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Geospatial Assessment of Deforestation in Federal Capital Territory Abuja, Nigeria from 1987 to 2021

[1*]AMAECHI, CF; [1, 2]ENUNEKU, AA; [1]OKHAI, SO; [1]OKODUWA, KA

*[*1]Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, PMB 1154, Benin City, Nigeria*
[2] Laboratory for Ecotoxicology and Environmental Forensics, University of Benin, PMB 1154, Benin City, Nigeria

**Corresponding author Email: chika.amaechi@uniben.edu*
Co-authors Email: *alex.enuneku@uniben.edu; odufasharon@gmail.com; akus.okoduwa@lifesci.uniben.edu*

ABSTRACT: The expansion of urban areas directly leads to deforestation resulting in the loss of ecosystems and environmental problems such as soil erosion, loss of biodiversity, water pollution, air pollution, as well as climate change. This study aims to assess deforestation in the Federal Capital Territory Abuja, Nigeria from the year 1987 to 2021 using Geographical Information Systems (GIS) and Remote Sensing (RS). The maximum likelihood supervised classification method in ENVI 5.3 was employed to classify the territory into four classes, which include forestland, grassland, built up area, and surface water. An increasing trend was observed in the built up area, grassland, and surface water. However, the forestland decreased significantly from 4059.43 km^2 in 1987 to 2265.28 km^2 in 2021. The result indicates massive deforestation in Abuja, and it is recommended that proper urban planning and policies that will mitigate urban sprawl be initiated and implemented in Abuja. Policies that mandate house owners to plant trees and lawns in their compounds should be made and implemented, and proper conservation policies should be implemented to conserve forestland.

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Forest clearance is the technical definition of deforestation. This clearance could be temporary or permanent, leading to the felling of some or all of the trees in the area; it could be a slow process or a rapid one; and it could be the result of natural or anthropogenic causes (Tariq and Aziz, 2015). Reasons for deforestation include making way for urbanisation or agriculture, meeting demand for wood products, facilitating mineral extraction, or clearing land for roads (Popoola *et al*., 2020). Many factors, such as biodiversity loss, human population growth, deteriorating air and water quality, and global warming, all contribute to the urgency of the problem of deforestation on a global scale (Feddema *et al*., 2005). The depletion of forest resources necessitates a continued focus on environmentally responsible methods of forest management in conservation initiatives. Between 1990 and 2000, Nigeria lost an average of 409,700 hectares of forest per year (Butler, 2015). This amounts to an average annual deforestation rate of 2.38%. Nigeria lost 35.7% of its forest cover, or around 6,145,000 hectares, between 1990 and 2005. During that time, Nigeria lost 1,230,000 hectares of primary forest cover (Olurode *et al*., 2018). The deforestation danger is so great that every year, many hectares of forest land are converted to non-forest land (Aigbe and Oluku, 2012). Increasing human populations and industrialization have been shown to negatively affect the natural world, particularly forests and forest resources, in a number

**Corresponding author Email: chika.amaechi@uniben.edu*

of studies (Madaki and Sayok, 2019; Arias-Gaviria *et al*., 2021). In light of the preceding, it is crucial to emphasise the fact that deforestation will cause severe environmental problems such as changes in climate, soil erosion, flooding, and a rise in atmospheric concentrations of greenhouse gases if not curtailed. Therefore, technological methods such as GIS and RS should be used to track the rapidity with which land usage and land changes occur because of human growth. This study seeks to assess the deforestation in the Federal Capital Territory Abuja, Nigeria from 1987 to 2021.

MATERIALS AND METHODS

Study Area: In 1976, Abuja was designated as the Capital of Nigeria. Its precise coordinates place it in the centre of Nigeria's Northern Central Region, between latitudes 80°25′ and 90°15′ and longitudes 60°45′ and 70°45′. It covers roughly 7322.59 square kilometres in total. Kaduna, Nassarawa, Kogi, and Niger are among the states that border it. According to the latest edition of Britannica (2018), Abuja is mostly savanna, with just a little bit of rainforest. Abuja is mostly an agricultural city. The four major cereal crops -yam, maize, beans, and millet make up the bulk of the agricultural output. Geologically, it is dominated by crystalline rocks like granites and gneisses (Britannica, 2018).

Data Collection and image classification: Cloud-free Landsat images (Path and row 189/054) for the study area were collected from the USGS (United States Geological Survey) website. Landsat 4 and Landsat 5 data were collected for 1987 and 1999 respectively while Landsat 7 data were collected for 2011 and 2021. The ENVI 5.3 FLAASH tool was utilized to preprocess the Landsat images obtained from the USGS website. The preprocessing steps included atmospheric and radiometric adjustments to enhance the image quality and remove any atmospheric effects. For the classification of LULC, the maximum likelihood supervised classification approach available in ENVI 5.3 was applied. Four main categories were defined to organize the Landsat images: forestland, grassland, built up area, and surface water. The classification process involved training the classifier using sample pixels representing each land cover class. The number of training samples varied for each dataset (Table 1).

Accuracy assessment: Accuracy assessment was conducted to evaluate the reliability of the LULC classification in the study area. The confusion matrix was used to compare the classified images with the ground truth data obtained from high resolution images (Google Earth images).

