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Acacia canopy structure and carbon stock in Ba Vi, Vietnam

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Abstract: Forest structure is a key component of its management and assessment in every forest ecosystem. In the study, 23 plots were established to obtain data on the acacia forest community based on tree size. Results from the study indicated that the acacia community could be broadly divided into two groups based on tree-size variables. The diameter and height frequency distributions of Group 1 were right-skewed, while those of Group 2 were more complicated. In both groups, there were positive correlations between tree-size variables, nonetheless the relationship between diameter at breast height and total height was best described using the cubic equation. Further, the Weibull and Sinh-Arcsinh (SHASH) best simulated the diameter and height frequency distribution. High-quality trees were found in a large diameter (> 30 cm) and height groups (> 22 m). In contrast, low-quality plants often concentrated on the smallest sizes. Therefore, trees with a diameter of 2–10 cm and a height lower than 8 m should receive attention to tend. Carbon stock in the two groups was 61.48 $Mg \cdot ha^{-1}$ and 64.21 $Mg \cdot ha^{-1}$, respectively. Tending solutions and measurements should be carried out regularly to promptly propose silvicultural measures and improve forest quality in future.

Keywords: *Acacia mangium*; distribution modelling; regression; tree quality

The forest overstorey structure plays a decisive role in managing and assessing forest ecosystems (Haidari et al. 2013). In particular, the forest structure affects the habitat, food supply and other living conditions of plant and animal species. The complex forest structure will create the microclimates, niches and habitats of many species (Pan et al. 2013). It also helps foresters understand and determine the functions of forest ecosystems (Spies 1998; Valbuena 2015). Changing the forest structure will directly af-

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fect biodiversity, erosion control, water availability and forest carbon stock (Gao et al. 2014). Indicators of forest structure, such as tree-size variables, biodiversity, branch arrangement within the canopy and regeneration growth, are considered for sustainable forest management (Valbuena 2015).

The structure of pure plantations is often more straightforward than that of natural forests. In Vietnam, several studies have focused on analysing the structure of acacia forests. Statistical characteristics of diameter and total height frequency distributions, and correlations between diameter and height of acacia forests were investigated in Thai Nguyen, Quang Tri, Ba Ria Vung Tau, Tuyen Quang, Vinh Phuc (Giang 2002; Hien 2014; Hang 2018). However, these studies have not employed multivariate analysis to analyse the structure of overstorey trees. The normal, lognormal, Sinh-Arcsinh (SHASH) and Johnson distributions have never been used to test the acacia diameter frequency distribution in the study area. Analysis of the relationship between the quality of trees and tree-size variables is very limited, and there has yet to be a study analysing the acacia overstorey structure in this regard.

Acacia is a crucial species for plantations and accounts for a large proportion in planting and restoring forests in many ecological regions throughout the country (Nghia 2007). As of 2022, the area of acacia forests is about 2.2 million ha, accounting for about 60% of the total planted forest area in the country (Hai 2022). Therefore, in 2000, the Vietnam Ruminant Breeding Centre planted more than 40 ha of acacia forest, mostly *Acacia mangium*, with good seeding quality. After more than 20 years of tending and management, the acacia forest here has grown well. However, there has not been any study on the structural characteristics of the overstorey, tree quality and biomass conducted here to manage the forest effectively. Therefore, this research was carried out with the aim to (*i*) analyse the overstorey characteristics of *Acacia mangium* in the study area; (*ii*) evaluate the relationship between tree quality and tree-size variables and (*iii*) to estimate biomass and carbon stock of the forest to understand the forest and manage it sustainably in future.

MATERIAL AND METHODS

Study site description

Pure acacia forest at Moncada Company in Ba Vi, Hanoi, Vietnam was selected as the research site. The forest is about 20 years old. The total area of acacia forest is about 40 ha. The study area extends from 233650 to 233750 north latitude and from 540000 to 541500 east longitude (Universal Transverse Mercator coordinate system, zone 48 North) (Figure 1). The topography of the Ba Vi area consists of low hills, with an altitude of 30–120 m a.s.l. The entire study area is covered with ferralitic soils with a medium clay texture. Total annual rainfall is from 1 700 mm to 2 000 mm. The rainy season is from April to October. The dry season is from November to March of the next year. The annual average temperature is within a range of the northern provinces (ranging from 23 °C to 25 °C) (Hai, Bao 2016; Phong 2019).

Data collection methods

In Ba Vi, 23 temporary plots were established with an area of 500 m^2 (20 m × 25 m). The sampling method was a stratified random method. This method is suitable when the forest is not homogeneous (Shiver, Borders 1996). Plot arrangement is indicated in Figure 1.

All acacia trees with diameter at breast height greater than or equal to 3 cm were measured in all plots. For each tree, the study used callipers for measuring diameter at breast height (*DBH*) (the degree of precision was 1 mm); Blume-Leisse hypsometer (Carl Leiss, Germany) for total height (*H*) and commercial height (*C_H*) (the degree of precision was 0.1 m); and measurement tapes for crown width (*C_D*) (the degree of precision was 0.1 m). In which, the total height was the distance from the ground to the uppermost part of the crown. Commercial height was the distance from the ground to the lowest living branch joining the main crown. The research also recorded and classified tree growth quality into 3 classes: good, medium and bad. Good trees were trees with a straight bole, good growth, well-developed crown, no diseases, without truncated tops. Bad trees were trees that were crooked, diseased, with topless boles, weakly developed crown and poor growth. Medium trees were plants with indicators between the good tree and the bad tree (Hoan, Ngu 2003; Zawieja, Kazmierczak 2015).

