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# SPECIFIC GRAVITY AND CARBON CONTENT OF WOODY SPECIES IN LOWLAND MOIST FOREST AND SAVANNA VEGETATIONS OF PARTS OF OSUN STATE, NIGERIA

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## ABSTRACT

This study assessed the wood-specific gravity (WSG), carbon content and above-ground biomass (AGB) of some woody species in forest and savanna vegetations of Osun State, Nigeria. Carbon concentration in the AGB was determined by oven-drying each woody stem core at $80^o$ C to constant weight prior to analysis. WSG of the stem cores of tree species was determined from the oven-dry wood mass and green volume. WSG was lowest in *Newbouldia laevis* (0.20) and *Piliostigma thonningii* (0.38) in forest and savanna, respectively while *Afzelia africana* had the highest WSG in forest (0.89) and savanna (0.87) vegetations. Carbon content in AGB ranged from 40.0% (*Oncoba spinosa*) to 53.3% (*Celtis zenkeri*) in the forest, but it varied from 41.0% (*Daniella oliverii*, *Ficus asperifolia*, *Gliridia sepium*, *Rauvolfia vomitoria*) to 56.00% (*Parkia biglobosa*) in the savanna. In the forest, *Mallotus mildbraedii* (39.49 kg) and *Funtumia elastica* (2428.93 kg) had the lowest and highest AGB in the savanna vegetation; *Cnestis ferruginea* (38.16 kg) and *Vitellaria paradoxa* (1530.62 kg) had the highest and the lowest AGB, respectively. The study showed that the specific gravity of the woody species, AGB and carbon content varied within and among species in forest and savanna vegetations.

**Keywords:** Biomass; allometry; forest; savanna; carbon and woody species
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## INTRODUCTION

Unraveling the contributions of natural systems in storing carbon and the inclusion of country-specific wood gravity in the allometric equation has been touted as a proactive measure to attenuate climate change. The assessment and quantification of forest biomass is hallmarked by a long history, and has received renewed attention in the last decades (Brown *et al.*, 1989; Nelson *et al.*, 1999; Montes *et al.*, 2000; Chung-Wang and Ceulemans, 2004; Basuki *et al.*, 2009; Navar, 2009). This is mainly due to its importance in national development planning, scientific studies on ecosystem productivity, determination of carbon budgets, and as a monitoring strategy in global climate mitigation (Zheng *et al.*, 2004; Pan *et al.*, 2011). There are several types of biomass, namely above-ground biomass (AGB) and below-ground biomass (BGB).

Among the different types of biomass, above-ground biomass has been given the highest importance in carbon inventories; and in several mitigation projects it is the most important pool for the clean development mechanism (CMD) projects under the Kyoto Protocol (Giri and Rawat, 2013). Majority of biomass assessments are done for above-ground biomass of trees, because this generally accounts for the largest fraction of total living biomass in a forest; and does not pose much logistical problems for field measurements (Brown, 1997). Estimating above-ground biomass is a critical step in quantifying carbon stocks and fluxes from tropical forests (Gibbs *et al.*, 2007), and is equally important for scientific and management issues such as forest productivity and nutrient cycling (Terakunpisut *et al.*, 2007).

In estimating above-ground biomass, different approaches have been used based on field measurements, remote sensing and GIS (Lu, 2006). The most widely used non-destructive method for estimating biomass of forest uses are the allometric equations, which are developed and applied to forest inventory data to assess the biomass and carbon stocks of forest (Vashum and Jayakumar, 2012). Many researchers have developed generalised biomass prediction equations for different types of forest and tree species (Brown *et al.*, 1989; Nelson *et al.*, 1999; Montes *et al.*, 2000; Chung-Wang and Ceulemans, 2004; Basuki *et al.*, 2009; Navar, 2009).

The allometric equations for biomass estimation were developed by establishing a relationship between the various physical parameters of the trees such as diameter at breast height, height of the tree trunk, total height of the tree, crown diameter, tree species, etc. Equations have been developed for single species as well as for mixtures of species. These provide an estimate of biomass for specific sites and for large-scale regional and global comparisons (Vashum and Jayakumar, 2012). Aside the biomass estimation, wood-specific gravity is also important in the estimation of the Carbon content in woody species.

