# Analyzing Tree Species Composition, Diversity and Carbon Storage in Damaturu, Yobe State, Nigeria

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**Abstract:**

*This study assessed the composition, diversity and aboveground carbon of woody species in Damaturu, Yobe State, Nigeria. A total of 60 sample points were randomly generated across the area and quadrats of 30x30m were laid. All woody species encountered were identified and enumerated. Species height and diameter at breast height (DBH), were measured directly during the field survey while species characteristics such as composition, diversity and dominance were computed from the field data. A total of 204 stems belonging to 17 species and 11 families were identified. Results show that the city is composed of few species with Azadirachta indica, Vatex doniana, Terminalia ivorensis and Polyalthia longifolia being the dominant species. Tree species in the city generally have small to moderate trunk diameter and height while species diversity is considerably low (H' = 1.65) which could be attributable to both human and climatic factors. The total carbon stored by trees in the city was estimated to be 6,395.11kg carbon which could be translated to approximately 6.4t. This is lower than what is obtained in many cities in the region. Higher carbon was contributed by Azadirachta indica, Vatex doniana, Terminalia ivorensis, Adansonia digitata and Khaya senegalensis. There is the need for planting more species of trees to boost the diversity and carbon storage of the city. This will go a long way in improving the ecosystem services provided by urban trees and the long run urban resilience.*

Keywords: Composition; Diversity; Carbon Storage, Urban Areas

## 1.0 INTRODUCTION

Carbon storage and sequestration are distinctive functions of the plant diversity (Dorendorf et al., 2015). The former refers to accumulation of woody biomass in plants tissues as they grow over time and the latter implies the annual storage rate of $CO^2$ in both above-ground and below-ground biomass over one growing season (McPherson, 1998). Plants generally serve as sinks of GHG's and other atmospheric pollutants by fixing carbon during photosynthesis and storing excess carbon as biomass (2002). The ability of trees and other plants materials to sequester carbon is a function of their composition, age and growing conditions (McPherson, 1998) as well as tree density (Nowak et al., 2013).

Urban areas accommodate more than half of the global population and serve as centres of economic and commercial (Dangulla et al., 2019). Hence, the role of trees in carbon storage and sequestration in urban environments have been variously studied and analyzed. For instance, Myeong et al. (2006) estimated the carbon stored by urban trees in Syracuse at 146,800, 149,430, and 148,660 tons for 1985, 1992, and 1999, respectively. Liu and Li (2012) also estimated 3.02% of the annual C of urban forests in Shenyang, China to be emitted through fossil fuel combustion. Similarly, Davies et al. (2011) found out the trees In Leicester, USA, stored about 97.3% of the 231 521 tonnes of carbon estimated in their study while Dangulla et al.(2019) found that the trees in Sokoto Metropolis stored an estimated 427.37 tonnes of carbon.

Researches have however expressed apprehensions that there is the possibility of a decline in the efficiency of global natural carbon sinks, which may fasten the rate of atmospheric $CO^2$ accumulation and thus, propelling the process of global warming (Canadell et al., 2010). This may not be unconnected with increasing anthropogenic GHG emissions, land use/cover changes and urbanization. There is thus, the need for assessing the total carbon storage and sequestration in cities within this region and modeling future trends. There is also the need for determining the carbon storage and sequestration potentials of individual tree species in Damaturu so as to guide urban ecological policies and climate change mitigation.

## 2.0 MATERIALS AND METHODS

### 2.1 The Study Area

The research was carried out in Damaturu City, North-eastern Nigeria. The city lies on Latitudes 11° 44' 40"N and Longitudes 11° 57' 40"E. It is the capital and administrative headquarters of Yobe State, hosting the State Government Ministries, Departments and Agencies as well as the headquarters of the Damaturu Emirate. The Local Government has a total area of 2,386 km2 and a population of 88,014 at the 2006 census. This was projected to 137,900 in 2022. It is bounded in the North by Tarmuwa Local Government, Fune Local Government to the West, Gujba Local Government to the South and Borno State to the East as shown in Fig.1.