Data processing methods

Community classification analysis. Hierarchical cluster was used to group plots based on multiple growth variables, such as *DBH*, *H*, *C_H* and

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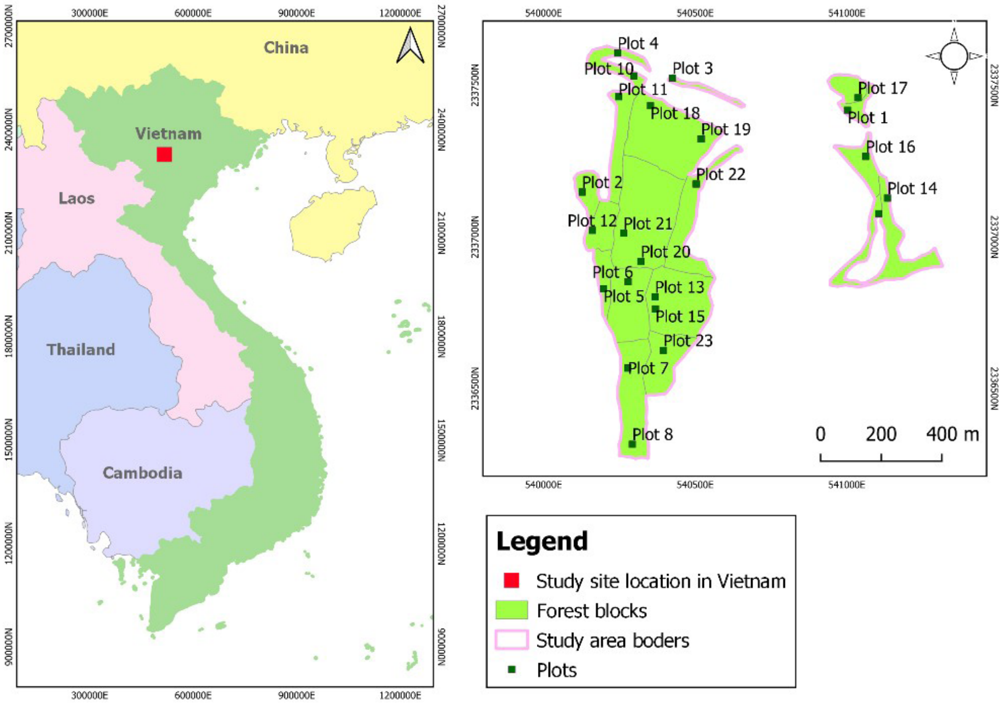

Figure 1. Plot arrangement in the study area

C_D. Clustering methods are based on a matrix of variable values. These methods are appropriate for categorizing communities into more homogeneous groups (McCune, Grace 2002).

Canopy structure analysis. Descriptive statistics were computed to provide information about the tree-size variables datasets. The study used descriptive statistics such as count, minimum, maximum, mean, standard deviation, skewness and kurtosis (Zar 2010). Mixed linear models were used to compare the difference in mean values of measured variables between forest groups. We only checked the fixed effects for fixed variables (forest groups) in the study. The tree-size variables were used as dependent variables in these mixed linear models (West et al. 2015).

Relations between measured variables were analysed using linear regression. The relationship between each pair of variables was analysed. *R*-squared method was used to evaluate the relationship strength between variables. Frequency distributions between the two groups were compared using permutational multivariate analysis of variance (PERMANOVA), as this is a nonlinear method, no assumptions are required (Hamann 2016; Mier 2012).

Six probability distributions were used to find the best one to model the *DBH* and total height frequency distributions, including normal, lognormal, Weibull, exponential, SHASH and Johnson ones. These distributions are continuous with 1–4 parameters (EasyFit Professional software; Version 5.6, 2020). The best distribution was determined based on the *AIC* (Akaike's information criterion) value. The distribution with the smallest *AIC* value was set to be the best distribution.

The *AIC* formula for the least squares case was calculated by the following Equation (1) (Burnham, Anderson 2002).

$$AIC = n \times \ln\left(\frac{RSS}{n}\right) + 2K \tag{1}$$

where:

AIC – Akaike's information criterion;
n – number of observations;
RSS – residual sum of squares;
K – number of parameters in the model.

Cramer-von Mises and Shapiro-Wilk tests were applied to compare the similarity between the experimental frequency and selected theoretical distributions (Laio 2004).

Regression analysis between the *DBH* and total height used 10 models [Equations (2–11)] as follows (Ho 2014; Milios et al. 2016).

$$\text{Linear: } Y = b_1 + b_2 \times X \tag{2}$$

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Logarithmic: $Y = b_1 + [b_2 \times \ln(X)]$ (3)

Inverse: $Y = b_1 + \dfrac{b_2}{X}$ (4)

Quadratic: $Y = b_1 + b_2 \times X + b_3 \times X^2$ (5)

Cubic: $Y = b_1 + b_2 \times X + b_3 \times X^2 + b_4 \times X^3$ (6)

Power: $Y = b_1 \times X^{b_2}$ (7)

Compound: $Y = b_1 \times b_2^X$ (8)

S: $Y = e^{b_1 + \frac{b_2}{X}}$ (9)

Growth: $Y = e^{b_1 + b_2 \times X}$ (10)

Exponential: $Y = b_1 \times e^{b_2 \times X}$ (11)

where:
Y – total height;
b – parameters;
X – diameter at breast height.

