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ORIGINAL ARTICLE

Evaluating Aboveground Biomass and Carbon Stock of *Leucaena leucocephala* in Bandar Jeli, Kelantan

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ABSTRACT - This study assesses the aboveground biomass and carbon stock of *Leucaena leucocephala*, a fast-growing leguminous tree species, in Bandar Jeli, Kelantan. *L. leucocephala* is recognised for its potential in agroforestry, soil improvement, and carbon sequestration, making it an ideal candidate for carbon stock evaluation in tropical regions. By applying non-destructive sampling techniques and allometric equations, the diameter at breast height (DBH) range of 5 to 15 cm was measured for each chosen stands in four stratified random sampling plots. The means for DBH, aboveground biomass, and carbon stock were 10.45cm, 70.682Mg/ha and 33.221MgC/ha respectively. The findings indicate significant carbon storage capacity, highlighting the ecological and economic benefits of *L. leucocephala* in reforestation and carbon offset initiatives. This study provides valuable insights into the potential role of *L. leucocephala* in local and regional carbon management strategies, offering a model for sustainable land use practices in tropical forest ecosystems.

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INTRODUCTION

As concerns about climate change and environmental sustainability intensify, quantifying carbon stocks in forested and reforested areas has become a critical area of research. Forests serve as essential carbon sinks, capturing atmospheric carbon dioxide and storing it in biomass, which vital role in mitigating global warming [1]. Among various vegetation types, fast-growing tree species are of particular interest for carbon storage due to their rapid biomass accumulation [2].

One such species, *Leucaena leucocephala,* commonly known as Leucaena or 'Petai belalang', is widely recognized for its potential in reforestation, agroforestry, and soil improvement [3]. Its adaptability, rapid growth, and ability to thrive in various climates make it an ideal candidate for assessing carbon storage potential efforts [4]. Accurate calculations of aboveground biomass and carbon stock are critical for designing effective climate change mitigation measures and satisfying international obligations such as those contained in the Paris Agreement [5].

This study focuses on assessing the aboveground biomass and carbon stock of *L. leucocephala* in Bandar Jeli, Kelantan, Malaysia, a region characterised by tropical forest ecosystems and dynamic land use patterns. Quantifying the aboveground biomass of *L. leucocephala* is crucial for understanding its carbon storage capacity and its role in local and regional carbon dynamics. Additionally, this information can provide valuable insights for land management, conservation efforts, and climate action initiatives, especially in Malaysia, where sustainable land management is gaining attention.

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Thus, this study aim to evaluate the aboveground biomass and carbon stock of *L. leucocephala* stands in Bandar Jeli using non-destructive sampling methods. The findings will contribute to the existing body of studies on carbon storage by fast-growing trees and offer baseline data to inform policies and practices on sustainable forest management and carbon offset strategies in the region.

MATERIALS AND METHODOLOGY

Study Area

This study was conducted in Bandar Jeli, located in Jeli District, Kelantan, Malaysia (5.6990°N, 101.8464°E) (Figure 1). Bandar Jeli lies in the northeastern region of Peninsular Malaysia, covering an area of 304.36km² characterized by a tropical rainforest climate with distinct wet and dry seasons. The region experiences high annual rainfall (approximately 2,500–3,000mm), and average temperatures range between 24°C and 32°C, creating ideal conditions for tropical vegetation growth.

The specific study site in Bandar Jeli was chosen due to the significant presence of *L. leucocephala*, a fast-growing leguminous tree species commonly used for soil improvement, fodder, and reforestation purposes. The area contains a mixture of natural and cultivated vegetation, with *L. leucocephala* being one of the dominant species. The choice of this location also allows for understanding the carbon stock potential of *L. leucocephala* in disturbed or managed landscapes typical of agricultural and reforested areas in Kelantan.

Stratified random quadrat plots measuring by 10×10m were established within the study site for systematic data collection on aboveground biomass and carbon estimation. The plots used were scattered across the larger 304.36km² in regions that represent the range of conditions in which *L. leucocephala* is discovered about 0.4km² (Figure 2). Within each plot, data for diameter at breast height (DBH) has been collected to determine the aboveground biomass and carbon stock contained on the stems.

