# Tree Biomass and Carbon Stock in the Orang National Park, Assam, India

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**Abstract**

The present study was conducted in the Orang National Park (ONP), which is the core area of the Orang Tiger Reserve (OTR), Assam, Northeast India. The study examines biomass and carbon stock of trees in the ONP in three different forest stands, i.e., dense, open, and swampy forest stands, respectively. Altogether 45 tree species from 38 genera and 24 families were recorded in the forest. In the dense forest stand, a total of 39 species from 34 genera and 23 families were recorded, in the open forest, 33 species from 29 genera and 20 families were recorded, and in the swampy forest stand, 17 species from 15 genera and 11 families were recorded. The tree density and basal area were 1081 individual $ha^{-1}$ and 82.62 $m^2$ $ha^{-1}$ in the dense forest stand, 392 individual $ha^{-1}$ and 23.54 $m^2$ $ha^{-1}$ in open forest stand, and 1013 individual $ha^{-1}$ and 39.43 $m^2$ $ha^{-1}$ in swampy forest stand, respectively. The total tree biomass was 526.499 Mg $ha^{-1}$ in dense, 160.089 Mg $ha^{-1}$ in open, and 325.920 Mg $ha^{-1}$ in the swampy forest stand. Similarly, the total carbon stock in dense was 263.939 Mg C $ha^{-1}$, 81.160 Mg C $ha^{-1}$ in open, and 162.962 Mg C $ha^{-1}$ in the swampy forest stand. The present study revealed that ONP is rich in tree diversity and has high carbon stock potential. The information from this study can help to understand the status of this forest and will be helpful for biodiversity conservation, and also to enhance the management strategies in the future.

**Keywords:** tree biomass, carbon stock, biodiversity conservation, orang national park, orang tiger reserve

## 1. Introduction

Forests are key ecosystem to combat climate change, absorbing $CO_2$ from the air (FAO 2005). Approximately 50% of the world's biodiversity exists in forests, which is a major contribution to the total global terrestrial carbon stocks and sustains human populations by providing a variety of goods and services (Ozukum *et al*. 2019). 20% of global carbon emissions are caused by deforestation (IPCC 2006). One of the primary greenhouse gases responsible for global warming is $CO_2$. The potential for carbon sequestration in forests is huge. During photosynthesis, plants absorb $CO_2$ gas and store it as biomass in different plant parts. It is

*Corresponding Author Email: moushumispk@gmail.com
Published: 09 July 2026
DOI: https://doi.org/10.70558/IJST.2026.v3.i3.241310
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estimated that 50% of all tree species biomass holds carbon (MacDicken 1997). The Northeastern (NE) part of India is one of the 36 biodiversity hotspots in the world, which covers an area of 7,15,342.61 km$^2$ (21.76%) of the total surface area of India (Anonymous 2023). The Eastern Himalayan biome represents the region's ecological model, and it is very abundant in endemism when it comes to both floral and faunal diversity (Giri *et al*. 2019). Assam is one of India's largest biodiversity-rich regions and holds a huge amount of phytodiversity (Joshi 2020). The present study aims to estimate the tree biomass and carbon stock in different forest stands in the core area of the Orang Tiger Reserve (Assam).

## 2. Methodology

### 2.1 Description of Study Site

The study was carried out in the Orang National Park (ONP) situated nearly 130 km apart from the state capital city, Guwahati, and under the jurisdiction of the Mangaldai Wildlife division of the Department of Environment and Forests, Govt. of Assam. Orang National Park (ONP) is the core area of Orang Tiger Reserve (OTR). The core area of the Orang Tiger Reserve is located in the districts of Sonitpur and Darrang on the northern bank of the Brahmaputra River. The core area of OTR is located between the latitudes 26º29´ N to 26º36´ N and the longitudes 92º15´ E to 92º25´ E (Anonymous 2021).

