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*Original Research Article*

# Impact of Forest Fragmentation on Aboveground Biomass Carbon Stock in selected Arid-Savanna Forest Landscape in Nigeria

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**ABSTRACT**

Forest structure in the arid regions of Nigeria is experiencing intense degradation due to its fragmentation. Forest Fragmentation (FF) associated with loss of Forested Land Cover (FLC) and aboveground biomass carbon stock (AGBC). Understanding the impact of fragmentations on FLC and AGBC in Jigawa State is necessary for conservation efforts. Hence this study was conducted. Baturia Forest Reserve (BFR) was purposively selected based on satellite imagery and accessibility. It was stratified into: Interior (I), Edge (E), and Matrix (M). A sample plot (20 x 20 m) with three replicates were randomly established in each stratum for the estimation of AGBC (kg $ha^{-1}$) using established allometric equations. Ground biomass was collected from 1 $m^2$ subplots laid at each opposite corners and the middle of the sample plots. The data were analysed using descriptive statistics, ANOVA and correlation at α0.05. The forest cover area in BFR is fragmented from 45,210 (ha) in year 2000 to 28,340 (ha) in year 2024. Agriculture and built-up areas increased from 62,500 to 78920, and 4,200 to 8900 ha respectively. The number of medium forest patches (>10 ha) increased from 48 to 72 between the years. The AGBCS varied significantly from 28.6±1.84 Mg C $ha^{-1}$ (I), 17.4±1.42 Mg C $ha^{-1}$ (E) and 4.8±0.65 Mg C $ha^{-1}$ (M). Significant relationship was obtained between forest patches and AGBCS ($r = 0.71$) showing high influence of FF on AGBCS. Forest interior is the less fragmented forest land-cover and most supports AGBCS in BFR, Jigawa State.

## INTRODUCTION

The conversion of natural forest ecosystems to other land-uses is an anthropogenic activity whose disturbances not only reduce the quality of the forest, it does a lot of harm to the forest quantity. The continuous human disturbances lead to the division of natural forested area into smaller patches, thereby creating some edges and disjointed patches between the original forested land area and an adjacent continuous forest (Pyngrope *et al.,* 2021). One of the worlds grates threats to biodiversity is the fragmentation of the forests (Bodart *et al.,* 2013). Forest fragmentation is the past setter for more forest edges as well as smaller patches, which changes the microclimatic conditions within a forest. Forest fragmentation and the creation of forest edges expose the forest environment to extreme environmental conditions such as; increased mosaic of patches due to agricultural practices, supporting isolated remnants vegetations to surrounded by pasture matrix, and reduced buffering ability on its internal microclimate, (Kayode and Ayobami, 2017). This leads to fluctuations in temperature, the atmospheric humidity, solar radiation, as well as soil moisture.

The savanna climate is undergoing unprecedented changes (IPCC, 2018), which exert pressure on the microclimates in the region. According to Robert and Cristina (2013), microclimate plays a role in maintaining the forest ecosystem health by influencing soil respiration, circulation of soil nutrients, plant resilience and regeneration, the mitigate bioorganic mortality. A fragmented forest can alter climatic parameters like temperature and humidity thereby, negatively impact biodiversity through the loss of species composition and structure, decline habitat area, and expose the forest to edges and species or genetic isolation. If sustained, it could lead to ecological challenges such as increased habitats isolation, endangering species, modifying species' population dynamics and expansion at the detriment of the interior forest habitat (Kayode and Ayobami, 2017); all of which contributes to increased carbon dioxide emissions.

