

# Tree species diversity and stand structural stability in secondary evergreen broadleaf forests of southern Vietnam

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<sup>1</sup>Faculty of Natural Resources & Environment, Dong Nai Campus, Vietnam National University of Forestry, Bien Hoa 810000, Dong Nai, Vietnam.  
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**Abstract.** *Ha NT, Ngoan TT, Hung DV, Hai NH. 2026. Tree species diversity and stand structural stability in secondary evergreen broadleaf forests of southern Vietnam. Biodiversitas 27 (2): d270209. <https://doi.org/10.13057/biodiv/d270209>.* Species diversity and stand structural stability are fundamental concepts in ecology, yet their relationship remains debated. This study was conducted to evaluate the link between tree species diversity and stand structural stability of evergreen broadleaf forests in La Nga Protection Forest Management Board, Lam Dong Province, Vietnam. Data were collected from 102 temporary sample plots (500 m<sup>2</sup> each) across three forest types: medium evergreen broadleaf forests (29 plots), poor evergreen broadleaf forests (33 plots), and woody-bamboo mixed forests (40 plots). The results identified a total of 128 species across the three forest types, with a moderate level of species similarity, as indicated by Jaccard indices ranging from 0.60 to 0.66. Species relationships showed an overall co-occurrence tendency across all forest types. Tree species diversity indices in the Evergreen Broadleaf Medium (EBM) Forests were higher than those in Evergreen Broadleaf Poor (EBP) and Woody-Bamboo Mixed (WBM) Forests, but the differences were not statistically significant ( $p > 0.05$ ), except for the Pielou Index ( $p < 0.05$ ). Stand structural stability based on the Godron Index showed the ranking EBM > EBP > WBM among the studied forest types. Both Simpson (D) and Pielou (J') Indices were positively correlated with stand structural stability ( $p < 0.05$ ). These findings highlight the importance of conserving tree species diversity to maintain stand structural stability, while providing a scientific basis for the sustainable management of rehabilitated forest ecosystems in Vietnam.

**Keywords:** Diversity indices, Godron Index, Jaccard Similarity, species association

**Abbreviations:** EBM: Evergreen Broadleaf Medium, EBP: Evergreen Broadleaf Poor, WBM: Woody-Bamboo Mixed

## INTRODUCTION

According to the 2024 forest inventory data, Vietnam has over 14.87 million hectares of forest, of which 10.13 million hectares are natural forests, accounting for 68.12% of the country's total forest area (Mard 2025). Natural forests have a complex canopy structure, diverse biodiversity, and high productivity, and they play an important role in soil and water conservation, biodiversity preservation, as well as in maintaining the balance of the carbon cycle in the atmosphere (Wang et al. 2023; Psistaki et al. 2024; Poudel et al. 2025). However, in recent decades, human activities-including land-use conversion, logging, and war-have led to a significant decline in both the area and quality of natural forests in Vietnam, resulting in biodiversity loss, reduced stability, and impaired ecological functions (Van Khuc et al. 2018; Nguyen-Dinh and Lai-Vinh 2021). To address this issue, the Vietnamese government implemented a national policy in 2014 to close natural forests and cease commercial logging activities. After more than a decade of implementation, evaluating the stability and species diversity of these forest stands has become essential for understanding the ecological outcomes of this policy intervention. Such assessments provide important scientific evidence on whether forest ecosystems are recovering toward more resilient and structurally complex states.

Consequently, investigating the biodiversity and stability of restored forests across different successional stages is of critical significance, as it helps clarify patterns of species composition, community interactions, and ecosystem functioning over time. These insights not only contribute to ecological theory but also support adaptive forest management, conservation planning, and sustainable use of forest resources in Vietnam and other tropical regions undergoing similar restoration efforts.

