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Carbon Content of Amazonian Commercial Tree Boles: Implications for Forest Management

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Abstract: Reliable values for carbon content in trees are essential for quantifying forest carbon stocks and estimating carbon dioxide emissions. This study analyzed the carbon content in the boles of commercial tree species in the Brazilian state of Acre, in the southwestern Amazon. Composite samples were prepared from wood wedges obtained along each individual's commercial bole (the trunk from the point of cut to the first significant branch). Fifty-seven trees were analyzed, spanning nine families, seventeen genera, and nineteen species in the Amazon forest. The results revealed a variation in carbon content ranging from 49.08% (±3.36) to 51.81% (±0.6), with an overall mean of 50.48% (±0.42). *Handroanthus serratifolius*, *Astronium lecointei*, and *Dipteryx odorata* exhibited the highest carbon contents. The statistical analysis included the calculation of 95% confidence intervals for each species, indicating the precision of the carbon content estimates. ANOVA analysis showed a large effect ($\eta^2 = 0.83$), indicating that 83% of carbon variability is due to species differences, highlighting the distinct carbon profiles across species. One species (*Ceiba pentandra*) showed a significant increase in carbon with height along the bole, while the others showed varying but non-significant trends with height. Mean carbon content differed significantly (Tukey's post hoc test) among the 19 species studied, with the greatest difference between *H. serratifolius* and *Ceiba pentandra*. Although differences between species may seem small, in some cases, they can lead to considerable underestimations or overestimations of carbon stocks and emissions when extrapolated to large areas such as the Amazon. The mean carbon content measured in this study (50.48%) exceeds the 0.47 IPCC default value generally used in national reports to the Climate Convention and in various estimates of deforestation emissions and Amazon carbon stocks. This suggests that both emissions and stocks may have been underestimated.

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1. Introduction

To properly understand the relationship between carbon content, vegetation, and climate change, it is crucial to recognize the fundamental role that forests play in the global carbon cycle [1,2]. Carbon content refers to the amount of carbon stored in a particular material or environment [3]. In the context of vegetation, this includes the carbon contained in plants, trees, and soil [4,5]. Particularly, large trees act as significant "carbon sinks", absorbing carbon dioxide (CO_2) from the atmosphere through photosynthesis and storing it in their trunks, branches, and roots [6,7]. This process is essential for global climate regulation and carbon sequestration.

In forest management, large trees are often harvested for timber production, following guidelines that allow the extraction of trees with diameters at breast height (DBH) of 50 cm or greater [8,9]. This method involves removing the trunk from the forest, while the canopy and other parts of the tree remain, contributing to nutrient cycling and habitat maintenance [6,10]. Although these practices are designed to minimize environmental impact, the removal of large trees can significantly disturb the natural balance of forests and affect the ecosystem's ability to function as a carbon stock [11].

Forest management practices aim to preserve ecosystem function, but human intervention, such as selective tree harvesting for timber, inevitably alters forest dynamics [12,13]. This can result in a reduction of the forest's overall capacity to store carbon, as mature trees, which are effective at storing CO_2, are removed [14]. It is important, therefore, that such practices are conducted in a way that does not exceed the forest's natural regeneration capacity and maintains ecological balance [15,16].

The variability in carbon content observed among different species and even within a single tree, as highlighted in the study by Ma et al. 2018 [17], underscores the importance of conducting detailed research on carbon content. This variability is crucial for developing more precise and environmentally responsible forest management strategies that maximize carbon storage and help mitigate climate change [18,19].

Initiatives such as REDD (reducing emissions from deforestation and forest degradation) and Nature-Based Projects [20,21], which currently encompass carbon credit projects intended to reduce atmospheric CO_2 concentrations through improved management practices, reforestation, renewable energy, energy efficiency, and waste management [22,23]. These efforts are essential to mitigate the adverse effects of climate change and promote environmental sustainability. However, the effectiveness of these projects fundamentally depends on a detailed understanding of carbon storage in forests and how management practices impact this storage [24]. Accurate assessments are crucial to ensure that the implemented strategies are effective and contribute significantly to global sustainability and climate stability [25]. This discussion is essential for the ongoing assessment of forest management policies and will be an important agenda item at COP 30, providing a crucial opportunity to review and reinforce global commitments towards a sustainable future.

Our study specifically examines the vertical variation in carbon content within the commercial boles of 19 tree species commercially harvested in a managed forest area in the state of Acre, Brazil. These species were selected for their ecological significance and representativeness within this managed forestry zone, providing a comprehensive view of the carbon dynamics within Amazonian forests subject to forest management. The research aims to refine our understanding of intra- and inter-species variations in carbon content, which are still poorly understood and surrounded by significant uncertainty. By focusing on key scientific questions—what is the variation in carbon storage capacities among selected tree species in the study area, and how do these variations impact the overall accuracy and reliability of carbon stock assessments in tropical forests?—this study seeks to enhance our understanding of the role of managed Amazon forests in the global carbon cycle and inform decision-making on forestry initiatives and payment for ecosystem services [26,27].

2. Materials and Methods

2.1. Study Area

The forest species chosen to be part of this study were large commercial species with significant timber potential. They were obtained in the Antimary I and II ranches (9°23′43″ South latitude, 67°58′50″ West longitude), located in the southwestern Amazon in the municipality of Porto Acre, Acre, Brazil (Figure 1). The vegetation at the site is classified as dryland humid forest [28–30], with a predominance of Open Forest with Bamboo, Open Forest with Palms, and Dense Forest [31–33].

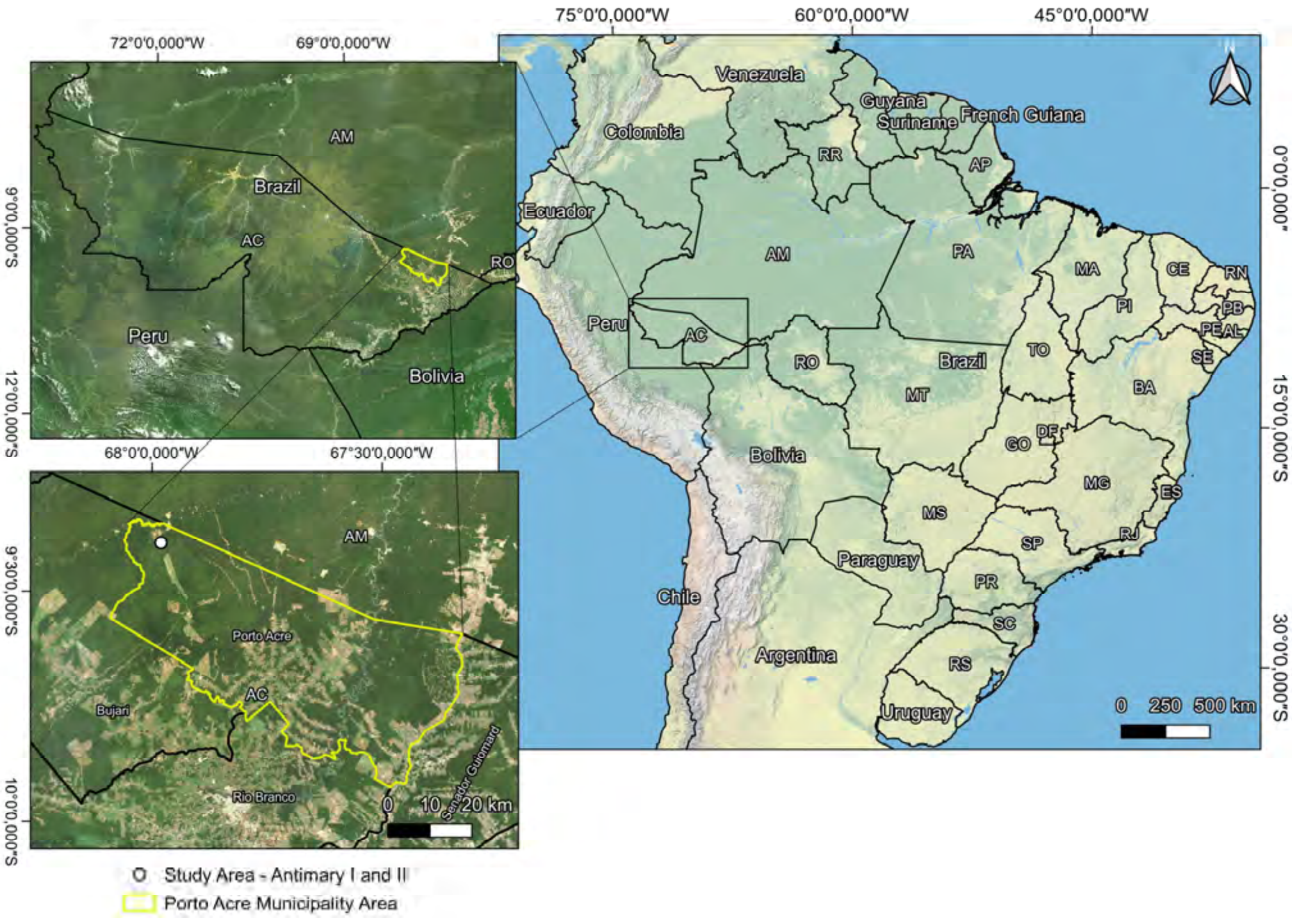

Figure 1. Antimary I and II study area in the municipality of Porto Acre, Acre, Brazil.