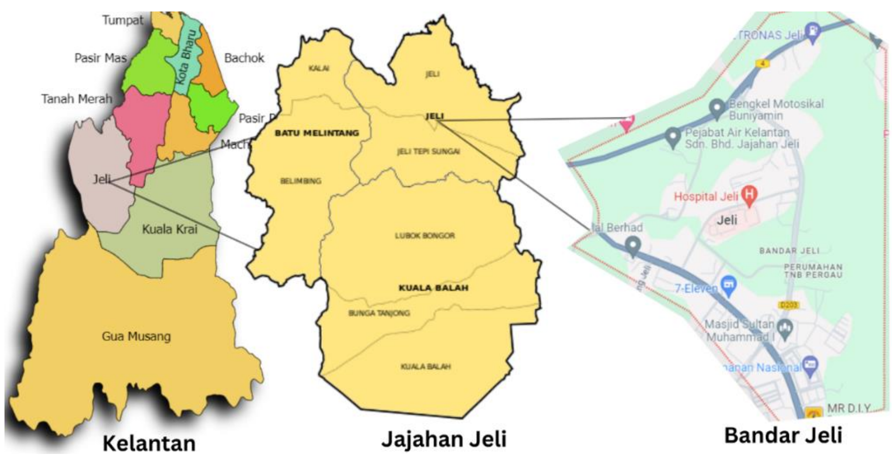

Figure 1. Location of Bandar Jeli, Kelantan [6]

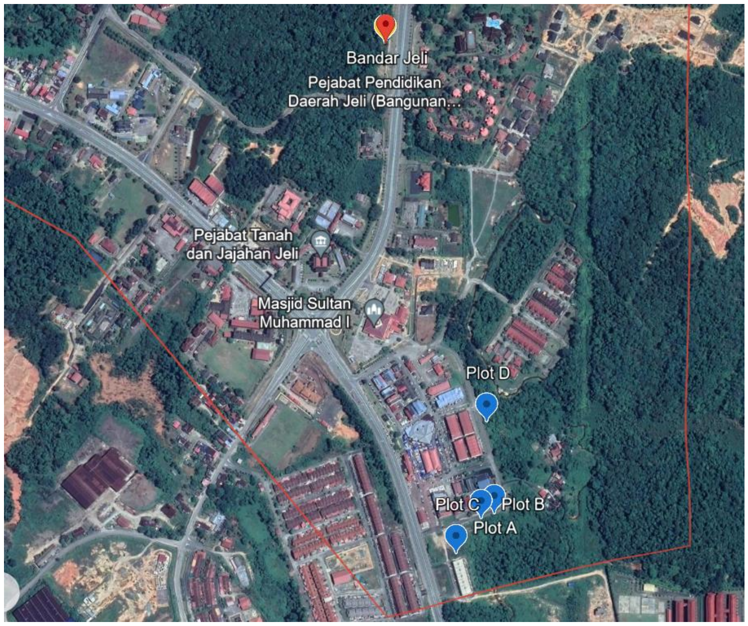

Figure 2. Location for four sampling plots at Bandar Jeli, Kelantan [6]

Materials

Aboveground biomass and carbon stock of *L. leucocephala* determined using DBH measurements and an allometric equation. The DBH of all standing *L. leucocephala* stems exceeding the 5 to 15 cm size threshold was using a diameter tape within four sampling plots that were decided early.

Aboveground Biomass

The most suitable allometric equation to apply in order to determine the aboveground biomass of *L. leucocephala* from the Fabaceae family is from Kato et al. [7], then modified by Kueh & Lim. [8]. This allometric equation is the most suitable for this study because Kueh & Lim estimate the aboveground biomass of trees in lowland tropical forests with DBH was ≥ 5cm and the dominant DBH data range for their study were trees with DBH below 15cm. On the other hand, there was a Fabaceae family tree was estimated as its aboveground biomass using this equation. So, to assess the aboveground biomass of *L. leucocephala* in Bandar Jeli, Kelantan, the allometric equation was used as shown by Equation 1.