Wood-specific gravity integrates many aspects of mechanical properties of wood (Chave *et al*., 2009; Bastin *et al*,. 2015). Consequently, this parameter is often used as a proxy to understand the stature and functioning of tropical tree species (Chave *et al.*, 2009, Reich, 2014). Most studies investigating forest biomass variations globally (Slik *et al*., 2013), regionally (Gourlet-Fleury *et al.*, 2011; Bastin *et al*., 2015) and locally (Gourlet-Fleury *et al.*, 2013; Bastin *et al*., 2014), use average wood-specific gravity values at the specific or the generic level extracted from global repositories such as DRYAD (Zanne *et al*., 2009). However, it has been shown locally that the use of such repositories can lead to an overe-stimation of the wood-specific gravity of approximately 16% for the species community (Ramananantoandro *et al*., 2015). Studies focusing on tree biomass often neglect both “within genera” and “within species” variations in wood-specific gravity; the latter potentially depend on tree size and mechanical constraints, or on environmental conditions. In contrast, studies describing the variability of wood-specific gravity, and stressing the potential consequences of such variations on the biomass of the tree (Plourde *et al*. 2015), barely consider biomass estimations in the framework of the carbon budget of the forest. Neglecting variability of wood-specific gravity might be essentially problematic for species that prominently contribute to forest biomass; i.e., species reaching large dimensions (Chave *et al*., 2001; Slik *et al*., 2013), or those that are frequently and/or locally ‘dominant’ (Bastin *et al*., 2014; Fauset *et al*., 2015). In order to accurately quantify landuse change carbon emissions, information about forest carbon stocks and deforestation rates is essential. An accurate estimation of forest biomass and carbon cycling in the context of disturbances is also required for implementing Reducing Emissions from Deforestation and Forest Degradation (REDD) policy (Gautam and Mandal, 2016). Furthermore, quantification of forest biomass, productivity and carbon stock demands the estimation of both the above-ground and below-ground components.

This study provides the wood-specific gravity of species contributing mainly to the biomass of the forest and savanna in Nigeria. Such datasets are scarce in tropical countries or completely absent, even though substantial rates of deforestation and forest degradation are occurring in tropical forests and savannas. This study was aimed at (i) extracting pith-to-bark wood-specific gravity profiles of the wood cores collected on ‘dominant’ tree species, (ii) determining the wood-specific gravity and above-ground biomass and (iii) evaluating the carbon content in the wood core.

## MATERIALS AND METHODS

### Study Area

The study was carried out in Osun State located in the southwestern part of Nigeria (Figure 1). The State lies within latitudes 7.0º and 9.0º N and longitudes 2.8º and 6.8º E of the equator. The original vegetation of Osun State has been described as lowland forest zone (Keay, 1959), semi-deciduous moist forest (Charter, 1968) and Guineo-Congolian forest drier type (White, 1983). Hall (1969) also described the vegetation as the dry forest sub-group. The vegetation lies in the lowland rain forest zone of southwestern Nigeria, with derived savanna featuring around Iwo and Osogbo (Abe, 1995).

There are two prominent seasons in Osun State: the wet and dry seasons. The dry season is short, usually lasting four months from November to March and a longer wet season prevails during the remaining months. The average rainfall of the area ranges from 1125 mm in derived savanna to 1475 mm in the rain forest belt of the State (OAU APRG, 2015). The mean annual temperature ranges from 27.2 ºC in the month of December to 39.0 ºC in June (Olatunde *et al*., 2013). The relative humidity in the early morning is generally high, usually over 90% throughout the year. At midday, it is rather low, around 80% in the wet season and as low as 50-60% in the dry season (Hall 1969; OAU APRG 2015).