Anthropogenic activities resulting from fragmentation and land-use change are contributing significantly to $CO_2$ emissions in Nigeria (Lawal *et al.,* 2024). These emissions have the tendency to causing environmental imbalance, affect plants distribution and biomass composition. It also limits the capacity of the fragmented landscapes to store adequate carbon particularly in the aboveground biomass which is critical at mitigating climate change and functions well in ecosystems maintenance (Elisha *et al.,* 2025). In a review reported by Lawal *et al.* (2025), aboveground carbon stocks in Akure, Ondo State, vary between 0.00407 t C (Habeeb *et al.,* 2019) to 0.00109 t C (Ige & Silas, 2023). The varying figures may be attributed to microclimatic variations and fragmentation effects on the aboveground biomass in the forest. In a similar study conducted by Abdullahi *et al.* (2014), the biomass composition in the savanna vegetation was reported to be 0.02402 t C. This is because in the savanna region of Nigeria, the expanding arable farmlands, pastoral activities and unsustainable fuelwood harvesting subjects the forests to degradation and fragmentation. The extent to which forest patches and edge habitat affects microclimatic status and carbon fluxes in the fragmented forest ecosystems of Jigawa State remains poorly understood. This research will provide information that will help guide on appropriate ecological models on the status of forested landscapes in the state and quantify stocks which will be useful for policy interventions on carbon budgeting and sustainable forest management.

## MATERIALS AND METHODS

Baturia Forest Reserve is located between Longitudes 12° 20' to 12 ° 40'' E to latitude 10° 10' to 10° 30' N, situated within Jigawa State. Baturiya Forest Reserve is the largest wetland in the state. The reserve covers an area of about 350,000 ha with an altitude of 152-305 m, located across three local government Areas (Auyo, Kirikasama and Guri) of Jigawa State (Bird life international, 2015). The region is one of the agricultural and commercial hubs for trans-Sahara trade (Usman *et al.,* 2017). The mean daily minimum and maximum temperatures are 27°C and 35°C respectively (Makama *et al.,* 2018). The temperature could increase to 45°C between March and May while it reduces to 15°C between December and January. The rainy season commences in May and lasts till September with an annual range of 600 mm-1000 mm (Makama *et al.,* 2018). The ecosystem is largely wetland savanna type with woody plants cover dominated with scattered plants comprising of xerophytes, shrubs and grasses. About 80% of its inhabitants engage in crop farming with livestock, or livestock farming. Arable crop farming, agroforestry, livestock grazing and farm fallows are the major occupation of the people around the reserve. It is characterised by undulating land, having some kilometers of sand dunes of varying sizes in some parts of the state. The soil is characteristically sandy; it supports cereals like: sorghum, millet, rice and legumes such as cowpea and groundnut (Ahmed *et al.,* 2019). The wetlands support the cultivation of crops such as tomatoes (*Solanum lycopersicum*), onion (*Allium cepa*), wheat (*Triticum aestivum*), lettuce (*Lactuca sativa*), carrots (*Daucus carota*), maize (*Zea mays*), sugarcane (*Saccharum officinarum*) and pepper (*Capsicum* sp.) through irrigation. In addition to agricultural productions, fish production and animal husbandry are largely practiced around the reserve with major livestock being cattle, sheep and goat.

### Methods of Data Collection

The study adapted a mixed method where field survey was conducted and also the use of remote sensing. Microclimate data monitoring tools were used and the carbon stocks were measured using the non-destructive allometric model. A total of six forest fragments were randomly selected with size ranging from 2 to 18 ha. A line transect was established to cut across the forest matrix, through the edge to the interior. Climatic weather parameter such as temperature (air and soil) and humidity was measure within the sample plots at 1, 3, 6 and 9 ha (Stevens and Olsen, 2004; Christopher and Benjamin, 2016). One 100 m×100 m sample plot was randomly established on each of the forest patches on the line transect for the above-ground carbon stock estimation. Five woody tree species with Diameter at Stumps Height (DSH) ≥ 5.0cm were randomly selected within the sample plot. The carbon stock of the five woody tree species was estimated using indirect estimation method. Tree growth variables such as trunk diameter $D_b$ at stump height (15cm above ground), diameter at the middle ($D_m$), diameter at the top ($D_t$ maximum at 7cm top diameter limit) and total tree height $H$ (m) were first measured for the five selected woody tree species. These tree growth variables were used to estimate the volumes (m³) of individual trees encountered within each 100m×100m sample plot using the Newton's formula of Hush *et al.* (2003) as cited by Shamaki and Adekunle (2013), Newton's formula is shown in equation 1:

$$V = \frac{\pi H}{24}\left(D^2{}_b + 4D^2{}_m + D^2{}_t\right) \quad (1)$$

The macroclimatic data obtained were subjected to analysis of variance to assess variations across fragmentation classes. Correlation was used to establish the relationships between fragmentation metrics and microclimatic variables.

## RESULTS AND DISCUSSION

The result revealed that forest cover in and around Baturia Forest Reserve have been now been overturned to isolated patches, particularly the vegetations along the riverine corridors. The surrounding matrix has been predominantly converted to agricultural land and open savanna. Figures in Table 1 shows that forested land area reduced from 45,210 in the year 2000 to 28,340 24 years later. This represents a loss of 37.3%. On the contrary, both agricultural land, and built-up area had a tremendous upsurge, increasing from 62,500 and 4,200 to 78,920 and 8,900; representing 26.3 and 111.9 % respectively.

**Table 1: Land Use/Land Cover Change from 2000 to 2024**

| Land Use/Land Cover Class | Area (ha) in 2000 | Area (ha) in 2024 | Change (ha) | Change (%) |
|---|---|---|---|---|
| Forest | 45,210 | 28,340 | -16,870 | -37.3 |
| Agricultural Land | 62,500 | 78,920 | +16,420 | +26.3 |
| Grassland/Open Savanna | 38,400 | 32,150 | -6,250 | -16.3 |
| Built-up Area | 4,200 | 8,900 | +4,700 | +111.9 |
| Water Bodies | 1,800 | 1,700 | -100 | -5.6 |

### Forest Fragmentation

It was observed that there was a trajectory increase of fragmentation of the landscape when the key landscape metrics was computed for the forest class cover from 2000 to 2024. Table 2 revealed that the forest has been broken into more pieces with number of patches increasing by over 150% (112 to 284) between the year 2000 to 2024. The mean patch size per hectare reduced from 403.7 in 2000 to 99.8 in the year 2024.

**Table 2: Forest Fragmentation Metrics (2000 vs. 2024)**

| Fragmentation Metric | 2000 | 2024 | Interpretation of Change |
|---|---|---|---|
| Number of Patches | 112 | 284 | +153.6% (Forest is being broken into more pieces) |
| Mean Patch Size (ha) | 403.7 | 99.8 | -75.3% (Patches are becoming significantly smaller) |
| Edge Density (m/ha) | 28.5 | 56.2 | +97.2% (Increased edge habitat relative to core area) |
| Core Area Index (%) | 42.3 | 18.7 | -55.8% (Less interior forest, more edge-affected forest) |

Figure 1 below further revealed patch size distribution in the study site. The figure illustrates that; there were 30 large patches (>100 ha) as at the year 2000. This number greatly reduced to 16 in 2024. On the contrary, number of small patches (>1 <10 ha) forests increased from 34 to 196 between 2000 and 2024.