The best model was the one with the largest R-squared value (Zar 2010).

Analysis of tree quality and relations with measured variables. The quality of forest trees between the two groups was compared using the chi-squared test. The multiple correspondence analysis was used to analyse the relationship between the tree quality and *DBH*, *H*, *C_H* and *C_D*. This is a multivariate analysis method based on the matrix values of the variables averaged for each plot (McCune, Grace 2002).

Biomass and carbon stock calculations. Because the study was not allowed to cut down trees (the reason is that the forest belongs to the protection forest area of Ba Vi, under the management of the Hanoi Forest Protection Department), so the fresh and dry biomass and carbon stock of forest trees were calculated according to the following Equations (12–14):

Fresh biomass for each tree (Bao, Phuc 2018):

$$FB = \exp[-0.567118 + 2.03792 \times \ln(DBH)] \quad (12)$$

where:
FB – fresh biomass;
DBH – diameter at breast height.

Dry biomass for each tree (Bao, Phuc 2018):

$$DB = \exp[-1.56325 + 2.15274 \times \ln(DBH)] \quad (13)$$

where:
DB – dry biomass.

Carbon stock for each tree (Petersson et al. 2012; Vu 2015):

$$CS = 0.5 \times DB \quad (14)$$

where:
CS – the carbon stock.

All calculations and analyses were performed using SPSS (Version 14.0, 2019) and R (Version 4.2.1., 2022).

RESULTS

Community classification

Data from 23 plots were used to classify into groups (Figure 2). Classification analysis divided the plots into two distinct groups. Group 1 included 13 plots, while Group 2 included 10 plots. The data of plots belonging to the same group were combined for further analyses.

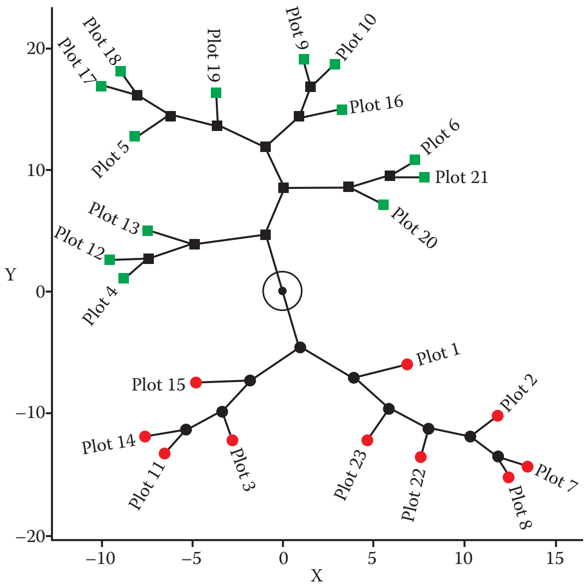

Figure 2. Community classification based on diameter at breast height, total height, commercial height and crown width

Red circles – Group 1; green rectangles – Group 2

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Canopy structure

Overview descriptions. Descriptive values were calculated for tree-size variables in each group. Results are presented in Table 1.

The results showed that the number of trees in Group 1 was lower than in Group 2. However, mean values were significantly greater than in Group 2 for all variables, such as *DBH*, *H*, *C_H* and *C_D* (mixed linear model, *P*-value < 0.0001). The data of all variables of Group 1 varied more than in Group 2 (Table 1). The frequency distribution of all variables of Group 1 was right-skewed, except for the commercial height. In contrast, the variables of Group 2 had left-skewed distributions, except for the total height. All variable distributions in both groups were platykurtic.

Relations between measured variables. Positive relationships in pairs of tree-size variables were found in both groups (linear regression, $r > 0$). In Group 1, the regression between *DBH* and other variables was stronger than that in Group 2, but other relations were weaker. In both groups, the relationship between total height and commercial height was strongest ($r = 0.8409$ in Group 1 and $r = 0.8879$ in Group 2). The second strongest relationship was between diameter at breast height and total height ($r = 0.7897$ and $r = 0.8524$, respectively). Weaker relations were between *DBH* and canopy width; total height and canopy width; *DBH* and commercial height. The weakest correlation was between commercial height and canopy width ($r = 0.5654$ and $r = 0.5785$, respectively) (Figure 3).

Diameter frequency distribution and modelling. For *DBH*, the frequency distribution was left-skewed in Group 1 and right-skewed in Group 2. The largest number of individuals was at classes of 22–30 cm in Group 1, and at classes of 2–10 cm in Group 2 (Figure 4). The frequency distributions between two groups were statistically different (PERMANOVA, $P < 0.0001$).

In Group 1, the Weibull distribution was the best of the 6 tested distributions (*AIC* = 3 010.26) to simulate the diameter frequency distribution. The shape parameter was 2.578 and the scale parameter was 24.45. Data was also from the Weibull distribution (Cramer-von Mises test = 0.46, $P = 0.01$). However, the SHASH distribution was the best one to simulate the diameter frequency distribution in Group 2 (*AIC* = 4 079.58). Data was also taken from the SHASH distribution (Shapiro-Wilk test = 0.99, $P = 0.0002$).

