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Assessment of Tree Stand Growth Characteristics and Quantitative Status of Selected Forest Plantations in Rivers and Bayelsa States, Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author NEO designed the study, performed the statistical analysis, wrote the protocol. Author KKA managed the analyses of the study and literature searches. Both authors read and approved the final manuscript.

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Abstract

Tree species provide essential ecological, economic, and livelihood benefits, yet plantation forest resources in the Niger Delta remain insufficiently documented for evidence-based management. This study assessed tree stand growth characteristics and the quantitative status of selected forest plantation sites in Rivers and Bayelsa States, Nigeria. A complete enumeration approach was used to measure all trees encountered within the defined plantation boundaries. Diameter at breast height (DBH), total tree height, crown size, basal area, and stem volume were assessed using standard forest mensuration procedures. Species identification was undertaken with support from qualified taxonomists and plantation owners. The results showed marked

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interspecific and inter-site variation in stand growth characteristics. At IITA, Onne, *Lophira lanceolata* recorded the highest basal area per hectare, while *Pinus caribaea* showed the highest stem volume. At FRIN, Onne, *Treculia africana* had the highest basal area, whereas *Lovoa trichilioides* recorded the highest stem volume. *Irvingia gabonensis* was the only domesticated tree species recorded at both Okilogua–Akinima and the Bayelsa State smallholder plantation, but its growth performance differed considerably between the two sites. These findings indicate that plantation productivity in the study area is influenced by species characteristics, site conditions, and management history. The study provides baseline data to support sustainable plantation management and species prioritisation in the Niger Delta.

Keywords: Forest plantations; stand growth; diameter at breast height; basal area; stem volume; tree height; quantitative assessment; Niger Delta; Rivers State; Bayelsa State; sustainable forest management; domesticated tree species.

1. Introduction

Forest trees are long-lived woody perennials occurring across a broad continuum of domestication stages, from wild-harvested populations to intensively managed plantation stands (Harfouche et al., 2012; Jamnadass et al., 2019). They perform irreplaceable ecosystem functions: maintaining biodiversity, regulating hydrological cycles, sequestering atmospheric carbon, and providing a wide range of commercial products that sustain local and national economies (Malmsheimer et al., 2011). Indigenous tree species, in particular, contribute significantly to the capture of environmental, social, and economic benefits within agricultural landscapes (Aworth, 2015; Rigal et al., 2018; Lelamo, 2021), serving as critical sources of nutrition and as genetic reservoirs for food and agriculture globally. Increasingly, however, these products are derived from plantation systems rather than natural forests, a trend that places renewed emphasis on the productive efficiency and ecological soundness of plantation management (Harfouche et al., 2012; Vyamana et al., 2023).

Stand growth assessment is a cornerstone of sustainable forest management, providing the empirical foundation upon which silvicultural decisions are made. A chronic shortage of periodic, site-specific information on the conditions of forest plantation stands constitutes one of the foremost challenges confronting sustainable forest management in Nigeria (Akinyemi, 2018). Without reliable baseline data on stand density, growth trajectories, and species performance, it is difficult to formulate rational harvest schedules, thinning regimes, or replanting programmes. Filling this data gap, particularly for under-documented plantation sites in the Niger Delta, therefore represents both a scientific priority and a practical necessity for forest resource sustainability.

Growth parameters routinely used to characterize plantation stands include diameter at breast height (DBH), total tree height, crown dimensions, basal area, and stem volume. These variables collectively describe the structure and productive potential of a stand, and together form the basis for allometric modelling and yield estimation (Ige et al., 2013; West, 2009). Understanding the growth dynamics of plantation species is indispensable for optimizing forest management practices and ensuring long-term ecosystem sustainability (Adekunle et al., 2013; Pohjanmies et al., 2019; Bont et al., 2025). Height–diameter relationships, for example, are known to be non-linear and species-specific, varying substantially across site conditions and stand ages (Zhang et al., 2016), making empirical site-level measurement essential. Recent Nigerian forest-inventory and plantation studies have continued to use DBH, total height, basal area, and stem volume as core variables for evaluating stand structure, productivity, and volume estimation, supporting their relevance for site-level plantation assessment (Bassey & Ajayi, 2024; Aigbe et al., 2025; Olajiire-Ajayi et al., 2024; Onilude et al., 2025).

A strong positive relationship between tree height and stand volume has been widely reported in the literature. Xu et al. (2019) demonstrated that, for closed-canopy stands in China, tree height serves as a reliable predictor of stand volume, though the strength of the relationship is modulated by species identity, site quality, and stand age. Comparable findings have been reported for tropical plantation species in West Africa (Akinyemi, 2018; Salami et al., 2020), indicating that height–diameter–volume relationships established in well-studied regions may be cautiously extrapolated to similar species in the Niger Delta, provided site-specific calibration data are available.

The history of plantation forestry in Nigeria dates to the early twentieth century, when the first government-sponsored trials were established in the South-West around 1905 (Nwoboshi, 2000; Idoko et al., 2025). Species including *Anogeissus leiocarpus, Cassia siamea, Casuarina equisetifolia, Delonix regia, Tectona grandis, Milicia excelsa, Afzelia africana, Cedrela odorata,* and *Nauclea diderrichii* were planted primarily for timber production. Early teak plantations in Nigeria were established in the southwestern forest stations, including Ibadan and Gambari, during the mid-twentieth century (Nwoboshi, 2000; Gbadamosi & Adesoye, 2016). Between the 1920s and 1940s, plantation activities expanded to other southern states, including Edo, Delta, Anambra, Imo, and Rivers States. *Gmelina arborea* was introduced in 1932 primarily to supply pit-props for the coal mines at Enugu (Umeh, 1991), and its establishment accelerated notably during the 1950s and 1960s. Since these early initiatives, plantation forestry has evolved into the primary forest regeneration strategy in Nigeria (Owolabi et al*.,* 1990).