The climate is type Am under the Köppen classification [34], with an average annual temperature of 24.5 °C [35]. Annual precipitation varies from 1750 to 2250 mm. The rainy season begins in October and lasts until May, with January to March having the greatest rainfall [35,36]. The study area has two types of soil: red argisol and dystrophic red-yellow latosol [33,37]. The predominant topography is flat, with a slope of around 5% [37]. The elevation varies between approximately 220 and 300 m above mean sea level [38].

2.2. Selection and Collection of Samples of Commercial Species

We selected 19 species that are of commercial interest due to their high frequencies of occurrence (stems ha^{-1}) and basal areas (m^2 ha^{-1}), collectively accounting for 84.4% of the total commercial basal area at the research site. This selection was based on their significant timber potential and high coverage index values [39], ensuring that our findings would be applicable to the most economically and ecologically important species within the area.

The sampling protocol was carefully designed to reflect the natural distribution of these species. The number of individuals sampled per species was determined in proportion to their relative density and frequency of occurrence [40]. We sampled across a variety of diameter classes to represent the diversity within each species, with the number of trees sampled in each class mirroring the diameter distribution recorded in the company's forest inventory. In total, 57 sample trees were selected—three from each species—to ensure a diverse and representative dataset. Each tree was initially cut 30 cm above ground level to standardize the starting point of the samples, including those with buttresses. The commercial boles of these trees were systematically sectioned into logs. From each log, a disc approximately 3 cm thick was removed starting from the base and continuing every 4.30 m up the top of the commercial bole for trees with DBH greater than 80 cm and every 8.30 m for trees with DBH between 50 and 80 cm. This method ensured that the first disc was consistently taken at 30 cm above the ground for all trees.

In total, 141 discs were collected, with each tree yielding between 2 and 4 discs based on its diameter and the commercial bole's height. These discs were classified into sections labeled A, B, C, and D along the commercial bole, providing detailed samples for carbon content analysis [40]. Section A always represented the base of the bole, just 30 cm above the ground, while the heights of Sections B, C, and D varied according to the predetermined sectioning strategy of the commercial bole [41].

2.3. Statistical Analysis and Tree Classification

Our study commenced with the collection of samples from the commercial boles of selected tree species, processed in a laboratory to determine carbon content using a universal analyzer (Elementar, model Vario Micro Cube, Langenselbold, Germany) [42]. This preliminary step set the foundation for our subsequent in-depth statistical analysis that was designed to explore variations in carbon storage capacities among the species and to assess the accuracy of carbon stock assessments.

We utilized both descriptive and inferential statistics to understand the variations in carbon content and other physical characteristics of tree species. Initially, for each species, we calculated the mean and standard deviation to summarize the central tendency and dispersion of carbon content. We constructed confidence intervals (95% CI) for each mean, providing a statistical range within which the true mean is likely to lie with 95% certainty [43].

We employed box plots to visually present the distribution of physical characteristics such as DBH (diameter at breast height), commercial height, basal area, and volume. These plots effectively summarize a range of data points by displaying the median, interquartile range (IQR) and potential outliers, aiding in the comparison of these metrics across different species [43,44].

In addition to descriptive statistics, we used Analysis of Variance (ANOVA) to compare the mean carbon content across multiple tree species. This statistical test for significant differences among species was complemented by the Shapiro–Wilk test to ensure data normality, aligning with the assumptions necessary for accurate ANOVA analysis [45]. During this analysis, we also carefully controlled for Type I error, ensuring the precision of our statistical inferences [46,47]. The size of the effect was calculated using eta-squared (η^2), providing insight into the magnitude of the differences observed [48].

Upon identifying significant differences through ANOVA, we conducted post hoc analysis using Tukey's honest significant difference (HSD) test [47,48]. This test pinpointed specific pairs of species with statistically significant differences in carbon content, providing critical insights into species-specific characteristics that are crucial for effective carbon storage and forest management strategies.

Advanced visualizations further supported our analysis. Line graphs with error bars depicted carbon content across vertical sections (A, B, C, D) of the tree boles, utilizing repeated measures or mixed-effects models to handle data from the same trees at different heights. Additionally, density plots illustrated the distribution of carbon content percentages, offering detailed comparisons across different conditions or species [41].

3. Results

Fifty-seven large trees were sectioned and measured, representing nine families, seventeen genera, and nineteen species, as shown in Table 1. The mean carbon contents in the commercial boles of these trees ranged from 49.08% (±3.36) to 51.81% (±0.6), with an overall average of 50.48% (±0.42). Among the species analyzed, *Handroanthus serratifolius* stood out with the highest carbon content at 51.81% (±0.6), followed by *Astronium lecointei* with 51.71% (±0.72), *Dipteryx odorata* with 51.60% (±0.31) and *Cedrela odorata* with 51.60% (±0.18).

Table 1. Variation in the carbon content in the commercial boles of large trees of the 19 species.

Family	Scientific Name	N	$\bar{x}$	S.D.	Confidence Interval (95% CI)	
					L.L.	UL
Euphorbiaceae	*Hura crepitans*	3	49.706	1.83	48.16	51.36
Fabaceae	*Parkia paraensis*	3	50.53	0.29	50.32	50.74
Malvaceae	*Sterculia apetala*	3	50.39	0.56	49.98	50.80
Lecythidaceae	*Eschweilera bracteosa*	3	50.52	0.35	50.24	50.80
Lecythidaceae	*Eschweilera grandiflora*	3	50.54	0.58	50.16	50.92
Moraceae	*Castilla ulei*	3	49.98	0.40	49.63	50.33
Meliaceae	*Cedrela odorata*	3	51.60	0.18	51.46	51.74
Fabaceae	*Copaifera multijuga*	3	51.51	0.37	51.27	51.75
Fabaceae	*Dipteryx odorata*	3	51.60	0.31	51.42	51.78
Fabaceae	*Albizia niopoides*	3	49.50	0.43	49.16	49.84
Fabaceae	*Apuleia leiocarpa*	3	51.04	0.27	50.86	51.22
Fabaceae	*Barnebydendron riedelii*	3	49.57	0.49	49.18	49.96
Bignoniaceae	*Handroanthus serratifolius*	3	51.81	0.60	51.37	52.25
Fabaceae	*Hymenaea courbaril*	3	50.68	0.25	50.52	50.84
Anacardiaceae	*Astronium lecointei*	3	51.71	0.72	51.18	52.24
Combretaceae	*Terminalia tetraphylla*	3	49.83	0.27	49.61	50.05
Fabaceae	*Schizolobium parahyba var. amazonicum*	3	50.11	0.17	49.98	50.24
Malvaceae	*Ceiba pentandra*	3	49.08	3.36	47.18	50.98
Malvaceae	*Ceiba samauma*	3	49.45	0.21	49.28	49.62
N, Mean, SD & CI		19	50.48	0.42	50.07	50.90

N = number of trees; $\bar{x}$ = mean percent carbon content; S.D. = standard deviation; lower limit (LL) and upper limit (UL) (95% CI).