Height frequency distribution and modelling. For *H*, the frequency distribution of Group 1 was left-skewed with a peak at class 16–18 m. However, the height frequency distribution was much more complex in Group 2 with 2 peaks at classes 6–8 m and 14–16 m (Figure 5). The height frequency distributions between two groups were significantly different (PERMANOVA, $P < 0.0001$).

Similar to the diameter, the Weibull distribution was also the best distribution to describe the height frequency distribution in Group 1 (*AIC* = 2 436.08). The shape parameter was 3.86, and the scale parameter was 17.14. The analysis results also proved that the data was from the Weibull distribution (Cramer-von Mises test = 0.27, $P = 0.01$). In Group 2, the SHASH distribution was also the best for modelling the height frequency distribution (*AIC* = 3 502.56). Data was also taken from the SHASH distribution (Shapiro-Wilk test = 0.99, $P = 0.0052$).

Regression between *DBH* and *H*

Among tested equations for the correlation analysis, the cubic function was the best one to simu-

Table 1. Descriptive characteristics calculated for variables

Group	Variable	*N*	Min.	Max.	Mean	Variance	Skewness	Kurtosis
Group 1	*DBH*	415	3.20	51.80	21.719	83.843	–0.005	–0.473
	H		4.10	25.80	15.486	21.040	–0.192	–0.500
	C_H		1.70	22.30	10.493	18.361	0.049	–0.769
	C_W		1.00	8.90	4.806	2.410	–0.331	–0.237
Group 2	*DBH*	585	3.00	50.00	15.314	88.462	0.681	–0.285
	H		2.80	25.30	13.162	26.269	–0.025	–1.065
	C_H		1.60	20.40	8.451	18.527	0.500	–0.640
	C_W		0.50	9.00	3.702	2.619	0.255	–0.463

DBH – diameter at breast height; *H* – total height; *C_H* – commercial height; *C_W* – crown width

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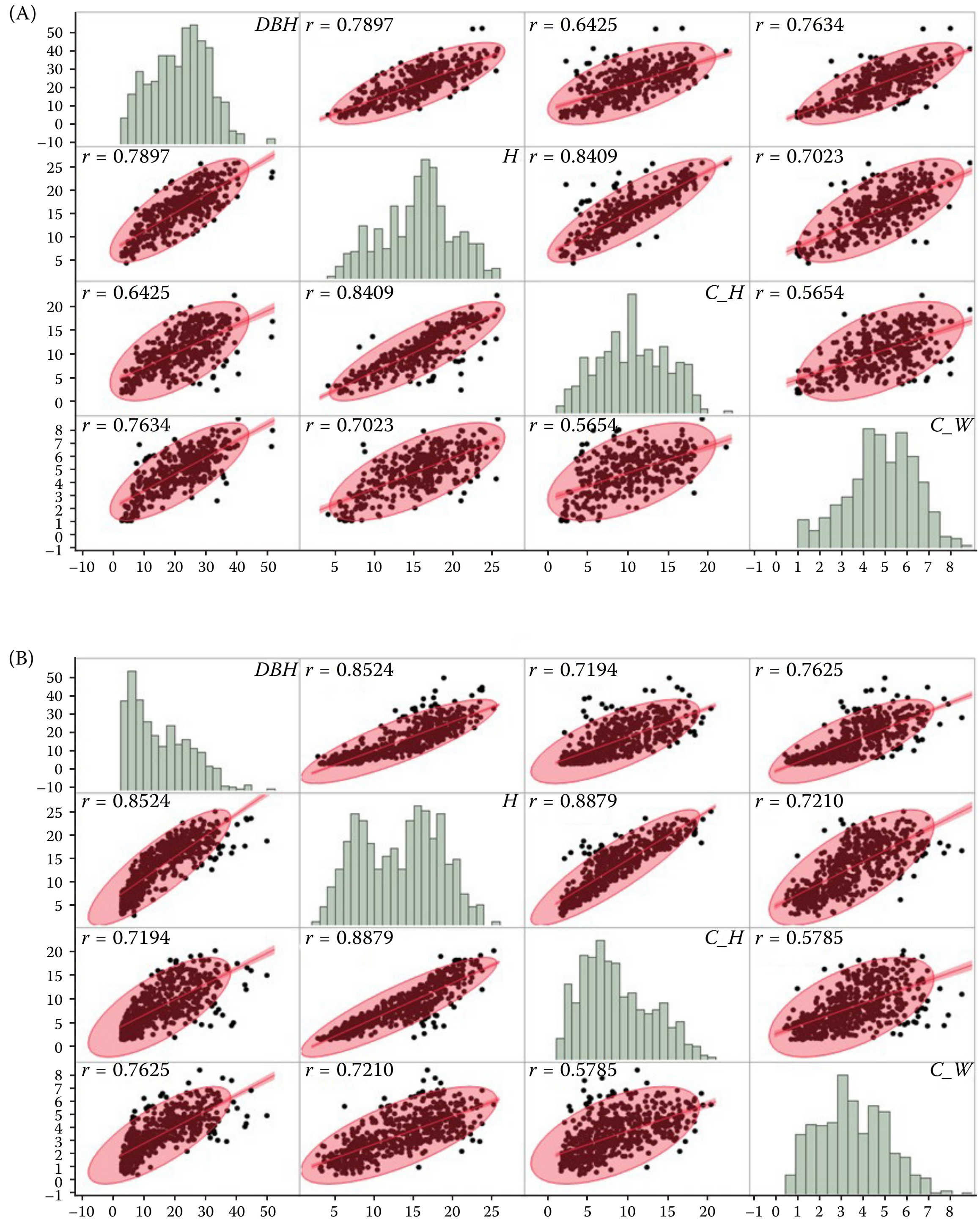