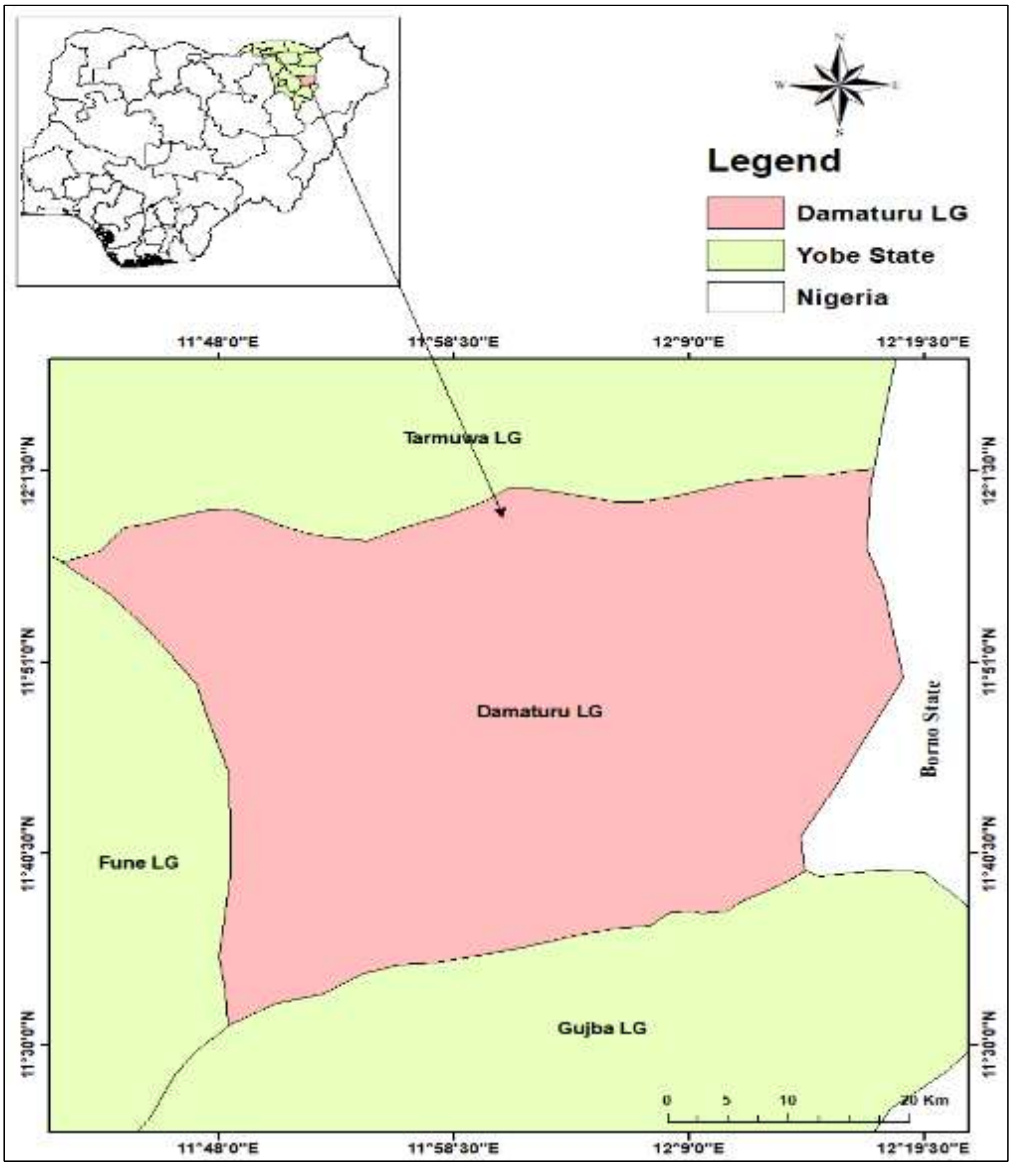


Figure 1: Damaturu Local Government and Yobe State

Climate of the area is typically the tropical wet and dry climate type (Koppen's Aw), characterized by significant seasonal variations in temperature and precipitation, The area experiences short rainy season which starts from May to September and long dry season which lasts from October to April, Mean annual rainfall in the area is about 800mm while mean annual temperature is around 29°C (84°F), with the hottest months being April and May.

### 2.2 Sampling and Data Collection

A total of 60 sample points were automatically generated across the city using TerrSet LiberaGIS software. TerrSet is an integrated geospatial software system for monitoring and modeling the earth system for sustainable development. The coordinates of these points were recorded in the way-point list of a GPS device and traced to the field for the detailed field survey (Figure 2).