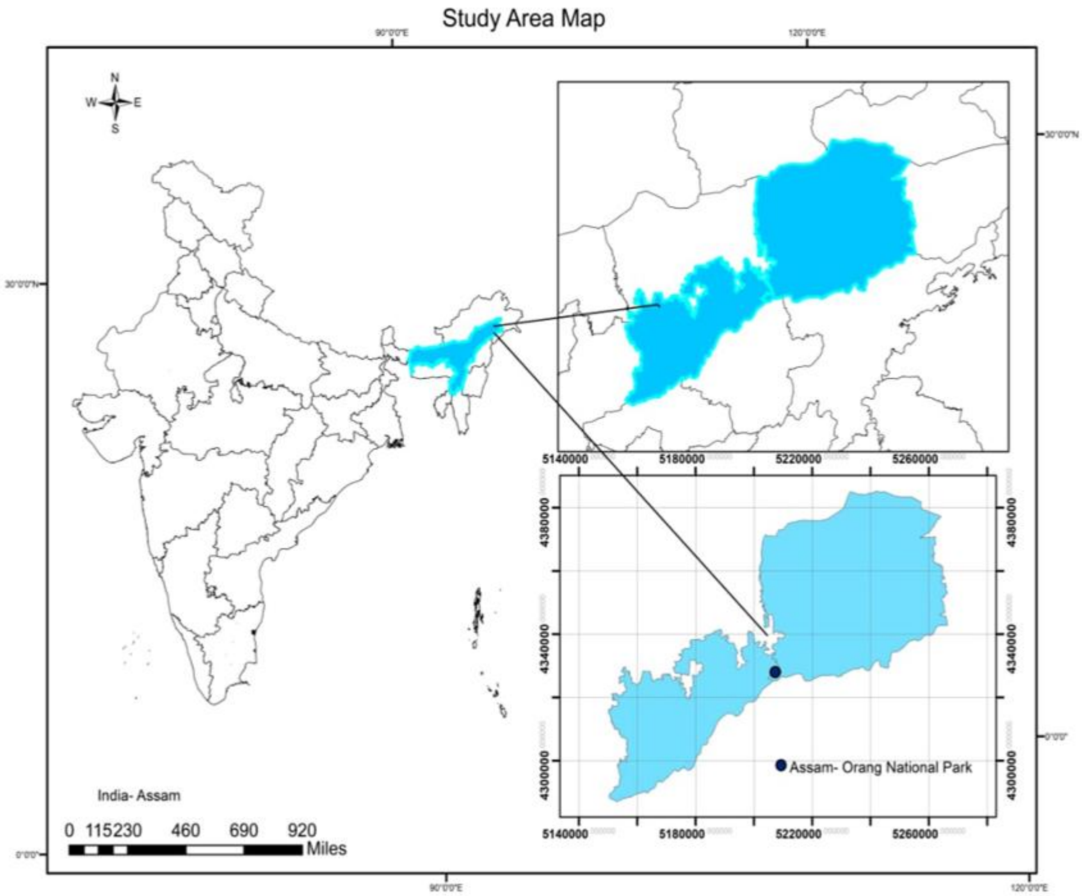


Fig 1. Study area map of the core area of the Orang Tiger Reserve, Assam

According to the Bio-geographic classification, the ONP is categorized under 9A: North- East Brahmaputra valley province (Rodgers & Panwar, 1988). According to Champion & Seth (1968), the habitat of the forest is composed mainly of Eastern Himalayan Moist deciduous forest (3C/C3b), Eastern Seasonal swamp forest (4D/SS1), Khair-Sissoo Forest (5/1S2), Eastern wet alluvial Grassland (4D/2S2), and Plantations. Based on the extent of land cover of the core area and Satellite imagery, the habitat for wildlife in the core area of OTR was divided into nine categories (Sarma 2010) According to satellite images of 2019 the extent of land cover of core area is Eastern Himalayan Moist Mix Deciduous Forest (Dense and Open) (11.2 $km^2$ &12.01 $km^2$), Dry Savannah Grassland (15.52 $km^2$), Wet alluvial grassland ( 17.14 $km^2$), Eastern seasonal swamp forest ( 3.87 $km^2$), Degraded grassland (8.16 $km^2$ ), water body (7.05 $km^2$) and sandy area (Dry and Moist) (2.94 $km^2$& 1.4 $km^2$ ) (Anonymous 2021). The ONP has a meso-thermal humid climate identical to the Brahmaputra valley (Hazarika 2007). Most of the year's rainfall is concentrated between June and September. The annual rainfall in the pre-monsoon period is 2000 mm, and the average rainfall is 400 mm (Anonymous 2021).

### 2.2 Data Collection

For the present investigation, 3 different forest stands were selected in the core area of the Orang Tiger Reserve, i. e, dense forest (DF), open forest (OF), and the swampy forest (SF) stands. (Anonymous 2021). Sampling was conducted across the forest stands to obtain the requisite data for analysis.

#### 2.2.1. Methods

An extensive field survey was conducted in the selected study site in the year 2024-2025. The stratified random sampling method was used for vegetation sampling using (10 m x 10 m) quadrat size. A total of 200 quadrats were laid across three forest stands and keeping in the view, 85 quadrat in dense, 85 in open, and 30 in the swampy forest stand were laid. The number of individuals of adult tree species with a diameter of ≥ 30 cm girth at breast height, i.e., 1.37 m above ground, was recorded using a measuring tape (Pandey and Shukla 1999). Tree species in all the quadrats were identified with the help of 'Flora of Assam' (Kanjilal *et al*. 1934-1940), The Flora of British India (Hooker 1872-1897), and also consulted plant taxonomists. Density and basal cover were calculated by using the formula given by Misra (1968). For AGB, the model developed by Nath *et al*. 2019 for the forests of Northeast India was used, i.e., AGB (Mg $ha^{-1}$) = $0.32(D^2H\delta)^{0.75}\times1.34$ where, D = Diameter, H = Height, δ= Specific density. The wood specific density of tree species had been taken from the World Agroforestry Database. Furthermore, for the species that are lacking wood- specific density, an average standard value (0.62 g $cm^{-3}$) was used (IPCC 2006). For BGB, the regression equation given by Cairns *et al.* 1997 was used, i.e, BGB (Mg $ha^{-1}$) = $\exp\{-1.059+0.884\times\text{InAGB}+0.284\}$. For the estimation of total biomass, AGB and BGB were summed up. Total Biomass (TB) = AGB+BGB. For each species, the total carbon stock (TCS) was calculated by multiplying the respective total biomass by a conversion factor of 0.5, indicating that 50% of TB is made up of carbon (IPCC 2003).

#### 2.2.2 Statistical Analysis

Correlation analysis was applied using IBM SPSS 23 to know the correlation between density, basal area and carbon stock in different forest stands.

