

The Influence of Different Land Use on the Morphology and Seed Characteristics of *Gmelina arborea* in Nasarawa State, Nigeria

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Abstract

This study evaluated the influence of various land use types on the morphological traits and seed characteristics of *Gmelina arborea* across four locations in Nasarawa State, Nigeria: Akwanga, Doma, Lafia, and Nasarawa Eggon. Significant variation in tree morphology was observed relative to land use, with conserved, residential, and recreational areas consistently supporting more robust growth. For instance, in Akwanga, trees in residential areas exhibited the greatest height (16.81 m) and crown area (687.38 m²), while conserved sites recorded the highest tree volume (61.52 m³). Similarly, in Doma, recreational sites had the tallest trees (14.93 m), largest crown areas (393.82 m²), and highest tree volume (123.96 m³). Lafia recorded the highest overall tree volume (70.78 m³), particularly within conserved areas (439.46 m³), with Nasarawa Eggon also showing significant growth differences among land uses. Tree morphometric parameters such as diameter at breast height (DBH), bole height, and tree slenderness varied markedly among land uses, reflecting the impact of anthropogenic disturbance on tree architecture. Seed morphometric traits also differed significantly by land use type. In Akwanga, seeds from recreational and hospital areas produced the heaviest pods (3.42 g) and longest pod lengths (2.63 cm), while conserved areas yielded the heaviest seeds (1.27 g). At Doma, the recreational site similarly produced the longest pods (2.73 cm) and heaviest seeds (1.23 g). Seed texture varied with rough textures observed mainly in mechanic and office areas, and seed color differences ranged between brown and black varieties across sites. The study concludes by showing that the kind of land use has a substantial impact on the morphological qualities and seed properties of *Gmelina arborea* in all four locations in Nasarawa State. Reduced anthropogenic disturbance improves tree vigor, as evidenced by the higher growth performance of trees growing in residential, recreational, and conservation environments in terms of height, crown development, and volume. Seed quality and potential regeneration capacity may also be impacted by environmental factors and human activity, according to differences in seed morphometric features among land use types.

Introduction

Gmelinaa borea Roxb, commonly known as "*gamhar*", "beech wood" or "white teak", is a fast-growing, deciduous tree native to tropical regions of South Asia, particularly India, that is valued for its timber used in construction and furniture making, as well as its medicinal properties where various parts of the plant are utilized in traditional medicine systems; it is characterized by a large, spreading crown, smooth grayish bark, large opposite leaves, and produces yellow flowers that yield high-quality honey; due to its rapid growth, it is often cultivated in plantations for reforestation purposes. Its ecological significance extends beyond timber production; it plays a vital role in soil conservation, restoration of degraded lands, and carbon sequestration.(Orwa et al., 2009; López-Aguirre *et al.*, 2023).

Land use is a major determinant of tree growth and morphology. *Gmelina arborea*, like many other tree species, responds to different land use types, such as forest reserves, agricultural lands, urban spaces, and disturbed areas. Disturbances associated with human activities, such as deforestation and land

conversion for agriculture, often result in changes in soil structure, nutrient availability, and moisture levels, all of which directly influence tree morphology (Mendoza et al., 2021).

Materials and methods

Research design

This study adopts a descriptive and analytical research design, using both qualitative and quantitative approaches, in line with contemporary mixed-methods frameworks (Creswell & Creswell, 2021).

Study area

The study was conducted in Lafia, Akwanga, Doma, and Nasarawa Eggon local government areas of Nasarawa State, known for the presence of *Albizia lebbbeck* (Adamu et al., 2023).

Tree selection and sampling

Tree selection followed randomized sampling across land-use types as guided by current urban forestry assessment protocols (FAO, 2021). Locations were recorded with GPS following the guidelines of precision forestry techniques (Sharma et al., 2022).

Morphological parameters

Morphological data such as height, DBH, crown radius, and volume were measured using methods outlined in recent forest biometrics literature (Wang et al., 2020).

Tree height and bole height: Measured using a hypsometer or telescopic tape (Sharma et al., 2022).

