Findings from remote sensing exercise conducted for Maje Abuchi presented in **Tables 10-13**. Forest covers an area of 7297.40 Ha (57%) cropland covers an area of 677.07 Ha (5%) waterbody covers an area of 46.03 Ha (1%) Bare surface covers an area of 147.08 Ha (1%) and settlement covers an area of 4584.45 Ha (36%). The overall classification accuracy is 88.65% and accuracy assessment is presented in **Tables 14-17**.

**Table 10.** Area in hectares and percentage of Maje-Abuchi forest in 1990.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	7297.408	57%
2	CROPLAND	677.0764	5%
3	WATERBODY	46.03092	1%
4	BARESURFACE	147.0855	1%
5	SETTLEMENT	4584.45	36%
	TOTAL	12752.05	100%

**Table 11.** Area in hectares and percentage of Maje-Abuchi forest in 2001.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	3811.179	30%
2	CROPLAND	1053.316	8%
3	WATER BODY	480.0481	4%
4	BARE SURFACE	6629.111	52%
5	SETTLEMENT	778.4717	6%
6	TOTAL	12752.13	100%

**Table 12.** Area in hectares and percentage of Maje-Abuchi forest in 2013.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	3740.57293	29%
2	CROPLAND	1554.74622	12%
3	WATER BODY	2212.097969	17%
4	BARE SURFACE	2743.540521	22%
5	SETTLEMENT	2501.620386	20%
6	TOTAL	12752.57803	100%

**Table 13.** Area in hectares and percentage of Maje-Abuchi forest in 2021.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	1833.39	14%
2	CROPLAND	6277.25	49%
3	WATER BODY	976.95	8%

**Continued**

4	BARE SURFACE	2873.52	23%
5	SETTLEMENT	796.23	6%
6	TOTAL	12757.14	100%

**Table 14.** Accuracy assessment of the Maje-Abuchi forest reserve of 1990 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	155	129	129	83.23%	100.00%
CROPLAND	11	11	11	100.00%	100.00%
WATERBODY	0	0	0	75.25%	64.87%
BARE SURFACE	2	2	2	100.00%	100.00%
SETTLEMENT	61	87	61	100.00%	70.00%
TOTAL	229	229	203	OVERALL ACCURACY = 88.65%	

**Table 15.** Accuracy assessment of the Maje-Abuchi forest reserve of 2001 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	39	39	39	100.00%	100.00%
CROPLAND	24	2	2	80.33%	100.00%
WATER BODIES	10	6	6	60.00%	100.00%
BARE SURFACE	38	64	38	100.00%	59.38%
SETTLEMENT	1	2	2	52.03%	92.17%
TOTAL	112	113	87	OVER ALL TOTAL ACCURACY = 89.00%	

**Table 16.** Accuracy assessment of the Maje-Abuchi forest reserve of 2013 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	12	13	12	100.00%	92.31%
CROPLAND	61	62	60	98.36%	96.77%
WATER BODIES	8	6	6	75.00%	100.00%
BARE SURFACE	27	28	27	100.00%	96.43%
SETTLEMENT	5	4	4	80.00%	100.00%
TOTAL	113	113	109	OVER ALL TOTAL ACCURACY = 96.46%	

The landcover map for Tukoki forest reserve is presented in **Figure 14**. Findings for Tukoki 1990 shows that the total land area of Tukoki forest was 1035.741338 hectares (ha). Individual class area and statistics for Tukoki forest in 1990 are summarized. The percentage area of each class as represented in **Tables 18-21** are as follow; forest 65%, cropland 28%, water bodies 1%, bare surface 0% and settlement 6%. The result also showed that forest area had the largest share of land mass of (675.649078 ha) of the total LULC categories assigned.

The resulting land use/land cover maps of the Tukoki 1990 showed had an overall map accuracy of 90.00% for the image by using error matrix/accuracy tools. This is the commonly employed approach for evaluating per-pixel classification. Kappa statistics/index was also computed for each classified map to measure the accuracy of the results. The resulting classification of land use/cover maps of the two periods had a Kappa statistics was 0.8750. This was reasonably good overall accuracy and accepted for the subsequent analysis and change detection. For Tukoki 2001, forest covers an area of 292.47 ha (28.23%), cropland covers an area of 330.09 ha (31.87%), water body covers an area of 44.84 ha (4.33%), while bare surface and settlement cover an area of 276.53 ha (26.70%), 91.92 ha (8.87%). The overall classification accuracy is 80.00% and the confusion matrix is presented in **Tables 22-25**. For Tukoki 2013, forest constitutes the largest area at 45.87% and water body with the least area at 7.51%. For Tukoki 2021, the forest class has largely been lost in Tukoki forest with percentage coverage of only 7.52%. This can be attributed to an upsurge in agricultural activities and settlement springing up with the coverage percentage of cropland currently at 41.78% and others at 37.10%.