Stand structural stability is crucial for ecosystem sustainability and serves as a key indicator of ecosystem health. Among the methods used to assess stability, species diversity is considered a primary determining factor (Yuanrun 2000; Ji and Ha 2003). At present, the relationship between stand structural stability and species diversity remains a subject of ongoing debate in ecological research. Although numerous empirical and theoretical studies have attempted to clarify this linkage, no universally accepted conclusion has been reached. For instance, some studies have shown that simpler ecosystems are less stable, as species diversity directly influences an ecosystem's resilience to external disturbances; consequently, higher diversity enhances the stability of plant communities. Conversely, some authors argue that higher species diversity can disrupt species balance and lead to reduced stability (Zheng et al. 2016; Lei et al.

2023). Additionally, some studies indicate that there is no significant correlation between species diversity and stand structural stability (Xu et al. 2015). Notably, the key factors governing stability, as well as their direct and indirect roles in various mechanisms, have yet to be clarified across different natural ecosystems (Valencia et al. 2020; Wang et al. 2020). Studies conducted in various regions have indicated that environmental factors such as topography, soil, and climate may play a crucial role in shaping species diversity and influencing the stand structural stability (Pinder et al. 1997; O'Brien et al. 2000). Therefore, it is necessary to conduct studies on the relationship between species diversity and stability for each specific ecosystem. Based on this context, the present study was carried out to assess the tree biodiversity and stand structural stability of natural forest states at the La Nga Forest Management Board, Lam Dong Province, Vietnam. This study proposes two hypotheses: (i) forest types that have been less disturbed or have longer recovery periods will exhibit higher tree species diversity and stand structural stability; and (ii) stand structural stability is closely associated with biodiversity indicators, as reflected by commonly used tree diversity and evenness indices. The results of this research provide an important scientific basis for managers to develop appropriate conservation and restoration strategies.

## MATERIALS AND METHODS

### Study area

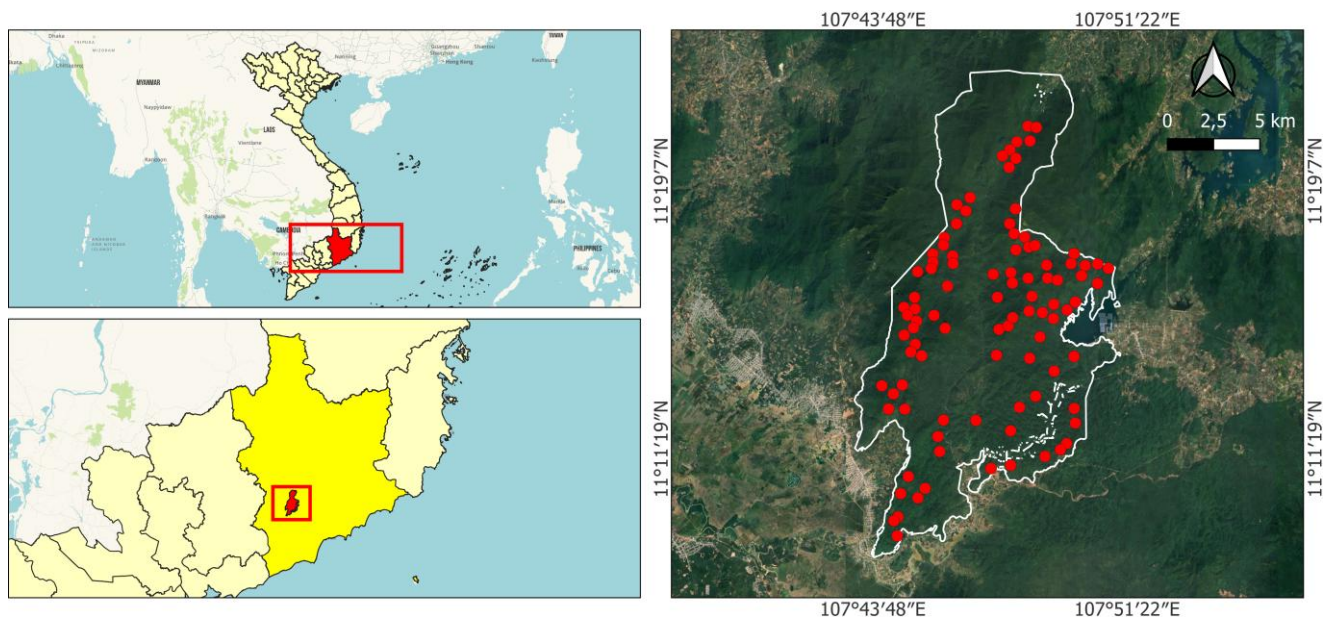
This study was carried out in the natural forests of the La Nga Protection Forest Management Board, Lam Dong Province, which is located in a transitional zone between the low hilly areas of Southeastern Vietnam and the Central Highlands. The coordinates (WGS 84) range from 11°06'