Shade radius and crown area: Estimated using the circular projection method (Okonkwo et al., 2023).

DBH: Taken at 1.3 meters above ground with a diameter tape.

Tree volume: Estimated using the cylindrical volume approximation formula:

$$V = \pi \times (DBH/2)^2 \times H,$$

Slenderness ratio: Calculated as Height/DBH to assess mechanical stability (Rodriguez et al., 2022).

Pod and seed morphometry

Pod and seed traits were assessed following ISTA (2021) protocols for seed testing and morphological assessment.

Pod sampling and drying: Following the 24-hour drying standard (ISTA, 2021).

Pod and seed dimensions: Measured using calipers; 10 pods per tree and 10 seeds per pod (Oluwafemi et al., 2022).

Seed texture and color: Qualitatively described using current descriptors in seed morphology studies (Adebayo & Sani, 2023).

Physiological parameters

Functional traits were assessed using up-to-date physiological protocols:

Water retention capacity: Seeds soaked for 6 hours in distilled water and reweighed (ISTA, 2021).

Seed volume: Determined via water displacement method (Ahmad et al., 2021).

Germination percentage: Measured after 4 weeks in a controlled environment, per updated germination protocol (ISTA, 2021; Adeyemi et al., 2024).

Data analysis

All statistical analyses were conducted using SPSS version 20. The Shapiro-Wilk test was used to assess the normality of the data. Results were presented as mean values in tables for each parameter. Analysis of Variance (ANOVA) was used to evaluate the effect of land use on tree and seed morphometric characteristics as well as water retention capacity and growth parameter of seed planted. Where significant differences were found, Least Significant Difference (LSD) and Tukey's HSD post hoc tests were applied at a 5% significance level ($p < 0.05$) to separate the means. Coefficients of variation (CV) were also calculated to assess the degree of variability across traits. Results were summarized and presented in tables.

Results

Table 1 presents a comparative assessment of average tree morphometric characteristics of *Gmelina arborea* across the four study locations. Lafia recorded the highest tree volume (70.78 m³), followed by Doma (40.65 m³) and Nasarawa Eggon (34.29 m³), suggesting superior biomass accumulation in these areas compared to Akwanga (23.83 m³), which had the lowest volume. Despite this, Akwanga had one of the tallest trees on average (13.01 m) and the broadest crown area (355.88 m²), indicating trees with more expansive canopy spread and vertical growth. Nasarawa Eggon had the highest average bole height (3.61 m), while Doma exhibited the largest mean DBH (1.89 m) and tree size (2.34 m), reflecting more robust stem development. Shade radius ranged from 8.34 m in Nasarawa Eggon to 10.18 m in Akwanga. Tree slenderness—a ratio of height to diameter—was highest in Akwanga (11.17), signifying taller, thinner trees, while Doma recorded the lowest (6.09), indicating thicker, sturdier trees. Statistically

significant differences ($p < 0.05$) were observed among most parameters, except for DBH, which did not show significant variation across locations.

Table 1
Comparative Analysis of Tree Morphometric Parameters across Four Locations

Land Use	Bole Height (m)	Crown Area (m ²)	DBH (m)	Shade Radius (m)	Tree Height (m)	Tree Slenderness (m)	Tree Volume (m ³)	Tree size (m)
Akwanga	3.15	355.88	1.61	10.18	13.01	11.17	23.83	1.61
Doma	2.46	230.16	1.89	8.52	11.4	6.09	40.65	2.34
Lafia	2.52	325.59	1.7	9.51	12.96	7.55	70.78	2.27
Nasarawa Eggon	3.61	241.24	1.59	8.34	11.44	7.89	34.29	1.75
LSD	0.17*	19.68*	0.10 ^{ns}	0.28*	0.30*	0.25***	7.83*	0.10*
Values represent means, N = 3. LSD = Least significant difference. *, significant at 0.05 probability level, **, significant at 0.01 probability level, ***, significant at 0.001 probability level								