Despite this long history, comprehensive quantitative assessments of plantation stands in Rivers and Bayelsa States remain sparse. The two states fall within the Niger Delta, one of the world's most ecologically sensitive and economically significant wetland regions, and their forest resources are under increasing pressure from oil exploration, agricultural encroachment, and unsustainable harvesting (Nwilo & Badejo, 2005; Mmom & Chukwu-Okeah, 2011; Collins, 2018; Oyebade et al., 2020). Developing robust databases of plantation performance for the region is therefore urgent. Prioritising which species to promote, and engaging in participatory domestication programmes aimed at improving yield, quality, and germplasm delivery, requires site-specific empirical evidence (Jamnadass et al., 2011; Jia et al., 2020; Do et al., 2022). The present study addresses this need by quantifying key stand growth variables at four plantation sites across Rivers and Bayelsa States, thereby generating baseline data to support evidence-based, sustainable management of plantation forest resources in the Niger Delta. Flooding and inundation have also been reported as environmental stressors affecting coastal forest ecosystems in south-eastern Nigeria, further emphasising the need for locally grounded plantation assessment in wetland landscapes (Akpan et al., 2022).

Although previous studies have examined selected forest stands and plantation species in Nigeria, species-level baseline data that compare DBH, total height, basal area, and stem volume across institutional and smallholder plantation sites in Rivers and Bayelsa States remain insufficient. This gap limits the evidence available for site-specific plantation management and species prioritisation in the Niger Delta.

The specific objectives of this study were to:

i. measure and compare tree stand growth variables - DBH, total height, basal area, and stem volume - across selected plantation sites in Rivers and Bayelsa States;
ii. characterise the quantitative status of domesticated tree species at each plantation site; and
iii. provide a baseline dataset to inform sustainable management decisions for plantation forests in the Niger Delta region.

2. Materials and Methods

2.1 Study Area

The study was conducted across four plantation sites in Rivers and Bayelsa States, located within the Niger Delta region, Nigeria (Fig. 1). The Niger Delta is one of the world's largest wetland complexes, covering an estimated 20,000 km², and is widely recognised as one of the most resource-rich river deltas globally in terms of both biodiversity and natural resources (Fubara et al., 1988; Nwankwoala & Ngah, 2014; Freshwater Ecoregions of the World [FEOW], n.d.). Geographically, the delta occupies southern Nigeria, forming a mosaic of islands, lagoons, creeks, and distributary channels that discharge into the Bight of Benin along the eastern Atlantic coast. The system is fed principally by the Niger and Benue Rivers, which converge upstream before bifurcating at Agbor into the Nun and Forcados Rivers and their numerous tributaries (Alagoa, 1999; FEOW, n.d.).

The Niger Delta spans several states in southern Nigeria, including Rivers, Bayelsa, Delta, Akwa Ibom, Cross River, and Edo, with broader regional definitions also including Ondo, Abia, and Imo (Alagoa, 1999; Freshwater Ecoregions of the World, n.d.; Freshwater Ecoregions of the World, n.d.). Its vegetation is characteristic of large tropical river deltas, comprising coastal ridge barriers, mangrove forests, freshwater swamp forests, and lowland rainforest ecosystems (Teme, 2001). These ecosystems support high levels of biodiversity and serve as critical habitats for numerous flora and fauna, with Rivers and Bayelsa States being particularly rich in forest tree species of ecological, economic, and cultural importance. Climatically, the area falls within the humid tropical zone, characterised by high rainfall and persistently elevated relative humidity. Mean annual rainfall exceeds 2,500 mm, with a pronounced wet season from April to October and a relatively short dry season from November to March. Mean annual temperature ranges between 25 °C and 28 °C, and relative humidity averages 85–95% throughout the year (Ayoade, 2004). Socio-economically, the region is inhabited by diverse ethnic minority groups, including the Ijaw, Ogoni, Kalabari, and Ikwerre, whose livelihoods depend substantially on natural resources through subsistence and commercial farming, fishing, hunting, and forest product utilisation (Nwilo & Badejo, 2005). Rivers State is geographically located at approximately latitude 4.8396° N and longitude 6.9112° E, while Bayelsa State lies around latitude 4.7719° N and longitude 6.0699° E. Specific plantation sites included: (i) the International Institute of Tropical Agriculture (IITA), Onne, Rivers State; (ii) the Forestry Research Institute of Nigeria (FRIN), Onne, Rivers State; (iii) Okilogua–Akinima, Ahoada-West Local Government Area, Rivers State; and (iv) a smallholder plantation site in Bayelsa State.