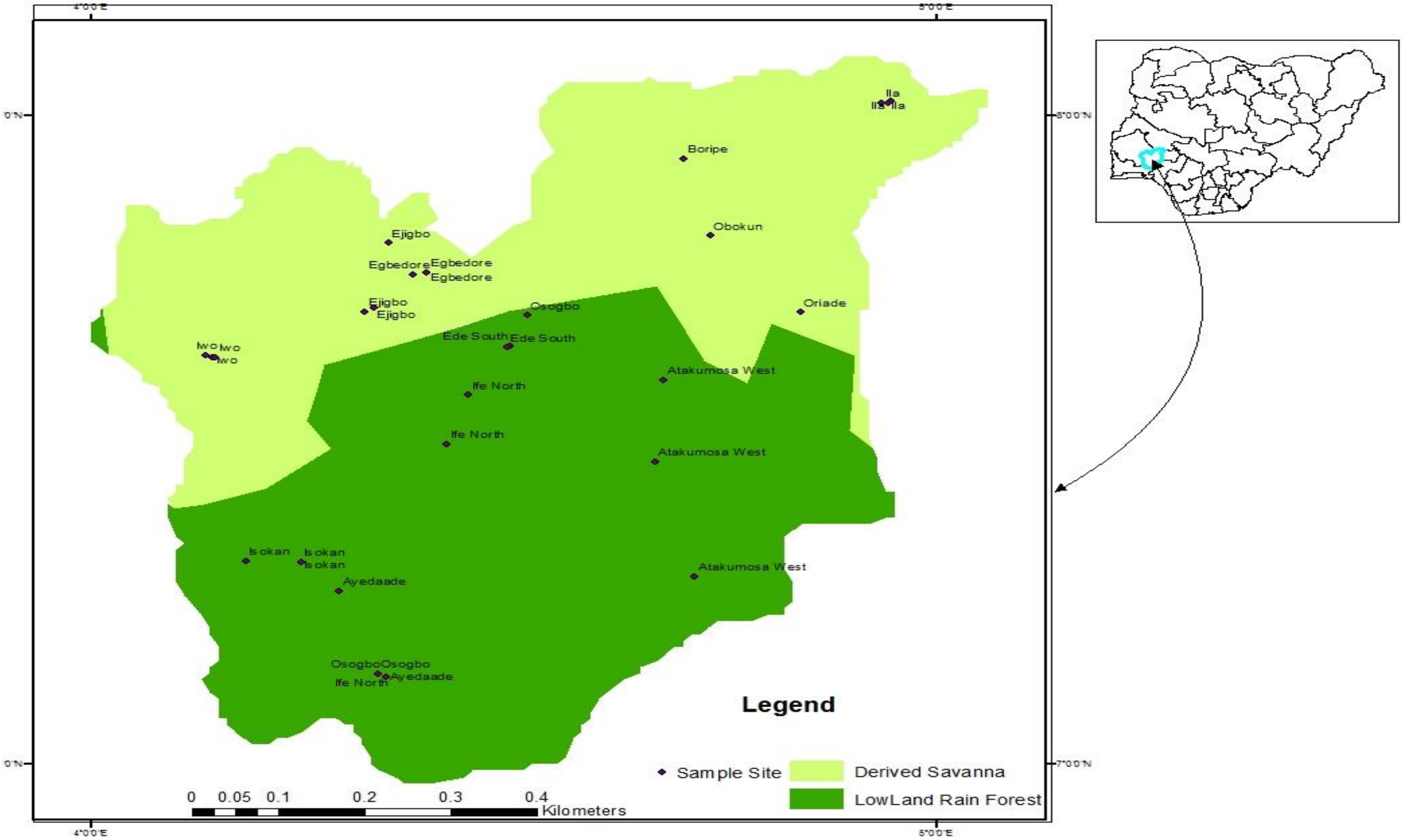

Figure 3.1: Map of the study area (Fieldwork, 2016).

Table 1: Sampling Plots for the Study

| Site (n=3) | Lowland Rainforest | Agricultural Zone | Derived Savanna | Agricultural Zone |
|---|---|---|---|---|
| I | Ayedaade | Iwo | Ila | Osogbo |
| II | Isokan | | Egbedore | |
| III | Ede South | Osogbo | Iwo | Iwo |
| IV | Ede North | | Ejigbo | |
| V | Ife North | Ife/Ijesha | Obokun, Oriade, Boripe | Ife/Ijesha |
| VI | Atakumosa West | | | |

**Sampling Procedure**

A vegetation study of the woody species was carried out in both the forest and savanna vegetations of Osun State (Table 1). During the study period, the woody plants were enumerated and their girths at breast height (GBH at 1.3 m) determined for trees ≥ 3 m high and those < 3 m height at midpoint were measured using a measuring tape. Once counted, a woody plant was marked to avoid double enumeration. Voucher specimens were collected as well as specimens of species not completely identified in the field. Plants collected were pressed, identified at IFE Herbarium, Obafemi Awolowo University, Ile-Ife using existing voucher specimens, and identification manuals including Flora of West Tropical Africa (Hutchinson and Dalziel 1963- 1972), Handbook of West African Weeds (Akobundu and Agyakwa, 1998) and Trees of Nigeria (Keay, 1989).

**Measurement of Species height**

The vertical length between the lowest part and the tallest living part for all trees > 3 m in height was measured using Haglof clinometer while the shorter ones were measured using the marked ranging pole.

**Determination of specific gravity**

The stem core of each woody species was taken at breast height using a stem increment borer and wood-specific gravity (WSG) and carbon content (CC) were determined. Green volume of each piece was measured accurately by water displacement, as described in Wiemann and Williamson (1988; 1989a; 1989b). A graduated cylinder was filled with water, placed on a balance and tared to zero. The core wood sample was held with a needle beneath the surface of water in the cylinder for some minutes to allow water to fill air spaces and the weight was subsequently determined. The weight of displaced water is equivalent to the sample's volume (green volume). The pieces were then oven-dried at 103 °C to constant weight (24 – 48 hours) and weighed on a top-loading balance. The specific gravity of the stem core of each woody species was calculated as the oven-dry wood mass divided by its green volume.

**Estimation of above-ground biomass**

Above-ground biomass (AGB) and carbon stock were estimated in each plot across the different vegetation types. The girth sizes of all trees (GBH at 1.3 m) ≥ 10 cm in size were measured with a tape rule, enumerated and identified to species level. The GBHs were converted to DBH using the equation:

$DBH = GBH/\pi$

Above-ground biomass was calculated using allometric equations developed from DBH, specific gravity and tree total height as predictors using regression model of Chave *et al*. (2005) for the various sites studied.