The study quantified the carbon content of each species, accompanied by the lower and upper bounds of the 95% confidence interval (Table 1). For example, for *Ceiba pentandra*, the 95% confidence interval was between 47.18% and 50.98%, indicating that, with high certainty, the true mean carbon content of this species lies within this range. Narrower confidence intervals reflect greater credibility in estimates of the mean, while wider intervals indicate higher variability in the data and consequently greater uncertainty in estimates. This information is crucial for species comparisons and for assessing the precision of estimates.

3.1. Variability of Diameter at Breast Height (DBH, Commercial Height, Basal Area and Volume in Commercial Boles

Figure 2 presents a comparative analysis of the variables diameter at breast height (DBH) in cm, commercial height in m, basal area in m^2 and volume in m^3 of the 19 species in this study. These variables are essential for evaluating the growth, biomass and timber production potential of the sampled species. Each boxplot illustrates the median, interquartile range and outliers, highlighting the variability of each metric among the species.

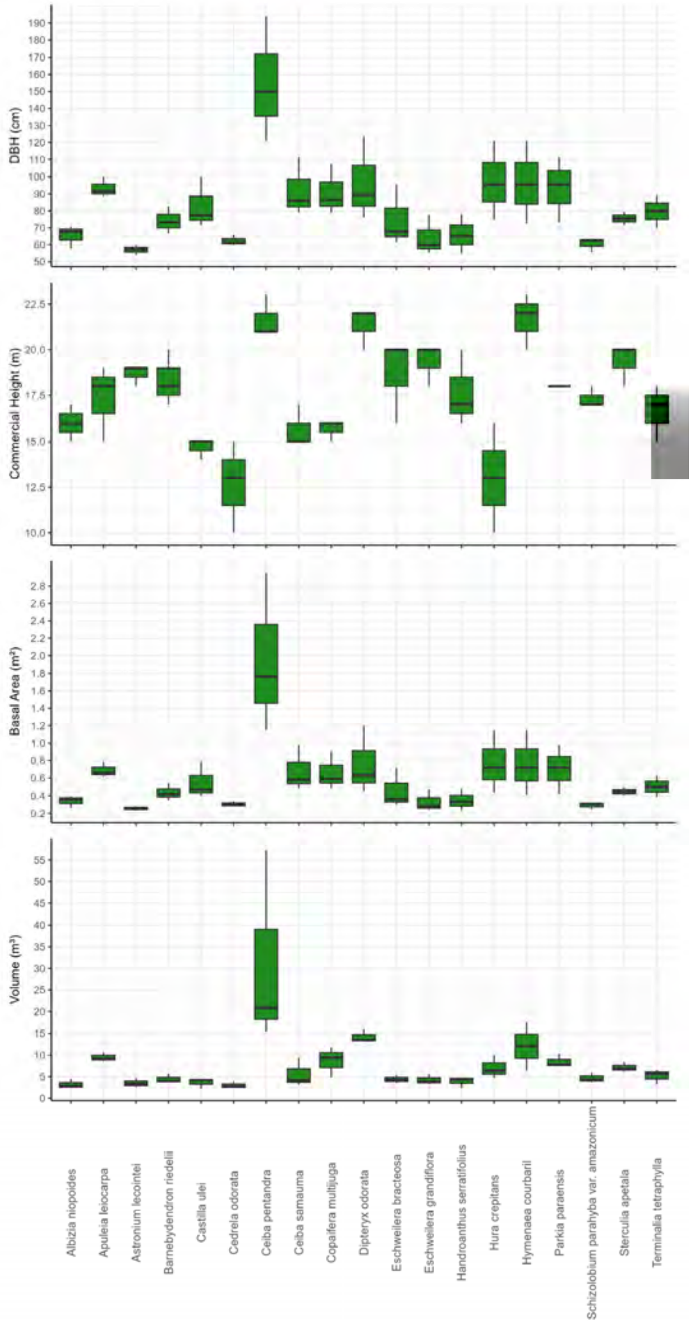

Figure 2. Variability of diameter at breast height (DBH) in cm, commercial height in m, basal area in m^2 and volume in m^3 in the commercial boles of 19 forest species.

The first graph, referring to DBH in cm, indicates that most species have median values between 50 and 100 cm. Some species, such as *Ceiba pentandra* and *Hura crepitans*, stand out with significantly higher DBH values. The dispersion within certain species, shows a considerable variation in tree size.

The second graph, referring to commercial height in m, shows that most species have commercial heights ranging from 10 to 20 m. *Ceiba pentandra* has the highest commercial height, exceeding 20 m. The variation in commercial height among species reflects the heterogeneity in timber utilization, directly influencing management and exploitation decisions.

The third and fourth graphs, which represent basal area and volume, respectively, show that species such as *Ceiba pentandra* contribute significantly to the total biomass of the forest stand. The high volumes of these species indicate their commercial potential, while the lower variability in smaller species suggests a more limited contribution to timber production. These metrics are essential for forest management, allowing the identification of key species for conservation and exploitation.

3.2. Variation in Carbon Content of the Commercial Bole Among Species

The Shapiro–Wilk normality test was conducted to assess the distribution of data across the species, and the results confirmed that all species exhibited normal distributions, with *p*-values greater than 0.05. An analysis of variance (ANOVA) was conducted to examine the differences in mean carbon content in the commercial boles of the 19 tree species.

The ANOVA revealed significant variations in carbon content among tree families, as detailed in Table 2, emphasizing the differences in carbon storage potential at the family level. The total sum of squares was 50.80, with 25.4 attributed to family differences and an equal amount (25.4) to residuals. The family variation had 8 degrees of freedom while the residuals had 48 degrees of freedom. The mean square for family was 3.18, substantially greater than that of the residuals (0.53), leading to an F value of 6.001. This result indicated a highly significant difference in mean carbon content among the families ($p < 0.0001$).

Table 2. ANOVA for differences in carbon content in commercial boles among 9 tree families.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	*p*-Value
Families	25.4	8	3.18	6.001	<0.0001
Residuals	25.4	48	0.53		
Total	50.8	56			

Expanding this analysis to species-level differences (Table 3), the ANOVA results further highlighted the diversity in carbon storage capabilities. The total sum of squares remained 50.80, but 41.91 was attributed to species and only 8.89 to residuals. The species variation had 18 degrees of freedom, while the residuals had 38 degrees of freedom. The mean square for species was 2.33, substantially higher than the mean square of the residuals, which was 0.23. The calculated F value for this analysis was 9.954, demonstrating a highly significant difference in mean carbon content among the species ($p < 0.0001$). These findings underscore the importance of species-specific characteristics in conservation strategies.

Table 3. ANOVA for differences in carbon content in commercial boles among 19 tree species.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	*p*-Value
Species	41.91	18	2.33	9.954	<0.0001
Residuals	8.89	38	0.23		
Total	50.80	56			

Comparison Between Species Using Tukey's Post Hoc Test and Eta-Squared (η^2)

To complement the analysis of variance (ANOVA), Tukey's post hoc test was conducted to compare the mean carbon contents among the 19 species. The objective was to identify which pairs of species exhibit significant differences in their carbon content. The results of Tukey's test reveal significant differences between several pairs of species (Table 4). The comparisons presented in Table 4 include only those that showed statistically significant differences, with pairs displaying a *p*-value below 0.05, which indicates significant variability in carbon content among the species. The most substantial difference was observed between *Handroanthus serratifolius* and *Ceiba pentandra*, with a highly significant *p*-value of less than 0.0001. Conversely, species such as *Barnebydendron riedellii* and *Ceiba samauma* did not exhibit statistically significant differences in carbon content, as shown by their higher *p*-values. For a comprehensive overview of all species comparisons, including those that did not exhibit significant differences, readers are directed to consult the complete table available in the Supplementary Materials (Table S1).

Table 4. Tukey's post hoc test results for species comparisons.