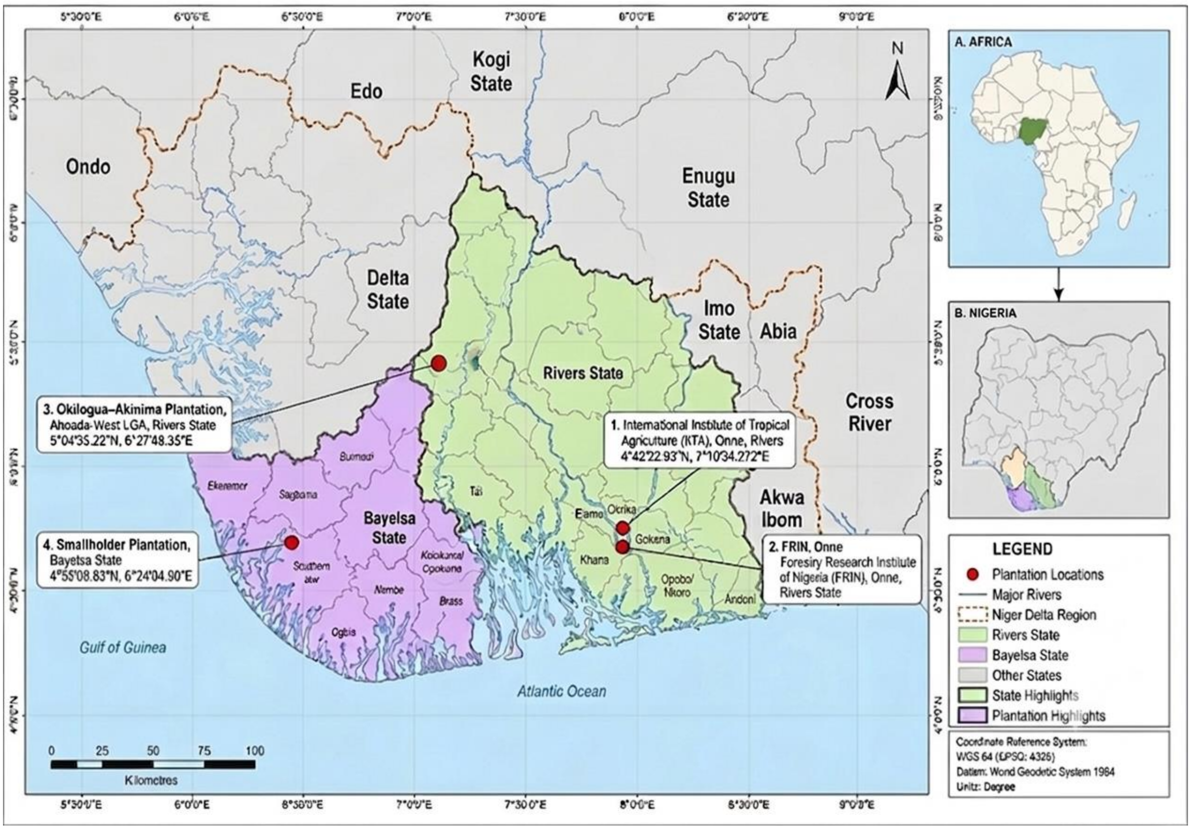

Fig. 1. Map of Study Areas in Rivers and Bayelsa States

2.2 Tree Variable Measurements

A complete enumeration (census) approach was employed at each plantation site. All trees encountered within the defined plot boundaries were counted and measured. DBH was recorded at 1.3 m above ground level using a diameter/linear tape (Forestry Suppliers Inc., catalogue no. 800-647-5368). In cases where fork bifurcation occurred at or above breast height, the tree was measured as a single individual; where bifurcation occurred below breast height, each stem was measured independently. For trees exhibiting bulges, branch whorls, or cankers at the breast height position, measurements were taken both above and below the deformity and the mean value adopted. Total tree height (Ht) was measured using a calibrated Haga altimeter in combination with a girthing tape. Crown size was assessed by projecting the edges of the tree crown vertically onto the ground surface and measuring the distance from edge to edge along two perpendicular axes using a linear measuring tape; mean crown radius was subsequently computed. Species identification was accomplished with the assistance of qualified taxonomists and plantation owners familiar with the study sites.

2.3 Data Analysis

Descriptive statistics, including mean, variance, and standard deviation, were computed for all measured growth variables (DBH, height, basal area, and volume) for each identified domesticated tree species at each plantation site. Statistical computations were performed using SPSS Version 25.0 (IBM Corp., Armonk, NY, USA). Species-level differences in growth characteristics were evaluated and presented graphically.

2.4 Computation of Derived Variables

2.4.1 Basal Area

The basal area (BA) of each individual tree was estimated following the standard mensuration formula described by Husch et al. (2003):

$$BA = \frac{\pi D^2}{4} \quad \text{(Eq. 1)}$$

where BA is basal area (m^2), π is the mathematical constant 3.142, and D is diameter at breast height (m). Stand-level basal area for each species was obtained by summing the individual tree basal areas within each plantation site.

2.4.2 Stem Volume

Individual tree stem volume (V) was estimated using the allometric formula adopted by Salami et al. (2020):

$$V = BA \times H \quad \text{(Eq. 2)}$$

where V is stem volume (m^3), BA is basal area (m^2), and H is total tree height (m). Stand-level volume for each species was obtained by summing individual tree volumes.

3. Results

Growth characteristics varied substantially across plantation sites and among species within sites. The following subsections present stand-level results for each of the four plantation sites surveyed: IITA Onne, FRIN Onne, Okilogua–Akinima, and the Bayelsa State smallholder plantation.