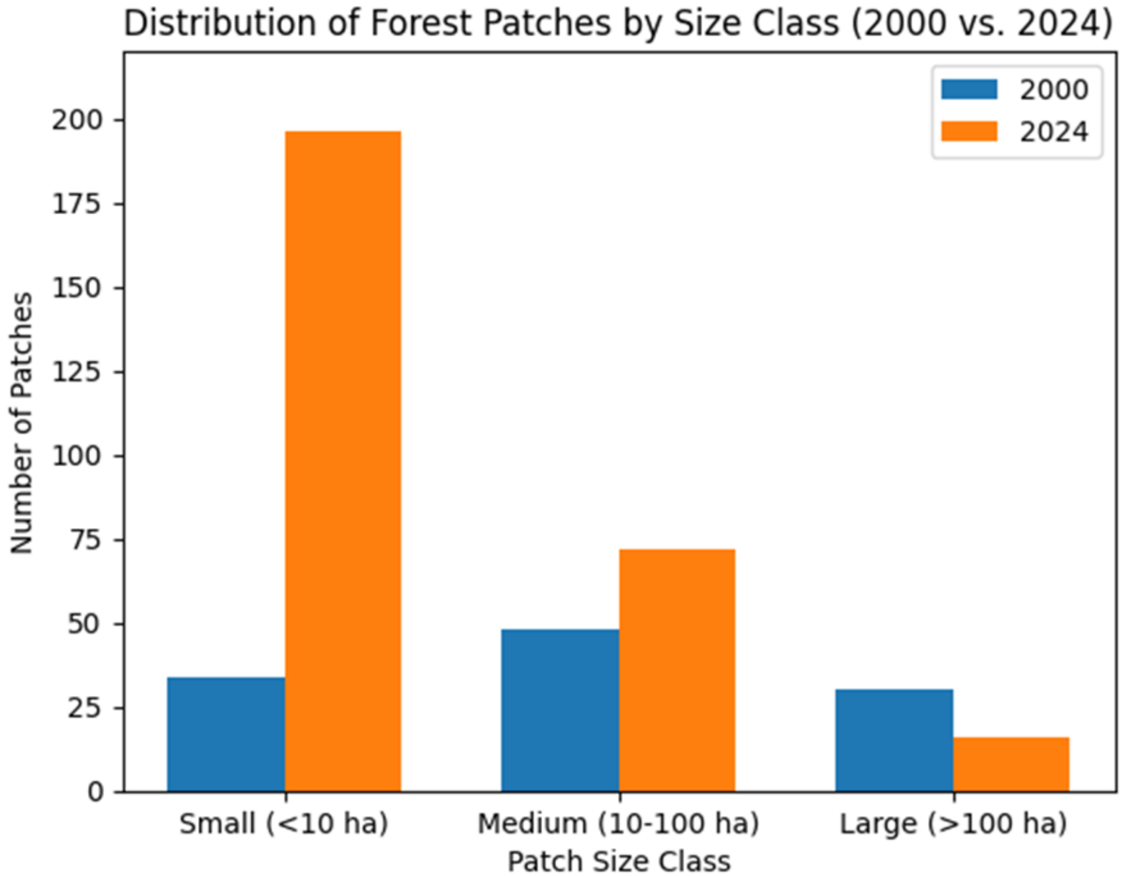


Figure 1: Distribution of Forest Patches by Size Class (2000 vs. 2024). *(A grouped bar chart showing the number of patches in three size classes: Small: <10 ha, Medium: 10-100 ha, Large: >100 ha.)*

**Aboveground Biomass Carbon Stock Across Zones**

The forest interior shows to have the largest carbon pools (28.6 Mg C ha$^{-1}$). It was followed by the forest edge, which shows an intermediate carbon stock value of 17.4 Mg C ha$^{1}$. The matrix could only account for a carbon pool of 4.8 Mg C ha$^{-1}$ (Table 3). This is further shown in a box plot where the median, and range for the aboveground carbon stock across the interior, edge and matrix of the forest further indicated the neutrality of the forest edge in carbon stock (Figure 2).