## 3. Results and Discussion

Altogether, a total of 45 tree species were recorded in dense, open, and swampy forest stands from 38 genera and 24 families. The number of tree species recorded was less than that of the Hmuifang forest of Mizoram (50 species) (Sharma *et al*. 2017) but higher than the Kamrup Sal forest of Assam (25 species) (Deka *et al*. 2012). The present study reported 39 species of trees in the dense forest, which belong to 34 genera and 23 families in the study area, where Fabaceae and Meliaceae were the most dominant families (4), followed by Euphorbiaceae, Moraceae, and Lythraceae (3). In the open forest, a total of 33 species belonging to 29 genera and 20 families were recorded. Fabaceae and Meliaceae were found to be the most dominated family (4), followed by Lythraceae and Euphorbiaceae (3), Phyllanthaceae, Lauraceae, and Myrtaceae (2). While in the swampy forest stand, a total of 17 species belonging to 15 genera and 11 families were reported. Fabaceae was the most dominant family, followed by Moraceae, Lythraceae, Euphorbiaceae, and Meliaceae (2). (Table 1 and Fig 2). Total tree density in the dense forest was 1081 ($ha^{-1}$), which was comparable to the sub-tropical pine forest of Meghalaya (810 – 1050 $ha^{-1}$) (Tripathi *et al*. 2004) but very high as compared to that of the Gibbon Wildlife Sanctuary (286.92 $ha^{-1}$) and the Kholahat reserve forest of Assam (416.25 $ha^{-1}$) (Borah *et al*. 2015). Highest tree density was represented by *Lagerstroemia reginae* (Roxb.) (180 $ha^{-1}$) followed by *Bombax ceiba* L. (159 $ha^{-1}$), *Trewia nudiflora* L. (119 $ha^{-1}$), *Lagerstroemia speciosa* (L.) Pers (118 $ha^{-1}$), *Litsea* spp (85 $ha^{-1}$). The tree density in the open forest was 392 ($ha^{-1}$), which is higher than the Hojai reserve forest and Kumorakata reserve forest (240 $ha^{-1}$ and 130 $ha^{-1}$) (Dutta and Devi 2013). Highest tree density was found in *Lagerstroemia reginae* Roxb. (39 $ha^{-1}$), followed by *Bombax ceiba* L. (33 $ha^{-1}$), *Lagerstroemia speciosa* (L.) Pers (29 $ha^{-1}$), *Litsea* spp (27 $ha^{-1}$), and *Trewia nudiflora* L. (20 $ha^{-1}$) respectively. In the swampy forest stand the tree density was 1013 $ha^{-1}$, which can be compared to that of the Sal plantation forest (1028 ha-1) in Nongkhyllem wildlife sanctuary of Meghalaya (Baishya *et al*. 2009). Highest tree density was represented by *Trewia nudiflora* L. (233 $ha^{-1}$), followed by *Mallotus phillippensis* (Lam.) Muell. Arg (140 $ha^{-1}$), *Bombax ceiba* L. (130 $ha^{-1}$), *Lagerstroemia reginae* Roxb. (123 $ha^{-1}$), *Lagerstroemia speciosa* (L.) Pers (87 $ha^{-1}$). In the dense forest stand, *Acacia catechu* (L. F) Wild had the highest WSG (0.88 g $cm^{-3}$) followed by *Ziziphus* sp. (0.76 g $cm^{-3}$) and *Syzygium cumini* (L.) Skeels (0.7 $cm^{-3}$). (Table 2). In an open forest stand, *Acacia catechu* (L. F) Wild had the highest density WSG (0.88 g $cm^{-3}$), followed by *Ziziphus* sp. (0.76 g $cm^{-3}$), *Cassia fistula* L. (0.71) respectively. While in the swampy forest stand, *Acacia catechu* (L. F) Wild had the highest density WSG (0.88 g $cm^{-3}$), followed by *Mallotus phillippensis* (Lam.) Muell. Arg (0.64 g $cm^{-3}$), *Trewia nudiflora* L. (0.62 g $cm^{-3}$), *Streblus asper* Lour (0.62 g $cm^{-3}$), *Dalbergia sissoo* Roxb. Ex DC (0.62 g $cm^{-3}$), *Careya arborea* Roxb. (0.62 g $cm^{-3}$), *Dysoxylum binectariferum* (Roxb.) Hook. f. ex Bedd. (0.62 g $cm^{-3}$), *Sterculia villosa* Roxb. Ex DC (0.62 g $cm^{-3}$), *Aphanamixis polystachya* (Wall.) R. Parker (0.62 g $cm^{-3}$), *Oroxylum indicum* (L.) Vent. (0.62 g $cm^{-3}$). In dense forest, *Bombax ceiba* L. contributed maximum total biomass and carbon stock (135.358 Mg $ha^{-1}$ and 67.599 Mg C ha-1), followed by *Lagerstroemia reginae* Roxb. (79.389 Mg $ha^{-1}$ and 39.695 Mg C $ha^{-1}$), *Neolamarckia cadamba* (Roxb.) (45.035 Mg $ha^{-1}$ and 22.518 Mg C ha-1), *Lagerstroemia speciosa* (L.) Pers (43.498 Mg $ha^{-1}$ and 22.518 Mg C $ha^{-1}$), *Trewia nudiflora* L. (41.776 Mg $ha^{-1}$ and 20.888 Mg C $ha^{-1}$) (Table 2). In open forest stand, *Neolamarckia cadamba* (Roxb.) had contributed the highest biomass and carbon stock (19.216 Mg ha$^{-1}$ and 9.608 Mg C ha$^{-1}$), followed by *Albizia procera* (Roxb.) Benth (14.641 Mg ha$^{-1}$ and 7.321 Mg C ha$^{-1}$), *Lagerstroemia speciosa* (L.) Pers (12.12 Mg ha$^{-1}$ and 7.163 Mg C ha$^{-1}$), *Lagerstroemia reginae* Roxb. (12.098 Mg ha$^{-1}$ and 6.06 Mg C ha$^{-1}$) *Gmelina arborea* Roxb. (12.047 Mg ha$^{-1}$ and 6.023 Mg C ha$^{-1}$) respectively (Table 2). In Swampy Forest stand *Trewia nudiflora* L. had the highest total biomass and carbon stock (76.183 Mg ha$^{-1}$ and 38.091 Mg C ha-1) followed by *Bombax ceiba* L. (51.241 Mg ha$^{-1}$ and 25.62 Mg C ha-1), *Mallotus phillippensis* (Lam.) Muell. Arg (29.557 Mg ha$^{-1}$ and 14.779 Mg C ha-1), *Bischofia javanica* Blume (26.152 Mg ha$^{-1}$ and 13.076 Mg C ha-1), and *Lagerstroemia reginae* Roxb. (25.582 Mg ha$^{-1}$ and 12.791 Mg C ha$^{-1}$) (Table 3) respectively. The total AGB, BGB, TB and TCS of all the tree species in dense forest stand were 351.569 Mg ha$^{-1}$, 174.930 Mg ha$^{-1}$, 526.499 Mg ha$^{-1}$ and 263.939 Mg C ha$^{-1}$ (Table 2) respectively, which were higher than that of the Sacred forest of Montane evergreen forest of Meghalaya 273 Mg ha$^{-1}$, 59.53 Mg ha$^{-1}$, 332.53 Mg ha$^{-1}$ and 160.5 Mg C ha$^{-1}$ (Mir *et al.* 2021) and lower than tropical semi evergreen forest of Eastern Himalaya 586.52 Mg ha$^{-1}$, 152.51 Mg ha$^{-1}$, 738.99 Mg ha$^{-1}$ and 369.52 Mg C ha$^{-1}$ (Yumnam and Deori 2025). Interestingly, the TCS value of dense forest stand (263.939 Mg C ha$^{-1}$) was found to be higher in comparison to the carbon stock findings of Orang National Park (51.2 Mg C ha$^{-1}$ total; comprising 33.2 for trees and 18 Mg C ha$^{-1}$ for ground) (Deb & Baruah, 2025). In open forest stand the total AGB, BGB, TB and TCS of the tree species were 106.193 Mg ha$^{-1}$, 53.896 Mg ha$^{-1}$, 160.089 Mg ha$^{-1}$ and 81.160 Mg C ha$^{-1}$ (Table 3) respectively, which is lower than Nambor wildlife sanctuary 192.32 Mg ha$^{-1}$, 50 Mg ha$^{-1}$, 242.32 Mg ha$^{-1}$ and 121.16 Mg C ha$^{-1}$ (Giri *et al.* 2019), tropical moist deciduous forest of Kamrup Metropolitan district, Assam 782.19 Mg ha$^{-1}$, 203.37 Mg ha$^{-1}$, 985.56 Mg ha$^{-1}$ and 492.78 Mg C ha$^{-1}$ (Kalita & Yumnam 2024). While, in the swampy forest stand AGB, BGB, TB and TCS of tree species were 212.459 Mg ha$^{-1}$, 113.461 Mg ha$^{-1}$, 325.920 Mg ha$^{-1}$ and 162.962 Mg C ha-1 (Table 4), respectively, which were higher than the Sal forest of Tripura (110.53 Mg ha$^{-1}$, 28.74 Mg ha-1, 139.27 Mg ha$^{-1}$ and 167.64 Mg C ha$^{-1}$) (Banik *et al.* 2018).