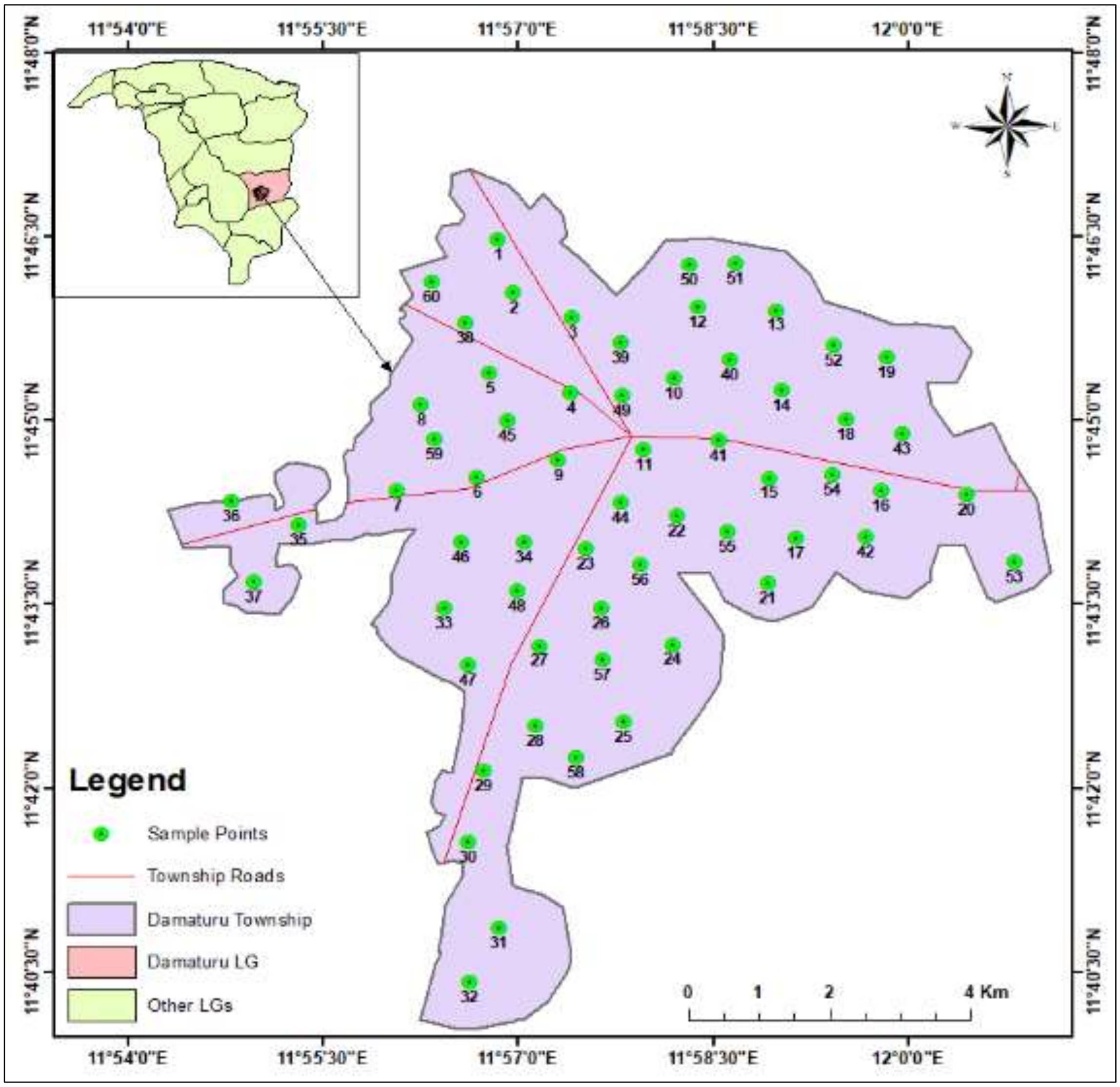


Figure 2: Sampling Points Distribution

Data collection for the study was achieved through an extensive field survey. A quadrat of 30x30m was established at each sample point and all trees encountered within the quadrats were identified, enumerated and measured. Species identification was based on Lely (1925) and Keay et al. (1989). Similarly, tree height was measured with a Clinometer while diameter at breast height (DBH) of trees was obtained by measuring the tree circumference at 1.3m above the ground and dividing by pi (3.14) as obtained in Kershaw et al. (2016).