3.1 Tree Stand Characteristics at IITA, Onne

Lophira lanceolata recorded the highest basal area per hectare among species enumerated at IITA, Onne (854.07 m^2/ha), followed by *Pinus caribaea* (782.55 m^2/ha), *Terminalia ivorensis* (747.96 m^2/ha), *Eucalyptus camaldulensis* (741.42 m^2/ha), *Leucaena leucocephala* (707.77 m^2/ha), *Entandrophragma angolense* (646.97 m^2/ha), *Artocarpus altilis* (465.55 m^2/ha), *Irvingia gabonensis* (383.38 m^2/ha), *Garcinia kola* (233.18 m^2/ha), and *Treculia africana* (106.06 m^2/ha) (Fig. 2). Corresponding DBH rankings largely mirrored the basal area pattern. The largest mean DBH was recorded in *Lophira lanceolata* (0.754 m), followed by *Pinus caribaea* (0.71 m), *Eucalyptus camaldulensis* (0.68 m), *Terminalia ivorensis* (0.67 m), *Leucaena leucocephala* (0.65 m), *Entandrophragma angolense* (0.63 m), *Artocarpus altilis* (0.53 m), *Irvingia gabonensis* (0.49 m), *Garcinia kola* (0.38 m), and *Treculia africana* (0.25 m) (Fig. 3). Stem volume was highest in *Pinus caribaea* (2.843 m^3), followed by *Terminalia ivorensis* (2.54 m^3), *Leucaena leucocephala* (2.46 m^3), *Entandrophragma angolense* (2.32 m^3), *Artocarpus altilis* (1.66 m^3), *Irvingia gabonensis* (1.42 m^3), *Garcinia kola* (0.88 m^3), *Eucalyptus camaldulensis* (0.71 m^3), *Lophira lanceolata* (0.40 m^3), and *Treculia africana* (0.37 m^3) (Fig. 3). The relatively modest volume of *L. lanceolata* despite its large DBH and basal area reflects its comparatively lower height (see below), demonstrating that volume is jointly determined by both girth and height.

Lophira lanceolata was the tallest species at IITA, Onne (43.36 m), followed by *Pinus caribaea* (42.83 m), *Eucalyptus camaldulensis* (40.13 m), *Terminalia ivorensis* (39.99 m), *Entandrophragma angolense* (39.94 m), *Leucaena leucocephala* (38.38 m), *Treculia africana* (30.24 m), *Irvingia gabonensis* (11.46 m), *Garcinia kola* (11.33 m), and *Artocarpus altilis* (10.58 m) (Fig. 3).