Figure 3. Relations between measured variables for (A) Group 1 and (B) Group 2

Red ellipses – confidence areas (95%); red solid lines – linear expected values; green bars – frequencies; *DBH* – diameter at breast height; *H* – total height; *C_H* – commercial height; *C_W* – crown width

late the relationship between *DBH* and total height in both groups (R^2 = 0.640 and 0.801, respectively) (Figure 6). The models existed in the population (nonlinear regression, Sig. value < 0.0001). The parameters of the cubic equation for Group 1 were 3.714, 0.823, –0.015 and 0.000125. These parameters in Group 2 were 1.261, 1.303, –0.032 and 0.000286.

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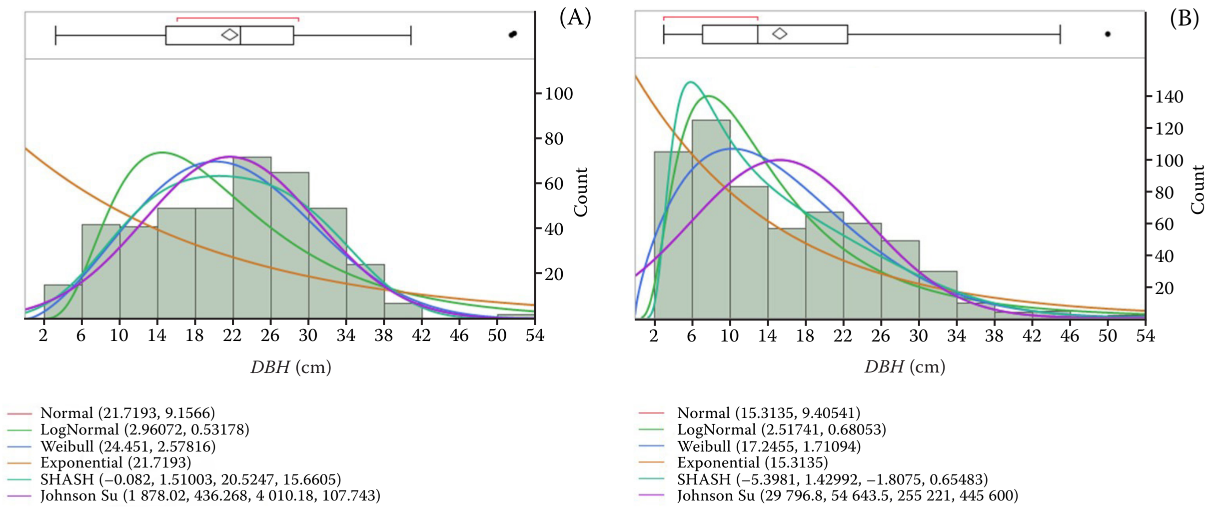

Figure 4. The diameter at breast height frequency distributions and modelling for (A) Group 1 and (B) Group 2

Green bars – number of individuals in each diameter class; curved solid lines – tested theoretical distributions

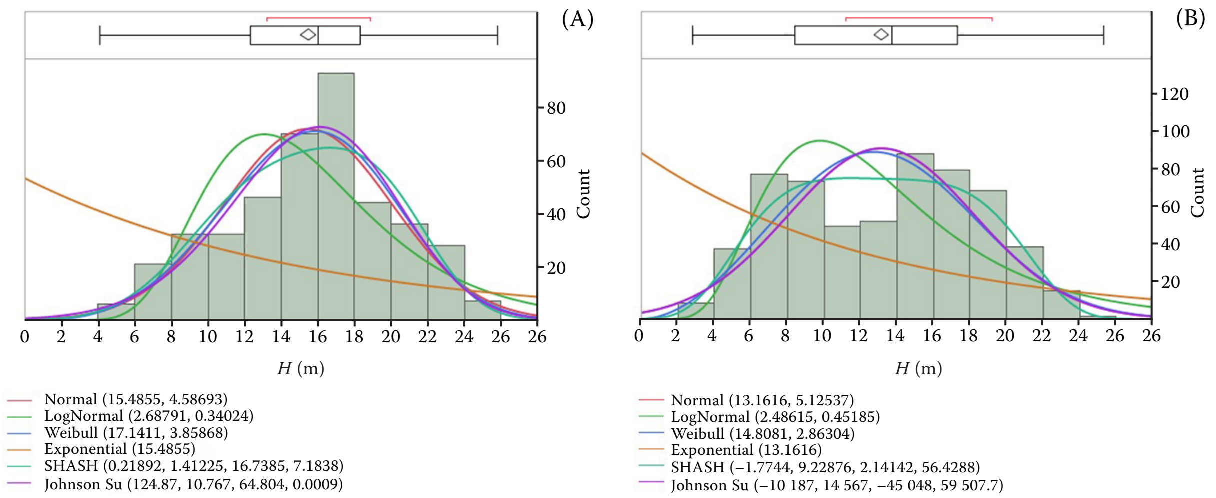

Figure 5. The total height frequency distribution and modelling for (A) Group 1 and (B) Group 2

Green bars –number of trees in each height class; curved solid lines – analyzed theoretical distributions

Acacia quality and its relations with measured variables

Acacia quality between groups. The percentages of trees with good, medium and bad quality in the two groups are presented in Table 2.