Biomass (in kg) = $\exp(-2.977 + \ln(\rho D^2 H))$ (Chave *et al.*, 2005)
D is trunk diameter at breast height (cm), $\rho$ is specific gravity (g $cm^{-3}$) and H is height (m) of individual tree species. Data obtained from these vegetation types on the DBH, specific gravity and height of the tree species were used as predictors in the above equations to estimate the tree biomass in the forest and savanna vegetations.

**Estimation of Carbon Concentration**
The carbon concentration in the above-ground biomass was determined by oven-drying each woody stem core at 80°C to constant dry weight and ground for carbon concentration analysis with a Leco CHN Elemental Analyzer.

## RESULTS

**Specific gravity, height, carbon content and above-ground biomass of plant species in forest vegetation**
The mean diameter of the forest tree species ranged from 8.25 cm to 80.80 cm with *Napoleana vogelli* having the lowest mean diameter (8.25 cm) and *Alstonia boonei* having the largest mean diameter (80.80 cm) (Table 2). The mean height of forest tree species varied from 6.32 m to 12.76 m. *Napoleana vogelli* had the smallest height (6.33 m) and *Xylopia aethiopica* had the highest height (12.76 m) (Table 2). The mean specific gravity of the forest tree species varied significantly ranging from 0.20 (*Newbouldia laevis*) to 0.89 (*Afzelia africana*) while the carbon content in the tree above-ground biomass ranged from 40.0% (*Oncoba spinosa*) to 53.3% (*Celtis zenkeri*) (Table 2). The biomass of the above-ground tree species varied in the forest plant species with *Mallotus mildbraedii* (39.49 kg) having the smallest above-ground biomass and *Funtumia elastica* (2428.93 kg) with the highest (Table 2).

Table 2: Specific gravity, height, carbon content and above-ground biomass of plant species in the forest vegetation