The comparative analysis of seed morphometric parameters across the four locations, as shown in Table 10, reveals generally minor variations in pod and seed characteristics of *Gmelina arborea*. Pod length was highest in both Lafia and Nasarawa Eggon (2.44 cm), while Akwanga recorded the lowest (2.27 cm), though these differences were not statistically significant. Similarly, pod weight ranged from 1.60 g in Doma to 2.03 g in Akwanga, and pod breadth remained relatively consistent across locations (1.72–1.79 cm), with none of these differences reaching statistical significance. Seed length was the only parameter with a significant difference among locations, being highest in Nasarawa Eggon (1.98 cm) and lowest in Akwanga (1.82 cm). Seed weight and seed thickness showed minor variations, with Nasarawa Eggon again exhibiting the highest values (0.85 g and 1.67 mm, respectively), though these differences were not significant. In summary, while most traits remained consistent across locations, seed length appeared to be the most influenced by geographical differences.

Table 2
Comparative Analysis of Seed Morphometric Parameters Across Four Locations

Location	Pod Length	Pod Weight	Pod Breadth	Seed Length	Seed Weight	Seed Thickness
Lafia	2.44	1.65	1.72	1.87	0.75	1.68
Akwanga	2.27	2.03	1.74	1.82	0.71	1.66
Doma	2.38	1.60	1.79	1.84	0.77	1.68
Nasarawa Eggon	2.44	1.87	1.77	1.98	0.85	1.67
LSD	0.19 ^{ns}	0.43 ^{ns}	0.07 ^{ns}	0.12 [*]	0.18 ^{ns}	0.05 ^{ns}
Values represent means, N = 3. LSD = Least significant difference. *, significant at 0.05 probability level, **, significant at 0.01 probability level, ***, significant at 0.001 probability level						

Table 3 presents detailed observations of plant height development for seeds grown under various land use types across four locations, with measurements taken weekly following emergence. Days to emergence varied notably, ranging from as early as 12 days (Akwanga-Company) to as late as 27 days (Lafia-Residence). In Akwanga, although seeds at the Company site emerged earliest, their growth was comparatively slower, reaching only 11.12 ± 0.18 cm by week 4. On the other hand, Akwanga-Residence, with a later emergence at 21 days, recorded the highest plant height across all sites (15.64 ± 0.50 cm), indicating that early emergence did not necessarily translate to taller growth. The Conserved, Office, and School areas in Akwanga also showed steady and significant weekly gains, with final heights of 12.75 ± 0.36 cm, 13.48 ± 0.69 cm, and 12.56 ± 0.08 cm, respectively. In Doma, data was available only for the School site, where plants emerged after 16 days and reached 13.97 ± 0.66 cm, showing a consistent upward trend. Lafia presented a contrast between the School and Residence sites; while Lafia-School reached 13.84 ± 0.23 cm by week 4, Lafia-Residence showed delayed emergence (27 days) and lower final height (9.61 ± 0.56 cm), suggesting suboptimal growth conditions. In Nasarawa Eggon, seeds in the Recreational land use showed the most vigorous growth, rising from 7.27 ± 0.38 cm in week 1 to 12.86 ± 0.51 cm in week 4, while the Dump and Residence sites exhibited more moderate growth with final heights of 10.34 ± 0.49 cm and 10.91 ± 0.12 cm, respectively. In summary, plant height outcomes were strongly influenced by both the land use and location, with Residence in Akwanga and School in Doma supporting the tallest plants, while Lafia-Residence and Nasarawa Eggon-Dump showed relatively lower performance.