**2.3 Data Analysis**

Species composition was established based on data computations in Microsoft Excel while species diversity was computed using the Shannon-Weiner's index. This index which combines species richness and relative abundance is frequently used for diversity analysis (Kuruneri-Chitepo and Shackleton, 2011; Roswell et al., 2021). The Shannon-Weiner's index is given as:

$$H' = -\sum_{i=1}^{k} \text{pi} \log pi$$

(Equation 1)

Where:

$K$ = Number of species,

pi = Proportional abundance of the *ith* species

Carbon stock of tree species was estimated using an allometric equation developed by Chave et al. (2014). This is a standard model for estimating carbon stock in tropical forests which estimates tree biomass and carbon stock based on tree height, diameter and wood density. It has been found to give more accurate estimates of biomass and carbon stock in tropical areas (Rutishauser et al., 2013) compared to other equations (e.g. Brown, 1997; Brown et al., 1989; Feldpausch et al., 2011). In addition, the model has been widely used in Africa and other areas with similar climatic characteristics (Pellikka et al., 2018; Solomon et al., 2018). It is given in Equation 2 as:

$$AGB = 0.0673 \times (\rho D2H)^{0.976} \quad \text{(Equation 2)}$$

where,

where $\rho$ = wood density (g $cm^{-3}$)

D = Diameter at Breast Height (cm)

H = Height (m)

The wood density ($\rho$) for all species will be obtained from the Global Wood Density Database (Chave et al., 2009; Zanne et al., 2009) and the World Agroforestry database (http://db.worldagroforestry.org/wd)(Chave et al., 2014). Wood density or specific gravity is an important predictor of AGB and thus, an important parameter used to estimate the trees biomass and its corresponding carbon stocks (Hasmadi et al., 2015). This however varies markedly between tree species, diameter class, life history strategies and environmental gradients (Chave et al., 2009).

Most of the allometric equations used in AGB estimation were derived from forest trees which have more biomass than the urban, open grown trees. To account for this difference therefore, the results will be multiplied by a conversion factor of 0.8 (Nowak et al., 2013). This will then be multiplied by 0.5 to obtain carbon stock as suggested by IPCC (2013) and obtained from other previous studies such as Chisanga at al. (2018), Rieger et al. (2015) and Tang et al. (2016). This is because, carbon constitutes 50% of total wood biomass (Salas Macías et al., 2017).

## 3.0 RESULTS

### 3.1 Woody Species Composition and Dominance

In this study, a total of 204 stems belonging to 17 species and 11 families were enumerated and recorded. The most dominant species in the city are *Azadirachta indica*, which had the highest number of stems, accounting for 57.4% of the species, followed by *Vatex doniana* (11.3%), *Terminalia ivorensis* (9.8%) and *Polyaltha longifolia* (3.9%). Together, these species accounted for 82.3% of all the species encountered in the city. Similarly, most of the stems encountered belong to the Meliaceae family. Although most of the species are native to the area, many of them were represented by a few individuals (Table 1 and Figure 3).

Table 1: Woody Species Composition and Dominance in Damaturu, Yobe State

| S/N | Species | Common Name | Family | Stems | % |
|---|---|---|---|---|---|
| 1 | *Adansonia digitata* | Baobab Tree | Malvaceae | 2 | 0.98 |
| 2 | *Azadirachta indica* | Neem Tree | Meliaceae | 117 | 57.35 |
| 3 | *Balanites aegyptiaca* | Desert Date | Balanitaceae | 5 | 2.45 |
| 4 | *Dalbergia sissoo* | Indian Rosewood | Fabaceae | 3 | 1.47 |
| 5 | *Ficus glumosa* | Mountain Fig | Moraceae | 1 | 0.49 |
| 6 | *Ficus platyphylla* | Broadleaf Fig | Moraceae | 2 | 0.98 |
| 7 | *Ficus thonningii* | Strangler Fig | Moraceae | 1 | 0.49 |
| 8 | *Ficus sycomorus* | Sycamore Fig | Moraceae | 1 | 0.49 |
| 9 | *Hyphaene thebaica* | Doum Palm | Arecaceae | 6 | 2.94 |
| 10 | *Khaya senegalensis* | African Mahogany | Meliaceae | 5 | 2.45 |
| 11 | *Mangifera indica* | Mango | Anacardiaceae | 3 | 1.47 |
| 12 | *Phoenix dactilifera* | Date Palm | Arecaceae | 3 | 1.47 |
| 13 | *Piliostigma reticulatum* | Camel's Foot | Fabaceae | 2 | 0.98 |
| 14 | *Polyalthia longifolia* | Masquerade/Mast Tree | Annonaceae | 8 | 3.92 |
| 15 | *Terminalia ivorensis* | Black Afara | Combretaceae | 20 | 9.80 |
| 16 | *Vatex doniana* | Black Plum | Lamiaceae | 23 | 11.27 |
| 17 | *Ziziphus mauritiana* | Indian Jujube | Rhamnaceae | 2 | 0.98 |
| | | | | 204 | 100.00 |