In both groups, the rate of medium trees was the highest, followed by the percentage of good trees and the lowest rate was bad trees. The rates of good and bad trees in Group 1 were lower than those in Group 2. In contrast, the rate of medium trees in Group 1 was higher than in Group 2. The results showed that the tree quality between the two groups was significantly different (χ^2 = 32.20, $P < 0.0001$).

Relationship between acacia quality and investigated variables. Multiple correspondence analysis revealed that the tree quality was strongly

Table 2. Rate of plant quality in the two groups

Group	Indicator	Bad	Medium	Good	Total
Group 1	count	41	270	104	415
	%	9.9	65.1	25.1	100.0
Group 2	count	126	288	171	585
	%	21.5	49.2	29.2	100.0
Total	count	167	558	275	1 000
	%	16.7	55.8	27.5	100.0

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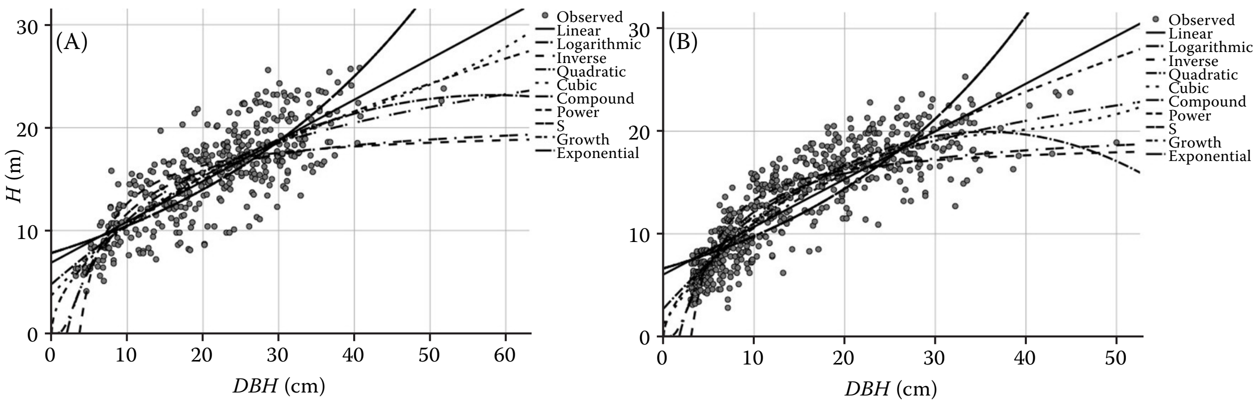

Figure 6. Regression analysis charts between diameter at breast height (*DBH*) and total height (*H*) for (A) Group 1 and (B) Group 2