| S/No | Plant Species | N | Mean Diameter (cm) ± SEM | Height (m) ± SEM | Specific gravity ρ ± SEM | Carbon content (%) | Above-ground biomass (AGB) (kg) ± SEM |
|---|---|---|---|---|---|---|---|
| 1 | *Afzelia Africana* | 7 | 39.43±3.87 | 10.34±0.40 | 0.89±0.02 | 41.0 | 752.62±132.90 |
| 2 | *Albizia adiantifolia* | 6 | 42.83±8.88 | 10.43±0.59 | 0.50±0.00 | 43.0 | 631.31±295.01 |
| 3 | *Albizia glabarima* | 6 | 40.83±12.81 | 9.97±0.68 | 0.51±0.02 | 44.0 | 686.46±370.68 |
| 4 | *Albizia lebbeck* | 10 | 25.60±3.22 | 10.01±0.17 | 0.56±0.02 | 46.0 | 202.74±46.31 |
| 5 | *Albizia zygia* | 13 | 42.69±8.82 | 11.05±0.60 | 0.44±0.02 | 42.0 | 805.99±468.98 |
| 6 | *Alchornea cordifolia* | 10 | 34.70±5.62 | 9.81±0.60 | 0.49±0.01 | 45.0 | 387.15±165.45 |
| 7 | *Alstonia boonei* | 5 | 80.80±16.05 | 11.04±0.29 | 0.46±0.02 | 47.0 | 2012.91±797.52 |
| 8 | *Annona squamosal* | 7 | 32.71±2.16 | 9.86±0.41 | 0.54±0.01 | 46.9 | 296.81±36.49 |
| 9 | *Anthocleista vogelli* | 6 | 45.50±7.10 | 9.97±0.62 | 0.50±0.03 | 47.6 | 681.07±263.94 |
| 10 | *Antiaris Africana* | 8 | 45.75±14.35 | 11.74±1.10 | 0.46±0.01 | 48.3 | 1178.86±815.71 |
| 11 | *Baphia nitida* | 6 | 31.50±9.23 | 10.07±0.57 | 0.47±0.04 | 49.0 | 404.20±284.31 |
| 12 | *Blighia sapida* | 7 | 49.29±7.84 | 10.71±0.66 | 0.70±0.01 | 49.7 | 1075.25±328.57 |
| 13 | *Blighia unijugata* | 4 | 38.25±9.93 | 10.73±0.55 | 0.74±0.01 | 50.4 | 700.19±337.41 |
| 14 | *Bombax buonopozense* | 11 | 42.09±4.98 | 9.38±0.32 | 0.44±0.02 | 51.1 | 445.15±95.22 |
| 15 | *Bridelia micrantha* | 7 | 33.14±4.87 | 9.51±0.36 | 0.52±0.01 | 51.9 | 325.16±118.27 |
| 16 | *Ceiba pentandra* | 2 | 29.00±6.00 | 10.20±0.10 | 0.56±0.04 | 52.6 | 263.53±122.80 |
| 17 | *Celtis zenkeri* | 5 | 35.40±7.88 | 11.04±0.11 | 0.43±0.00 | 53.3 | 363.64±137.76 |
| 18 | *Chrysophyllum albidum* | 6 | 38.50±12.21 | 10.80±0.43 | 0.48±0.01 | 43.0 | 627.21±402.40 |
| 19 | *Cola gigantean* | 11 | 29.18±5.37 | 10.25±0.42 | 0.49±0.00 | 44.0 | 315.72±147.63 |
| 20 | *Cola nitida* | 7 | 56.71±19.87 | 10.24±0.71 | 0.47±0.01 | 46.0 | 1118.42±663.01 |
| 21 | *Diospyros barteri* | 7 | 25.57±1.74 | 9.77±0.61 | 0.53±0.03 | 47.3 | 175.10±24.45 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 22 | *Dracaena arborea* | 5 | 23.20±3.32 | 7.80±0.68 | 0.434±0.002 | 42.0 | 102.32±31.23 |
| 23 | *Dracaena mannii* | 7 | 31.75±7.04 | 9.84±0.44 | 0.32±0.02 | 44.0 | 244.91±80.79 |
| 24 | *Ficus asperifolia* | 6 | 62.17±5.99 | 12.32±0.38 | 0.46±0.01 | 43.0 | 1168.94±221.94 |
| 25 | *Ficus exasperate* | 12 | 46.75±4.13 | 11.43±0.63 | 0.54±0.01 | 41.0 | 736.64±145.39 |
| 26 | *Ficus sur* | 6 | 33.17±3.64 | 10.28±0.71 | 0.41±0.01 | 42.0 | 236.41±38.54 |
| 27 | *Funtumia elastic* | 10 | 53.30±14.72 | 11.50±0.75 | 0.60±0.04 | 45.0 | 2428.93±1395.88 |
| 28 | *Gmelina arborea* | 8 | 37.50±6.47 | 10.23±0.99 | 0.60±0.02 | 46.0 | 577.69±280.20 |
| 29 | *Hedranthera barteri* | 6 | 43.50±4.90 | 11.03±0.80 | 0.55±0.01 | 45.1 | 667.39±192.27 |
| 30 | *Holarrhena floribunda* | 10 | 30.00±4.38 | 10.34±0.46 | 0.47±0.02 | 45.6 | 286.33±87.41 |
| 31 | *Irvingia gabonensis* | 6 | 39.00±6.06 | 10.27±0.85 | 0.47±0.02 | 46.1 | 398.49±114.14 |
| 32 | *Khaya senegalensis* | 6 | 48.33±7.00 | 10.60±0.52 | 0.72±0.01 | 46.5 | 994.32±280.81 |
| 33 | *Leucaena leucocephala* | 5 | 25.40±2.29 | 8.70±0.84 | 0.35±0.00 | 47.0 | 104.78±24.40 |
| 34 | *Lophira alata* | 5 | 66.400±7.20 | 11.42±0.34 | 0.59±0.01 | 47.5 | 1592.81±352.63 |
| 35 | *Macaranga barteri* | 7 | 11.29±1.02 | 10.26±0.62 | 0.66±0.03 | 47.9 | 48.18±10.11 |
| 36 | *Mallotus mildbraedii* | 4 | 16.25±0.95 | 8.73±0.65 | 0.34±0.01 | 48.4 | 39.49±3.79 |
| 37 | *Mallotus oppositifolius* | 7 | 43.86±5.91 | 8.30±0.49 | 0.30±0.04 | 48.9 | 276.16±82.88 |
| 38 | *Mallotus subulata* | 4 | 9.80±2.50 | 9.48±0.79 | 0.50±0.02 | 49.3 | 36.02±3.37 |
| 39 | *Mangifera indica* | 5 | 34.20±9.90 | 9.68±0.63 | 0.44±0.00 | 49.8 | 349.88±205.60 |
| 40 | *Milletia thonningii* | 6 | 16.00±1.39 | 9.25±0.76 | 0.37±0.03 | 50.3 | 46.54±9.52 |
| 41 | *Morus mesozygia* | 5 | 29.40±3.88 | 9.78±0.62 | 0.43±0.07 | 50.7 | 176.41±35.24 |
| 42 | *Myrianthus arboreus* | 7 | 42.29±6.61 | 10.87±1.21 | 0.69±0.01 | 44.0 | 884.76±322.63 |
| 43 | *Napoleonaea imperalis* | 3 | 16.00±1.16 | 9.17±0.84 | 0.49±0.05 | 42.0 | 57.36±4.85 |
| 44 | *Napoleonaea vogelli* | 4 | 8.25±1.25 | 6.33±0.80 | 0.35±0.05 | 41.0 | 7.376±2.13 |
| 46 | *Oncoba spinosa* | 9 | 32.78±5.01 | 10.70±0.42 | 0.42±0.03 | 40.0 | 304.33±107.87 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 47 | *Pycnanthus angolensis* | 7 | 67.43±12.30 | 12.03±0.57 | 0.47±0.03 | 43.0 | 1742.18±751.06 |
| 48 | *Rauvolfia vomitora* | 9 | 48.00±5.23 | 10.04±0.44 | 0.44±0.01 | 47.0 | 559.94±90.05 |
| 49 | *Senna occidentalis* | 7 | 23.57±2.67 | 9.39±0.51 | 0.35±0.07 | 48.0 | 108.19±30.61 |
| 50 | *Senna siamea* | 3 | 25.33±5.36 | 9.60±1.31 | 0.31±0.01 | 47.2 | 108.04±45.98 |
| 51 | *Spondias mombin* | 5 | 55.60±14.14 | 12.06±1.26 | 0.42±0.01 | 47.9 | 1109.62±626.64 |
| 52 | *Sterculia rhinopetala* | 8 | 46.25±4.85 | 10.84±0.47 | 0.43±0.03 | 48.7 | 537.73±110.30 |
| 53 | *Sterculia tragacantha* | 6 | 35.00±2.42 | 11.13±0.98 | 0.57±0.00 | 49.5 | 421.22±73.22 |
| 54 | *Tectona grandis* | 6 | 52.33±8.55 | 11.20±0.53 | 0.57±0.04 | 51.0 | 1089.29±456.62 |
| 55 | *Terminalia superba* | 6 | 64.33±8.51 | 12.85±0.67 | 0.46±0.04 | 50.2 | 1277.95±273.51 |
| 56 | *Trichilia welwitschii* | 5 | 55.00±10.07 | 11.60±0.71 | 0.40±0.06 | 42.0 | 814.79±251.74 |
| 57 | *Triplochiton scleroxylon* | 3 | 34.33±8.67 | 11.80±3.11 | 0.44±0.04 | 44.0 | 384.16±179.16 |
| 58 | *Xylopia aethiopica* | 8 | 34.00±4.28 | 12.76±1.18 | 0.52±0.02 | 48.0 | 454.89±131.29 |
| 59 | *Voacanga Africana* | 10 | 35.20±5.88 | 10.48±0.35 | 0.49±0.01 | 46.0 | 420.86±144.42 |
| 60 | *Zanthoxylum zanthoxyloides* | 3 | 51.33±5.81 | 13.23±0.52 | 0.55±0.02 | 52.0 | 1004.60±249.31 |