Moreover, TCS had a strong positive correlation with density ($r = 0.851$), basal area ($r = 0.949$), and basal area also had a positive correlation with density ($r = 0.702$) (Table 5). Such findings were also reported from the Tropical Semi-evergreen forest at the foothills of the Eastern Himalayas (Yumnam & Deori 2025).

**Table 1.** Family dominance in forest stands

| Family Rank | Family | No. of species (DF) | Family | No. of species (OF) | Family | No. of species (SF) |
|---|---|---|---|---|---|---|
| 1 | Fabaceae | 4 | Fabaceae | 4 | Fabaceae | 3 |
| 2 | Meliaceae | 4 | Meliaceae | 4 | Moraceae | 2 |
| 3 | Euphorbiaceae | 3 | Lythraceae | 3 | Lythraceae | 2 |
| 4 | Moraceae | 3 | Euphorbiaceae | 3 | Euphorbiaceae | 2 |
| 5 | Lythraceae | 3 | Phyllanthaceae | 2 | Meliaceae | 2 |
| 6 | Dilleniaceae | 2 | Lauraceae | 2 | Lecythidaceae | 1 |
| 7 | Rubiaceae | 2 | Myrtaceae | 2 | Apocynaceae | 1 |
| 8 | Phyllanthaceae | 2 | Lamiaceae | 1 | Bignoniaceae | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 9 | Myrtaceae | 2 | Bombacaceae | 1 | Phyllanthaceae | 1 |
| 10 | Lamiaceae | 2 | Malvaceae | 1 | Malvaceae | 1 |
| 11 | Boraginaceae | 1 | Apocynaceae | 1 | Bombacaceae | 1 |
| 12 | Tetramelceae | 1 | Bignoniaceae | 1 | | |
| 13 | Theaceae | 1 | Rubiaceae | 1 | | |
| 14 | Apocynaceae | 1 | Dilleniaceae | 1 | | |
| 15 | Lauraceae | 1 | Magnoliaceae | 1 | | |
| 16 | Magnoliaceae | 1 | Moraceae | 1 | | |
| 17 | Malvaceae | 1 | Combretaceae | 1 | | |
| 18 | Combretaceae | 1 | Moraceae | 1 | | |
| 19 | Bignoniaceae | 1 | Combretaceae | 1 | | |
| 20 | Lecythidaceae | 1 | Rhamnaceae | 1 | | |
| 21 | Verbena family | 1 | | | | |
| 22 | Rhamnaceae | 1 | | | | |
| 23 | Bombacaceae | 1 | | | | |