**Table 3: Aboveground Biomass Carbon Stock Across Forest Zones**

| Zone | Mean AGB Carbon Stock (Mg C ha$^{-1}$) | Standard Error | Range (Mg C ha$^{-1}$) |
|---|---|---|---|
| Forest Interior | 28.6 | ±1.84 | 18.2 – 38.5 |
| Forest Edge | 17.4 | ±1.42 | 10.8 – 24.7 |
| Matrix | 4.8 | ±0.65 | 1.2 – 8.9 |

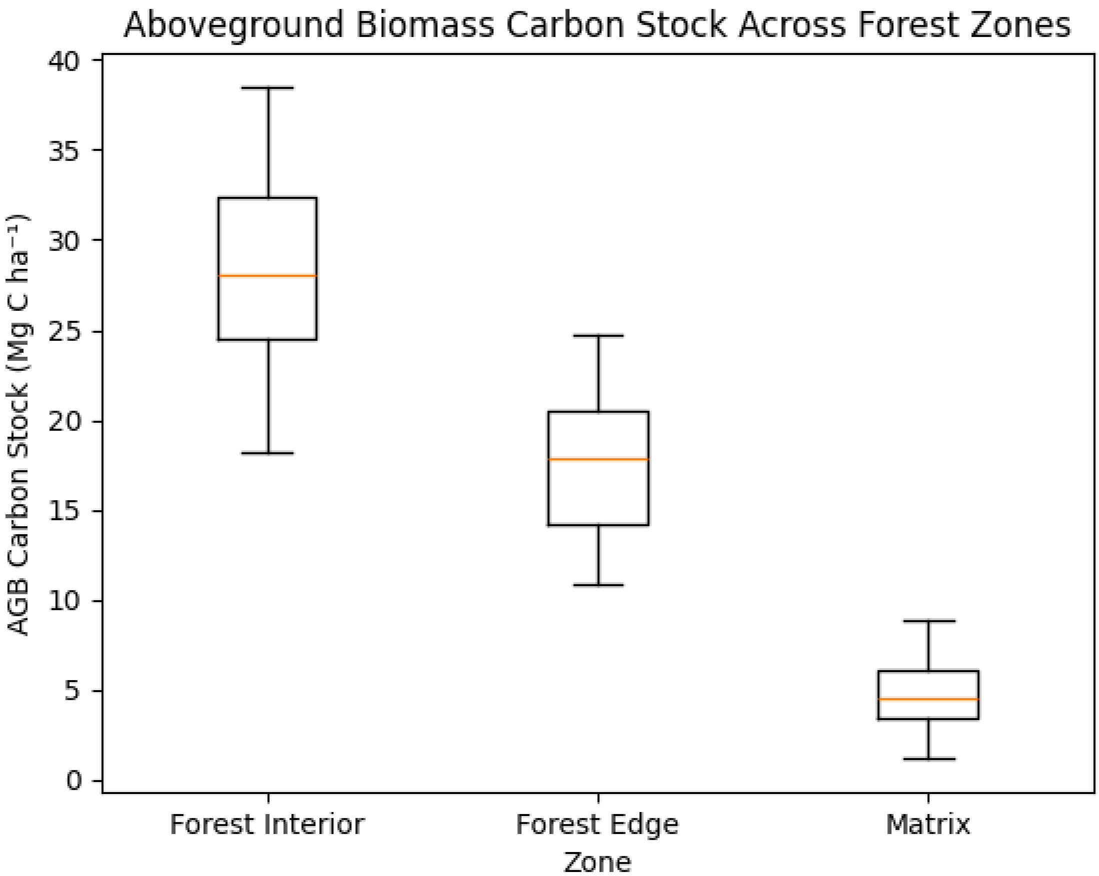


Figure 2: Aboveground Biomass Carbon Stock Across Forest Zones *(A box plot showing median, interquartile range, and outliers for AGB carbon stock across forest interior, edge, and matrix zones. Y-axis: AGB Carbon Stock (Mg C ha $^{-1}$), X-axis: Zone.)*

**Correlation Between Fragmentation Metrics and Carbon Stocks**

The correlation analysis set to quantify the predictive relationship between fragmentation metric (i.e patch size), and carbon stock variable shows a positive relationship ($r$ = 0.71, p = 0.001) (Table 4).