Table 3
Plant height for seeds planted in the four locations

Location	Land Use	Days to Emergence	Week 1	Week 2	Week 3	Week 4	LSD
Akwanga	Company	12	2.83 ± 0.47	6.50 ± 0.71	8.33 ± 0.47	11.12 ± 0.18	0.98***
Akwanga	Conserved	21	6.66 ± 0.23	9.21 ± 0.41	10.79 ± 0.30	12.75 ± 0.36	1.69***
Akwanga	Hospital	19	4.42 ± 0.59	5.78 ± 0.31	9.13 ± 0.52	10.05 ± 0.07	1.69***
Akwanga	Office	19	5.94 ± 0.09	9.57 ± 0.11	10.84 ± 0.23	13.48 ± 0.69	1.39***
Akwanga	Residence	21	6.39 ± 0.55	10.88 ± 0.18	15.36 ± 0.50	15.64 ± 0.50	1.69**
Akwanga	School	23	5.44 ± 0.08	8.18 ± 0.25	11.29 ± 0.40	12.56 ± 0.08	1.69***
Doma	School	16	6.88 ± 0.54	10.18 ± 0.26	13.26 ± 0.37	13.97 ± 0.66	1.39***
Lafia	Residence	27	5.48 ± 0.69	6.59 ± 0.58	9.12 ± 0.18	9.61 ± 0.56	1.69**
Lafia	School	18	3.33 ± 0.46	9.98 ± 0.69	10.63 ± 0.52	13.84 ± 0.23	1.39***
Nasarawa Eggon	Dump	23	3.04 ± 0.05	4.91 ± 0.13	8.26 ± 0.37	10.34 ± 0.49	1.39**
Nasarawa Eggon	Recreational	23	7.27 ± 0.38	9.57 ± 0.60	10.79 ± 0.30	12.86 ± 0.51	1.39***
Nasarawa Eggon	Residence	19	5.54 ± 0.64	7.95 ± 0.07	9.64 ± 0.51	10.91 ± 0.12	1.69**
LSD			1.18***	0.86***	1.20***	0.99***	
Values represent mean ± standard deviation, N = 3. LSD = Least significant difference. *, significant at 0.05 probability level, **, significant at 0.01 probability level, ***, significant at 0.001 probability level.							

Table 4 provides a comprehensive account of the number of leaves produced by seedlings across different land use types and locations over four weeks following emergence. In Akwanga, emergence was earliest in the Company site (12 days), where leaf production started modestly at 4.24 ± 0.34 and increased steadily to 10.09 ± 0.13 by week 4. The Hospital site in Akwanga, despite a later emergence (19 days), showed the most vigorous leaf development, culminating in 23.20 ± 0.28 leaves, far surpassing all other sites. Leaf counts in other Akwanga sites varied: the Office site showed consistent growth, reaching 13.69 ± 0.44 leaves by week 4, while Conserved, Residence, and School plots displayed more moderate increases, ending at 8.64 ± 0.51 , 10.64 ± 0.50 , and 8.02 ± 0.03 , respectively. In Doma, only

the School site was reported, and although emergence was relatively early (16 days), leaf growth was moderate with a week 4 count of 9.88 ± 0.16 . Lafia showed contrasting patterns: the Residence site, which had the latest emergence (27 days), nonetheless achieved 11.50 ± 0.70 leaves by week 4, whereas the School site showed slower development, ending at 8.18 ± 0.25 leaves. Nasarawa Eggon results highlighted balanced leaf development across land use types. The Recreational site reached 10.04 ± 0.06 leaves, and the Residence site achieved a similar value (10.16 ± 0.23), despite earlier differences in weekly counts. The Dump and School plots had slightly lower final counts, 8.07 ± 0.10 and 8.28 ± 0.39 respectively, reflecting steady but less vigorous growth. In summary, leaf production was notably influenced by both land use and location, with Akwanga-Hospital and Akwanga-Office supporting the most prolific development, while other locations displayed varied but significant growth patterns over time.