No.	Species Comparison *	Mean Difference	L.L.	U.L.	*p*-Value
1	*Handroanthus serratifolius* vs. *Ceiba pentandra*	2.71	1.22	4.20	<0.0001
2	*Dipteryx odorata* vs. *Ceiba pentandra*	2.52	1.03	4.01	<0.0001
3	*Copaifera multijuga* vs. *Ceiba pentandra*	2.43	0.94	3.92	<0.0001
4	*Handroanthus serratifolius* vs. *Ceiba samauma*	2.34	0.85	3.83	<0.0001
5	*Astronium lecointei* vs. *Albizia niopoides*	2.33	0.84	3.82	0.0001
6	*Handroanthus serratifolius* vs. *Albizia niopoides*	2.29	0.80	3.78	0.0001
7	*Handroanthus serratifolius* vs. *Barnebydendron riedelii*	2.23	0.74	3.72	0.0002
8	*Dipteryx odorata* vs. *Ceiba samauma*	2.15	0.66	3.64	0.0004
9	*Cedrela odorata* vs. *Albizia niopoides*	2.10	0.61	3.59	0.0007
10	*Dipteryx odorata* vs. *Albizia niopoides*	2.10	0.61	3.59	0.0007
11	*Copaifera multijuga* vs. *Ceiba samauma*	2.06	0.57	3.55	0.0009
12	*Cedrela odorata* vs. *Barnebydendron riedelii*	2.03	0.54	3.52	0.0011
13	*Dipteryx odorata* vs. *Barnebydendron riedelii*	2.03	0.54	3.52	0.0011
14	*Copaifera multijuga* vs. *Albizia niopoides*	2.01	0.52	3.50	0.0013
15	*Copaifera multijuga* vs. *Barnebydendron riedelii*	1.94	0.45	3.43	0.0021
16	*Handroanthus serratifolius* vs. *Castilla ulei*	1.76	0.27	3.25	0.0081
17	*Hymenaea courbaril* vs. *Ceiba pentandra*	1.59	0.10	3.08	0.0260
18	*Cedrela odorata* vs. *Castilla ulei*	1.57	0.08	3.06	0.0304
19	*Dipteryx odorata* vs. *Castilla ulei*	1.57	0.08	3.06	0.0304
20	*Apuleia leiocarpa* vs. *Albizia niopoides*	1.55	0.06	3.04	0.0346

Where lower limit (LL) and upper limit (UL); * for a comprehensive view of all species comparisons, including those without sig-nificant differences, refer to the complete table provided in the Supplementary Materials (Table S1).

The eta-squared (η^2) for the ANOVA is 0.83, indicating a large effect, meaning that 83% of the variability in carbon content is explained by the differences between species. These results indicate that there are statistically significant differences between the mean carbon contents of the species, with some species having means distinctly different from others. The confidence intervals provide plausible ranges for the true population means of the species (Table 1).

3.3. Variability of Carbon Content Along the Commercial Boles

Figure 3 demonstrates the variability in carbon content across four vertical sections (labeled A, B, C, and D) of commercial tree trunks from 19 tree species. Each line represents a different species, illustrating the vertical variation in carbon content within the stem. Notably, species such as *Ceiba pentandra* show a significant increase in carbon content from one section to the next, highlighting their unique pattern of carbon accumulation. In contrast, other species exhibit more stable or less pronounced trends in carbon content changes along the stem. This line graph is employed to clearly depict trends and differences in carbon content, making it easier to observe both general and species-specific patterns. The lines allow for direct visual comparison of carbon content across different sections and across species, effectively capturing the dynamics of carbon distribution within tree trunks.

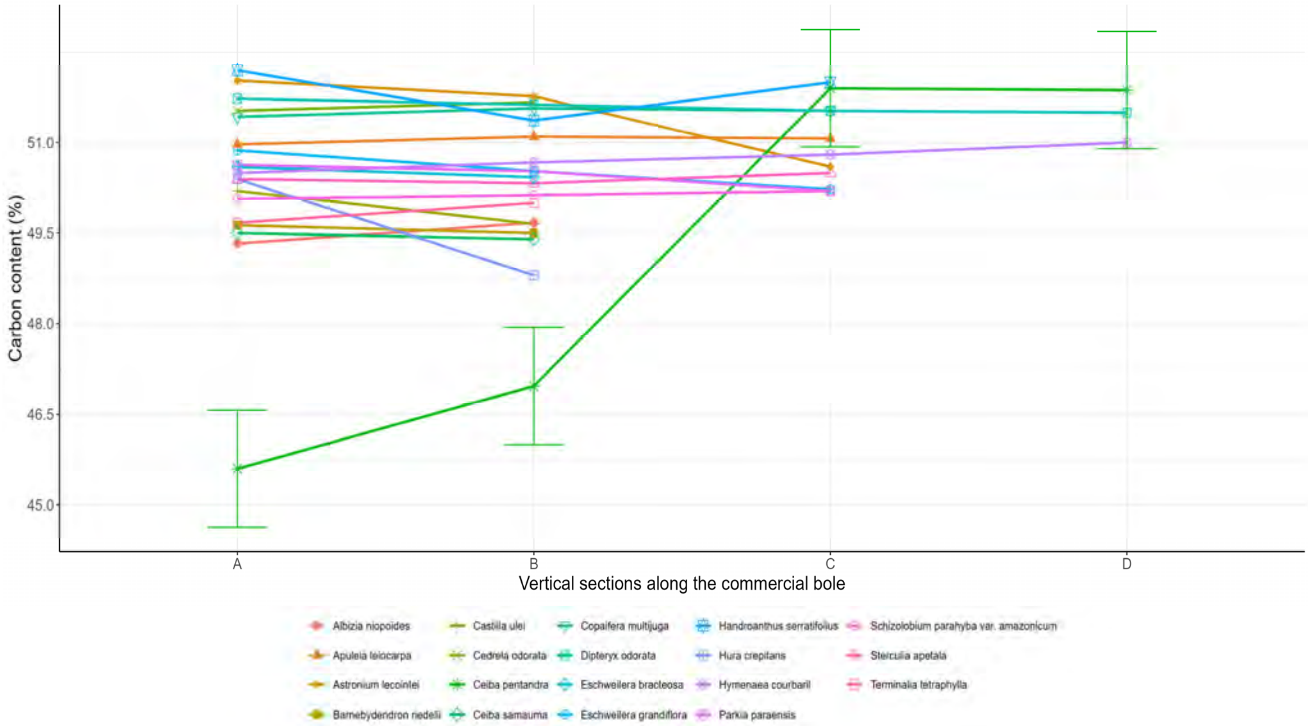

Figure 3. Variability of carbon content along the commercial boles of 19 forest species.

Figure 4 shows the variation in carbon content (%) in five vertical sections of the commercial trunk of the trees analyzed, identified as A, B, C and D. The figure illustrates the distribution of carbon values in each section. The vertical sections are displayed on the x-axis, while the y-axis represents the carbon content in percentage, varying from 43.5% to 52.9%. In sections A and B, the trees show similar behavior, with medians close to 50.5% and relatively wide interquartile ranges. The presence of a value in section A for one species that is far below the values for other species, indicates the existence of local variability in carbon content. Section D presents a more consistent behavior, with a narrower interquartile range and a median of 51.3%. This smaller variation suggests greater uniformity in the distribution of carbon in the upper parts of the stem, indicating a stabilization in the wood composition.