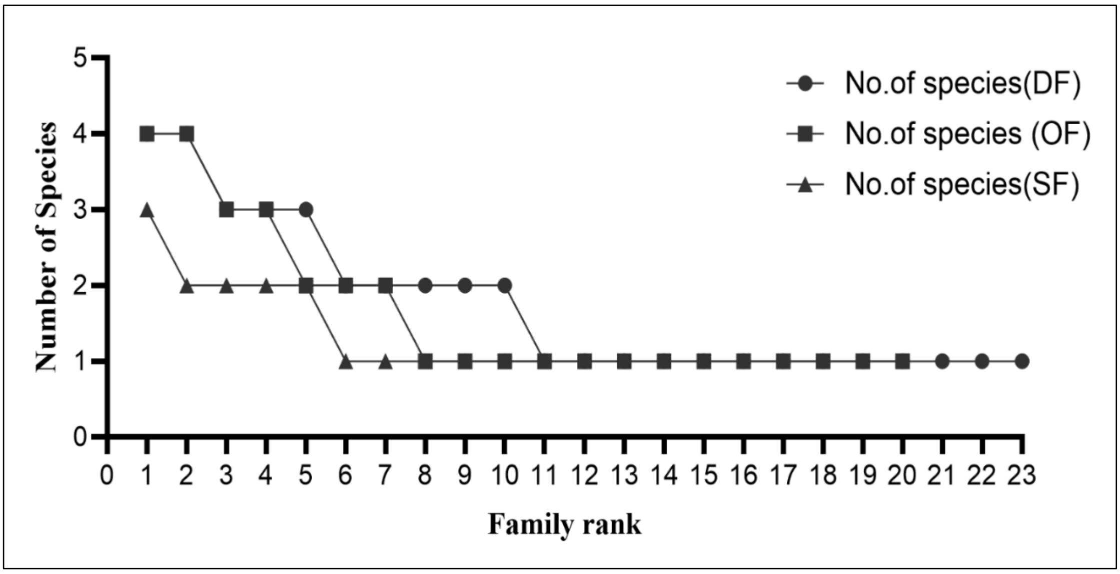


**Fig 2.** Family dominance-distribution curve in forest stands

**Table 2.** Family, Wood Specific Density (WSD), Density, Aboveground biomass (AGB), Belowground Biomass (BGB), Total Biomass (TB) and Total Carbon Stock (TCS) of the different tree species in the dense forest stand

| **Name of the Species** | **Families** | **WSD ($g\ cm^{-3}$)** | **Density ($ha^{-1}$)** | **AGB Mg $ha^{-1}$** | **BGB Mg $ha^{-1}$** | **TB Mg $ha^{-1}$** | **TCS Mg C $ha^{-1}$** |
|---|---|---|---|---|---|---|---|
| *Lagerstroemia reginae* Roxb. | Lythraceae | 0.55 | 180 | 52.405 | 26.985 | 79.389 | 39.695 |
| *Lagerstroemia speciosa (*L.) Pers | Lythraceae | 0.53 | 118 | 28.460 | 15.038 | 43.498 | 22.518 |
| *Bischofia javanica* Blume | Phyllanthaceae | 0.54 | 29 | 11.719 | 5.583 | 17.302 | 8.651 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Neolamarckia cadamba* (Roxb.) | Rubiaceae | 0.62 | 41 | 30.607 | 14.428 | 45.035 | 22.518 |
| *Bombax ceiba* L. | Bombacaceae | 0.33 | 159 | 92.084 | 43.274 | 135.358 | 67.599 |
| *Ficus glomerata* Roxb. | Moraceae | 0.39 | 1 | 1.850 | 0.809 | 2.659 | 1.329 |
| *Albizia procera* (Roxb.) Benth | Fabaceae | 0.52 | 5 | 3.913 | 1.782 | 5.695 | 2.848 |
| *Dalbergia sissoo* Roxb.ex DC | Fabaceae | 0.62 | 14 | 8.763 | 4.104 | 12.867 | 6.434 |
| *Litsea* sp. | Lauraceae | 0.4 | 85 | 12.993 | 7.032 | 20.025 | 10.012 |
| *Tectona grandis* Roxb. | Lamiaceae | 0.5 | 2 | 0.165 | 0.103 | 0.268 | 0.134 |
| *Tetrameles nudiflora* R.Br. | Tetramelceae | 0.3 | 1 | 0.239 | 0.133 | 0.372 | 0.186 |
| *Dillenia pentagyna* Roxb. | Dilleniaceae | 0.53 | 7 | 2.573 | 1.326 | 3.899 | 1.950 |
| *Trewia nudiflora* L. | Euphorbiaceae | 0.62 | 119 | 27.369 | 14.407 | 41.776 | 20.888 |
| *Toona hexandra* (Wall.ex Roxb.) Roem | Meliaceae | 0.62 | 2 | 0.550 | 0.298 | 0.848 | 0.424 |
| *Schima wallichi* (DC.) Korth | Theaceae | 0.62 | 4 | 0.388 | 0.227 | 0.614 | 0.307 |
| *Alstonia scholaris* (L.) R.Br. | Apocynaceae | 0.36 | 6 | 0.682 | 0.394 | 1.077 | 0.538 |
| *Dillenia indica* L. | Dilleniaceae | 0.59 | 7 | 1.398 | 0.739 | 2.137 | 1.069 |
| *Syzygium* sp. | Myrtaceae | 0.69 | 25 | 6.689 | 3.467 | 10.156 | 5.078 |
| *Chukrassia tabularis* A. Juss | Meliaceae | 0.57 | 9 | 1.623 | 0.902 | 2.524 | 1.262 |
| *Syzygium cumini* (L.) Skeels | Myrtaceae | 0.7 | 8 | 0.876 | 0.511 | 1.387 | 0.694 |
| *Gmelina arborea* Roxb. | Lamiaceae | 0.41 | 19 | 10.129 | 4.920 | 15.049 | 7.524 |
| *Michelia champaca* Linn. | Magnoliaceae | 0.43 | 9 | 7.325 | 3.391 | 10.716 | 5.358 |
| *Acacia catechu* (L.F) Wild | Fabaceae | 0.88 | 18 | 13.994 | 6.328 | 20.322 | 10.161 |
| *Mallotus tetracocus* (Roxb.) Kurz. | Euphorbiaceae | 0.62 | 8 | 1.671 | 0.924 | 2.595 | 1.298 |
| *Hymenodictylon excelsum* (Roxb.) | Rubiaceae | 0.62 | 2 | 0.225 | 0.136 | 0.361 | 0.181 |
| *Sterculia villosa* Roxb.ex DC | Malvaceae | 0.62 | 34 | 6.368 | 3.289 | 9.657 | 4.828 |
| *Streblus asper* Lour. | Moraceae | 0.62 | 20 | 2.019 | 1.197 | 3.217 | 1.608 |
| *Mallotus phillippensis* (Lam.) Muell. Arg | Euphorbiaceae | 0.64 | 49 | 4.665 | 2.729 | 7.394 | 3.697 |
| *Bridelia retusa* (L.) spreng | Phyllanthaceae | 0.5 | 22 | 5.527 | 2.863 | 8.390 | 4.195 |
| *Terminalia myriocarpa* Heurck & Muell. Arg | Combretaceae | 0.53 | 7 | 2.348 | 1.213 | 3.561 | 1.780 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Lagerstroemia parviflora* Roxb. | Lythraceae | 0.62 | 26 | 4.928 | 2.608 | 7.535 | 3.768 |
| *Bauhinia purpurea* L. | Fabaceae | 0.67 | 7 | 0.378 | 0.243 | 0.621 | 0.310 |
| *Aphanamixis polystachya* (Wall.) R.Parker | Meliaceae | 0.62 | 8 | 1.593 | 0.873 | 2.465 | 1.233 |
| *Oroxylum indicum* (L.) Vent | Bignoniaceae | 0.62 | 9 | 1.650 | 0.910 | 2.560 | 1.280 |
| *Melia azederach* L. | Meliaceae | 0.62 | 1 | 1.101 | 0.511 | 1.612 | 0.806 |
| *Careya arborea* Roxb. | Lecythidaceae | 0.62 | 2 | 0.289 | 0.167 | 0.455 | 0.228 |
| *Ficus fistulosa* Reinw.ex Blume | Moraceae | 0.39 | 4 | 1.245 | 0.603 | 1.849 | 0.924 |
| *Callicarpa arborea* Roxb. | Verbena | 0.53 | 1 | 0.096 | 0.059 | 0.155 | 0.077 |
| *Ziziphus* sp. | Rhamnaceae | 0.76 | 11 | 0.676 | 0.424 | 1.100 | 0.550 |
| Total | | | 1081 | 351.569 | 174.93 | 526.499 | 263.939 |