Table 4
Number of leaves for seeds planted in the four locations

Location	Land Use	Days to Emergence	Week 1	Week 2	Week 3	Week 4	LSD
Akwanga	Company	12	4.24 ± 0.34	5.67 ± 0.46	7.96 ± 0.06	10.09 ± 0.13	0.84***
Akwanga	Conserved	21	6.33 ± 0.46	7.73 ± 0.38	8.32 ± 0.46	8.64 ± 0.51	1.33**
Akwanga	Hospital	19	7.20 ± 0.28	9.73 ± 0.38	15.92 ± 0.11	23.20 ± 0.28	0.97**
Akwanga	Office	19	6.21 ± 0.30	5.81 ± 0.27	8.08 ± 0.11	13.69 ± 0.44	0.78***
Akwanga	Residence	21	6.05 ± 0.08	5.72 ± 0.39	7.50 ± 0.71	10.64 ± 0.50	1.26*
Akwanga	School	23	6.03 ± 0.04	6.03 ± 0.04	8.51 ± 0.69	8.02 ± 0.03	0.82***
Doma	School	16	5.57 ± 0.61	8.20 ± 0.28	9.75 ± 0.36	9.88 ± 0.16	1.08***
Lafia	Residence	27	6.08 ± 0.11	6.21 ± 0.30	8.68 ± 0.45	11.50 ± 0.70	1.24***
Lafia	School	18	4.03 ± 0.04	5.65 ± 0.49	6.46 ± 0.65	8.18 ± 0.25	1.19**
Nasarawa Eggon	Dump	23	5.69 ± 0.45	6.30 ± 0.43	8.28 ± 0.39	8.07 ± 0.10	1.06***
Nasarawa Eggon	Recreational	23	6.46 ± 0.64	6.06 ± 0.09	8.28 ± 0.39	10.04 ± 0.06	1.02**
Nasarawa Eggon	Residence	19	5.70 ± 0.43	7.67 ± 0.47	8.25 ± 0.36	10.16 ± 0.23	1.00***
LSD			0.99***	1.18***	1.34***	0.89***	
Values represent mean ± standard deviation, N = 3. LSD = Least significant difference. *, significant at 0.05 probability level, **, significant at 0.01 probability level, ***, significant at 0.001 probability level.							

Plate 1: Water retention capacity of *Gmelina arborea* Plate 2: Plant growth at 4WAP

Plate 3: Experimental layout in the nursery Plate 4: Plant growth at 2 WAP

Table 5 presents the water absorption and retention capacity of *Gmelina arborea* seeds across four locations. The initial volume was uniform (50 ml), but significant differences were observed in the final volume, where Lafia (59.09 ml) and Akwanga (58.90 ml) retained more water than Doma (58.37 ml) and Nasarawa Eggon (58.06 ml). Initial seed weight varied markedly, with Doma seeds (7.80 g) absorbing

more water compared to Nasarawa Eggon (7.37 g), Akwanga (7.18 g), and Lafia (6.42 g). Similarly, Doma recorded the highest final weight (9.85 g), while Lafia (9.01 g) and Nasarawa Eggon (9.48 g) showed intermediate values, and Akwanga the lowest (8.99 g). These results suggest that location significantly influences the water absorption and retention capacity of *Gmelina arborea* seeds, with Doma performing best in weight gain after soaking, while Lafia and Akwanga showed superior retention in terms of final volume.

Table 5
Comparative Analysis of Water Retention Capacity Across Four Locations

Location	Initial Volume	Final Volume	Initial Weight	Final Weight
Lafia	50	59.09 ^b	6.42 ^a	9.01 ^{ab}
Akwanga	50	58.90 ^b	7.18 ^b	8.99 ^a
Doma	50	58.37 ^a	7.80 ^c	9.85 ^b
Nasarawa Eggon	50	58.06 ^a	7.37 ^b	9.48 ^{ab}
LSD		0.82***	0.94***	1.74*
Values represent means, N = 3. LSD= Least significant difference. *, significant at 0.05 probability level, **, significant at 0.01 probability level, ***, significant at 0.001 probability level, “ns” = not significant.				

DISCUSSION

According to Xu et al. (2020) studies on the impact of urbanization on landscape patterns show that different urbanization models exhibit varying effects on the landscape. Ecological restoration and protection projects, as comprehensive ecological restoration initiatives, are implemented with region-specific considerations based on local conditions. The differences in plant density and growth metrics, such as height and DBH, between the four sites and land use areas are consistent with findings from Rojina *et al.* (2025), who studied the carbon stocks and biomass accumulation of soil and tree components of various agroforestry systems in Bangladesh's tropical moist regions.