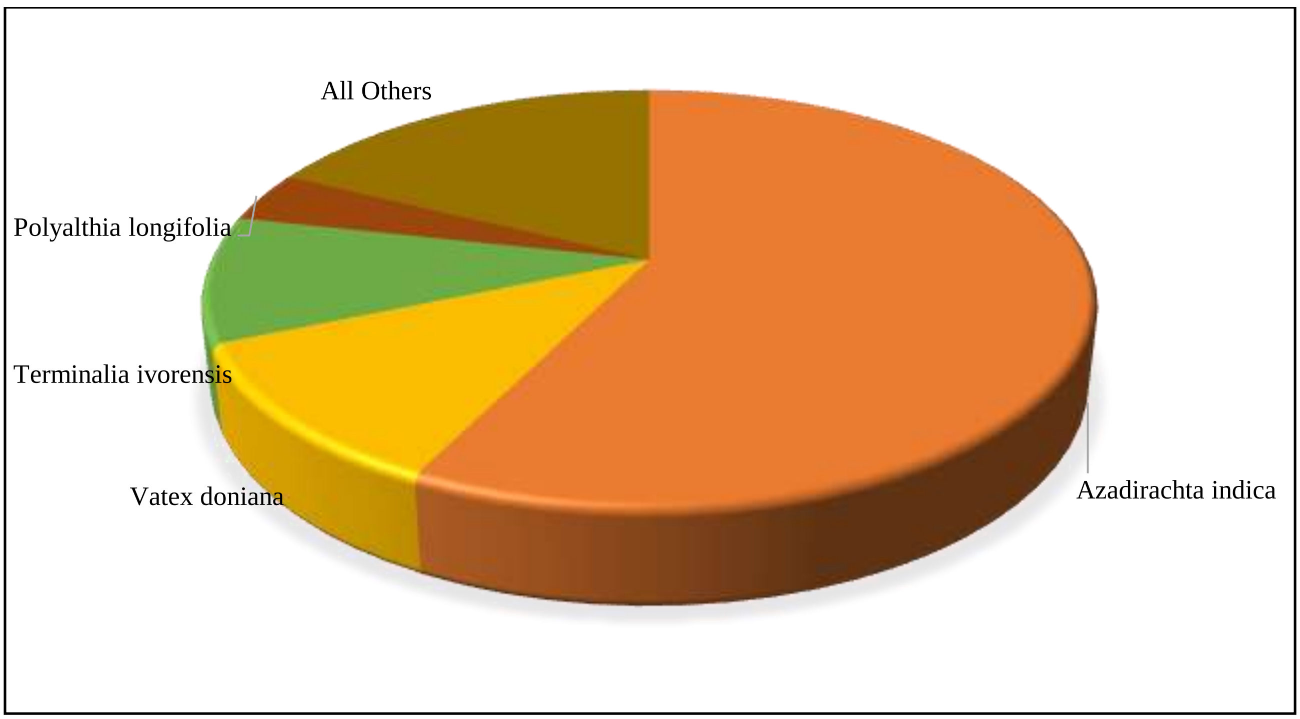

Figure 3: Woody Species Dominance in Damaturu, Yobe State

### 3.2 Tree Species Diversity

The diversity of woody species in Damaturu, Yobe State as assessed with the Shannon-Weiner's index revealed low diversity level (H' = 1.65). Unlike many cities in Northern Nigeria where there a many different species, this city has only a few species. From Table 2, it can be seen that *Azadirachta indica* is the most common species, having a diversity value of 0.31, followed by *Vatex doniana* which has diversity value of 0.24 and *Terminalia ivorensis* which has a diversity value of 0.22. All other species have very low diversity values.

Table 2: Tree Species Diversity in Damaturu, Yobe State

| S/N | Species | Stems | Pi | LnPi | H' |
|---|---|---|---|---|---|
| 1 | *Adansonia digitata* | 2 | 0.0098 | -4.625 | 0.04534 |
| 2 | *Azadirachta indica* | 117 | 0.57353 | -0.5559 | 0.31885 |
| 3 | *Balanites aegyptiaca* | 5 | 0.02451 | -3.7087 | 0.0909 |
| 4 | *Dalbergia sissoo* | 3 | 0.01471 | -4.2195 | 0.06205 |
| 5 | *Ficus glumosa* | 1 | 0.0049 | -5.3181 | 0.02607 |
| 6 | *Ficus platyphylla* | 2 | 0.0098 | -4.625 | 0.04534 |
| 7 | *Ficus thonningii* | 1 | 0.0049 | -5.3181 | 0.02607 |
| 8 | *Ficus sycomorus* | 1 | 0.0049 | -5.3181 | 0.02607 |
| 9 | *Hyphaene thebaica* | 6 | 0.02941 | -3.5264 | 0.10372 |
| 10 | *Khaya senegalensis* | 5 | 0.02451 | -3.7087 | 0.0909 |
| 11 | *Mangifera indica* | 3 | 0.01471 | -4.2195 | 0.06205 |
| 12 | *Phoenix dactilifera* | 3 | 0.01471 | -4.2195 | 0.06205 |
| 13 | *Piliostigma reticulatum* | 2 | 0.0098 | -4.625 | 0.04534 |
| 14 | *Polyalthia longifolia* | 8 | 0.03922 | -3.2387 | 0.12701 |
| 15 | *Terminalia ivorensis* | 20 | 0.09804 | -2.3224 | 0.22769 |
| 16 | *Vatex doniana* | 23 | 0.11275 | -2.1826 | 0.24608 |
| 17 | *Ziziphus mauritiana* | 2 | 0.0098 | -4.625 | 0.04534 |
| | | 204 | | | 1.65087 |