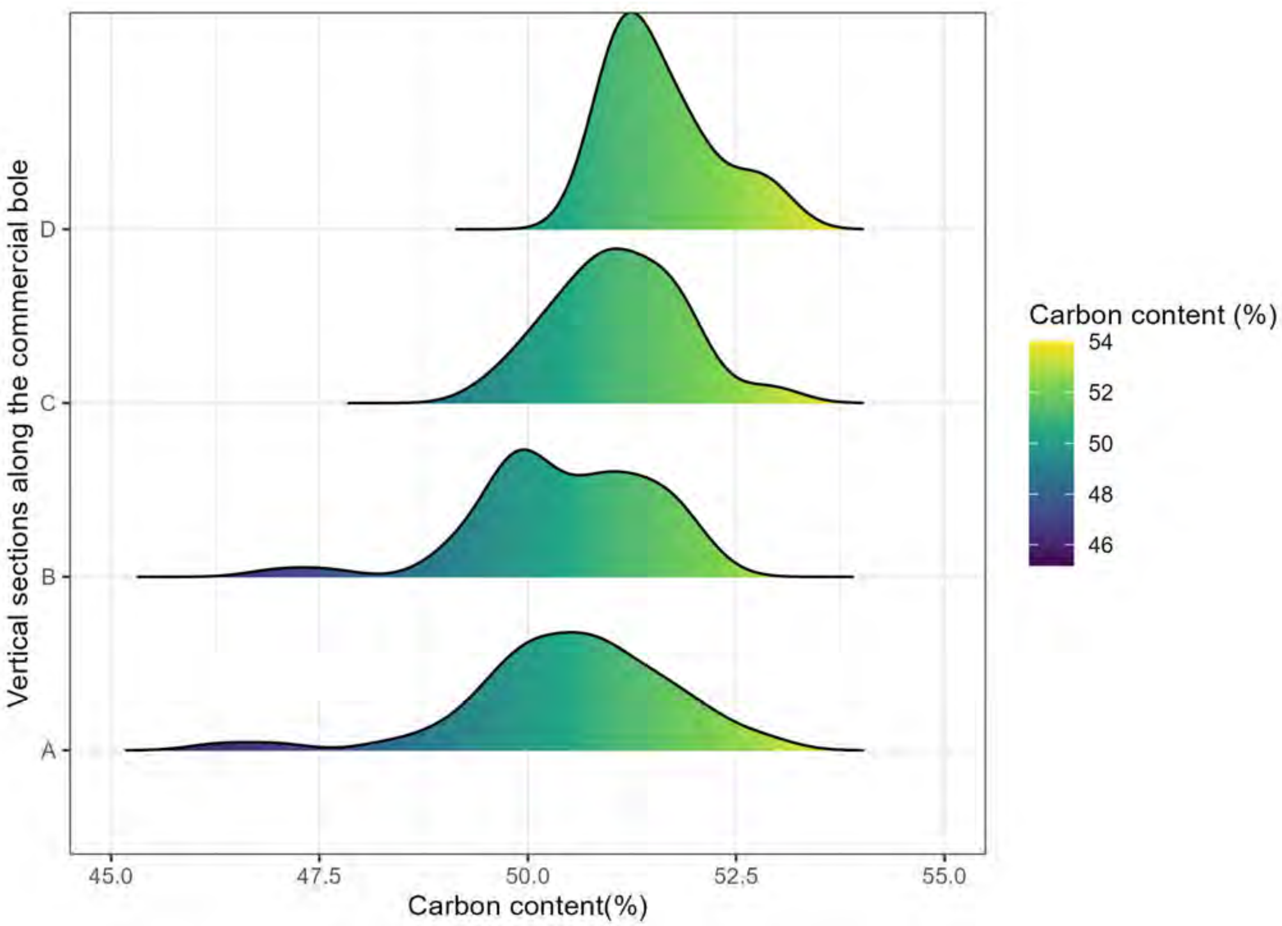

Figure 4. Variability of carbon content in sections A, B, C and D in commercial boles of 19 forest species.

4. Discussion

In this study, a detailed analysis of carbon content was conducted across 57 large trees, encompassing nine families, seventeen genera, and nineteen species. The observed carbon content variation in the commercial boles of these trees ranged significantly from 49.08% to 51.81%, with an overall average of 50.48%. *Handroanthus serratifolius* stood out with the highest carbon content at 51.81%, followed by *Astronium lecointei*, *Dipteryx odorata*, and *Cedrela odorata*. Therefore, this study highlights the biological diversity and variability in carbon sequestration capacity among the species, suggesting that forest management and conservation strategies should consider these differences to optimize carbon sequestration [49].

The 95% confidence intervals for each species provide important insights into the precision of carbon estimates. For example, for *Ceiba pentandra*, the confidence interval ranged from 47.18% to 50.98%, indicating high certainty that the true average carbon content of this species lies within this range [50]. Narrower confidence intervals reflect greater credibility in average estimates, while wider intervals indicate greater variability in the data and, consequently, more uncertainty in the estimates [51].

Variations in carbon content among different species underscore the complexity of carbon management in tropical forests and the importance of approaches tailored to the specific characteristics of each species [52,53]. This biological diversity must be considered when developing strategies for forest management, ensuring that the carbon sequestration potential of each species is fully utilized [54]. Additionally, the data obtained reinforce the need for policies based on solid scientific evidence to maximize the effectiveness of conservation and forest management initiatives.

4.1. Variability in Biomass and Its Contribution to Timber Production

The variability observed in the physical dimensions of the trees, as evidenced by results for diameter at breast height (DBH), commercial height, basal area, and volume, has significant implications for sustainable forest management. Trees with larger DBH and commercial height, such as *Ceiba pentandra* and *Hura crepitans*, not only indicate maturity and structural stability but also possess a high potential for carbon storage due to their large biomass. These characteristics make them crucial for management strategies aimed at maximizing carbon storage, a key element in combating climate change.

The analysis of basal area and volume shows that certain species contribute significantly to the total biomass of the forest. These trees, due to their high volume, are of substantial commercial interest but are also important for maintaining biodiversity and ecological integrity of the forest. The management of these trees must balance timber production with environmental conservation, ensuring that extraction does not compromise the forest's regenerative capacity [55].

Specific species, such as *Ceiba pentandra*, stand out not only for their larger diameters, greater heights, and significant volumes but also for demonstrating a substantial increase in carbon content from one section to the next. This reflects a specialized adaptation to optimize light capture and photosynthetic efficiency in the canopy [56,57]. Conversely, other species, such as *Handroanthus serratifolius*, although exhibiting a similar pattern of carbon content increase, have smaller diameters and lower heights, resulting in smaller volumes but with higher carbon content than *Ceiba pentandra*.

The accumulation in the upper parts of the trunk indicates an effective carbon storage strategy, important for regulating the carbon cycle in the ecosystem. This characteristic is particularly important, considering that the 19 species analyzed exhibit various carbon storage strategies, influenced by their physical dimensions and adapted to their specific ecological conditions [58,59]. Understanding these differences is essential for developing forest management practices that respect the unique characteristics of each species, optimizing both timber production and carbon storage.

4.2. Variability of Carbon Content Along the Commercial Boles Among Species

The analysis of variance (ANOVA) highlighted significant variations in carbon content among the studied species, emphasizing the diversity in their carbon storage capabilities. The marked differences between species, indicated by an F value of 9.954 and $p < 0.0001$, not only highlight biological heterogeneity but also have significant implications for forest resource management and conservation policy formulation [60].

The Tukey post hoc test identified significant differences in carbon content between pairs of species, providing essential insights for forest management. For example, the notable difference between *Handroanthus serratifolius* and *Ceiba pentandra* suggests that specific management strategies may be needed to optimize carbon storage in the forest for these species. The high eta-squared value ($\eta^2 = 0.83$) reveals that most of the variability in carbon content is explained by differences between species, highlighting the importance of carbon models that integrate this specific variability to refine carbon estimates.

Figures 3 and 4 illustrate the variability of carbon content along different vertical sections of the commercial boles of various tree species, revealing distinct patterns of carbon accumulation. These patterns are crucial for understanding the dynamics of carbon storage in forests and their implications for forest management and conservation strategies.

The observed variability in vertical sections of the boles indicates that carbon stock estimates that overlook this variability might significantly underestimate the amount of carbon stored. This underscores the need for carbon stock models that incorporate detailed data from different parts of the trees to enhance the accuracy of estimates.

Understanding these patterns of carbon accumulation can guide forest management strategies, particularly in selecting species and harvesting practices that consider the carbon storage profile of the trees. Strategies that preserve parts of the trunk with higher carbon content can increase carbon retention in the system, significantly contributing to climate change mitigation.

The consistency observed in section D, with less variability, suggests that the wood composition stabilizes in the upper parts of the trunk, an important consideration for management strategies focused on the use of specific parts of the tree for different commercial purposes. It may also indicate that the younger parts of the trunk, which generally grow more rapidly, might play a less significant role in carbon storage compared to the lower parts.

This point is corroborated by a review by Ma et al. [17], who calculated an average carbon content of 47.9% in tree trunks on a global scale, a value lower than that for any species we studied in southwestern Amazonia. In contrast, a study near Manaus (in central Amazonia) conducted by da Silva ([61], p. 61) reported an average carbon content of 48.5% (±0.3%) in the trunks of 44 trees, suggesting that carbon values can vary significantly between different regions of the Amazon, although both studies in the Amazon show higher carbon content than the 47% IPCC (Intergovernmental Panel on Climate Change) default value [62].