One of the most hotly contested environmental topics among scientists and politicians worldwide today is the rise in atmospheric quantities of greenhouse gases (GHGs), particularly CO2. (Zhang & others, 2022).Global warming and climate change are caused by a number of anthropogenic activities, including the burning of fossil fuels, excessive changes in land use patterns, and deforestation. These activities are responsible for the continual production of atmospheric carbon dioxide (CO2) (Nawaz et al., 2017) CO2 has been rapidly increasing in the air since industrialization, making it the largest single contributor (> 70%) to global warming and a key source of greenhouse gases (Gupta *et al.*, 2019). This information is therefore indispensable in term of management, timber allocation and its power to sequester carbon.

The *Gmelina* trees in Akwanga and Lafia have the most potential for having more CO₂ in the atmosphere than those in the other places, according to the results of our investigation. Understanding the carbon cycle and sequestration mechanism between these pools depends critically on obtaining data on tree biomass (Durkaya et al. 2013). Variations in growth rates and girth sizes may be the cause of the notable disparities in tree stem volume among the species. Tree size (diameter and height) is a function of a tree's volume increment, which may have played a role in the trend seen in the species under study. This is in line with our present research. A function of biomass growth is the volume increment, according to Egbe and Tabot (2011).

According to Clark & Clark (1996) and Enquist et al. (2020), large trees are among the largest organisms in a forest. They serve a variety of ecological purposes, offer shelter to numerous other organisms, including birds (Blicharska & Mikusinski, 2014; Lindenmayer and Laurance, 2017), and have various cultural and aesthetic values for humans.

On the other hand, Akwanga had one of the tallest trees on average (13.01 m) and the broadest crown area (355.88 m²), indicating trees with more expansive canopy spread and vertical growth. These tall trees with their superlative characteristics play an essential role in maintaining the structure and functionality of tropical forests. With their high biomass, they act as significant carbon sinks, both on a global and biome scale, directly contributing to climate change mitigation. These trees also regulate the microclimate and support a complex network of ecological interactions, sheltering and sustaining high biodiversity (Lindenmayer & Laurance, 2016; Lutz et al., 2018; Pinho et al., 2020). This in line with the reports by Oyemakin et al. (2013) and Offiong et al. (2023) who recorded variations in the tree sizes of *Gmelina* studied in different locations. Height-Diameter models are expressed mathematically and relate to tree's measurable variables such as the tree heights and diameters. The average content of trees species with various sizes can be estimated by models (Avery and Burkhardt, 2002)

The differences in plant density and growth metrics, such as height and DBH, between the four sites and land use areas are consistent with findings from Rojina *et al.* (2025). Diameter is the widely used descriptor of stand structure, stand models that provide accurate estimates of stand growth and yield have become essential tool for evaluating the numerous management and utilization decision (Adeyemi and Ukaegbu, 2016). In this context, Doma exhibited the largest mean DBH (1.89 m) and tree size (2.34 m), reflecting more robust stem development.

Few studies have been conducted on the impact of pod length on seed germination, particularly in *Gmelina* plants. Lack of knowledge on how to get high-quality seeds is one of the challenges in putting its development into practice. According to Mahyuni & Hutasoit (2022), one of the elements influencing the high rate of germination is the quality of the seeds. Morphological characteristics, such as pod size and color, are a first step in selecting high-quality seeds. The *Gmelina* seed pod size that is appropriate for harvesting is currently unknown. The different seed colors and pod lengths that we saw in our research support (Mahyuni & Hutasoit, 2022). This supports the findings of Logo et al. (2017), who found that the size of the pod influences the traits of the seeds produced by soybean plants. In groundnuts,