N= Number of samples, SEM: standard error of mean

**Specific gravity, height, carbon content and above-ground biomass of plant species in savanna vegetation**

The mean diameter of the savanna tree species ranged from 12.83 cm to 58.67 cm with *Combretum racemosa* having the lowest mean diameter (12.83 cm) and *Vitellaria paradoxa* having the highest mean diameter (58.67 cm) (Table 3). The height of savanna tree species varied from 7.50 m to 11.36 m. *Cnestis ferruginea* had the lowest height (7.50 m) while *Vitellaria paradoxa* had the highest height (11.36 m) (Table 3).

The specific gravity of the savanna tree species varied from 0.38 (*Piliostigma thonningii*) to 0.87 (*Afzelia africana*) while the carbon content in the above-ground biomass varied from 41.0% (*Daniella oliverii, Ficus asperifolia*, *Gliricidia sepium, Rauvolfia vomitoria*) to 56.0 % (*Parkia biglobosa*) (Table 3). The biomass in the above-ground woody species varied in the savanna plant species with *Cnestis ferruginea* (38.16 kg) having the lowest above-ground biomass and *Vitellaria paradoxa* (1530.62 kg) having the highest (Table 3).

Table 3: Specific gravity, height, carbon content and above-ground biomass of plant species in savanna vegetation