**Table 17.** Accuracy assessment of the Maje-Abuchi forest reserve of 2021 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	19	20	17	89.57%	85.00%
CROPLAND	21	20	18	85.71%	90.00%
WATER BODIES	21	20	18	85.71%	90.00%
BARE SURFACE	20	20	18	90.00%	90.00%
SETTLEMENT	19	20	18	94.74%	90.00%
TOTAL	100	100	89	OVER ALL TOTAL ACCURACY = 89.00%	

**Table 18.** Showing area in hectares and percentage of Tukoki forest reserve in 1990.

S/N	CLASSES	AREA (Hectare)	AREA (%)
1	FOREST	675.649078	65%
2	CROPLAND	283.279299	28%
3	WATERBODY	13.127213	1%

**Continued**

4	BARE SURFACE	2.051461	0%
5	SETTLEMENT	61.634287	6%
6	TOTAL	1035.741338	100%

**Table 19.** Showing area in hectares and percentage of Tukoki forest reserve in 2001.

S/N	CLASSES	AREA (Hectare)	Area (%)
1	FOREST	292.47	28%
2	CROPLAND	330.09	32%
3	WATER BODY	44.84	4%
4	BARE SURFACE	276.53	27%
5	SETTLEMENT	91.92	9%
6	TOTAL	1035.85	100.00%

**Table 20.** Showing area in hectares and percentage of Tukoki forest reserve in 2013.

S/N	CLASSES	AREA (ha)	AREA (%)
1	FOREST	81.873387	8.00%
2	CROPLAND	426.698952	41.00%
3	WATERBODIES	19.930948	2.00%
4	BARE SURFACES	128.389633	12.00%
5	SETTLEMENT	379.415908	37.00%
	TOTAL	1036.308828	100.00%

**Table 21.** Showing area in hectares and percentage of Tukoki forest reserve in 2021.

S/N	CLASSES	AREA (Hectare)	Area (%)
1	FOREST	475.1985	45.87%
2	CROPLAND	233.0228	22.49%
3	WATER BODY	77.7927	7.51%
4	BARE SURFACE	140.1578	13.53%
5	SETTLEMENT	109.835	10.60%
6	TOTAL	1036.007	100.00%

**Table 22.** Shows accuracy assessment of the Tukoki forest reserve of 1990 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	19	20	17	89.47%	85.00%
CROPLAND	21	20	18	85.71%	90.00%
WATER BODIES	20	20	18	90.00%	90.00%
BARE SURFACE	21	20	19	90.48%	90.00%

**Continued**

SETTLEMENT	19	20	18	94.74%	90.00%
TOTALS	100	100	92	OVER TOTAL ACCURACY = 90.00%	

**Table 23.** Shows accuracy assessment of the Tukoki forest reserve of 2001 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	17	16	13	76.47%	81.25%
CROPLAND	18	16	13	72.22%	81.25%
WATER BODIES	13	15	13	100.00%	81.25%
BARE SURFACE	13	16	12	92.31%	75.00%
SETTLEMENT	19	16	13	68.42%	81.25%
TOTAL	80	80	54	OVER ALL TOTAL ACCURACY = 80.00%	

**Table 24.** Shows accuracy assessment of the Tukoki forest reserve of 2013 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	33	33	28	84.85%	84.85%
CROPLAND	33	33	28	84.85%	84.85%
WATER BODIES	38	33	32	84.21%	96.97%
BARE SURFACE	31	33	29	93.55%	87.88%
SETTLEMENT	30	33	30	100.00%	90.91%
TOTAL	165	165	147	OVERALL TOTAL ACCURACY = 89.09%	

**Table 25.** Shows accuracy assessment of the Tukoki forest reserve of 2021 LU/LC.

CLASS NAME	REFERENCE TOTAL	CLASSIFIED TOTAL	NUMBER CORRECT	PRODUCERS ACCURACY	USERS ACCURACY
FOREST	4	4	4	100%	100%
CROPLAND	35	39	35	100%	89.74%
WATER BODIES	2	2	2	100%	100%
BARE SURFACE	12	5	5	51.67%	90.00%
OTHERS	36	39	36	100.00%	92.31%
TOTAL	87	87	80	OVER ALL TOTAL ACCURACY = 91.95%	

## 4. Conclusions

Findings in this study show significant land use and land cover changes that have occurred in the Federal Capital Territory over the past 31 years which have also affected the forest reserve. Based on the LU/LC analyses of Landsat data for the years 1990, 2001, 2013, and 2021, it was found that the LU/LC change trends varied significantly during the periods mentioned above. The results showed that in the period 1990-2013, most LULC was converted to cropland except Tukoki forest reserve and Maje-Abuchi forest reserve that reduced to settlement from 1990 to 2021. This indicates that the expansion of cropland and settlement was as a result of population growth, in the Federal Capital Territory, while the primary socio-economic activity remains agriculture and also infrastructural development in Gwagwalada and Kuje Area Council. In the same vein, between 2013 and 2021, most of the forest reserve like Buga Hill, Chihuma, Chikwei, Kusoru, NG\_61, Odu, Shaba and Tufa forest reserve, the forest class gained more area in this period due to insecurity around these forest reserve.

Forests have declined, while cultivated land and artificial surfaces have increased in the area, and deforestation appears to be more pronounced in the Tukoki and Maje-abuchi forest reserve. Severe deforestation in Tukoki forest reserve appears to be strongly linked to increased soil erosion as a result of land use and land cover change. Notable drivers for LUCC include rapid population growth and macroeconomic activities occurring in Federal Capital Territory especially in the part of Kuje Area Council, and poor national policies that have failed to effectively enforce ban of uncontrolled harvesting of forest resources. It shows that remote sensing and GIS for forest quantification analysis of multiple forests areas of this present investigation are feasible with satellite remote sensing as opposed to time-consuming and expensive ground surveys as an alternative.

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## Conflicts of Interest

The authors declare no conflicts of interest.

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