pod traits—especially pod length—are very important in influencing seed yield and yield components. One heritable characteristic that affects seed size, number of seeds per pod, and overall pod filling efficiency is pod length (Khedikar et al., 2018). Longer pods can hold more seeds, which increases the potential production, according to studies (Upadhyaya *et al.*, 2012). Our study's variance points to genetic diversity in pod morphology, which can be used in breeding programs to increase yield. It also supports the findings of Pajo et al. (2025), who found substantial differences ($P < 0.05$) in pod length among the ten groundnut genotypes they examined. Pod length has a positive correlation with seed weight and harvest index, according to earlier studies (Hamidou *et al.*, 2019). Furthermore, environmental elements like temperature variations, rainfall patterns, and soil fertility might affect pod development and yield (Ntare *et al.*, 2017). Recommending appropriate genotypes for afforestation requires an understanding of these interactions. When compared to other sites and land use areas, the plant in the Akwanga residential area performed the best. According to Amika *et al.* (2014), seed size is a crucial physical measure of seed quality that influences vegetative growth and is commonly linked to yield, market grade parameters, and harvest efficiency. Our study's findings that seed size has no bearing on or influence on seed emergence are consistent with those of Baysah et al. (2018), who examined the impact of seed size on four cowpea types and found that it had no effect on germination. But according to Massimi (2018), barley seed size may have an effect on seed viability and vigor. According to earlier studies on lentil seeds, the weight of the seed had a substantial impact on the germination characteristics (Hojjat, 2011).

The following growth of seedlings is greatly influenced by the optimal water level for germination. Results from our study suggests that location significantly influences the water absorption and retention capacity of *Gmelina arborea* seeds, with Doma performing best in weight gain after soaking, while Lafia and Akwanga showed superior retention in terms of final volume. Germination success is greatly influenced by microclimatic parameters, which also differ greatly depending on the kind of land use. Higher germination rates are facilitated by, for instance, colder temperatures and more consistent moisture levels in regions with higher vegetation densities. These intricate relationships highlight how crucial it is to take management intensity and land use history into account when assessing *A. lebbek's* capacity for regeneration (Isaac *et al.*, 2022). Similarly, trees planted in urban settings may show reduced crown size and leaf area, likely due to air pollution and competition for light (Bashir et al., 2020).

Considering plants raised in the Research garden, it was recorded that plant height outcomes were strongly influenced by both the land use and location, with Residence in Akwanga and School in Doma supporting the tallest plants, while Lafia-Residence and Nasarawa Eggon-Dump showed relatively lower performance. Recent studies caution that while *G. arborea* thrives in open, well-drained agricultural and fallow lands, its growth and wood quality may be compromised when planted on nutrient-poor, waterlogged, or heavily degraded soils (López-Aguirre *et al.*, 2023). Popoola&Ukohol (2024) demonstrated significant variation in height-diameter relationships of *G. arborea* across different land uses in Makurdi, Nigeria, indicating that soil fertility, competition, and management intensity influence stand structure and biomass yield. Further, Egonmwan & Orukpe (2022) highlighted that volume

prediction models for *G. arborea* must be site-specific due to the variable growth responses under different land use histories and site conditions in southwestern Nigeria.

Conclusion

The study concludes by showing that the kind of land use has a substantial impact on the morphological qualities and seed properties of *Gmelina arborea* in all four locations in Nasarawa State. Reduced anthropogenic disturbance improves tree vigor, as evidenced by the higher growth performance of trees growing in residential, recreational, and conservation environments in terms of height, crown development, and volume. Seed quality and potential regeneration capacity may also be impacted by environmental factors and human activity, according to differences in seed morphometric features among land use types.

Overall, the results demonstrate the significance of conservation tactics and sustainable land use practices in fostering *Gmelina arborea*'s ideal growth and reproductive performance, which is crucial for its management, conservation, and application in forestry and agroforestry systems.

Declarations

Ethics approval and consent to participate (NA)

Consent for publication

This is to state clearly that all authors have their consent to the publication of this work

Availability of data and materials

Authors are ready to share the data from this work if required

Competing interests

The authors share no conflict of interest in this work

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Authors have no funding of this research

Authors' contributions

MBP supervised and designed the work; EGJ, AMM, ANH, LAA collected the data; GSO, ZRF wrote the paper; ERO edit the work; BUA analyzed the data

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Plates

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