$$y = 0.2544 \, x \, D^{2.368} \quad (1)$$

Where,

y is aboveground biomass
D is the diameter at breast height

Carbon Stock

According to IPCC [9], carbon stock estimation was assumed that approximately 47-50% of the dry biomass is carbon, a common approximation for tropical tree species which is called carbon fraction. Thus, the calculation for carbon stock is to multiply the estimated aboveground biomass of each tree by the carbon fraction (0.47) to determine the carbon stock as shown by Equation 2.

$$Carbon\ stock = Aboveground\ biomass\ x\ 0.47 \quad (2)$$

Data Analysis

The primary findings from the assessment of aboveground biomass and carbon stocks of *L. leucocephala* across the study area were presented using bar graphs for the mean for DBH, aboveground biomass, and carbon stock.

RESULTS AND DISCUSSION

Descriptive Analysis on DBH, Aboveground Biomass and Carbon Stock of *L. leucocephala*

Mean for DBH, aboveground biomass, and carbon stock for each plot were presented as bar graphs to illustrate them in a better way as shown in Figure 3-5, respectively. Figure 3 shows the mean DBH for *L. leucocephala* across four plots. Plot C has the highest mean DBH, close to 12cm, with a moderate error bar indicating some variability in DBH measurements within this plot. Plot B follows closely behind Plot C with a mean DBH of around 11cm, also showing a small degree of variability. Meanwhile, Plot A has a slightly lower mean DBH than Plot B, around 10cm, with minimal variability indicated by the error bar and Plot D has the lowest mean DBH, around 8cm, with a small error bar, suggesting relatively consistent DBH measurements within this plot. The DBH values across the plots could indicate differences in tree maturity, growth conditions, or density that might be influencing the size of the *L. leucocephala* trees. The larger DBH in Plot C could correlate with the higher aboveground biomass observed in that plot, as larger trees generally contribute to greater biomass and carbon storage.

Figure 4 shows the mean aboveground biomass for four plots of *L. leucocephala*. Plot C has the highest aboveground biomass mean, reaching close to or over 100Mg/ha, meanwhile Plot B has the second highest biomass mean, around 80Mg/ha. Plot A follows Plot B with a slightly lower mean biomass, around 70Mg/ha and Plot D has the lowest biomass mean, which appears to be around 40Mg/ha. The chart highlights differences in aboveground biomass across the plots, with Plot C showing the most aboveground biomass, while Plot D has the least. The error bars represent the standard error or variability in the biomass measurements, indicating that Plot C might have higher variability compared to Plot D.

Figure 5 illustrates the mean carbon stock for *L. leucocephala* across four plots. Plot C has the highest mean carbon stock, approximately 50MgC/ha, with an error bar indicating some variability within this plot's carbon measurements. Plot B has the second highest carbon stock, around 40MgC/ha, with moderate variability. Meanwhile, Plot A follows with a mean carbon stock of around 35MgC/ha, showing slightly more variability than Plot B, while Plot D has the lowest carbon stock, about 20MgC/ha, with minimal variability, as indicated by the small error bar. The trend in carbon stock aligns with the previously observed patterns in aboveground biomass and DBH values for these plots, as larger trees and higher aboveground biomass generally contribute to greater carbon storage. Plot C, having the highest aboveground biomass and DBH, also has the highest carbon stock, while Plot D, with the lowest aboveground biomass and DBH, shows the least carbon stock. This information highlights the relationship between tree size, aboveground biomass, and carbon storage potential in different plots.

There are factors influencing aboveground biomass and carbon stock for tree individuals or species. The main factor is DBH. The study by Basuki et al. [10] stated that the most significant predictor to calculate aboveground biomass is DBH. This factor also stated by Chave et al. [11], which is DBH is the main effective predictor to estimate aboveground biomass and carbon stock for trees.

However, other factors like using scientific allometric equation [12], the structure and composition of the forest itself can influence the aboveground biomass and carbon stock for tree species [13]. Furthermore, factors like stem density, basal area and wood specific gravity can be the influences too, for total aboveground biomass and carbon stock for the trees.

