BORNEO JOURNAL OF SCIENCES AND TECHNOLOGY (BJoST)
VOL.: 8, ISSUE: 2, 98-105
DOI: http://doi.org/10.35370/bjost.2026.8.2-08
e-ISSN: 2672-7439, UTS Publisher.

University of Technology Sarawak

ORIGINAL ARTICLE

Aboveground Biomass and Carbon Stock Assessment of *Acacia mangium* in Northeastern Peninsular Malaysia

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ABSTRACT - Forest plays a significant role in global carbon sequestration, yet localized data for specific species and regions remain limited. *Acacia mangium*, widely cultivated and wildly growing in Malaysia, has strong growth potential and adaptability but lacks comprehensive biomass and carbon quantification studies in Kelantan. This study aimed to estimate aboveground biomass (AGB) and carbon stock of *A. mangium* species in Bandar Jeli, Kelantan, and to evaluate their contribution to climate change mitigation. Tree diameter at breast height (DBH) were measured across four sample plots. Species-specific allometric equations were applied to estimate AGB, followed by conversion to carbon stock using the Intergovernmental Panel on Climate Change (IPCC) standard coefficient of 0.47. Results showed that mean DBH ranged from 15.5 cm to 16.8 cm, with corresponding mean AGB values of 100–120 Mg/ha and carbon stock of 48–60 MgC/ha. The average AGB and carbon stock across all plots were 150 Mg/ha and 75 MgC/ha, respectively. These findings were slightly lower than those reported in other Malaysian regions but remained within the national range. Variability in biomass and carbon storage between plots reflected local environmental conditions and stand dynamics. The study highlights the significant role of *A. mangium* plantations as carbon sinks and contributes to Malaysia's commitments to climate change mitigation.

ARTICLE HISTORY
Received: 08 Sept 2025
Revised: 17 Dec 2025
Accepted: 15 Apr 2026

KEYWORDS
Acacia mangium, aboveground biomass, carbon stock, allometric model, Kelantan.

INTRODUCTION

The rapid increase in atmospheric carbon dioxide (CO_2) concentration has intensified global concerns regarding climate change and its ecological consequences. Forest ecosystems play a pivotal role in mitigating greenhouse gas emissions through carbon sequestration, primarily by storing carbon in tree biomass [1-2]. Quantifying aboveground biomass (AGB) and carbon stock is fundamental to understanding the contribution of forest trees to the global carbon cycle, as well as to informing sustainable forest management and climate mitigation strategies [3].

Acacia mangium a fast-growing species exotic to Southeast Asia, has been widely cultivated and wildly growing in tropical regions due to its adaptability, high growth rate, and ability to thrive on degraded soils [4-5]. This species contributes significantly to commercial timber production, reforestation, and ecological restoration initiatives while providing crucial ecosystem services, including soil improvement and carbon storage [6-7]. In Malaysia, *A. mangium* is among the most extensively cultivated plantation

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species, particularly in Peninsular Malaysia and Borneo, supporting both timber industries and environmental services [8-9].

Despite the species' ecological and economic importance, regional studies on *A. mangium* carbon dynamics remain limited, especially in northeastern Peninsular Malaysia. Bandar Jeli, located in Kelantan, offers a unique opportunity to investigate carbon sequestration potential due to its favorable tropical rainforest climate, high annual precipitation, and active reforestation programs [10]. Previous studies in Sarawak and Sabah have quantified *A. mangium* biomass using allometric models [11-12], but localized studies in Kelantan remain scarce. Site-specific estimations are essential because biomass accumulation is influenced by environmental factors such as soil type, stand age, and management practices [13].

This study aims to quantify the AGB and carbon stock of *A. mangium* in Bandar Jeli, Kelantan, using species-specific allometric equations and standardized field measurements. The findings are expected to provide empirical data on the carbon sequestration potential of *A. mangium* in northeastern Peninsular Malaysia, then to compare the results with previous regional and global studies on *A. mangium* biomass and carbon storage. Last but not least, support sustainable forest management practices and contribute to Malaysia's climate change mitigation and carbon accounting initiatives. By addressing this knowledge gap, the present study contributes to ongoing discussions on the role of fast-growing plantation species in enhancing terrestrial carbon sinks in Southeast Asia.