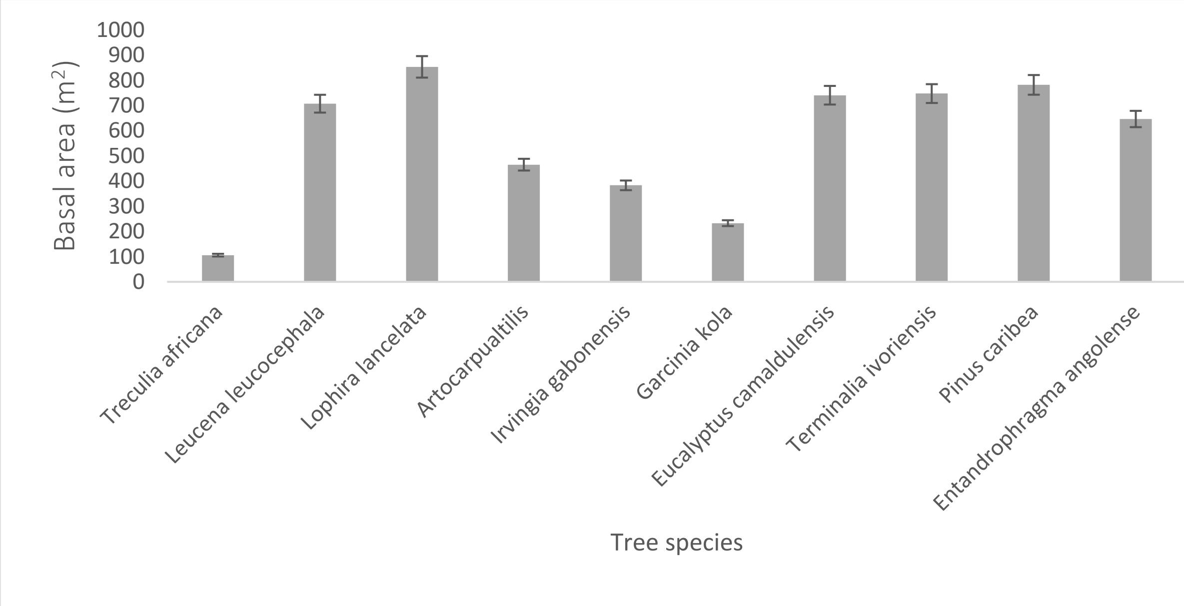

Fig. 2. Basal Area per Hectare of Domesticated Trees in IITA, Onne

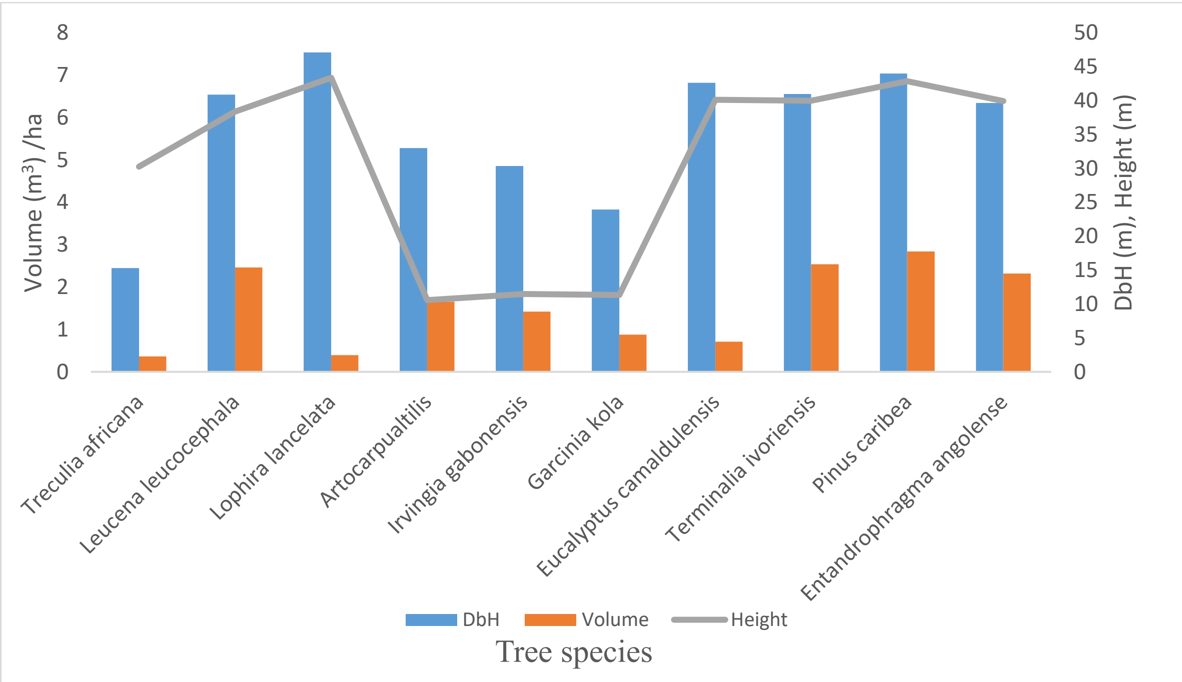

Fig. 3. DBH, Volume and Height of Domesticated Trees in IITA, Onne

3.2 Tree Stand Characteristics at FRIN, Onne

At the Forestry Research Institute of Nigeria (FRIN) plantation in Onne, the highest basal area was recorded for *Treculia africana* (93.71 m²), followed by *Garcinia kola* (61.37 m²), *Lovoa trichilioides* (58.59 m²), *Irvingia* *gabonensis* (48.37 m²), *Mansonia altissima* (43.04 m²), *Dacryodes edulis* (40.39 m²), *Terminalia ivorensis* (39.27 m²), *Entandrophragma angolense* (37.73 m²), *Nauclea diderrichii* (36.78 m²), *Allanblackia floribunda* (31.12 m²), *Pentaclethra macrophylla* (18.37 m²), *Chrysophyllum albidum* (15.53 m²), *Tectona grandis* (13.11 m²), *Artocarpus altilis* (6.32 m²), *Gmelina arborea* (3.17 m²), and the lowest in *Diospyros crassiflora* (3.56 m²) (Fig. 4).

The highest mean DBH at FRIN, Onne was recorded in *Gmelina arborea* (0.96 m), followed by *Lovoa trichilioides* (0.85 m), *Allanblackia floribunda* (0.76 m), *Dacryodes edulis* (0.706 m), *Mansonia altissima* (0.69 m), *Chrysophyllum albidum* (0.69 m), *Entandrophragma angolense* (0.68 m), *Nauclea diderrichii* (0.66 m), *Terminalia ivorensis* (0.62 m), *Garcinia kola* (0.59 m), *Diospyros crassiflora* (0.56 m), *Pentaclethra macrophylla* (0.55 m), *Artocarpus altilis* (0.47 m), *Irvingia gabonensis* (0.47 m), *Tectona grandis* (0.35 m), and the smallest in *Treculia africana* (0.26 m) (Fig. 5).

Lovoa trichilioides recorded the highest stem volume at FRIN, Onne (4.06 m³), followed by *Allanblackia floribunda, Pentaclethra macrophylla,* and *Treculia africana* (3.34 m³ each), *Gmelina arborea* (3.00 m³), *Dacryodes edulis* (2.84 m³), *Terminalia ivorensis* (1.60 m³), *Garcinia kola* (1.39 m³), *Artocarpus altilis* (1.32 m³), *Irvingia gabonensis* (1.26 m³), *Nauclea diderrichii* and *Tectona grandis* (0.71 m³ each), *Diospyros crassiflora* (0.63 m³), *Chrysophyllum albidum* (0.52 m³), and the lowest volume in *Mansonia altissima* (0.40 m³) (Fig. 5).

Regarding tree height, the tallest species at FRIN, Onne was *Terminalia ivorensis* (41.85 m), followed by *Lovoa trichilioides* (28.55 m), *Treculia africana* (27.93 m), *Tectona grandis* (26.75 m), *Gmelina arborea* (24.98 m), *Entandrophragma angolense* (24.22 m), *Mansonia altissima* (22.66 m), *Nauclea diderrichii* (21.81 m), *Irvingia gabonensis* (20.05 m), *Garcinia kola* (15.75 m), *Pentaclethra macrophylla* (14.03 m), *Dacryodes edulis* (13.49 m), *Allanblackia floribunda* (13.33 m), *Artocarpus altilis* (11.60 m), *Chrysophyllum albidum* (10.98 m), and the shortest being *Diospyros crassiflora* (7.23 m) (Fig. 5).