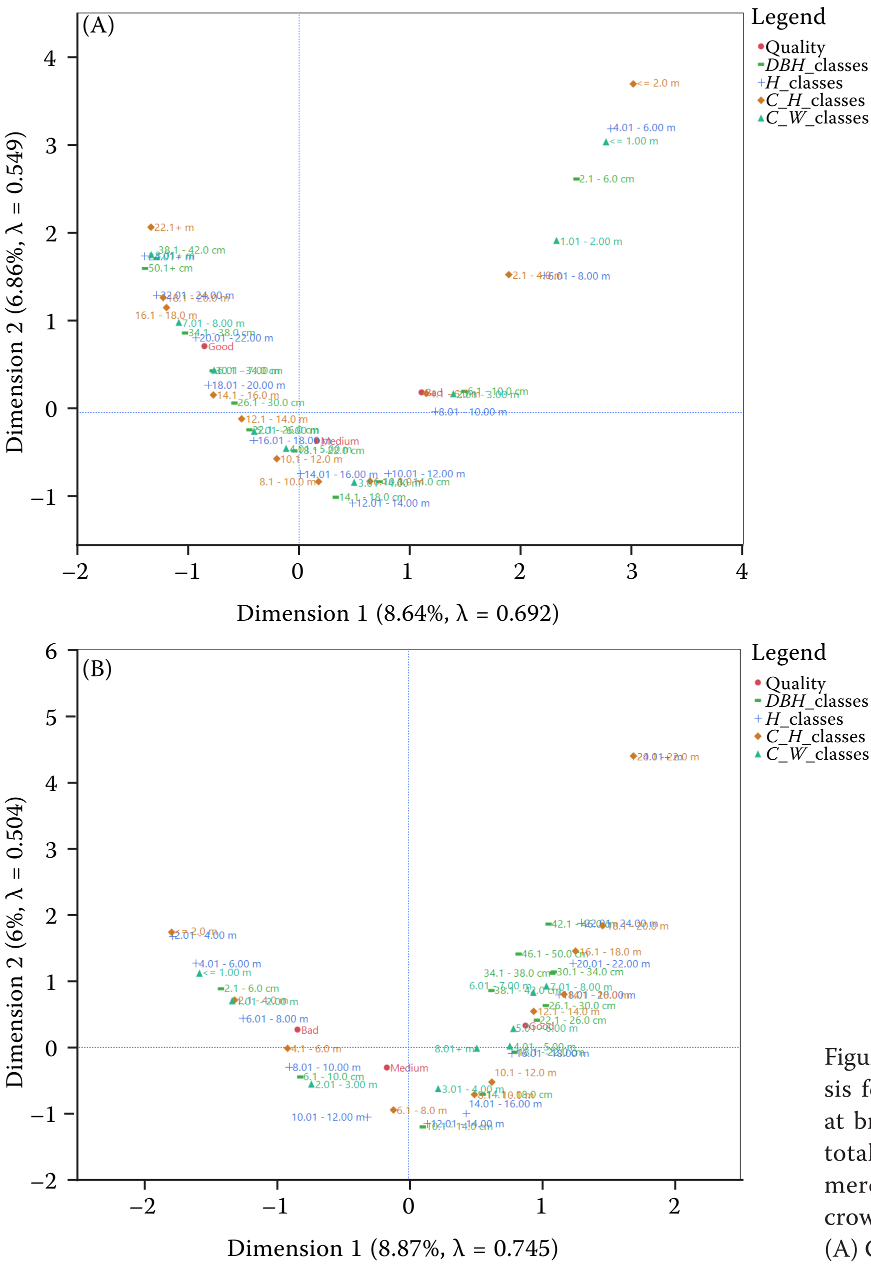

Figure 7. Multiple correspondence analysis for tree quality (Quality), diameter at breast height classes (*DBH*_classes), total height classes (*H*_Classes), commercial height classes (*C*_*H*_Classes), crown width classes (*C*_*W*_Classes) for (A) Group 1 and (B) Group 2

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Table 3. Fresh biomass, dry biomass and carbon stocks results from acacia studied stands

Group	Density (trees·ha^{-1})	Fresh biomass per tree (kg)	Fresh biomass per ha (Mg)	Dry biomass per tree (kg)	Dry biomass per ha (Mg)	Carbon stock per ha (Mg)
Group 1	638	356.97	227.75	192.72	122.95	61.48
Group 2	1 170	206.41	241.50	109.77	128.43	64.21

associated with *DBH*, *H*, *C_H* and *C_D* classes (chi-squared test, $P < 0.0001$) in both groups (Figure 7). Good trees were usually concentrated in *DBH* classes greater than 30 cm, total height greater than 22 m, commercial height greater than 16 m, crown width from 6 m to 7 m. In contrast, poor quality trees were concentrated in small trees with a diameter of 2–10 cm, total height of 2–8 m, commercial height of 2–10 m and crown width less than 1 m.

Biomass and carbon stock

Calculation results of fresh biomass, dry biomass and carbon stock per individual forest trees and hectares in both groups are presented in Table 3.

Calculations have shown that the average fresh and dry biomass per tree of Group 1 was greater than that of Group 2. However, the total fresh biomass, dry biomass and carbon stock per hectare of Group 1 were smaller than those of Group 2 (Table 3).

DISCUSSION

Overstorey characteristics. Forest communities are often classified into groups. These groups will be more homogeneous in terms of structure and environmental characteristics. These groups will then be used for a more detailed analysis (Zhang et al. 2006; Bhutia et al. 2019; De Cáceres et al. 2019). In this study, the forest community was categorized into two groups. The number of plots and individuals did not differ much between the two groups (415 individuals in Group 1 and 512 individuals in Group 2).

In this study, although the acacia forest was started planting 20 years ago, the average diameter and height are about 5–6 years old forests in other research, especially in Group 2. The main reason is the criteria used to measure the tree diameter and height. Previous studies only measured acacia trees with a diameter greater than or equal to 6 cm (Vu 2015; Loi et al. 2017; Bao, Phuc 2018), whereas all trees with 3 cm in *DBH* were involved in this study. Therefore, the number of trees with small diameter is large, reducing the average diameter.

The analysed results indicated that mean values of all variables in Group 1 were higher than in Group 2 and the distribution has a left-skewed shape. This can be explained by selective logging of some large trees in the past years. Another reason is that there are more big broken-down trees attacked by diseases in Group 2. After cutting or tree felling, extensive gaps are created in the forest. These gaps will be a favourable environment for growth and development of natural regeneration (Zhu et al. 2014). Therefore, a certain number of regenerating and smaller diameter trees occurs more frequently in Group 2 than in Group 1. Thus, it has resulted in a smaller mean and a left-shifted peak of the frequency distribution. These findings are completely similar to the results from China (Zheng, Zhou 2010). Another reason from the interview with company's manager shows that the acacia forest in Group 2 was harvested first because the diseased tree rate was quite large in this group. This reduced the number of large trees in Group 2 at the time of the survey. The canopy opening process, together with the natural regeneration of acacia in Group 2 made the range and variability of the investigated variables greater.