MATERIALS AND METHODOLOGY

Study area

The study was conducted in Bandar Jeli, Jeli District, Kelantan, Malaysia (5.6990°N, 101.8464°E) (Figure 1). Bandar Jeli lies within the northeastern region of Peninsular Malaysia, covering an area of approximately 304.36 km². The region is characterized by a humid tropical rainforest climate with distinct wet and dry seasons, high annual rainfall (2,500–3,000 mm), and mean annual temperatures ranging from 24°C to 32°C (Malaysian Meteorological Department, 2022). These climatic conditions are conducive to the growth of fast-growing tree species such as *A. mangium*.

Figure 1. Location of Bandar Jeli, Kelantan, Malaysia [14].

The selected study sites comprised secondary forest area where *A. mangium* was dominant, grows naturally and wildly. The choice of this location was motivated by its active growing of *A. mangium*, making it ideal for evaluating carbon storage potential in tropical ecosystems.

Plot Establishment and Sampling Design

A random sampling design was applied to ensure representation across different site conditions. Four quadrat plots measuring 20 × 25 m (0.05 ha) [15] each were established within the larger 304.36 km^2 area, targeting approximately 0.002 km^2 dominated by *A. mangium*. The plots were distributed to capture stand heterogeneity.

Within each plot, all *A. mangium* individuals with a diameter at breast height (DBH) ≥ 10 cm were identified and measured using a standard DBH tape at 1.3 m above the ground. The DBH threshold follows established biomass assessment protocols in tropical forests [16-17].

Aboveground Biomass Estimation

AGB was estimated using the species-specific allometric equation developed by Adam and Jusoh [11], based on 77 *A. mangium* samples from second-generation stands in Sarawak. Equation (1) shows the allometric equation.

$$AGB=[\![0.1173 \times D]\!]^{2.454} \quad (1)$$

Where,

AGB is aboveground biomass (kg)
D is diameter at breast height (cm)

This equation was selected because of its species-specific accuracy, suitability for tropical plantations, and validation within Malaysian ecosystems. While generalized pan-tropical equations [16] exist, species-specific models provide higher predictive accuracy for single-species plantations.

Carbon Stock Estimation

Carbon stock was derived by applying the IPCC [16] recommended carbon fraction of 0.47, representing the proportion of dry biomass that is carbon as shown by Equation (2).

$$\text{Carbon stock}=AGB \times 0.47 \quad (2)$$

This fraction has been widely adopted in tropical biomass studies [7;20].

Data Analysis

Descriptive statistics, including mean DBH, mean AGB, and mean carbon stock per plot, were calculated. The results were visualized using bar charts with standard error bars to indicate variability across plots. Comparative analysis with previous studies in Malaysia and other tropical regions was performed to evaluate the carbon sequestration potential of A. mangium in Bandar Jeli relative to other sites.

RESULTS AND DISCUSSION

Diameter at Breast Height Distribution

The mean DBH of *A. mangium* across the four plots ranged from 15.5 cm to 16.8 cm (Figure 2). Plot 4 had the largest mean DBH (16.8 cm) but also the highest variability, while Plot 3 had the lowest mean DBH

(15.5 cm) with relatively consistent values. These variations can be explained by differences in microclimatic conditions, soil fertility, and stand density [13; 21]. Larger DBH values generally contribute to higher biomass accumulation, indicating that environmental heterogeneity in Plot 4 favored tree growth despite greater variability.