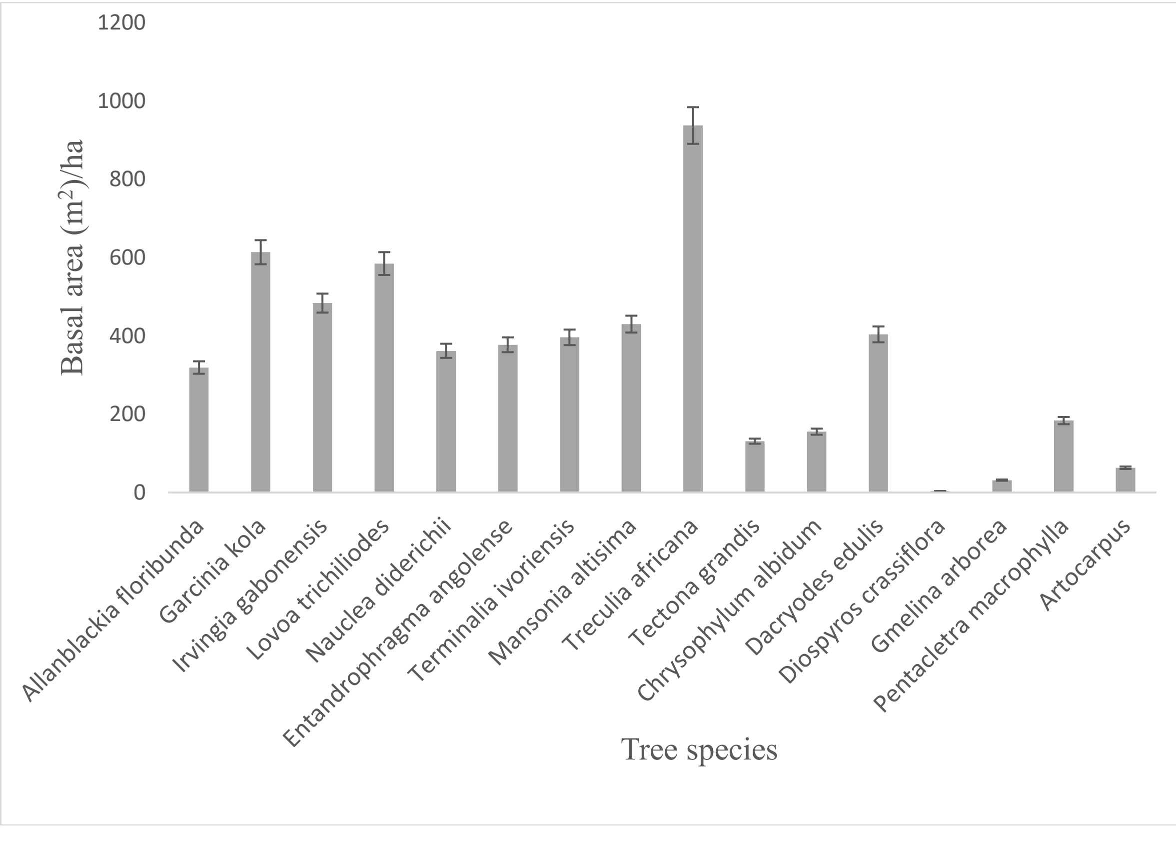

Fig. 4. Basal Area (m²) of Tree Species at FRIN, Onne

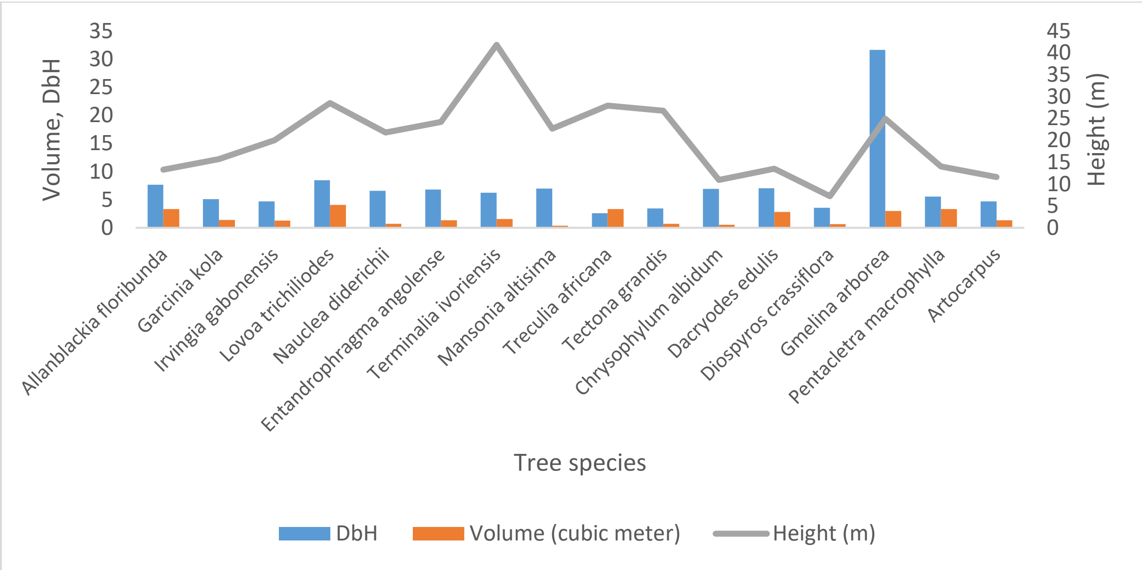

Fig. 5. DBH, Volume, Height of Domesticated Trees at FRIN, Onne

3.3 Tree Stand Characteristics at Okilogua–Akinima

Irvingia gabonensis was the sole domesticated tree species recorded at the Okilogua plantation in Akinima, Ahoada-West Local Government Area, Rivers State. The mean DBH recorded was 1.75 m, mean stem volume was 5.78 m³, mean total height was 21.10 m, and mean basal area was 1.49 m² (Fig. 6). The notably large DBH relative to other plantation sites is consistent with older, less intensively managed individual trees that have been allowed to mature without scheduled thinning or harvesting intervention.