4.3. Implications for Climate Change Policies and Forest Management

Substantial variations in carbon content among species underscore the urgent need to adapt forest management practices and conservation strategies to optimize carbon sequestration. Incorporating detailed knowledge of each species' unique characteristics into land use and conservation policies can significantly enhance the management of forest resources, boosting the contribution of forests in combating climate change.

The carbon content data collected provide a fundamental basis for future research into species' adaptive responses in forest management areas, particularly in scenarios where trees undergo cutting and regeneration cycles ranging from 20 to 30 years [63]. Each species uniquely contributes to the biodiversity and ecological functionality of forests, and harvesting these trees can result in the loss of critical ecological functions.

The study highlights concerns about the vulnerability of species in managed areas, exemplified by mahogany (*Swietenia macrophylla*), which is banned from exploitation in Brazil due to its threatened status. Similarly, garapeira (*Apuleia leiocarpa*), despite its abundance in study areas, is classified as vulnerable, emphasizing the urgent need for its conservation to prevent extinction [63]. Human exploitation has globally accelerated species extinction, with events that would naturally occur once in periods of millennia recurring in just a few decades [64–66]. This acceleration not only threatens the survival of species like garapeira but also compromises the ecological integrity of their habitats.

Previous research shows that the overexploitation of key species, particularly commercial large trees that store significant amounts of carbon, results in significant ecological imbalances. By extracting the trunk and leaving only the crown and stump, the forest loses regenerative capacity [67]. This underscores the need to develop conservation strategies that not only quantify but also enhance the ecological quality of regeneration. Such strategies should focus on replenishing carbon stocks and recovering ecological diversity.

Reviewing carbon estimates based on local studies is crucial, especially considering the significant impact of deforestation in the Amazon on global emissions. The data collected in this study reveal a notable discrepancy between the mean carbon content of the analyzed species, at 50.48%, and the standard value of 47% used by the IPCC [62]. This difference is particularly relevant in forest management areas, where large trees with higher basic densities (hardwood) predominate, which are directly related to biomass stocks [47,68].

To put this in perspective, the difference between the average carbon content of the 19 tree species we studied (50.48) and the IPCC standard value of 47% used in Brazil's most recent climate communication ([69], p. 161) implies 7.40% higher emissions from deforestation, or an increase of 29.42 $TgCO_2e$ (8.02 TgC) above the 397.4 $TgCO_2e$ reported in the last inventory year (2016) ([69], p. 12). The entire energy sector of Brazil, including all fossil fuel use for vehicles and electricity generation, emitted 423.6 $TgCO_2e$ in 2016 ([70], p. 12). The metropolitan area of São Paulo, the fourth largest city in the world, represents 10% of Brazil's population and approximately this percentage of its energy emissions, meaning the implicit underestimation of annual deforestation emissions due to the Amazon forest's carbon content represents approximately 68% of São Paulo's energy emissions. This merely illustrates the scale of the problem, as 19 species are insufficient to adequately characterize the Amazon Forest. However, disregarding differences in carbon content may compromise the accuracy of estimates of carbon stocks and the impact of degradation and loss of Amazon Forest on global climate.

5. Conclusions

This study has detailed the variability in carbon content among different tree species in the Amazon, revealing significant differences that could influence forest management strategies and climate change policies. We observed that the mean carbon content (50.48%) across the 19 species studied is higher than the IPCC's standard value of 47%, suggesting that previous estimates of carbon stocks in the Amazon might have been underestimated. This finding is crucial as it implies that current policies based on standard values may not be robust enough to capture the real contribution of tropical forests in carbon storage and climate change mitigation.

The diversity in carbon storage capacity among species underscores the need to develop forest management models that consider the specific characteristics of each species to maximize carbon storage potential. Additionally, the observed variability suggests that standard management practices may not be suitable for all species, reinforcing the importance of tailored approaches to conservation and forest management.

For the future, we recommend conducting further studies to explore more deeply the intra- and interspecific variability in carbon content in other regions of the Amazon. This will help refine carbon estimates further and develop more effective management strategies that align with global sustainability and environmental conservation goals. Finally, this study not only contributes to the scientific understanding of carbon storage in tropical forests but also provides practical insights for forest management and conservation policies that are essential for combating climate change on a global scale.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su17072960/s1, Table S1. Tukey's Post-Hoc test results for species comparisons.

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SUPPLEMENTARY MATERIAL

Carbon Content of Amazonian Commercial Tree Boles: Implications for Forest Management

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Table S1. Tukey's Post-Hoc test results for species comparisons

No.	Species Comparison	Mean Difference	L.L.	U.L.	p-value
1	*Apuleia leiocarpa* vs. *Albizia niopoides*	1.55	0.06	3.04	0.0346
2	*Astronium lecointei* vs. *Albizia niopoides*	2.33	0.84	3.82	0.0001
3	*Barnebydendron riedelii* vs. *Albizia niopoides*	0.07	-1.42	1.56	1.0000
4	*Castilla ulei* vs. *Albizia niopoides*	0.53	-0.96	2.02	0.9963
5	*Cedrela odorata* vs. *Albizia niopoides*	2.10	0.61	3.59	0.0007
6	*Ceiba pentandra* vs. *Albizia niopoides*	-0.42	-1.91	1.07	0.9998
7	*Ceiba samauma* vs. *Albizia niopoides*	-0.05	-1.54	1.44	1.0000
8	*Copaifera multijuga* vs. *Albizia niopoides*	2.01	0.52	3.50	0.0013
9	*Dipteryx odorata* vs. *Albizia niopoides*	2.10	0.61	3.59	0.0007
10	*Eschweilera bracteosa* vs. *Albizia niopoides*	1.02	-0.47	2.51	0.5178
11	*Eschweilera grandiflora* vs. *Albizia niopoides*	1.04	-0.45	2.53	0.4730
12	*Handroanthus serratifolius* vs. *Albizia niopoides*	2.29	0.80	3.78	0.0001
13	*Hura crepitans* vs. *Albizia niopoides*	0.02	-1.47	1.51	1.0000
14	*Hymenaea courbaril* vs. *Albizia niopoides*	1.17	-0.32	2.66	0.2845
15	*Parkia paraensis* vs. *Albizia niopoides*	1.04	-0.45	2.53	0.4785
16	*Schizolobium parahyba var. amazonicum* vs. *Albizia niopoides*	0.62	-0.87	2.11	0.9830
17	*Sterculia apetala* vs. *Albizia niopoides*	0.92	-0.57	2.41	0.6768
18	*Terminalia tetraphylla* vs. *Albizia niopoides*	0.33	-1.16	1.82	1.0000
19	*Astronium lecointei* vs. *Apuleia leiocarpa*	0.78	-0.71	2.27	0.8788
20	*Barnebydendron riedelii* vs. *Apuleia leiocarpa*	-1.48	-2.97	0.01	0.0528
21	*Castilla ulei* vs. *Apuleia leiocarpa*	-1.01	-2.50	0.48	0.5234
22	*Cedrela odorata* vs. *Apuleia leiocarpa*	0.55	-0.94	2.04	0.9945
23	*Ceiba pentandra* vs. *Apuleia leiocarpa*	-1.97	-3.46	-0.48	0.0018
24	*Ceiba samauma* vs. *Apuleia leiocarpa*	-1.60	-3.09	-0.11	0.0249
25	*Copaifera multijuga* vs. *Apuleia leiocarpa*	0.46	-1.03	1.95	0.9993
26	*Dipteryx odorata* vs. *Apuleia leiocarpa*	0.55	-0.94	2.04	0.9945
27	*Eschweilera bracteosa* vs. *Apuleia leiocarpa*	-0.53	-2.02	0.96	0.9966
28	*Eschweilera grandiflora* vs. *Apuleia leiocarpa*	-0.50	-1.99	0.99	0.9981
29	*Handroanthus serratifolius* vs. *Apuleia leiocarpa*	0.75	-0.74	2.24	0.9114
30	*Hura crepitans* vs. *Apuleia leiocarpa*	-1.53	-3.02	-0.04	0.0385
31	*Hymenaea courbaril* vs. *Apuleia leiocarpa*	-0.38	-1.87	1.11	1.0000
32	*Parkia paraensis* vs. *Apuleia leiocarpa*	-0.51	-2.00	0.98	0.9980
33	*Schizolobium parahyba var. amazonicum* vs. *Apuleia leiocarpa*	-0.93	-2.42	0.56	0.6657
34	*Sterculia apetala* vs. *Apuleia leiocarpa*	-0.62	-2.11	0.87	0.9811
35	*Terminalia tetraphylla* vs. *Apuleia leiocarpa*	-1.21	-2.70	0.28	0.2326
36	*Barnebydendron riedelii* vs. *Astronium lecointei*	-2.26	-3.75	-0.77	0.0002
37	*Castilla ulei* vs. *Astronium lecointei*	-1.79	-3.28	-0.30	0.0064
38	*Cedrela odorata* vs. *Astronium lecointei*	-0.23	-1.72	1.26	1.0000
39	*Ceiba pentandra* vs. *Astronium lecointei*	-2.75	-4.24	-1.26	<0.0001
40	*Ceiba samauma* vs. *Astronium lecointei*	-2.38	-3.87	-0.89	<0.0001
41	*Copaifera multijuga* vs. *Astronium lecointei*	-0.32	-1.81	1.17	1.0000
42	*Dipteryx odorata* vs. *Astronium lecointei*	-0.23	-1.72	1.26	1.0000
43	*Eschweilera bracteosa* vs. *Astronium lecointei*	-1.31	-2.80	0.18	0.1421
44	*Eschweilera grandiflora* vs. *Astronium lecointei*	-1.28	-2.77	0.21	0.1637