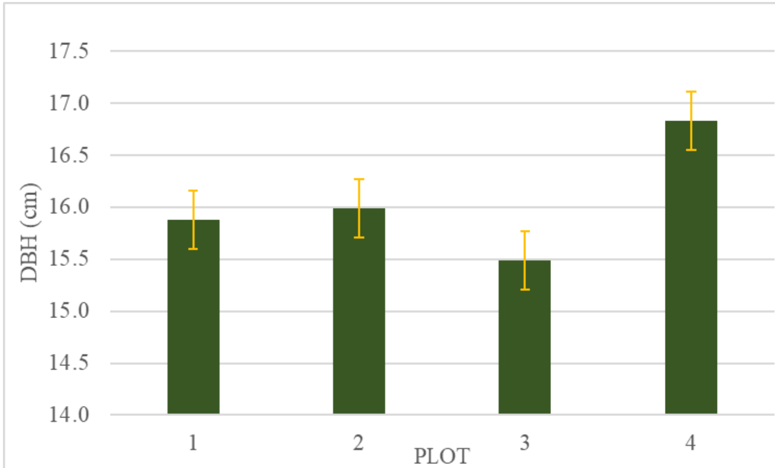

Figure 2. Mean for DBH of *A. mangium* at four different plots

Aboveground Biomass

The estimated mean AGB ranged from 100 Mg/ha (Plot 3) to 120 Mg/ha (Plot 4) (Figure 3). Plot 4 recorded the highest biomass accumulation but also showed high variability, suggesting heterogeneous site conditions. Differences in AGB may be influenced by local factors such as nutrient availability, rainfall distribution, and silvicultural practices [22-24]. These findings are consistent with other studies demonstrating that environmental drivers, including solar radiation and water accessibility, significantly impact biomass productivity in tropical plantations.

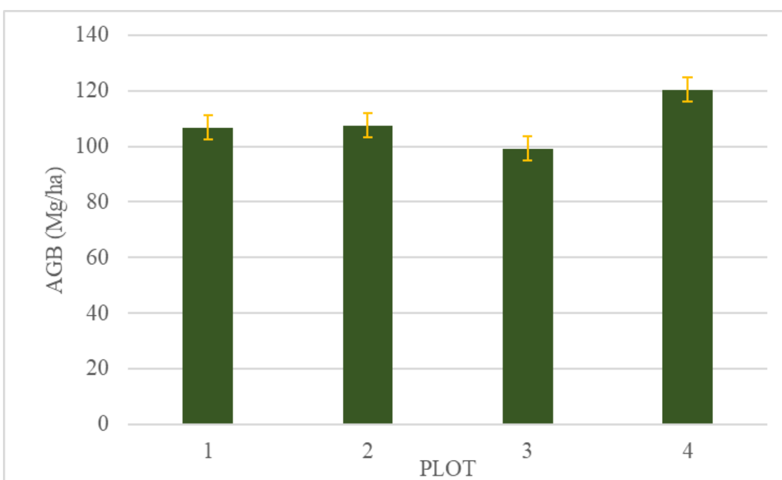

Figure 3. Mean for AGB of *A. mangium* at four different plots

Carbon Stock

Carbon stock estimates ranged from 48 MgC/ha (Plot 3) to 60 MgC/ha (Plot 4) (Figure 4). As expected, the carbon stock patterns mirrored those of AGB, reflecting the strong influence between DBH, AGB and carbon storage [25-26]. Plot 4 demonstrated the greatest carbon sequestration potential, though with higher variability, which could be attributed to uneven growth conditions.