N to 11°24'N and 107°42' E to 107°54' E (Figure 1). The natural forest of study area lies on relatively complex terrain. In the north, it is surrounded by high mountain ranges with elevations ranging from 300 to 1500 m and slopes of 10–35°. The terrain inclines from the northeast toward the southwest, with elevation gradually decreasing in that direction. The lowest point in the southern part is 150 m above sea level (m a.s.l.). The study area has three main soil types: Ferralsols, Fluvisols, and Acrisols.

The study area has a tropical monsoon climate with two distinct seasons: a rainy season and a dry season. The average temperature ranges from 25 to 28°C, with a maximum of 32°C and a minimum of 18°C. The rainy season lasts from April to October, while the dry season begins in November and ends in March. The months with the highest rainfall are July and August.

### Data collection

Due to substantial human impacts, most notably selective logging and shifting cultivation, secondary evergreen broadleaf forests have been categorized by Vietnam's Forest Inventory and Planning Institute into three groups according to their standing volume ( $V$ ,  $m^3 ha^{-1}$ ). These classes include: poor forests (high intensity logging with  $V \leq 100 m^3 ha^{-1}$ ), medium forests (medium intensity logging with  $100 < V \leq 200 m^3 ha^{-1}$ ), rich forests (low intensity logging with  $V > 200 m^3 ha^{-1}$ ) (Tuan et al. 2022). In this study, the dataset was collected across three forest types: Evergreen Broadleaf Medium (EBM) Forests, Evergreen Broadleaf Poor (EBP) Forests, and Woody-Bamboo Mixed (WBM) Forests. These three forest types were selected because they constitute the dominant forest cover within the management area, accounting for 88.83% of the total natural forest area.



**Figure 1.** The location of the sample plots in La Nga Protection Forest Management Board, Lam Dong Province, Vietnam

Field surveys were conducted between June and December 2019. A total of 102 temporary sample plots, each with an area of  $25 \times 20$  m ( $500 \text{ m}^2$ ), were established using a stratified sampling approach based on the forest status map of the study area, in which each stratum represented a specific forest type. Forest types were assigned to individual plots following the criteria outlined in Circular No. 33/2018/TT-BNNPTNT on forest survey, inventory, and forest change monitoring in Vietnam. Within each stratum, sample plots were randomly selected across the entire area following a stratified random sampling approach, ensuring that the distance between any two plots within the same stratum exceeded 200 m. Among the 102 established sample plots, 40 were assigned to the WBM Forests, 29 to the EBM Forests, and 33 to the EBP Forests. The spatial distribution of all plots is presented in Figure 1. The location of each sample plot was recorded at the plot center using a handheld GPS device (Garmin 64) with an accuracy of approximately 2 m. Within each plot, all trees with a Diameter at Breast Height (DBH) greater than 5 cm were surveyed. Measurements included DBH, taken with a diameter tape, and species identification, which was conducted using morphological comparison methods (Thin 1997). Species that could not be confidently identified during fieldwork were collected as voucher specimens. Voucher specimens were prepared following standard botanical procedures and subsequently examined by taxonomic specialists at the Botany Laboratory, Dong Nai Campus, Vietnam National University of Forestry. Species names were updated and standardized based on expert identification. Taxa that remained unresolved after laboratory examination were retained in the dataset and recorded as *morphospecies* sp.. Species name was supported by botanical books (Ho 1999; Hop 2002). Finally, the scientific names of all recorded species were standardized according to Kew Science (<https://www.kew.org/>) and the World Flora Online (<https://www.worldfloraonline.org/>).