**Table 3.** Family, Wood Specific Density (WSD), Density, Aboveground biomass (AGB), Belowground Biomass (BGB), Total Biomass (TB) and Total Carbon Stock (TCS) of the different tree species in the open forest stand

| **Name of the Species** | **Families** | **WSD ($g\ cm^{-3}$)** | **Density ($ha^{-1}$)** | **AGB Mg $ha^{-1}$** | **BGB Mg $ha^{-1}$** | **TB Mg $ha^{-1}$** | **TCS Mg C $ha^{-1}$** |
|---|---|---|---|---|---|---|---|
| *Lagerstroemia reginae* Roxb. | Lythraceae | 0.55 | 39 | 7.916 | 4.182 | 12.098 | 7.163 |
| *Litsea glutinosa* (Lour) | Lauraceae | 0.4 | 2 | 0.073 | 0.417 | 0.490 | 0.245 |
| *Gmelina arborea* Roxb. | Lamiaceae | 0.41 | 16 | 8.080 | 3.967 | 12.047 | 6.023 |
| *Bombax ceiba* L. | Bombacaceae | 0.33 | 33 | 6.247 | 3.371 | 9.618 | 4.809 |
| *Acacia catechu* (L.F) Wild | Fabaceae | 0.88 | 11 | 2.842 | 1.478 | 4.320 | 2.160 |
| *Bridelia retusa* (L.) spreng | Phyllanthaceae | 0.5 | 9 | 2.687 | 1.384 | 4.071 | 2.036 |
| *Amoora* sp. | Meliaceae | 0.6 | 6 | 1.057 | 0.588 | 1.644 | 0.822 |
| *Albizia procera* (Roxb.) Benth | Fabaceae | 0.52 | 8 | 10.228 | 4.413 | 14.641 | 7.321 |
| *Syzygium cumini* (L.) Skeels | Myrtaceae | 0.7 | 6 | 2.411 | 1.211 | 3.622 | 1.811 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Sterculia villosa* Roxb.ex DC | Malvaceae | 0.62 | 16 | 1.918 | 1.113 | 3.031 | 1.516 |
| *Bischofia javanica* Blume | Phyllanthaceae | 0.54 | 15 | 3.101 | 1.672 | 4.772 | 2.386 |
| *Lagerstroemia speciosa* (L.) Pers | Lythraceae | 0.53 | 29 | 8.140 | 3.980 | 12.120 | 6.060 |
| *Litsea* sp. | Lauraceae | 0.4 | 27 | 4.494 | 2.487 | 6.981 | 3.490 |
| *Chukrassia tabularis* A. Juss | Meliaceae | 0.57 | 6 | 4.112 | 1.911 | 6.023 | 3.012 |
| *Toona hexandra* (Wall.ex Roxb.) Roem | Meliaceae | 0.62 | 4 | 0.848 | 0.452 | 1.300 | 0.650 |
| *Alstonia scholaris* (L.) R.Br. | Apocynaceae | 0.36 | 8 | 0.482 | 0.303 | 0.785 | 0.393 |
| *Oroxylum indicum* (L.) Vent | Bignoniaceae | 0.62 | 2 | 0.309 | 0.179 | 0.488 | 0.244 |
| *Neolamarckia cadamba*(Roxb.) | Rubiaceae | 0.62 | 14 | 13.177 | 6.039 | 19.216 | 9.608 |
| *Bauhinia purpurea* L. | Fabaceae | 0.67 | 9 | 0.694 | 0.419 | 1.113 | 0.556 |
| *Dillenia pentagyna* Roxb. | Dilleniaceae | 0.53 | 15 | 2.514 | 1.403 | 3.917 | 1.958 |
| *Trewia nudiflora* L. | Euphorbiaceae | 0.62 | 20 | 6.247 | 3.206 | 9.453 | 4.726 |
| *Aphanamixis polystachya*(Wall.) R.Parker | Meliaceae | 0.62 | 12 | 1.551 | 0.891 | 2.441 | 1.221 |
| *Syzygium* sp. | Myrtaceae | 0.69 | 8 | 1.520 | 0.817 | 2.337 | 1.168 |
| *Mallotus tetracoccus (Roxb.)Kurz* | Euphorbiaceae | 0.62 | 1 | 0.500 | 0.255 | 0.755 | 0.378 |
| *Michellia champaca* Linn. | Magnoliaceae | 0.43 | 9 | 7.085 | 3.301 | 10.386 | 5.193 |
| *Streblus asper* Lour. | Moraceae | 0.62 | 8 | 1.618 | 0.876 | 2.495 | 1.247 |
| *Mallotus phillippensis* (Lam.) Muell. Arg | Euphorbiaceae | 0.64 | 20 | 1.283 | 0.809 | 2.092 | 1.046 |
| *Terminalia myriocarpa* Heurck & Muell.-Arg | Combretaceae | 0.53 | 1 | 0.403 | 0.210 | 0.613 | 0.306 |
| *Lagerstroemia parviflora* Roxb. | Lythraceae | 0.62 | 12 | 1.608 | 0.917 | 2.525 | 1.263 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Ficus glomerata* Roxb. | Moraceae | 0.39 | 1 | 0.036 | 0.025 | 0.060 | 0.031 |
| *Terminalia arjuna* (Roxb.) Wight & Arn. | Combretaceae | 0.68 | 1 | 1.090 | 0.507 | 1.596 | 0.799 |
| *Cassia fistula* L. | Fabaceae | 0.71 | 4 | 0.651 | 0.353 | 1.005 | 0.502 |
| *Ziziphus* sp. | Rhamnaceae | 0.76 | 16 | 1.272 | 0.761 | 2.033 | 1.017 |
| Total | | | 392 | 106.193 | 53.896 | 160.089 | 81.16 |

**Table 4.** Family, Wood Specific Density (WSD), Density, Aboveground biomass (AGB), Belowground Biomass (BGB), Total Biomass (TB) and Total Carbon Stock (TCS) of the different tree species in the Swampy forest stand

| **Name of the Species** | **Families** | **WSD ($g\ cm^{-3}$)** | **Density ($ha^{-1}$)** | **AGB Mg $ha^{-1}$** | **BGB Mg $ha^{-1}$** | **TB Mg $ha^{-1}$** | **TCS Mg C $ha^{-1}$** |
|---|---|---|---|---|---|---|---|
| *Trewia nudiflora* L. | Euphorbiaceae | 0.62 | 233 | 49.469 | 26.714 | 76.183 | 38.091 |
| *Streblus asper* Lour | Moraceae | 0.62 | 67 | 10.193 | 5.673 | 15.866 | 7.933 |
| *Mallotus phillippensis* (Lam.) Muell. Arg | Euphorbiaceae | 0.64 | 140 | 18.862 | 10.696 | 29.557 | 14.779 |
| *Lagerstroemia reginae* Roxb. | Lythraceae | 0.55 | 123 | 16.423 | 9.159 | 25.582 | 12.791 |
| *Lagerstroemia speciosa* (L.) Pers | Lythraceae | 0.53 | 87 | 13.470 | 7.429 | 20.899 | 10.450 |
| *Bombax ceiba* L. | Bombacaceae | 0.33 | 130 | 33.655 | 17.586 | 51.241 | 25.620 |
| *Dalbergia sissoo* Roxb.ex DC | Fabaceae | 0.62 | 23 | 9.614 | 4.850 | 14.464 | 7.232 |
| *Acacia catechu* (L.F) Wild | Fabaceae | 0.88 | 10 | 3.610 | 1.849 | 5.459 | 2.729 |
| *Careya arborea* Roxb. | Lecythidaceae | 0.62 | 10 | 4.163 | 2.119 | 6.282 | 3.141 |
| *Albizia procera* (Roxb.) Benth | Fabaceae | 0.52 | 3 | 2.205 | 1.066 | 3.271 | 1.637 |
| *Ficus* sp. | Moraceae | 0.39 | 7 | 2.867 | 1.451 | 4.318 | 2.159 |
| *Bischofia javanica* Blume | Phyllanthaceae | 0.54 | 37 | 17.433 | 8.719 | 26.152 | 13.076 |
| *Dysoxylum binectariferum* (Roxb.) Hook.f. | Meliaceae | 0.62 | 73 | 12.380 | 6.828 | 19.207 | 9.604 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Sterculia villosa* Roxb.ex DC | Malvaceae | 0.62 | 30 | 13.710 | 6.758 | 20.468 | 10.234 |
| *Aphanamixis polystachya* (Wall.)R. Parker | Meliaceae | 0.62 | 13 | 1.816 | 1.052 | 2.868 | 1.434 |
| *Alstonia scholaris* (L.) R.Br. | Apocynaceae | 0.36 | 23 | 1.871 | 1.121 | 2.992 | 1.496 |
| *Oroxylum indicum* (L.) Vent | Bignoniaceae | 0.62 | 3 | 0.717 | 0.395 | 1.112 | 0.557 |
| Total | | | 1013 | 212.459 | 113.461 | 325.92 | 162.962 |