| S/No | Plant Species | N | Mean Diameter (cm) ± SEM | Height (m) ± SEM | Specific gravity, ρ ± SEM | Carbon content (%) | Aboveground biomass (AGB) (kg) ± SEM |
|---|---|---|---|---|---|---|---|
| 1 | *Afzelia africana* | 7 | 36.86±5.45 | 9.66±0.25 | 0.87±0.02 | 48.0 | 692.15±218.50 |
| 2 | *Albizia adiantifolia* | 8 | 29.00±3.32 | 8.88±0.35 | 0.60±0.00 | 44.0 | 256.64±59.91 |
| 3 | *Albizia lebbeck* | 6 | 24.33±1.33 | 9.28±0.32 | 0.589±0.02 | 43.0 | 167.93±20.28 |
| 4 | *Albizia zygia* | 5 | 33.80±1.20 | 10.08±0.70 | 0.58±0.01 | 45.0 | 349.12±53.16 |
| 5 | *Alchornea cordifolia* | 4 | 23.000±1.78 | 7.18±0.34 | 0.54±0.01 | 46.0 | 103.04±10.95 |
| 6 | *Allophyllus africanus* | 5 | 13.80±1.356 | 8.36±0.70 | 0.50±0.01 | 49.0 | 41.02±6.75 |
| 7 | *Anacardium occidentale* | 5 | 17.60±1.17 | 8.86±0.25 | 0.63±0.01 | 47.0 | 90.02±11.49 |
| 8 | *Alstonia boonei* | 7 | 25.429±2.64 | 8.93±0.45 | 0.50±0.01 | 41.0 | 165.09±41.55 |
| 9 | *Annona senegalensis* | 2 | 29.00±6.00 | 8.75±0.85 | 0.60±0.01 | 42.0 | 240.61±112.87 |
| 10 | *Anthocleista djalonensis* | 5 | 33.80±2.38 | 9.18±0.52 | 0.67±0.01 | 45.0 | 370.53±70.73 |
| 11 | *Anthocleista vogelii* | 6 | 34.33±8.48 | 9.72±0.36 | 0.57±0.03 | 44.0 | 412.03±187.00 |
| 12 | *Antiaris africana* | 8 | 29.88±1.77 | 8.45±0.28 | 0.53±0.01 | 48.0 | 208.91±28.25 |
| 13 | *Blighia sapida* | 8 | 37.625±7.52 | 9.06±0.66 | 0.74±0.01 | 46.0 | 725.92±384.49 |
| 14 | *Bridelia ferruginea* | 11 | 35.00±2.632 | 9.06±0.34 | 0.59±0.01 | 43.0 | 347.50±51.38 |
| 15 | *Bridelia micrantha* | 6 | 33.67±4.31 | 8.38±0.42 | 0.55±0.02 | 43.0 | 271.13±56.34 |
| 16 | *Citrus sinensis* | 4 | 34.50±0.96 | 8.88±0.38 | 0.70±0.01 | 42.0 | 375.25±10.93 |
| 17 | *Cnestis ferruginea* | 6 | 14.67±1.15 | 7.50±0.39 | 0.45±0.01 | 42.0 | 38.16±5.80 |
| 18 | *Combretum hispidium* | 6 | 13.17±0.48 | 7.88±0.56 | 0.77±0.01 | 44.0 | 53.87±4.94 |
| 19 | *Combretum racemosum* | 12 | 12.83±0.64 | 7.94±0.43 | 0.82±0.01 | 42.0 | 56.96±7.47 |
| 20 | *Daniellia oliveri* | 7 | 34.57±2.24 | 11.30±0.68 | 0.65±0.01 | 41.0 | 466.59±69.69 |
| 21 | *Ficus asperifolia* | 4 | 40.50±4.17 | 9.55±0.57 | 0.48±0.01 | 41.0 | 392.21±88.38 |
| 22 | *Ficus capensis* | 7 | 53.43±6.16 | 10.83±0.70 | 0.47±0.01 | 48.0 | 882.25±252.12 |
| 23 | *Ficus exasperata* | 5 | 41.60±9.83 | 8.80±0.55 | 0.49±0.03 | 45.0 | 556.95±353.55 |
| 24 | *Ficus sur* | 7 | 27.86±1.93 | 9.27±0.29 | 0.45±0.01 | 42.0 | 173.08±27.30 |

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|---|---|---|---|---|---|---|---|
| 25 | *Gliricidia sepium* | 7 | 20.86±1.30 | 8.03±0.26 | 0.39±0.01 | 41.0 | 70.86±10.75 |
| 26 | *Holarrhena floribunda* | 15 | 41.07±2.28 | 10.33±0.35 | 0.54±0.01 | 44.0 | 509.25±71.62 |
| 27 | *Hoslundia opposita* | 4 | 18.00±1.68 | 7.90±0.68 | 0.62±0.01 | 42.0 | 79.56±10.91 |
| 28 | *Hymenocardia acida* | 4 | 34.00±4.38 | 8.58±0.89 | 0.55±0.03 | 46.0 | 272.75±46.91 |
| 29 | *Leucaena leucocephala* | 6 | 20.50±1.03 | 8.17±0.38 | 0.39±0.01 | 45.0 | 70.82±9.93 |
| 30 | *Lonchocarpus sericeus* | 12 | 27.42±1.93 | 9.15±0.29 | 0.74±0.01 | 43.0 | 283.52±45.13 |
| 31 | *Millettia thonningii* | 6 | 23.17±2.10 | 8.00±0.34 | 0.40±0.01 | 44.0 | 92.99±18.55 |
| 32 | *Nauclea latifolia* | 10 | 38.30±3.06 | 9.68±0.46 | 0.75±0.01 | 47.0 | 599.85±110.58 |
| 33 | *Parkia biglobosa* | 13 | 47.85±4.94 | 11.18±0.57 | 0.83±0.01 | 56.0 | 1281.50±323.27 |
| 34 | *Persea americana* | 6 | 26.17±4.19 | 8.12±0.43 | 0.56±0.01 | 49.0 | 176.27±63.48 |
| 35 | *Piliostigma thonningii* | 11 | 44.36±2.71 | 11.19±0.40 | 0.38±0.00 | 42.0 | 454.79±58.33 |
| 36 | *Rauvolfia vomitora* | 9 | 19.78±0.95 | 8.19±0.42 | 0.47±0.01 | 41.0 | 79.81±10.76 |
| 37 | *Spondias mombin* | 6 | 26.00±4.83 | 9.65±0.55 | 0.47±0.01 | 43.0 | 227.13±52.41 |
| 38 | *Tectona grandis* | 4 | 45.50±2.53 | 9.90±0.57 | 0.57±0.05 | 46.0 | 600.33±87.49 |
| 39 | *Terminalia sp* | 5 | 45.40±4.06 | 10.74±0.53 | 0.63±0.01 | 48.0 | 736.09±133.91 |
| 40 | *Trema orientalis* | 7 | 23.00±3.02 | 8.90±0.51 | 0.39±0.01 | 45.0 | 108.04±36.32 |
| 41 | *Vitellaria paradoxa* | 9 | 58.67±3.30 | 11.36±0.43 | 0.73±0.01 | 54.0 | 1530.62±210.36 |
| 42 | *Vitex doniana* | 10 | 54.40±7.41 | 10.18±0.55 | 0.71±0.01 | 47.0 | 1285.57±333.96 |
| 43 | *Voacanga africana* | 8 | 47.00±5.29 | 10.24±0.59 | 0.61±0.01 | 43.0 | 812.49±242.06 |