## Data analysis

### Importance Values (IV)

The Importance Value (IV) is an integrative index commonly used to assess the ecological significance and functional dominance of plant species within a community. In this study, IV was used as the primary criterion for identifying dominant tree species, as it provides a comprehensive measure of ecological importance that extends beyond simple abundance. The Importance Value of species  $i$  ( $IV_i$ ) for each forest type was calculated as follows (Chai et al. 2016).

$$IV_i = (RD_i + Rd_i + RF_i)/3$$

Where, RD, Rd, and RF are the Relative Density, Relative dominance, and Relative Frequency of species  $i$ , respectively. The formulas used to calculate RD, Rd, and RF are as follows:

$$RD_i = \frac{D_i}{\sum_{i=1}^S D_i} \times 100$$

Where,  $D_i$  is number of individuals of species  $i$ ,  $S$  is the total number of species.

$$RF_i = \frac{F_i}{\sum_{i=1}^S F_i} \times 100$$

$F_i$  = Number of plots containing species  $i$  / total number of plots.

$$Rd_i = \frac{d_i}{\sum_{i=1}^S d_i} \times 100$$

Where,  $d_i$  is total basal area of species  $i$ .

### Tree species diversity

Species diversity indices of tree community was quantified using widely four indices: Shannon-Wiener (H), Margalef (d), Pielou ( $J'$ ), and Simpson (D), following the formulas outlined by Gao et al. (2024):

Margalef Index (d):  $d = (S-1)/\ln(N)$

Shannon-Wiener Index (H):

$$H' = - \sum_{i=1}^S p_i \ln p_i$$

Simpson index (D):

$$D = 1 - \sum_{i=1}^S p_i^2$$

Pielou Index ( $J'$ ):  $J' = H'/\ln(S)$

Where,  $S$  represents the total number of species in each plot,  $N$  denotes the total number of individuals across all species, and  $p_i$  refers to the relative frequency/proportion of species  $i$  in the community.

### Stand structural stability

In this study, the Godron Index was used to assess stand structural stability (Godron et al. 1972). This index quantifies stability by analyzing the distribution of tree species frequencies within the community. The calculation was performed at two distinct scales: the forest-type level (using aggregated data) and the individual plot level. At each scale, all tree species within the sampling unit (either a specific forest type or a single plot) were ranked in descending order based on their frequency (forest-type level) or the number of individuals per species (plot level) (Zeng et al. 2024; Wang et al. 2025). Relative frequencies were then calculated for each species. Subsequently, the cumulative percentages of the inverse species count and relative frequency are interpolated to obtain the fitted curve described by the equation:  $y = ax^2 + bx + c$ . The intersection point ( $x, y$ ) between this fitted curve and the line  $y = 100 - x$  is then determined, followed by the calculation of the Euclidean distance (ESD value) from this point to the coordinate (20, 80). The formula for Euclidean distance (ESD) is expressed as follows (Jin et al. 2022; Chen et al. 2024; He et al. 2025):

$$ESD = \sqrt{[(x - 20)^2 + (y - 80)^2]}$$

A smaller distance indicates a more stable community, whereas a larger distance reflects lower stability. Finally, the inverse of the Euclidean distance (ESD value) is used as the Godron Index ( $G = 1/ESD$ ) to characterize stand structural stability.

### Jaccard Similarity coefficient

The Jaccard Similarity coefficient ( $q$ ) was used to evaluate the degree of similarity in species composition among forest types (Jaccard 1901):

$$q=c/(a+b-c)$$

Where,  $a$  and  $b$  are the number of species in the two tree communities, and  $c$  is the number of species common to the two tree communities. The value of the similarity coefficient  $q$  ranges from 0 to 1, in which: values from 0 to 0.25 indicate a highly dissimilar between tree communities; 0.25 to 0.50 indicate moderately dissimilar; 0.50 to 0.75 indicate a moderate level of similarity; and values ranging from 0.75 to 1.00 indicate a highly similar relationship between tree communities (Zeng et al. 2024).