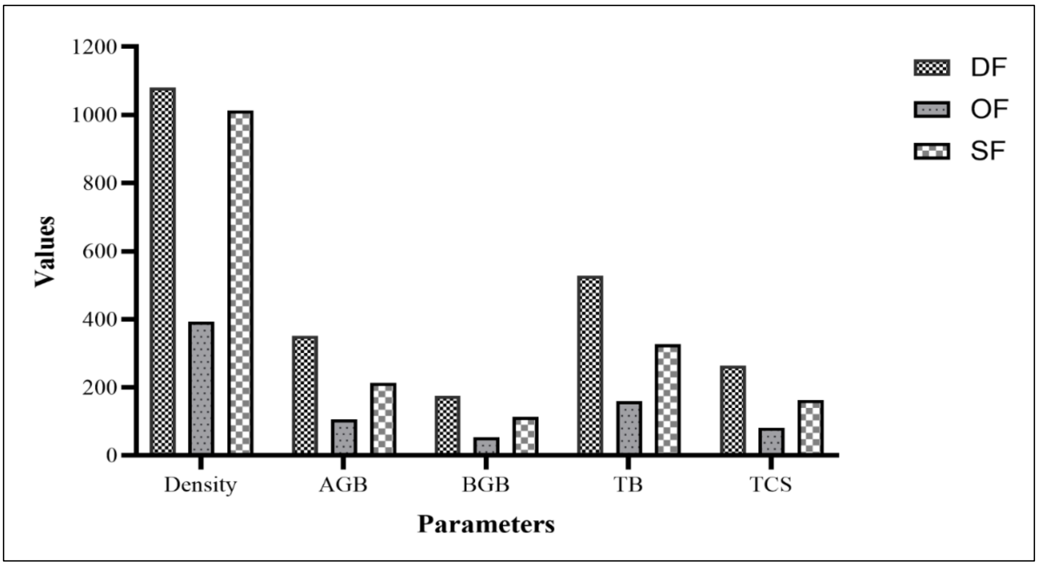


**Fig 3.** Tree density (individual ha$^{-1)}$, Biomass (Mg ha$^{-1}$), and total carbon stock (Mg C ha$^{-1}$) of the trees in dense, open, and swampy forest stands.

**Table 5.** Correlation between density, basal area and total carbon stock

| | **Density** | **Basal area** | **Total carbon stock** |
|---|---|---|---|
| Density | 1 | | |
| Basal area | 0.702** | 1 | |
| Total carbon stock | 0.851** | 0.949** | 1 |

**. Correlation is significant at the 0.01 level (2-tailed)

**4 Conclusion**

Altogether 45 tree species belonging to 38 genera and 24 families were recorded in Orang National Park. In the dense forest the tree density, total above ground biomass, total below ground biomass, total biomass and total carbon stock were 1081 ind ha$^{-1}$, 351.569 Mg ha$^{-1}$, 174.93 Mg ha$^{-1}$, 527.894 Mg ha$^{-1}$, and 263.939 Mg C ha$^{-1}$ respectively while in the open forest were 392 ind ha$^{-1}$, 106.193 Mg ha$^{-1}$, 53.896 Mg ha$^{-1}$, 160.089 Mg ha$^{-1}$, and 81.16 Mg C ha$^{-1.}$ and in the swampy forest were 1013 ind ha$^{-1}$, 212.459 Mg ha$^{-1}$, 113.461 Mg ha$^{-1}$, 325.92 Mg ha$^{-1}$, and 162.962 Mg C ha$^{-1}$ respectively. The dense forest has higher density, biomass, and carbon stock compared to OF and SF, which can be due to its closed canopy, which helps in better use of sunlight, and well- drained soil allows for optimal growth, while OF has many gaps and SF is limited by seasonal flood and less oxygen in the soil. The biomass and carbon of the Orang National Park are significantly higher. The results of this research proved that the Orang National Park has great potential to store carbon in the biomass. This shows that tree species recorded in the forest stand are contributing to the conservation of biodiversity and the local carbon sink, and should also establish long-term monitoring of the forest stands to track how these metrics change over time.

**5 Acknowledgement**

The authors are thankful to the University Grants Commission (UGC) for providing financial assistance to carry out this work. We are grateful to the DST, New Delhi, for support in terms of laboratory equipment under the DST-FIST Programme. We are also thankful to the Department of Environmental Science at Mizoram University and Tezpur University for extending research facilities to complete this piece of work effectively. We are grateful to PCCF (Wildlife) & Chief Wildlife Warden Assam, Aranya Bhawan, Panjabari, Guwahati, Govt. of Assam for giving permission to work. We are also thankful to Sri Pradipta Baruah (Divisional Forest Officer), Mangaldoi Wildlife Division, and the Range officer for all the necessary help to complete this work. We would like to extend our gratitude to all the forest staff who helped during the work.

**AI Tool Used:** Quillbot was used for language clarity.

**Conflicts of Interests**

The authors stated that they had no conflicts of interest related to the research, authorship, or publication of this paper.

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