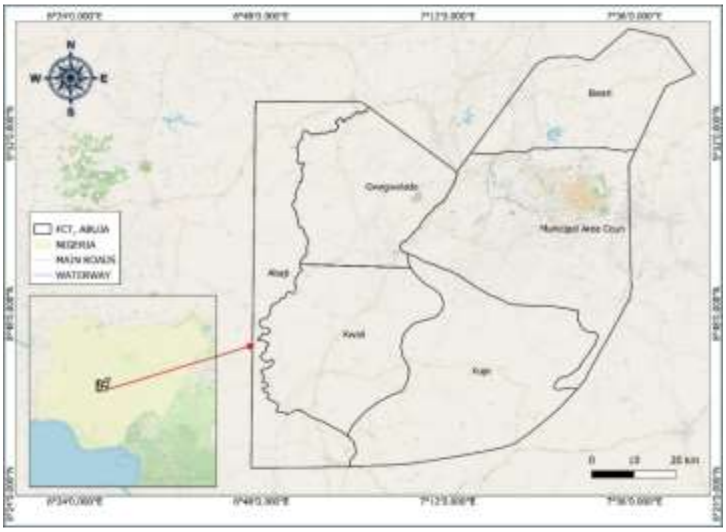

Fig 1: Map of study area, Abuja FCT, Nigeria.
Source: Researcher Field work, 2023

Table 1. LULC classes, description, and number of trained samples for each of Landsat datasets

Class	Description	Number of samples (1987)	Number of samples (1999)	Number of samples (2011)	Number of samples (2021)
Forestland	Tress	54	51	54	52
Grassland	Grasses and rangeland	42	37	41	49
Built up	Buildings, roads and concrete structures	51	52	53	51
Water	Reservoirs and rivers	24	28	23	21

Source: Researcher Field work, 2023

RESULTS AND DISCUSSION

Table 2 presents the accuracy results. The Kappa coefficient values, which measure the agreement between the classified images and the ground truth data, ranged from 0.83 to 0.87, indicating substantial to almost perfect agreement. The overall accuracy values ranged from 89.77% to 92.80%, indicating a high level of correctness in the classification results. The producer accuracy values ranged from 79.99% to 87.87%, indicating the proportion of correctly classified pixels for each land cover class. The user accuracy values ranged from 82.76% to 89.69%, indicating the proportion of correctly classified pixels among all pixels assigned to a specific land cover class. These accuracy measures demonstrate the effectiveness of the LULC classification method used in accurately identifying forest, grassland, built-up areas, and surface water in the study area. The high Kappa coefficient and overall accuracy values indicate a substantial level of agreement between the classified images and the ground truth data. The results of the LULC of Abuja from 1987 to 2021 are presented in Table 3 and Figure 2. The mean and percentage of each parameter for LULC in Abuja are given. Chi square was used to determine the level of significance in the various LULC using SPSS 16.0 software. The superscript appeared in cases in which the ANOVA indicated significant differences. Table 3 shows the LULC of Abuja from 1987 to 2021. The mean values of LULC over the 34 year period were 4059.43, 3785.7, 3261.45, and 2265.28 Km^2 for forest cover, 2827.54, 2803.96, 3186.46, and 4207.19 Km^2 for grassland, 419.97, 715.55, 776.79, and 825.61 Km^2 for Built up and 15.65, 17.37, 17.87, and 24.49 Km^2 for surface water respectively. Using the chi square goodness of fit, there was a highly significant difference ($p<0.01$) between the trend of forest cover, grassland, and built up for LULC, while there was no significant difference ($p>0.05$) between the trend of surface water in Abuja over a 34 year period.

Table 2. Accuracy results showing the Kappa coefficient, producer, user, and overall accuracy for all classified images from 1987 – 2021.

Class	1987		1999		2011		2021	
	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy	User's Accuracy	Producer's Accuracy
Forest	85.45	92.14	89.74	89.63	87.21	79.99	85.61	89.69
Grassland	93.80	90.67	79.66	82.76	86.82	87.87	85.72	86.47
Built-up	87.51	84.55	86.00	85.73	90.50	88.75	89.90	87.40
Water	89.82	95.42	92.45	88.72	90.82	93.42	91.91	92.52
Overall Accuracy (%)	**92.40**		**89.77**		**92.80**		**91.76**	
Kappa Coefficient	**0.85**		**0.83**		**0.87**		**0.86**	

Kappa coefficient values 0.81 -1.0 = perfect agreement, 0.61 – 0.80 = substantial agreement, 0.41-0.60 = moderate agreement and 0 – 0.4 = poor agreement. Source: Researcher Field work, 2023