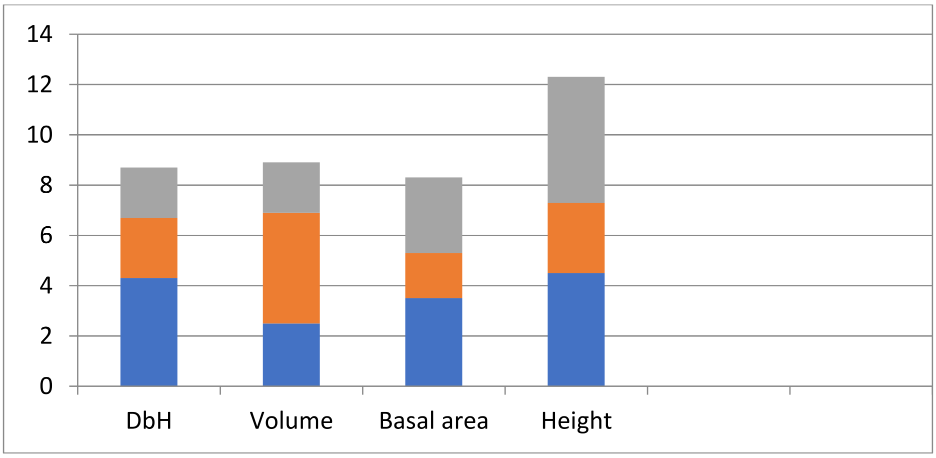

Fig. 6. Domesticated Tree Stand Characteristics in Okilogua–Akinima

3.4 Tree Stand Characteristics in Bayelsa State

Irvingia gabonensis was also the sole domesticated tree species recorded at the smallholder plantation site in Bayelsa State. Mean DBH was 0.55 m, mean stem volume was 1.78 m³, mean total height was 6.80 m, and mean basal area was 0.24 m² (Fig. 7). Compared to the Okilogua–Akinima site, trees at the Bayelsa site were considerably smaller in all growth dimensions, suggesting either younger stand age, lower site quality, or the influence of recurrent flooding and other environmental stresses characteristic of low-lying Bayelsa State terrain.

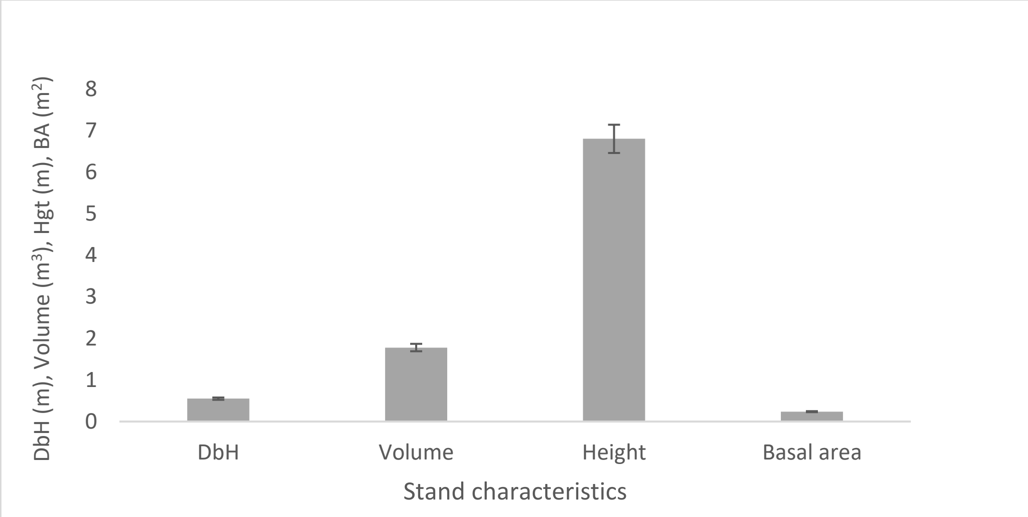

Fig. 7. DBH, Volume, Basal Area, and Height of Domesticated Trees in Bayelsa State

4. Discussion

The present study provides quantitative baseline data on tree stand growth characteristics across four plantation forest sites in Rivers and Bayelsa States, Niger Delta, Nigeria. The findings reveal considerable interspecific and inter-site variation in growth performance, reflecting the combined influence of species biology, site ecology, plantation management history, and environmental conditions. These results are discussed in relation to established literature on plantation forestry in Nigeria and the broader tropics.

4.1 Diameter at Breast Height and Basal Area

DBH is among the most fundamental measurable variables in forest inventory, serving as the primary predictor of basal area and a key component of volume estimation. In the present study, DBH ranged from 0.25 m (*Treculia africana*, IITA) to 1.75 m (*Irvingia gabonensis*, Okilogua–Akinima), a range that reflects both species-level growth potential and the substantial differences in stand age and management intensity across sites. The exceptionally large DBH of *I. gabonensis* at the Okilogua–Akinima site likely reflects prolonged growth under minimal silvicultural intervention, a pattern typical of on-farm agroforestry systems in which trees are retained for decades and allowed to attain near-natural dimensions (Jamnadass et al., 2011; Olusola et al., 2012; M'bo et al., 2025).

At IITA, Onne, *Lophira lanceolata* achieved the highest basal area per hectare (854.07 m^2/ha), closely followed by *Pinus caribaea* (782.55 m^2/ha) and *Terminalia ivorensis* (747.96 m^2/ha). These values indicate high stand-level stocking and are consistent with the productive potential of these species under research-station conditions, where management inputs, including planting density control, weed management, and phytosanitary care, are typically more rigorous than on smallholder farms. Comparable basal area values for *Terminalia ivorensis* and *Gmelina arborea* have been reported from Nigerian plantation stands (Akinyemi, 2018; Salami et al., 2020), supporting the validity of the present measurements.