### Overall species association

Inter-specific correlations among plant species indicate adaptive responses to different forest types and provide clear insights into plant community structure. The variance ratio method based on the null-linkage model (Roxburgh et al. 2004) was used to quantify and verify the overall correlation among forest types. The formula is as follows:

$$\delta_T^2 = \sum_{i=1}^S p_i(1 - p_i)$$

$$S_T^2 = \frac{1}{N} \sum_{j=1}^N (T_j - t)^2$$

Variance ratio:

$$VR = \frac{S_T^2}{\delta_T^2}$$

In this formulation,  $S$  represents the total number of species, while  $p_i = n_i/N$ ,  $n_i$  is the number of samples in which species  $i$  occurs and  $N$  denotes the total number of samples.  $T_j$  refers to the number of species recorded in sample plot  $j$ , and  $t$  is the mean species richness per sample. Under the null assumption that species occur independently of one another, the expected VR value is 1, indicating that no meaningful ecological interactions or shared habitat preferences are influencing their distributions. When VR is substantially greater than 1, species tend to co-occur more often than predicted by random placement, implying positive interspecific relationships such as facilitation, mutualism, or similar environmental requirements. In contrast, VR values well below 1 reflect reduced co-occurrence, pointing to negative associations that may result from competition, niche differentiation, or other antagonistic interactions.

The statistic  $W$  is applied to evaluate whether VR significantly differs from 1, calculated as  $W = VR \times N$ . The associations among species are not statistically significant at the 95% confidence level when the  $W$  value falls within the interval  $[\chi^2(0,05, N); \chi^2(0,95, N)]$  (Jian et al. 2018).

### Statistical analysis

The Kruskal-Wallis nonparametric test was employed to compare differences among forest types. When a significant difference was detected, Dunn's test was subsequently applied for post-hoc ranking, with significance values adjusted using the Bonferroni correction to control for Type I error inflation in multiple comparisons. In addition, Pearson's correlation coefficient was used to examine the linear relationship between stand structural stability and tree species diversity based on plot-level

values. Prior to analysis, linearity was evaluated through visual inspection of scatterplots. Tree species diversity indices were normalized to a 0-1 range (simple min-max scaling) to ensure comparability across different measurement scales and to prevent variables with larger magnitudes from disproportionately influencing the analysis. All statistical tests and analyses were conducted at a significance level of 0.05. All figures and analyses were performed in R version 4.3.3.

## RESULTS AND DISCUSSION

### Variation in species composition and importance values among forest types

A total of 128 species were recorded across 102 sampling plots. Of these, the numbers of species in WBM, EBP, and EBM Forests are 85, 94, and 104, respectively. The mean number of species per plot was  $13.4 \pm 3.87$  for EBM Forests,  $12.9 \pm 3.92$  for EBP Forests, and  $11.3 \pm 3.63$  for WBM Forests. Stem density and basal area per hectare were 710 stems and 28.8 m<sup>2</sup> for WBM Forests, 715 stems and 16.5 m<sup>2</sup> for WBP forests, and 522 stems and 21.0 m<sup>2</sup> for WBM Forests. Based on the Jaccard index, species similarity between each pair of forest types was at a moderate level, with  $q$  values ranging from 0.6 to 0.66 (Table 1).

In addition, Figure 2 shows that all three forest types exhibit a moderate level of similarity, with 64 species occurring in all forest types, accounting for 50% of the total species. The WBM Forests share 71 species with either the EBM or EBP Forests, while the EBM and EBP Forest types share a total of 77 species. The number of species restricted to a single forest type—that is, occurring exclusively in one type and absent from all others—are 20 species in EBM, 10 species in EBP, and 7 species in WBM, respectively.