45	*Handroanthus serratifolius* vs. *Astronium lecointei*	-0.03	-1.52	1.46	1.0000
46	*Hura crepitans* vs. *Astronium lecointei*	-2.31	-3.80	-0.82	0.0001
47	*Hymenaea courbaril* vs. *Astronium lecointei*	-1.16	-2.65	0.33	0.3019
48	*Parkia paraensis* vs. *Astronium lecointei*	-1.29	-2.78	0.20	0.1609
49	*Schizolobium parahyba var. amazonicum* vs. *Astronium lecointei*	-1.71	-3.20	-0.22	0.0115
50	*Sterculia apetala* vs. *Astronium lecointei*	-1.40	-2.89	0.09	0.0840
51	*Terminalia tetraphylla* vs. *Astronium lecointei*	-1.99	-3.48	-0.50	0.0015
52	*Castilla ulei* vs. *Barnebydendron riedelii*	0.47	-1.02	1.96	0.9993
53	*Cedrela odorata* vs. *Barnebydendron riedelii*	2.03	0.54	3.52	0.0011
54	*Ceiba pentandra* vs. *Barnebydendron riedelii*	-0.49	-1.98	1.00	0.9987
55	*Ceiba samauma* vs. *Barnebydendron riedelii*	-0.12	-1.61	1.37	1.0000
56	*Copaifera multijuga* vs. *Barnebydendron riedelii*	1.94	0.45	3.43	0.0021
57	*Dipteryx odorata* vs. *Barnebydendron riedelii*	2.03	0.54	3.52	0.0011
58	*Eschweilera bracteosa* vs. *Barnebydendron riedelii*	0.95	-0.54	2.44	0.6319
59	*Eschweilera grandiflora* vs. *Barnebydendron riedelii*	0.98	-0.51	2.47	0.5862
60	*Handroanthus serratifolius* vs. *Barnebydendron riedelii*	2.23	0.74	3.72	0.0002
61	*Hura crepitans* vs. *Barnebydendron riedelii*	-0.05	-1.54	1.44	1.0000
62	*Hymenaea courbaril* vs. *Barnebydendron riedelii*	1.10	-0.39	2.59	0.3776
63	*Parkia paraensis* vs. *Barnebydendron riedelii*	0.97	-0.52	2.46	0.5920
64	*Schizolobium parahyba var. amazonicum* vs. *Barnebydendron riedelii*	0.55	-0.94	2.04	0.9948
65	*Sterculia apetala* vs. *Barnebydendron riedelii*	0.86	-0.63	2.35	0.7814
66	*Terminalia tetraphylla* vs. *Barnebydendron riedelii*	0.27	-1.22	1.76	1.0000
67	*Cedrela odorata* vs. *Castilla ulei*	1.57	0.08	3.06	0.0304
68	*Ceiba pentandra* vs. *Castilla ulei*	-0.95	-2.44	0.54	0.6262
69	*Ceiba samauma* vs. *Castilla ulei*	-0.58	-2.07	0.91	0.9903
70	*Copaifera multijuga* vs. *Castilla ulei*	1.48	-0.01	2.97	0.0539
71	*Dipteryx odorata* vs. *Castilla ulei*	1.57	0.08	3.06	0.0304
72	*Eschweilera bracteosa* vs. *Castilla ulei*	0.48	-1.01	1.97	0.9988
73	*Eschweilera grandiflora* vs. *Castilla ulei*	0.51	-0.98	2.00	0.9978
74	*Handroanthus serratifolius* vs. *Castilla ulei*	1.76	0.27	3.25	0.0081
75	*Hura crepitans* vs. *Castilla ulei*	-0.52	-2.01	0.97	0.9974
76	*Hymenaea courbaril* vs. *Castilla ulei*	0.64	-0.85	2.13	0.9769
77	*Parkia paraensis* vs. *Castilla ulei*	0.51	-0.98	2.00	0.9980
78	*Schizolobium parahyba var. amazonicum* vs. *Castilla ulei*	0.08	-1.41	1.57	1.0000
79	*Sterculia apetala* vs. *Castilla ulei*	0.39	-1.10	1.88	0.9999
80	*Terminalia tetraphylla* vs. *Castilla ulei*	-0.20	-1.69	1.29	1.0000
81	*Ceiba pentandra* vs. *Cedrela odorata*	-2.52	-4.01	-1.03	<0.0001
82	*Ceiba samauma* vs. *Cedrela odorata*	-2.15	-3.64	-0.66	0.0004
83	*Copaifera multijuga* vs. *Cedrela odorata*	-0.09	-1.58	1.40	1.0000
84	*Dipteryx odorata* vs. *Cedrela odorata*	0.00	-1.49	1.49	1.0000
85	*Eschweilera bracteosa* vs. *Cedrela odorata*	-1.08	-2.57	0.41	0.4084
86	*Eschweilera grandiflora* vs. *Cedrela odorata*	-1.06	-2.55	0.43	0.4510
87	*Handroanthus serratifolius* vs. *Cedrela odorata*	0.19	-1.30	1.68	1.0000
88	*Hura crepitans* vs. *Cedrela odorata*	-2.08	-3.57	-0.59	0.0007
89	*Hymenaea courbaril* vs. *Cedrela odorata*	-0.93	-2.42	0.56	0.6657
90	*Parkia paraensis* vs. *Cedrela odorata*	-1.06	-2.55	0.43	0.4456