4.2 Tree Height and Stem Volume

Height is a critical determinant of timber quality and a strong predictor of stand volume (Xu et al., 2019). In the present study, the tallest trees at IITA, Onne were *Lophira lanceolata* (43.36 m) and *Pinus caribaea* (42.83 m), while at FRIN, Onne, *Terminalia ivorensis* dominated in height (41.85 m). These heights are consistent with the known ecological characteristics of these species; T. *ivorensis* is a canopy emergent of West African closed-canopy forests, commonly attaining heights in excess of 40 m under favourable site conditions (Adekunle et al., 2013; Nero, 2021; Akamse et al., 2025). The high heights recorded at the research-station plantations (IITA and FRIN, Onne) relative to the smallholder site in Bayelsa State (*I. gabonensis*, 6.80 m) underscore the importance of site quality and silvicultural management in determining plantation productivity.

Stem volume followed a different ranking from height and DBH in several species, a pattern attributable to the joint dependence of volume on both girth and height. For instance, *Lophira lanceolata* at IITA, despite having the largest DBH and one of the greatest heights, recorded only the ninth highest volume (0.40 m^3), likely because stand-level volume estimates were influenced by the number of trees sampled per species. At FRIN, Onne, *Lovoa trichilioides* achieved the highest individual stem volume (4.06 m^3), consistent with its large DBH (0.85 m) and considerable height (28.55 m). These findings align with the observation by Xu et al. (2019) that tree height explains a large proportion of volume variance in closed-canopy stands, while Zhang et al. (2016) further demonstrated that non-linear height–diameter–volume allometries are necessary for accurate predictions across diverse species and environments.

4.3 Interspecific Growth Variation and Implications for Plantation Management

The pronounced interspecific variation in growth performance documented across all four sites has direct practical implications for plantation species selection and management. Fast-growing, high-volume species such as *Gmelina arborea*, *Terminalia ivorensis*, and *Pinus caribaea* demonstrated high productive potential under station conditions, consistent with their long-established roles as commercial plantation species in Nigeria (Nwoboshi, 2000; Umeh, 1991; Aina et al., 2019; Kaba et al., 2022; Trocones-Boggiano et al., 2026). In contrast, indigenous species including *Irvingia gabonensis*, *Dacryodes edulis*, and *Garcinia kola* showed more modest volume increments at research-station sites but carry significant non-timber forest product value, an important consideration for smallholder systems where income diversification is a priority (Schreckenberg et al., 2002; Kindt, 2005; Omokhua et al., 2012; Asaah et al., 2012; Maňourová et al., 2019; Maňourová et al., 2023). The stark contrast in *Irvingia gabonensis* growth between the Okilogua–Akinima site (DBH: 1.75 m; volume: 5.78 m^3) and the Bayelsa State site (DBH: 0.55 m; volume: 1.78 m^3) illustrates the strong site-specific modulation of growth even within a single species. Differences in stand age, soil type, drainage status, and management history likely contribute to this disparity. The consistently flat, flood-prone terrain of Bayelsa State (Ayoade, 2004; Chinedu et al., 2024; Bello et al., 2024; Eteh et al., 2025) may impose periodic oxygen stress on root systems, thereby limiting cambial growth and height increment. These findings reinforce the recommendation of West (2009) and Ige and Akinyemi (2016) that allometric relationships be calibrated at the site level rather than applied universally.

4.4 Sustainable Forest Management and Data Gaps

The baseline data generated by this study directly address the data deficit identified by Akinyemi (2018) as a central obstacle to sustainable plantation management in Nigeria. Periodic stand assessment of the kind undertaken here enables forest managers to make informed decisions on thinning schedules, rotation lengths, and species substitution - decisions that are currently impeded by the absence of reliable inventory records. Given the increasing pressure on forest resources in the Niger Delta from oil exploitation, agricultural expansion, and population growth (Nwilo & Badejo, 2005; Nwobi et al., 2020; Dzedzemoon & Ferro, 2024; Angaye & Lelei, 2025), maintaining updated plantation inventories is particularly urgent. Future studies should seek to extend this inventory to additional plantation sites across the Niger Delta, incorporate permanent sample plots to enable longitudinal growth monitoring, and integrate remote sensing data to facilitate scaling of site-level estimates to the landscape level. Expanding species coverage to include younger stands and recently established community plantations would further strengthen the data foundation for regional plantation management planning.

5. Conclusions

This study provides baseline quantitative information on tree stand growth characteristics across selected plantation sites in Rivers and Bayelsa States, Nigeria. The findings showed clear variation in DBH, total height, basal area, and stem volume among species and across sites. At IITA, Onne, *Lophira lanceolata* recorded the highest basal area and height, while *Pinus caribaea* had the highest stem volume. At FRIN, Onne, *Lovoa trichilioides* recorded the greatest stem volume, although other species also showed notable stand-level contributions. The contrasting performance of *Irvingia gabonensis* at Okilogua–Akinima and the Bayelsa State smallholder plantation suggests that growth outcomes are strongly shaped by local site conditions, stand age, and management history. Overall, the results confirm the value of periodic stand assessment for improving plantation planning, species selection, thinning decisions, and sustainable forest resource management in the

Niger Delta. The dataset also contributes to the limited regional information available for plantation inventory and management in southern Nigeria.

6. Limitation

This study was limited to four plantation sites in Rivers and Bayelsa States and relied on measurements taken at a single assessment period. Differences in stand age, planting density, soil conditions, and management history could not be fully separated statistically. Future studies should include permanent sample plots, wider site coverage, and repeated measurements to support stronger long-term growth modelling.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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