Each forest type contains two species with an Importance Value (IV) exceeding 5%. Specifically, *Lithocarpus pseudosundaicus* (Hickel & A. Camus) A. Camus (IV=5.36%) and *Lagerstroemia undulata* Koehne (IV=5.26%) in WBM Forests; *Syzygium borneense* (Miq.) Miq. (IV=6.73%) and *L. undulata* (IV=5.04%) in EBM Forests; *L. pseudosundaicus* (IV=5.22%) and *S. borneense* (IV=5.22%) in EBP Forests. In addition, the numbers of species with an importance value (IV) greater than 3% in the WBM Forests, EBP Forests, and EBM Forests are 7 species (*L. pseudosundaicus*, *L. undulata*, *Parinari annamensis* Hance, *Symplocos macrophylla* Wall. ex DC., *Vitex pinnata* L., *Cratoxylum formosum* (Jack) Benth. & Hook. fil. ex Dyer, *Irvingia malayana* Oliv. ex A.W. Benn.), 9 species (*L. pseudosundaicus*, *S. borneense*, *Dalbergia oliveri* Gamble ex Prain, *C. formosum*, *L. undulata*, *Hymenodictyon orixense* (Roxb.) Mabb., *Nephelium cuspidatum* Blume, *Xylopia vielana* Pierre, *P. annamensis*), and 9 species (*L. pseudosundaicus*, *S. borneense*, *C. formosum*, *L. undulata*, *P. annamensis*, *I. malayana*, *V. pinnata*, *Heritiera javanica* (Blume) Kosterm., *Litsea cubeba* (Lour.) Pers.), respectively (Figure 3 and Table S1).

**Characterization of tree community diversity**

The Shannon-Wiener (H), Margalef (d), Pielou (J'), and Simpson (D) indices were used to characterize the changes in tree community diversity. H, d, J' and D indexes were the highest for EBM Forests at 2.34, 3.55, 0.91, and 0.88, respectively. However, J' Index of the EBM Forest was significantly higher ( $p < 0.05$ ) than that of the EBP Forests, while the other tree species diversity indices did not differ significantly across forest types ( $p > 0.05$ ). The average H values of the forest types ranged from 2.16 to 2.33; D from 0.84 to 0.87; d from 3.22 to 3.54; and J' from 0.87 to 0.91 (Figure 4).

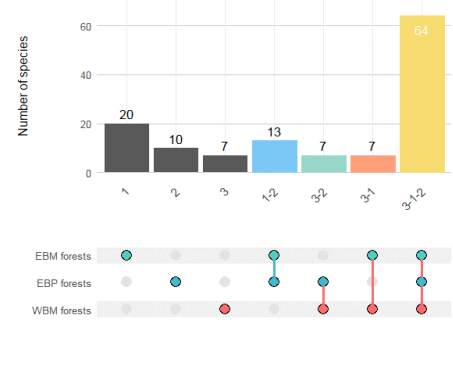
**Analysis of stand structural stability**

Based on the results of the variance ratio method in Table 2, all three forest types had VR values greater than 1, indicating positive correlations among species. The results suggest that tree species in all three forest types generally exhibit positive co-occurrence tendency. In addition, this positive association was further confirmed to be statistically significant by the W test, as the value fell outside the interval ( $\chi^2_{0.05}(N); \chi^2_{0.95}(N)$ ).

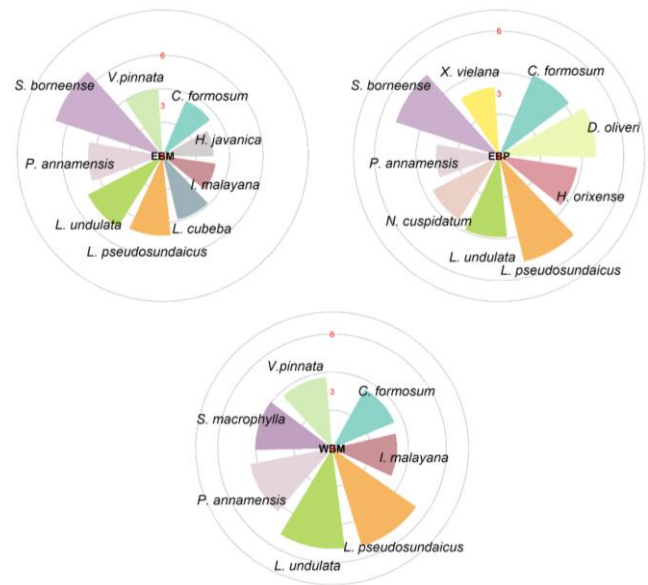
The Godron method was used to simulate the stand structural stability of the forest types using a quadratic smoothing curve (Figure 5). The G values for WBM Forests, EBP Forests, and EBM Forests were 0.067, 0.078, and 0.08, respectively (Table 3).