Table 3. Land use Land cover of Abuja from 1987 to 2021

Year	Forest Cover (Km^2)	Grassland (Km^2)	Built up (Km^2)	Water (Km^2)
1987	4059.43 ^{a}	2827.54 ^{c}	419.97 ^{c}	15.65
	55.43 %	38.61 %	5.74 %	0.21 %
1999	3785.7 ^{b}	2803.96 ^{c}	715.55 ^{b}	17.37
	51.7 %	38.29 %	9.77 %	0.24 %
2011	3261.45 ^{c}	3186.46 ^{b}	776.79 ^{b}	17.87
	44.54 %	43.52 %	10.61 %	0.24 %
2021	2265.28 ^{d}	4207.19 ^{a}	825.61 ^{a}	24.49
	30.94 %	57.45 %	11.27 %	0.33 %

Source: Researcher Field work, 2023

Abuja's forest cover changed throughout the time, with grassland increasing and forest cover decreasing. As the amount of grassland grows, the percentage of forest cover falls. The proportion of grassland to total land cover has grown during the last 34 years, while the proportion of forest cover has dropped. Bashir et al. (2022) have recently noted a decrease in forest covers from 14.23% in 1988 to 3.66% in 2020, 29.93% in 1988 to 3.56% in 2020, and 11.26% in 1988 to 1.08% in 2020 for Mpape, Dawaki, and Kubwa-Dutse Alhaji districts respectively due to population increase and continuous urbanisation. Over the last 34 years, Abuja's metropolitan area has been more urbanised, with a corresponding rise in the built environment. Deforestation is a direct result of urban sprawl, which in turn is caused by rising populations (Meyerson, 2004). Our research confirmed this theory by showing that deforestation rates rose with the expansion of human made landscapes like cities and farmlands. This is in line with the work of Nwafor (2006), who also found that vegetal lands in Owerri decreased as built up area increased. From 1987 (4059.43 km^2) to 2021, the area covered by forests shrank by about half (2265.28 km^2). The built up category consumed around 190 km^2 of forested area between 1987 and 1999, contributing to the deforestation crisis. Since Abuja was designated as Nigeria's capital in 1991, there has been widespread anticipation of a rise in the city's population as a result of internal migration from the countryside. The core-periphery model, which illustrates the distribution of demographic, economic, cultural, and political power in core or dominating regions, provides support for the idea that urban areas are mostly to blame for the decline of forestland from 1987 to 1999. (Klimczuk and Klimczuk-Kocas-Ska, 2019). Grassland was a major cause of the decline in forest cover from 1999 to 2021. The constant clearing of forestland for building and agriculture is to blame.

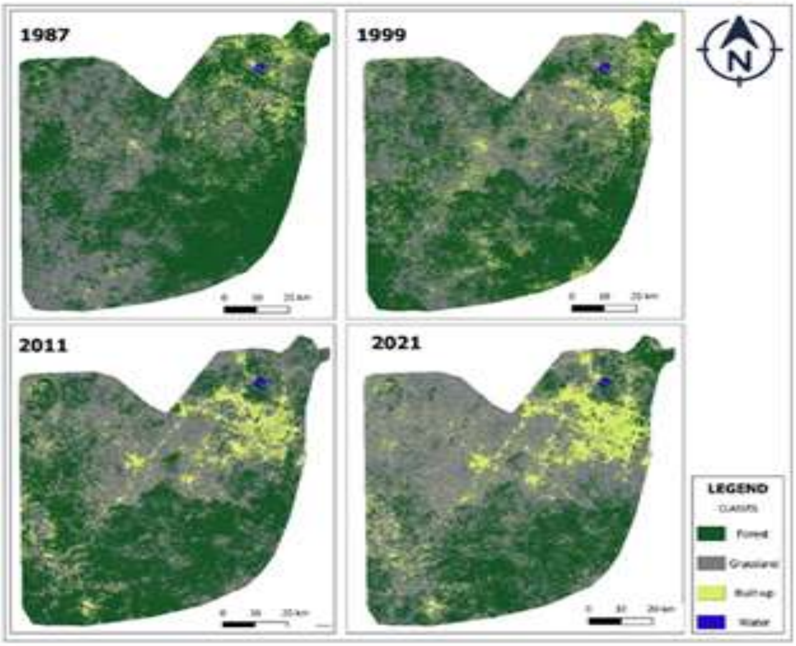

Fig 2: Spatial distribution of LULC classes of Abuja, Nigeria from 1987 to 2021
Source: Researcher Field work, 2023

Mapulanga and Naito (2019) found a significant relationship between hydrology and forest loss. It has been shown that when forests are cut down, less rain makes its way into the ground and more water is carried off into streams and rivers (Andréassian, 2004). This may explain why Abuja had a comparable rise in surface water from 1987 to 2021. There was a linear progression from 15.65 km^2 to 24.49 km^2 of water on the surface. Surface water has seen an increase in silt load as a result of these shifts throughout time. An increase in impervious surfaces, such as unpaved roads, causes increased erosion, which in turn increases silt deposition in surface water bodies as the amount of impervious area rises (Li *et al*., 2018).

Conclusion: From 1987 to 2021, the Federal Capital Territory, Abuja, Nigeria, had a significant decline in forest cover, with a corresponding increase in grassland and built-up areas. These findings emphasises the significance of protecting and regenerating forested areas in order to counteract adverse environmental effects originating from deforestation. To construct resilient and livable cities, balancing urban growth with sustainable land use planning, green infrastructure development should be prioritized.

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