### 3.3 Species Diameter and Height

The distribution of mean DBH and height of species in the city are presented in Figure 4 and Figure 5 respectively. Species in the city generally have small to medium trunk diameter which could be attributable to both human and climatic factors. However, species with the highest mean diameter include *Adansonia digitata* (25.95cm), *Ficus glumosa* and *Ficus sycomorus* (16.87cm each), *Ficus thonningii* (16.24cm), *Ficus platyphylla* (14.17cm), *Azadirachta indica* (13.62cm) and *Khaya senegalensis* (13.62cm). All other species have a mean trunk diameter of 10cm or less (Figure 4).

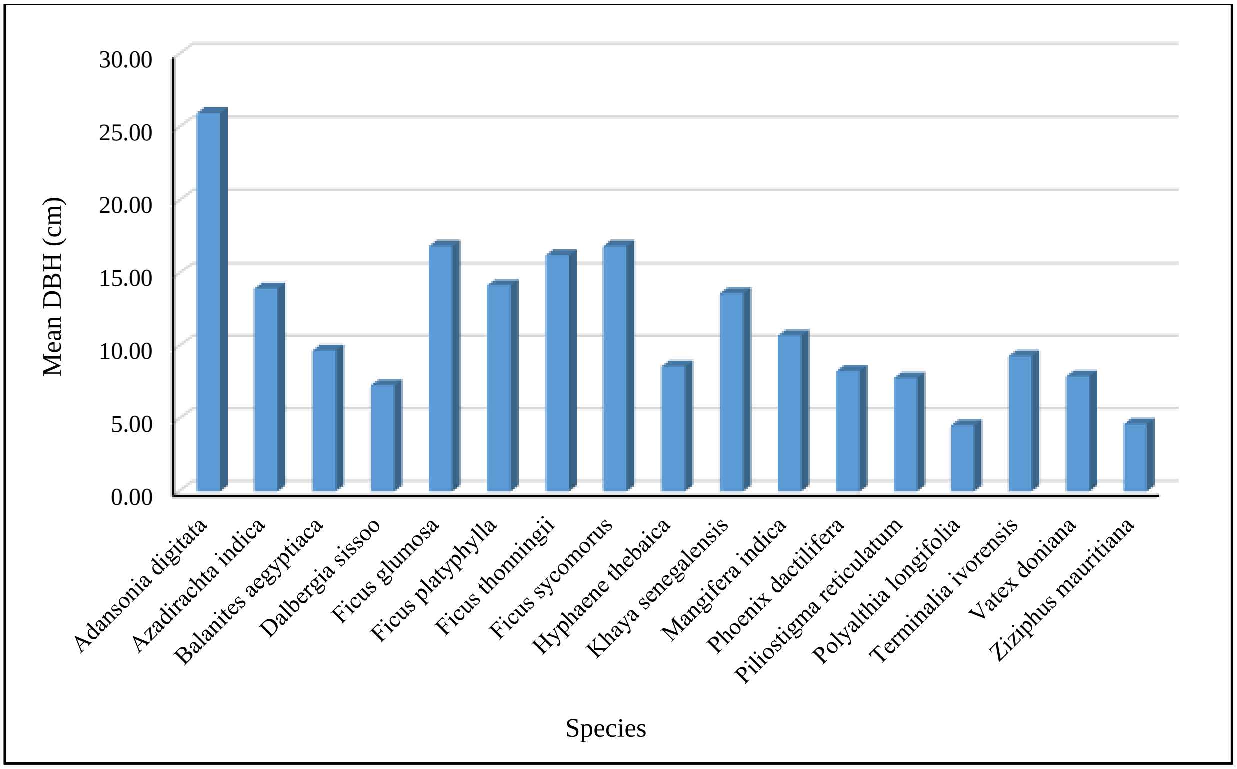


Figure 4: Mean Species Diameter at Breast Height (DBH)