The relationships between tree-size variables are all positive. Two pairs with the strongest correlation are commercial height and total height; *DBH* and total height. These findings are consistent with those of previous studies conducted for pine species in Turkey (Avsar 2004), urban trees in United Kingdom (Monteiro et al. 2016) and oak forests in Poland (Kazmierczak et al. 2011). For the relationship between *DBH* and total height, the cubic function was the best function to simulate the relationship between them. This finding is supported by a study in South Anhui Province, China (Gao et al. 2016). However, more robust equations should be tested to analyse the correlation between

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diameter and total height for future studies in the study area in particular and Vietnam in general (Chenge 2021).

The normal, lognormal, Weibull, exponential, SHASH and Johnson distributions are commonly used to simulate the diameter and height frequency distribution in forest biometrics (Fonseca et al. 2009; Mirzaei et al. 2016). This research illustrated that Weibull is the best distribution to model the diameter and height frequency distribution in Group 1. This result is also supported by research conducted for *Quercus persica* forests in Iran in 2015 (Mirzaei et al. 2016). Many studies in Vietnam have also shown that the Weibull distribution is the best distribution to model the diameter and height frequency distributions (Hung, Truong 2017; Trieu, Hung 2018). In contrast, the best distribution was SHASH in Group 2. The Johnson and SHASH distributions can simulate frequency distributions well (Palahí et al. 2007). However, these distributions have not been tested much in previous studies to simulate frequency distributions for tree-size variables. Especially, in Vietnam, the SHASH and Johnson distributions were used for the first time in 2021 to model the stump diameter distribution in Ba Vi (Hung et al. 2021). In Vietnam, only 4 distributions have been used to model the frequency distribution of tree-size variables. They are normal, Weibull with 2 parameters, Mayer and distance (Hung, Truong 2017; Tuat, Khoi 2009). But this study has shown that the SHAHS distribution is better than the distribution commonly used in Vietnam.

Tree quality and relations with tree-size classes. The number of trees with good quality in both groups accounted for about one third of the trees. This ratio is similar to *Cunninghamia lanceolata* forests in Si Ma Cai, Lao Cai (Huy, Hung 2018), but lower than in natural forests in Bac Kan (Tuan, Hung 2018). Good trees were often found in large diameter and height classes. In contrast, bad trees often concentrate on the smallest sizes. This trend is also found in Bac Kan natural forest (Tuan, Hung 2018). Therefore, when tending acacia forests, it is necessary to focus on nurturing trees with a diameter of 2–10 cm and a height less than 8 m because these trees are usually bad trees. In addition, when harvesting, it is necessary to leave some large trees with diameter greater than 30 cm and height greater than 22 m to form good quality mother trees. These relationships are rarely analysed. However, when analysing them, there is a weakness that the assessment and classification of tree quality still depend on the experience of investigators.

Biomass and carbon stock in the acacia forest. The average biomass and carbon stock per tree of this study are greater than those of studies conducted in Ba Ria Vung Tau province (Bao, Phuc 2018) and Ca Mau province (Loi et al. 2017). The main reason for this is that the forest in this study was planted longer by about 14 years. Therefore, the average diameter and height of trees will be bigger. However, the total biomass and carbon stock tend to be lower than in some other studies carried out in Vietnam. The explanation for that is the forest density in this study is much lower than in other studies. The average stand density in the two groups of this study was about 900 plants·ha^{-1}, while the average density in Ba Ria Vung Tua was 1 696 plants·ha^{-1} (Bao, Phuc 2018), in Ca Mau it was 1 780 trees·ha^{-1} (Loi et al. 2017). The total fresh biomass of acacia forest in the study area is greater than in Malaysian acacia forest conducted in 1988 (90.4 Mg·ha^{-1}) because the average diameter and stand density of the forest are larger than in Malaysia with the same species (Tsai 1988). The acacia forest in the study site also proves a good capacity to absorb carbon dioxide and contributes to reduce the global greenhouse effects.

CONCLUSION

In conclusion, the canopy characteristics were analysed. In which investigated plots were divided into two distinct groups based on tree-size variables including *DBH*, *H*, *C_H* and *C_D*. Mean values of Group 1 were greater than in Group 2 for all variables. In general, the diameter and height frequency distributions of Group 1 were right-skewed, while those of Group 2 were left-skewed and more complicated. Positive correlations in pairs of variables were found in both groups. The regression in pairs was stronger in Group 1. The Weibull and SHASH were the best distributions to model the diameter and height frequency distribution. The study indicated that the cubic equation was the best function to simulate the relationship between the *DBH* and *H* of *Acacia mangium*. Relationships between tree quality and tree-size variables were also assessed and revealed. The number of trees with good quality in both groups accounted for about one third of the trees. Good trees were often found in large

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diameter and height classes. In contrast, bad trees often concentrate on the smallest sizes. Biomass of the forest was 122.95 Mg·ha^{-1} and 128.43 Mg·ha^{-1} in the two groups, respectively, while carbon stock was 61.48 Mg·ha^{-1} and 64.21 Mg·ha^{-1}. Therefore, when tending acacia forests, it is necessary to pay attention to trees with a diameter of 2–10 cm and a height less than 8 m. In addition, when doing cuttings, foresters should leave some large trees with diameter greater than 30 cm and height greater than 22 m to form good quality mother trees. Tending measures should be carried out every year seasonally to be able to protect and develop the acacia forest sustainably in future.

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