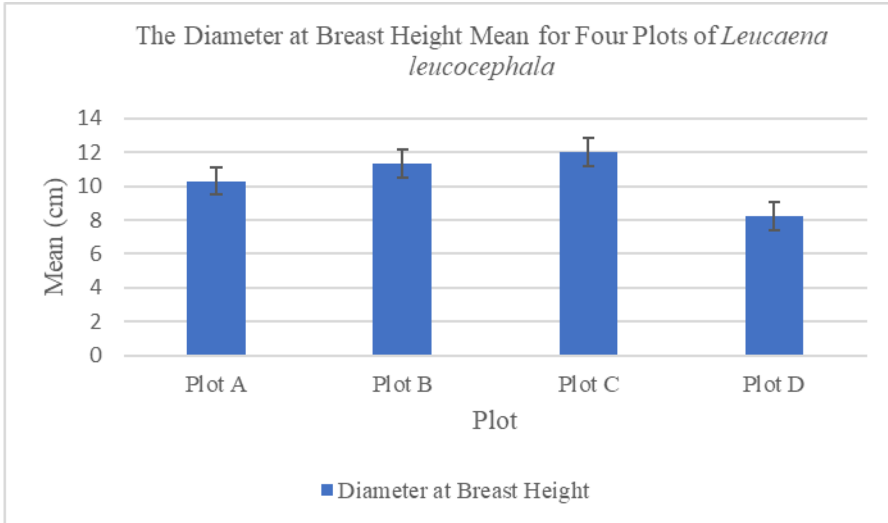

Figure 3. Mean for DBH of *L. leucocephala* at four different plots

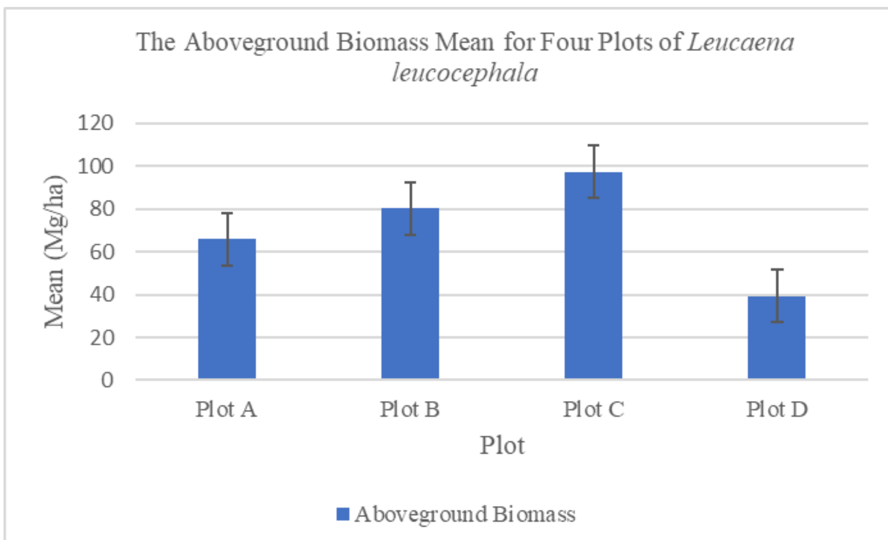

Figure 4. Mean for aboveground biomass of *L. leucocephala* at four different plots