N= Number of samples, SEM: Standard Error of Mean

## DISCUSSION

Wood-specific gravity (WSG) has become a popular topic as plant biologists search for broad-spectrum functional traits and determine their ecological and evolutionary significance (Muller-Landau 2004; Chave *et al*., 2006, 2009; King *et al*., 2006; van Gelder *et al*., 2006; Swenson and Enquist, 2007, 2008). Specific gravity has been acclaimed as the integrator of wood properties in the “wood economics spectrum” given its importance in structure, storage and translocation (Chave *et al*., 2009). In addition, WSG is the primary variable in the estimation of biomass to assess global carbon stocks (Brown and Lugo, 1992; Fearnside, 1997; Chave *et al*., 2005; Nogueira *et al*., 2005; Malhi *et al*., 2006; Keeling and Phillips, 2007; Nogueira *et al*., 2007, 2008a, b). This study is probably the first of its kind reporting specific gravity for some woody species of Nigerian forest and savanna.

In this study, wood-specific gravity was observed to be useful for allometric biomass estimation on the different values of specific gravity; which is in line with Tetemke *et al.* (2019), who noted that specific gravity inherently varies within or among tree species. The tree species in this study had different values for specific gravity in forest and savanna vegetations. This indicates that specific gravity of tree species could vary depending on the environmental conditions prevalent in the site or vegetation type where the species grow. Nangendo *et al.* (2007) reported that anthropogenic and environmental factors are mainly responsible for species composition in a typical vegetation. The specific gravity of the trees of different regenerational guilds (canopy and understorey) and successional guilds (pioneer, early and late) differs. This is in agreement with Espinoza (2004) who noted that specific gravity of shade-tolerant trees is higher than those of pioneer species. This has been demonstrated by *Piliostigma thonningii*, a pioneer species with the mean DBH of 44.364±2.708 cm in savanna and specific gravity of 0.382. The result indicates that GBH/DBH of woody species affect the specific gravity since GBH/DBH size of a tree is an indication of its age. There exists considerable evidence that specific gravity increases with age/diameter in individual tropical forest trees. The extent to which this variability is a source of error in biomass estimates remains debatable. Specific gravity appears to increase with the age of trees and successional status of forests. This implies that older forests are more important biomass sinks than the younger ones due to the presence of large trees and the increased carbon present in woody debris, leaf litter and soils.

The result of this study also provides an insight into the problem of dearth of information on the specific gravity of trees in tropical vegetation. In majority of the tropical region, there is inadequate information and specific gravity has been published for only a fraction of the world’s timber species. For example, Chave *et al*. (2009) data for 8,412 taxa, 1,683 genera, 191 families worldwide; that is less than 10% of the global tree flora, estimated at 100,000 species (Oldfield *et al*., 1998). The list of 8,412 taxa is roughly equal to the number of taxa threatened with global extinction (Schatz, 2009). The majority of tree species which specific gravity has not been reported are from the tropics. This study has helped to provide baseline data that may elicit further investigation on Nigerian tree species especially for conservation and protection against adverse effects of climate change. Data on tree AGB in the tropics, most especially in Nigeria, are presently unavailable. Chave *et al*. (2004) and Henry *et al*. (2010) have noted that the omission of specific gravity from allometric models could lead to less precise estimates of tree AGB.

## CONCLUSION

This study has demonstrated that the specific gravity, AGB and carbon content of woody species varied among species in forest and savanna vegetations. The result on specific gravity in this study has provided a better approach in the determination of above-ground biomass of woody species.

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