**Table 4: Correlation Table Between Fragmentation Metrics and Carbon Fluxes**

| **Parameter** | **Value** |
|---|---|
| Regression Equation | AGB Carbon = 4.82 + 0.38 × Patch Size (log-transformed) |
| $R^2$ | 0.71 |
| p-value | <0.001 |
| Interpretation | Patch size explains 71% of the variation in AGB carbon stock, with larger patches supporting disproportionately higher carbon storage. |

**Discussion**

The findings highlighted the causal effects of the expansion agricultural activities and also urbanization as the main drivers of forest fragmentation in the savanna landscapes. These factors clearly alter microclimatic conditions and accelerate loss of carbon storage. This is in line with Ashcroft and Gollan (2011); Ford *et al.* (2013); and Christopher and Benjamin (2016) who reported similar observations in studies conducted in different tropical regions. It is also similar to what was reported by Abdullahi et al. (2022), in a study conducted in the West African savanna forests. The fact that there are still significant hectarage of the interior forest in Baturia highlights the significance of the policy protecting the area. The increased number of patches around the forest reserve could be linked to population pressures.

Aboveground biomass carbon stock was observed to have steadily decline from the forest interior to the matrix. This clearly revealed the effects of the removal of trees during the land-use change. Similarly, it also shows the direct effect fragmentated forest to have a reduced capacity to sustain woody biomass composition. This is in agreement with Mujuru *et al.* (2014) reports where he mentioned that more biomass is contained in the aboveground pool for the forest than in other sub-compartments or fragmented landscapes. The reported values of carbon stocks in this study compares well to the other studies reported in the savanna dry forest (Abdullahi et al., 2022; Idowu et al.; and Elisha et al. 2025).

## CONCLUSION

Jigawa State Forest (Baturia Forest Reserve), have experience high decline in its vegetation cover over the past two decades. This has given room for an increase in the number of patches around the forest, showing a steady shift a large vegetation cover landscape to numbers of small and isolated covers. The decline in aboveground biomass carbon stock from the interior to the matrix is a reflection of intense tree removal and the effects of the fragmentations on woody biomass functions. Of course, agricultural and urbanization expansion are the major drivers in this regard, however, the effects of these factors are not limited to the state alone. There is the need to strengthened the already established buffer zones systems around the forest reserve to checkmate the effects of land-use change. The forest regulations in the state should be enhanced to curb the activities of illegal exploitations.

## REFERENCES


Abdullahi, J., Sule, M.Z., Aishatu, A., Sakoma, J.K. & Amos, B.B. (2014) 'Carbon sequestration potentials of Kpashimi Forest Reserve, Niger State, Nigeria', *International Journal of Geography and Geology*, 3(12), pp. 145–158.

Ahmed, A., Najib, A., Jibrin, M. A, and Ahmed, C. A. 2019a. Vegetation Change Detection Analysis in the Northwest Jigawa State Local Government Area of Babura. *Pure Applied Science Dutse Journal* 5.1a:135-146.

Ashcroft, M. B. and Gollan, J. R. (2011). Fine-resolution (25 m) topoclimatic grids of near-surface (5 cm) extreme temperatures and humidities across various habitats in a large (200 × 300 km) and diverse region. - Int. J. Climatol. 32: 2134–2148.

Bird Life International. 2015. Bird Areasfactsheet: Hadejia-Nguru wetlands. Cambridge, United Kingdom.

Bodart, C.; Brink, A.B.; Donnay, F.; Lupi, A.; Mayaux, P.; Achard, F. Continental estimates of forest cover and forest cover changes in the dry ecosystems of Africa between 1990 and 2000. J. Biogeogr. 2013, 40, 1036–1047.

Christopher E. Latimer and Benjamin Zuckerberg (2016). Forest fragmentation alters winter microclimates and microrefugia in human-modified landscapes.