Analysis of species height in Damaturu city revealed that the species are of moderate and low height (Figure 5). Most of the stems encountered are less than 10m tall but species with the highest mean height are those belonging to Moraceae family, including *Ficus thonningii* (12m), *Ficus glumosa* and *Ficus sycomorous*, each with mean height of 10m. Conversely, species with lowest mean height are *Ziziphus mauritian*a (3.5m) and *Hyphaene thebaica* (4.17m).

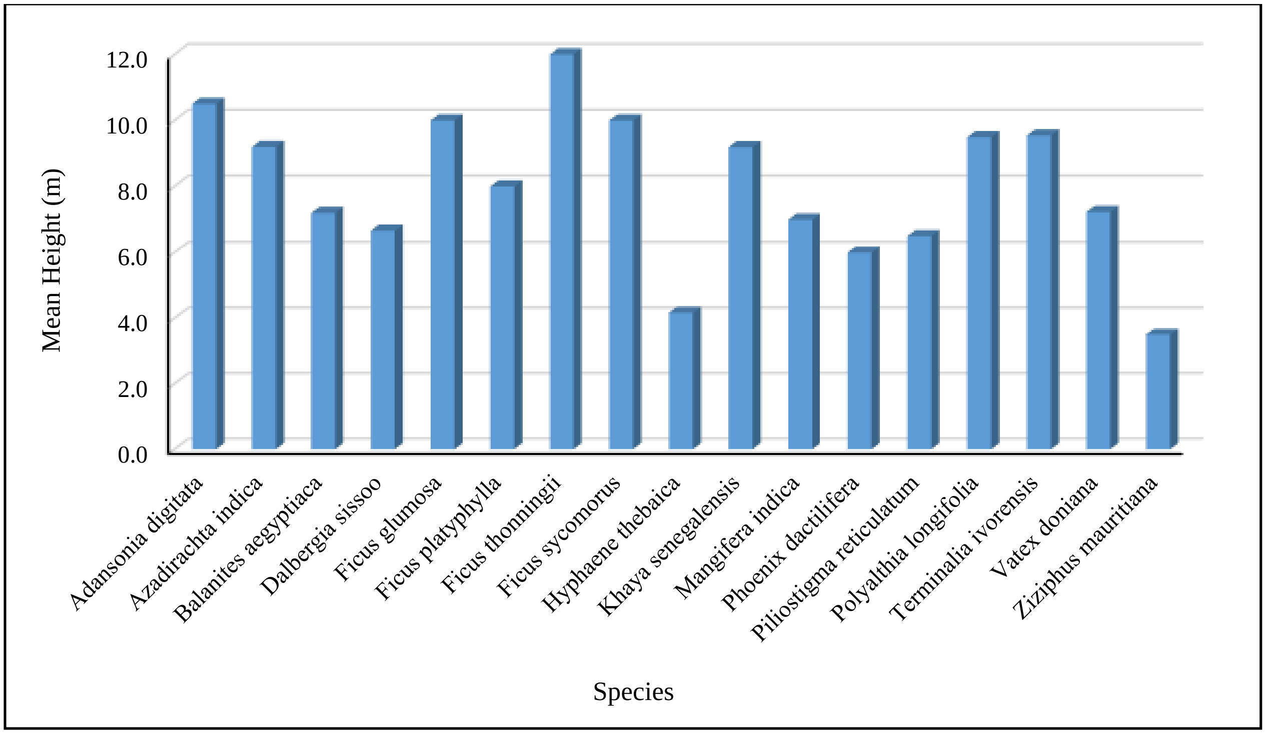


Figure 5: Mean Species Height

### 3.4 Tree Biomass and Carbon Stock

The enumerated trees stored an estimated 6,395.11kg carbon which could be translated to approximately 6.4t. The total and mean contribution of species to the city's carbon stock is shown in Table 3. The highest total carbon (4,946.5kg) was contributed by *Azadirachta indica* which has correspondingly, highest number of individual stems. This was followed by *Vatex doniana* (286.4kg), *Terminalia ivorensis* (252.6kg), *Adansonia digitata* (225.4kg) and *Khaya senegalensis* (219.8kg). However, the highest mean carbon contribution was by *Adansonia digitata* (112.7kg/stem), *Ficus thonningii* (55.1kg/stem), *Ficus glumosa* (49.7kg/stem), *Ficus sycomorus* (45.9kg/stem), *Khaya senegalensis* (44kg/stem), *Azadirachta indica* (42.3kg/stem) and *Ficus platyphylla* with a mean contribution of 28.1kg/stem. All other species have a mean contribution of less than 20kg/stem (Table 3).