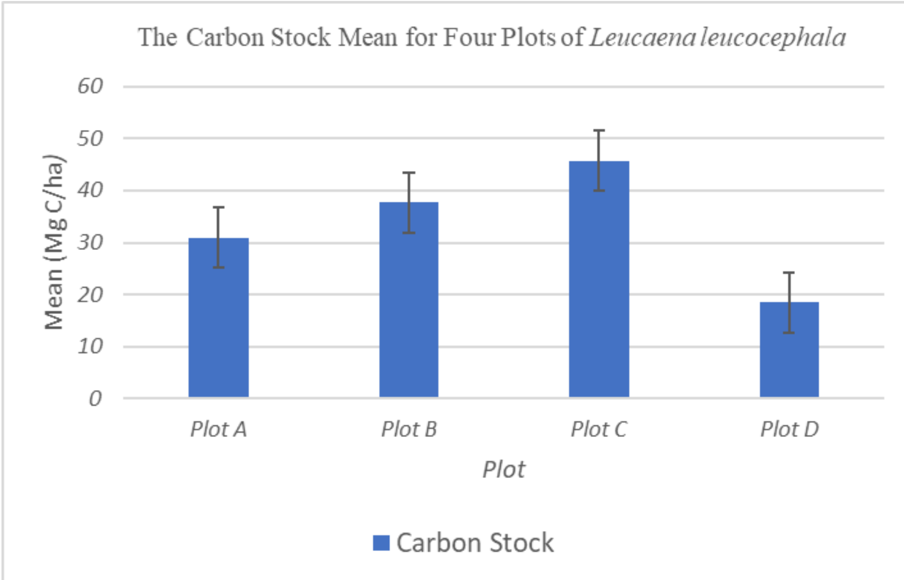

Figure 5. Mean for carbon stock of *L. leucocephala* at four different plots

Comparison of Aboveground Biomass and Carbon stock of *L. Leucocephala* with other FabaceaeSpecies Growth in Malaysia

Based on the previous studies, Table 1 shows the comparison of the aboveground biomass and carbon stock of *L. leucocephala* with other Fabaceae species growth in Malaysia. This table illustrates how *L. leucocephala* from this study compares to different ages and types of *Acacia mangium* from other studies in terms of mean DBH, aboveground biomass, and carbon stock.

Table 1. Comparison of the aboveground biomass and carbon stock between *L. leucocephala* with other Fabaceae species in Malaysia

Study	Species	Mean DBH (cm)	Aboveground Biomass (Mg/ha)	Carbon Stock (Mg C/ha)
This study	*Leucaena leucocephala*	8.25 - 12	70.682	35.341
Adam & Jusoh [14]	*Acacia mangium* (hybrid)	12.8 – 40.9	113.3	53.3
	Acacia mangium (2^{nd} gen)	11.6 – 41.5	178.9	84.1
Lee et al. [15]	*Acacia mangium* (1 year old)	8.84	19.76	9.37
	Acacia mangium (3 years old)	15.10	66.68	39.26
	Acacia mangium (5 years old)	18.39	139.99	66.36

From Table 1, the mean DBH of *L. leucocephala* in this study (8.25 - 12 cm) is lower compared to some *Acacia mangium* samples, particularly the older trees. The aboveground biomass of *L. leucocephala* (70.68Mg/ha) is lower than the aboveground biomass of both the *Acacia mangium* hybrids and second-generation *Acacia* reported by Adam & Jusoh [14], but it is comparable to younger *Acacia* (1 to 3 years old) as reported by Lee et al. [15]. Similarly, the carbon stock of *L. leucocephala* (35.34MgC/ha) is lower than the carbon stocks of *Acacia mangium* hybrids and second-generation *Acacia*, but is closer to values for 3-year-old *Acacia mangium*.

These comparisons suggest that *L. leucocephala* has lower aboveground biomass and carbon stock potential compared to older or second-generation *Acacia mangium*, though it performs comparably to young *Acacia* in terms of carbon storage. This data is useful for assessing the carbon storage potential of *L. leucocephala* relative to other species and ages of *Acacia*.

CONCLUSION

As conclusion, the aboveground biomass of *L. leucocephala* held by four plots at Bandar Jeli is around 2261.838Mg/ha, meanwhile for carbon stock is around 1063.064MgC/ha for all plots. Thus, the mean for an individual *L. leucocephala* stand holds about 70.682Mg/ha aboveground biomass and 35.341MgC/ha for carbon stock. The main factor influencing the aboveground biomass and carbon stock for this tree species is their DBH. For the next studies to improve the technique for estimating aboveground biomass and carbon stock of this species, the increment of plots in the study area to gain more accuracy in data collection which can lead to a better result. On the other hand, there might be another allometric equation which is most suitable to use in estimating the aboveground biomass of *L. leucocephala* should be discovered.

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