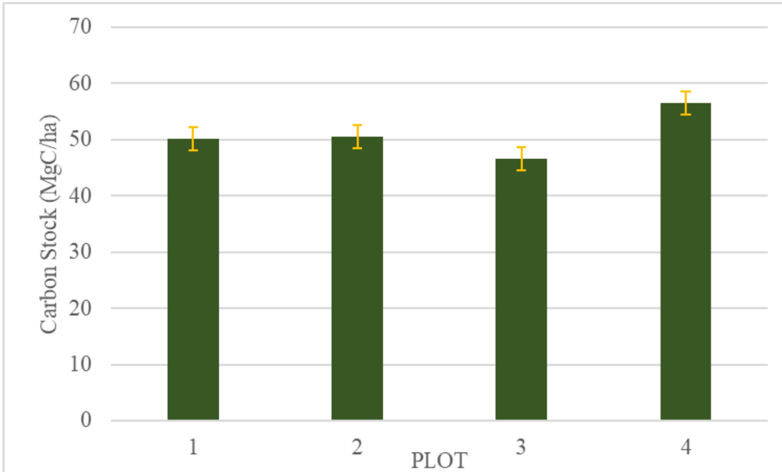

Figure 4. Mean for carbon stock of *A. mangium* at four different plots

Influence of DBH on AGB and Carbon Storage

DBH emerged as the primary predictor of AGB and carbon stock, consistent with global findings [13; 16]. Plot 4, with the highest mean DBH, recorded the greatest AGB and carbon stock, while Plot 3, with the smallest DBH, had the lowest values. These results support the strong DBH–biomass relationship observed in tropical tree species [17].

The present study demonstrates that *A. mangium* in Bandar Jeli store substantial AGB and carbon stock, consistent with findings from other tropical regions. These values are comparable to values reported for young to mid-aged *A. mangium* plantations in Malaysia and Southeast Asia [4; 12]. Similarly, Nguyen et al. [20] in Vietnam found carbon stocks of 30–55 MgC/ha for comparable stand ages. These consistencies validate the applicability of species-specific allometric equations for regional biomass assessments.

Comparison with Previous Studies

The mean carbon stock values from Bandar Jeli were 48-60 MgC/ha and this value were slightly lower than those reported in Sarawak (100 MgC/ha) [11], Sabah (90-110 MgC/ha) [27], and Perak (95 MgC/ha) [28]. However, they were within the range reported for Negeri Sembilan (80-100 MgC/ha) [29]. Table 1 shows the summarize.

Table 1. Comparison the AGB and carbon stock of *A. mangium* with previous studies in Malaysia

Study Area	Year	AGB (Mg/ha)	Carbon Stock (MgC/ha)	Reference
Bandar Jeli, Kelantan	2024	100-120	48-60	This study
Sarawak	2018	200	100	[11]
Sabah	2015	180-220	90-110	[27]
Perak	2015	190	95	[28]
Negeri Sembilan	2020	160-200	80-100	[29]

These differences highlight the influence of site-specific factors such as soil fertility, rainfall, and silvicultural practices, including planting density and thinning [30-31]. While Bandar Jeli's values were slightly lower, they confirm that *A. mangium* remains an effective carbon sink across diverse Malaysian landscapes.

CONCLUSION

This study quantified the AGB and carbon stock of *A. mangium* in Bandar Jeli, Kelantan, with mean values of 100–120 Mg/ha for aboveground biomass and 48–60 MgC/ha for carbon stock, which fall within the national range reported for Malaysian plantations. The strong influence observed between DBH, biomass, and carbon stock confirms DBH as a robust and cost-effective indicator for estimating carbon storage at the stand level.

Observed variability among plots highlights the influence of site conditions and silvicultural practices on biomass accumulation, emphasizing the importance of site-specific management. From a policy and management perspective, these findings provide valuable baseline data to support improved carbon accounting, inform forest management decisions, and strengthen the credibility of plantation-based carbon offset initiatives, besides contribute to the growing body of knowledge on carbon sequestration potential in tropical area and underscore the role of *A. mangium* in Malaysia's climate mitigation strategies.

Future studies should focus on long-term growth monitoring to capture temporal carbon dynamics, incorporate belowground and soil carbon pools to improve total ecosystem carbon estimates, and develop site-specific allometric models for greater accuracy. The integration of remote sensing techniques with field-based measurements is also recommended to support scalable carbon monitoring frameworks aligned with REDD+ and Malaysia's national climate mitigation and reforestation strategies.

ACKNOWLEDGEMENT

The authors would like to thank the Faculty of Earth Science, Universiti Malaysia Kelantan for facilitating this study.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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