Table 3: Total and mean tree carbon in Damaturu, Yobe State

| S/N | Species | Total Stems | Total C (kg) | Mean C (kg) |
|---|---|---|---|---|
| 1 | *Adansonia digitata* | 2 | 225.38 | 112.69 |
| 2 | *Azadirachta indica* | 117 | 4946.52 | 42.28 |
| 3 | *Balanites aegyptiaca* | 5 | 86.91 | 17.38 |
| 4 | *Dalbergia sissoo* | 3 | 19.34 | 6.45 |
| 5 | *Ficus glumosa* | 1 | 49.67 | 49.67 |
| 6 | *Ficus platyphylla* | 2 | 56.25 | 28.13 |

| | | | | |
|---|---|---|---|---|
| 7 | *Ficus thonningii* | 1 | 55.09 | 55.09 |
| 8 | *Ficus sycomorus* | 1 | 45.94 | 45.94 |
| 9 | *Hyphaene thebaica* | 6 | 33.61 | 5.60 |
| 10 | *Khaya senegalensis* | 5 | 219.83 | 43.97 |
| 11 | *Mangifera indica* | 3 | 39.41 | 13.14 |
| 12 | *Phoenix dactilifera* | 3 | 22.78 | 7.59 |
| 13 | *Piliostigma reticulatum* | 2 | 18.07 | 9.03 |
| 14 | *Polyalthia longifolia* | 8 | 34.27 | 4.28 |
| 15 | *Terminalia ivorensis* | 20 | 252.55 | 13.10 |
| 16 | *Vatex doniana* | 23 | 286.36 | 12.45 |
| 17 | *Ziziphus mauritiana* | 2 | 3.14 | 1.57 |
| | | 204 | 6395.11 | |

## 4.0 DISCUSSION

Tree species composition in this city was found to be dominated by few species which accounted for more than 80% of the total stems encountered in the study. As reported in many studies such as Dangulla et al. (2020) in Sokoto and Zaria cities, Agbelade et al. (2016) in Ibadan, Agbelade et al. (2017) in the Federal Capital Territory, Abuja among others, many cities in Nigeria have a large number of different tree species. The relatively few species in the city may be attributed to the climatic condition of the area but may also show weak institutional efforts at planting and maintaining urban trees. Similarly, people's attitude towards tree planting is not appreciable. Hence there is the need for rigorous public awareness campaigns on tree planting in the city.

Species diversity as recorded in this study is also low (H = 1.65). This implies relative monoculture where a single species is prominent or a very low number of different species within the city. As can be deduced from Table 1, *Azadirachta indica* accounts for more than half of the stems and thus, predominates in the city. By implication, woody species in the city may be prone to attacks as highly diverse areas are said to be more resilient to environmental shocks and less vulnerable to ecological disturbance and adverse impacts of climate change (Moussa et al., 2020).

The total carbon stored by species in this city (6.34t) is considerably lower than what is obtained in other cities in the region. Dangulla et al. (2019) for instance, recorded 427.4t of carbon in Sokoto Metropolis while Dangulla et al. (2021) recorded 657.05t of carbon in Zaria city. Similarly, Woldegerima et al. (2017) recorded 552,415t in Addis Ababa, Ethiopia while Liu and Li, (2012) reported higher carbon in Shenyang, Hangzhou and Beijing cities. The trees are generally of moderate to small diameter and height. These parameters to a greater extent, determine the carbon storage potential of tree stems. As opined by Mensah et al. (2016) and Moussa et al. (2020) trees with larger diameter store more carbon than those with smaller diameter. Similarly, species diversity which is positively correlated to increased carbon sequestration due to complementarity effects

(Hicks et al., 2014) was found to be low in the city. Hence, carbon storage potential of the trees in this city would be invariably low.

## 5.0 CONCLUSION

This paper assessed tree diversity and carbon stock in Damaturu, North-eastern Nigeria. Findings from the study reveal that the area has low species diversity, with few dominant species accounting for more than 80% of the trees. The study also highlights the role of the different species in carbon storage but the total carbon stored by these trees is relatively low, compared to other urban areas in Northern Nigeria. There is therefore the need to plant more species of trees to boost the diversity and carbon storage of the city. This will go a long way in improving the ecosystem services provided by urban trees and the long run urban resilience.

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