Elisha, N. 1., Ben, E. A. and Peter, S. (2025). Effect of Climatic Aridity on Above-Ground Biomass, Modulated by Forest Fragmentation and Biodiversity in Ghana. *Earth*. 7 (7): 2-26 https://doi.org/10.3390/earth7010007

Ewers RM, Banks-Leite C (2013) Fragmentation Impairs the Microclimate Buffering Effect of Tropical Forests. PLoS ONE 8(3): e58093. https://doi.org/10.1371/journal.pone.0058093

Ford, K. R. et al. 2013. Spatial heterogeneity in ecologically important climate variables at coarse and fine scales in a high-snow mountain landscape. - PLoS One 8: e65008.

Habeeb, A.Y., Jesumbo, J.O., Oluwatoyin, O.A. & Idowu, E.O. (2019) 'Carbon stocks in aboveground and belowground biomass of sub-humid tropical forest in southwestern Nigeria', *Open Access Library Journal*, 6(5588). https://doi.org/10.4236/oalib.1105588.

Idowu, E. O., Akinola, A. K., Johnson, T. F., and Ayorinde, A. O. (2019). Biomass carbon stocks of different land use management in the forest vegetative zone of Nigeria. *Acta Oecologica*. https://doi.org/10.1016/j.actao.2019.01.004

Ige, P.O. & Silas, A.E. (2023) 'Evaluation of aboveground biomass and carbon stock content of seven most abundant tree species in Oluwa Forest Reserve, Ondo State, Nigeria', *Journal of Applied Science and Environmental Management*, 27(12), pp. 2737–2741.

Intergovernmental Panel on Climate Change (IPCC). 2018. Global warming of 1.5°C: Summary for policymakers. Retrieved from https://www.ipcc.ch/sr15/.

IPCC 2014. Climate change 2014: synthesis report. – Intergovernmental Panel on Climate Change.

Lawal, A. A., Jimoh, S. O., Salami, K. D., Amina G. H., Tukur, N. Y., Saidu M., and Bishiriyya, D. S. (2025). AI-Driven Assessment of Ethnobotanical Tree Species Diversity in Baturia Game Reserve, Jigawa State, Nigeria. *Proceedings of the 1st Faculty of Renewable Natural Resources, University of Ibadan Conference.* 1(1): 494-502.

Lawal, A.A, Jimoh, S.O., Jibo, A.U., Salami, K.D., and Girei, A.H. (2024). Influence of Land Use and Ecosystems on Woody Plant Species Diversity in Jigawa State, Nigeria. *FUDMA Journal of Agriculture and Agricultural Technology*. (10)3: 155-166 https://jaat.fudutsinma.edu.ng/index.php/jaat/issue/view/11

Makama, S. A., Ilu, I. Y., Usman, S., and Haruna, S. K. 2018. Assessing the effect of agricultural extension services on sesame farmers' productivity and efficiency in Jigawa State, Nigeria. *Nigerian Journal of Agricultural Extension* 19.1:14-27.

Mujuru, L., Gotora, T., Velthorst, E.J., Nyamangara, J., Hoosbeek, M.,R., 2014. Soil carbon and nitrogen sequestration over an age sequence of Pinus patula plantations in Zimbabwean Eastern Highlands. For. Ecol. Manag. 313, 254–265.

Pyngrope, O.R.; Kumar, M.; Pebam, R.; Singh, S.K.; Kundu, A.; Lal, D (2021). Investigating Forest fragmentation through earth observation datasets and metric analysis in the tropical rainforest area. SN Appl. Sci. 2021, 3, 705.

Shamaki, S. B. and Akindele, S. O. 2013. Volume estimation models from stump diameter for Teak Tectona grandis Linn f.) plantation in Nimbia forest reserve, Nigeria. *Journal of Environmental Sciences and Water Resources* 2.3:89-94.

Stevens, D. L. and Olsen, A. R. 2004. Spatially Balanced Sampling of Natural Resources. - J. Am. Stat. Assoc. 99: 262–278.