91	*Schizolobium parahyba var. amazonicum* vs. *Cedrela odorata*	-1.48	-2.97	0.01	0.0517
92	*Sterculia apetala* vs. *Cedrela odorata*	-1.18	-2.67	0.31	0.2761
93	*Terminalia tetraphylla* vs. *Cedrela odorata*	-1.77	-3.26	-0.28	0.0077
94	*Ceiba samauma* vs. *Ceiba pentandra*	0.37	-1.12	1.86	1.0000
95	*Copaifera multijuga* vs. *Ceiba pentandra*	2.43	0.94	3.92	<0.0001
96	*Dipteryx odorata* vs. *Ceiba pentandra*	2.52	1.03	4.01	<0.0001
97	*Eschweilera bracteosa* vs. *Ceiba pentandra*	1.44	-0.05	2.93	0.0688
98	*Eschweilera grandiflora* vs. *Ceiba pentandra*	1.46	-0.03	2.95	0.0585
99	*Handroanthus serratifolius* vs. *Ceiba pentandra*	2.71	1.22	4.20	<0.0001
100	*Hura crepitans* vs. *Ceiba pentandra*	0.44	-1.05	1.93	0.9997
101	*Hymenaea courbaril* vs. *Ceiba pentandra*	1.59	0.10	3.08	0.0260
102	*Parkia paraensis* vs. *Ceiba pentandra*	1.46	-0.03	2.95	0.0597
103	*Schizolobium parahyba var. amazonicum* vs. *Ceiba pentandra*	1.04	-0.45	2.53	0.4841
104	*Sterculia apetala* vs. *Ceiba pentandra*	1.34	-0.15	2.83	0.1184
105	*Terminalia tetraphylla* vs. *Ceiba pentandra*	0.75	-0.74	2.24	0.9054
106	*Copaifera multijuga* vs. *Ceiba samauma*	2.06	0.57	3.55	0.0009
107	*Dipteryx odorata* vs. *Ceiba samauma*	2.15	0.66	3.64	0.0004
108	*Eschweilera bracteosa* vs. *Ceiba samauma*	1.07	-0.42	2.56	0.4348
109	*Eschweilera grandiflora* vs. *Ceiba samauma*	1.09	-0.40	2.58	0.3928
110	*Handroanthus serratifolius* vs. *Ceiba samauma*	2.34	0.85	3.83	<0.0001
111	*Hura crepitans* vs. *Ceiba samauma*	0.07	-1.42	1.56	1.0000
112	*Hymenaea courbaril* vs. *Ceiba samauma*	1.22	-0.27	2.71	0.2253
113	*Parkia paraensis* vs. *Ceiba samauma*	1.09	-0.40	2.58	0.3980
114	*Schizolobium parahyba var. amazonicum* vs. *Ceiba samauma*	0.67	-0.82	2.16	0.9648
115	*Sterculia apetala* vs. *Ceiba samauma*	0.97	-0.52	2.46	0.5920
116	*Terminalia tetraphylla* vs. *Ceiba samauma*	0.38	-1.11	1.87	0.9999
117	*Dipteryx odorata* vs. *Copaifera multijuga*	0.09	-1.40	1.58	1.0000
118	*Eschweilera bracteosa* vs. *Copaifera multijuga*	-0.99	-2.48	0.50	0.5576
119	*Eschweilera grandiflora* vs. *Copaifera multijuga*	-0.97	-2.46	0.52	0.6034
120	*Handroanthus serratifolius* vs. *Copaifera multijuga*	0.28	-1.21	1.77	1.0000
121	*Hura crepitans* vs. *Copaifera multijuga*	-1.99	-3.48	-0.50	0.0015
122	*Hymenaea courbaril* vs. *Copaifera multijuga*	-0.84	-2.33	0.65	0.8050
123	*Parkia paraensis* vs. *Copaifera multijuga*	-0.97	-2.46	0.52	0.5977
124	*Schizolobium parahyba var. amazonicum* vs. *Copaifera multijuga*	-1.39	-2.88	0.10	0.0890
125	*Sterculia apetala* vs. *Copaifera multijuga*	-1.09	-2.58	0.40	0.4031
126	*Terminalia tetraphylla* vs. *Copaifera multijuga*	-1.68	-3.17	-0.19	0.0145
127	*Eschweilera bracteosa* vs. *Dipteryx odorata*	-1.08	-2.57	0.41	0.4084
128	*Eschweilera grandiflora* vs. *Dipteryx odorata*	-1.06	-2.55	0.43	0.4510
129	*Handroanthus serratifolius* vs. *Dipteryx odorata*	0.19	-1.30	1.68	1.0000
130	*Hura crepitans* vs. *Dipteryx odorata*	-2.08	-3.57	-0.59	0.0007
131	*Hymenaea courbaril* vs. *Dipteryx odorata*	-0.93	-2.42	0.56	0.6657
132	*Parkia paraensis* vs. *Dipteryx odorata*	-1.06	-2.55	0.43	0.4456
133	*Schizolobium parahyba var. amazonicum* vs. *Dipteryx odorata*	-1.48	-2.97	0.01	0.0517
134	*Sterculia apetala* vs. *Dipteryx odorata*	-1.18	-2.67	0.31	0.2761
135	*Terminalia tetraphylla* vs. *Dipteryx odorata*	-1.77	-3.26	-0.28	0.0077
136	*Eschweilera grandiflora* vs. *Eschweilera bracteosa*	0.03	-1.46	1.52	1.0000

137	*Handroanthus serratifolius* vs. *Eschweilera bracteosa*	1.28	-0.21	2.77	0.1695
138	*Hura crepitans* vs. *Eschweilera bracteosa*	-1.00	-2.49	0.49	0.5462
139	*Hymenaea courbaril* vs. *Eschweilera bracteosa*	0.15	-1.34	1.64	1.0000
140	*Parkia paraensis* vs. *Eschweilera bracteosa*	0.02	-1.47	1.51	1.0000
141	*Schizolobium parahyba var. amazonicum* vs. *Eschweilera bracteosa*	-0.40	-1.89	1.09	0.9999
142	*Sterculia apetala* vs. *Eschweilera bracteosa*	-0.09	-1.58	1.40	1.0000
143	*Terminalia tetraphylla* vs. *Eschweilera bracteosa*	-0.68	-2.17	0.81	0.9564
144	*Handroanthus serratifolius* vs. *Eschweilera grandiflora*	1.25	-0.24	2.74	0.1943
145	*Hura crepitans* vs. *Eschweilera grandiflora*	-1.03	-2.52	0.46	0.5008
146	*Hymenaea courbaril* vs. *Eschweilera grandiflora*	0.13	-1.36	1.62	1.0000
147	*Parkia paraensis* vs. *Eschweilera grandiflora*	0.00	-1.49	1.49	1.0000
148	*Schizolobium parahyba var. amazonicum* vs. *Eschweilera grandiflora*	-0.43	-1.92	1.06	0.9998
149	*Sterculia apetala* vs. *Eschweilera grandiflora*	-0.12	-1.61	1.37	1.0000
150	*Terminalia tetraphylla* vs. *Eschweilera grandiflora*	-0.71	-2.20	0.78	0.9400
151	*Hura crepitans* vs. *Handroanthus serratifolius*	-2.28	-3.77	-0.79	0.0002
152	*Hymenaea courbaril* vs. *Handroanthus serratifolius*	-1.12	-2.61	0.37	0.3481
153	*Parkia paraensis* vs. *Handroanthus serratifolius*	-1.25	-2.74	0.24	0.1911
154	*Schizolobium parahyba var. amazonicum* vs. *Handroanthus serratifolius*	-1.68	-3.17	-0.19	0.0145
155	*Sterculia apetala* vs. *Handroanthus serratifolius*	-1.37	-2.86	0.12	0.1018
156	*Terminalia tetraphylla* vs. *Handroanthus serratifolius*	-1.96	-3.45	-0.47	0.0019
157	*Hymenaea courbaril* vs. *Hura crepitans*	1.15	-0.34	2.64	0.3063
158	*Parkia paraensis* vs. *Hura crepitans*	1.02	-0.47	2.51	0.5065
159	*Schizolobium parahyba var. amazonicum* vs. *Hura crepitans*	0.60	-0.89	2.09	0.9870
160	*Sterculia apetala* vs. *Hura crepitans*	0.91	-0.58	2.40	0.7042
161	*Terminalia tetraphylla* vs. *Hura crepitans*	0.32	-1.17	1.81	1.0000
162	*Parkia paraensis* vs. *Hymenaea courbaril*	-0.13	-1.62	1.36	1.0000
163	*Schizolobium parahyba var. amazonicum* vs. *Hymenaea courbaril*	-0.55	-2.04	0.94	0.9945
164	*Sterculia apetala* vs. *Hymenaea courbaril*	-0.25	-1.74	1.24	1.0000
165	*Terminalia tetraphylla* vs. *Hymenaea courbaril*	-0.84	-2.33	0.65	0.8096
166	*Schizolobium parahyba var. amazonicum* vs. *Parkia paraensis*	-0.42	-1.91	1.07	0.9998
167	*Sterculia apetala* vs. *Parkia paraensis*	-0.12	-1.61	1.37	1.0000
168	*Terminalia tetraphylla* vs. *Parkia paraensis*	-0.71	-2.20	0.78	0.9423
169	*Sterculia apetala* vs. *Schizolobium parahyba var. amazonicum*	0.31	-1.18	1.80	1.0000
170	*Terminalia tetraphylla* vs. *Schizolobium parahyba var. amazonicum*	-0.28	-1.77	1.21	1.0000
171	*Terminalia tetraphylla* vs. *Sterculia apetala*	-0.59	-2.08	0.90	0.9891

Lower Limit (LL) and Upper Limit (UL).