**Relationship between tree species diversity and stand structural stability**

Simpson and Pielou Indices exhibited positive correlations with stand structural stability across all three forest types (Table S2). Both Simpson and Pielou Indices were significantly correlated with the stand structural stability index ( $p < 0.05$ ), indicating statistically meaningful relationships. Notably, the correlation between the Pielou Index and stand structural stability was particularly strong in all three forest types, with  $R^2$  values ranging from 0.896 to 0.907 ( $p < 0.001$ ). In contrast, Shannon and Margalef indices showed no significant correlation with stand structural stability across all three forest types ( $p > 0.05$ ) (Figure 6).



**Figure 2.** Diagram of species similarity among forest types



**Figure 3.** Composition and importance value (IV>3%) index of the tree species in three forest types

**Table 1.** Similarity coefficients of evergreen broadleaf forests and woody-bamboo mixed forest

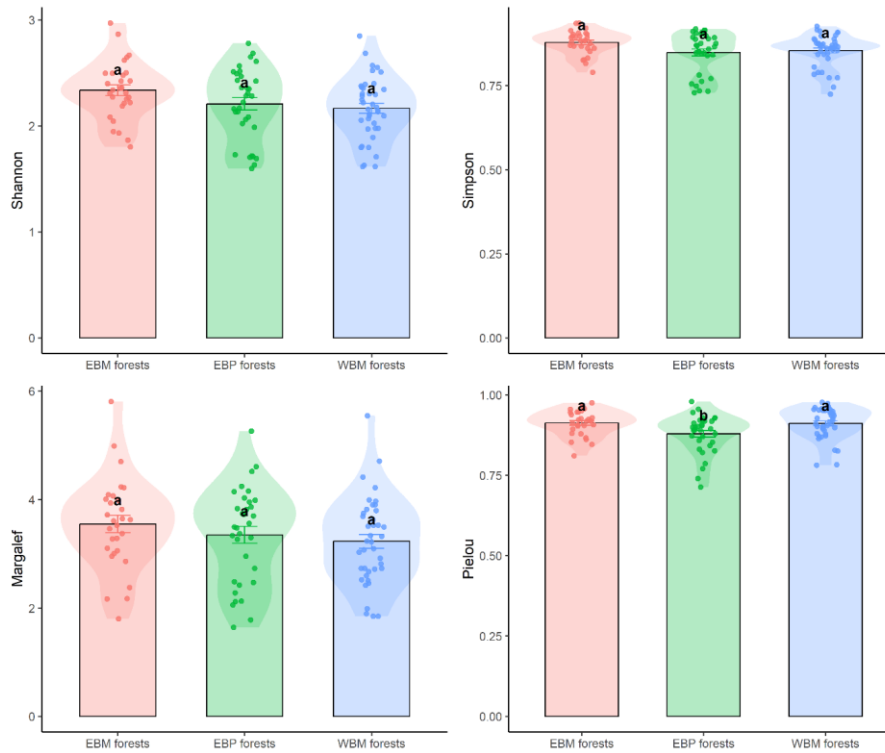
Forest types	WBM Forests	EBM Forests	EBP Forests
WBM Forests	1	0.60	0.66
EBM Forests	0.60	1	0.64
EBP Forests	0.66	0.64	1

**Table 2.** Results of the overall interspecific association analysis for species

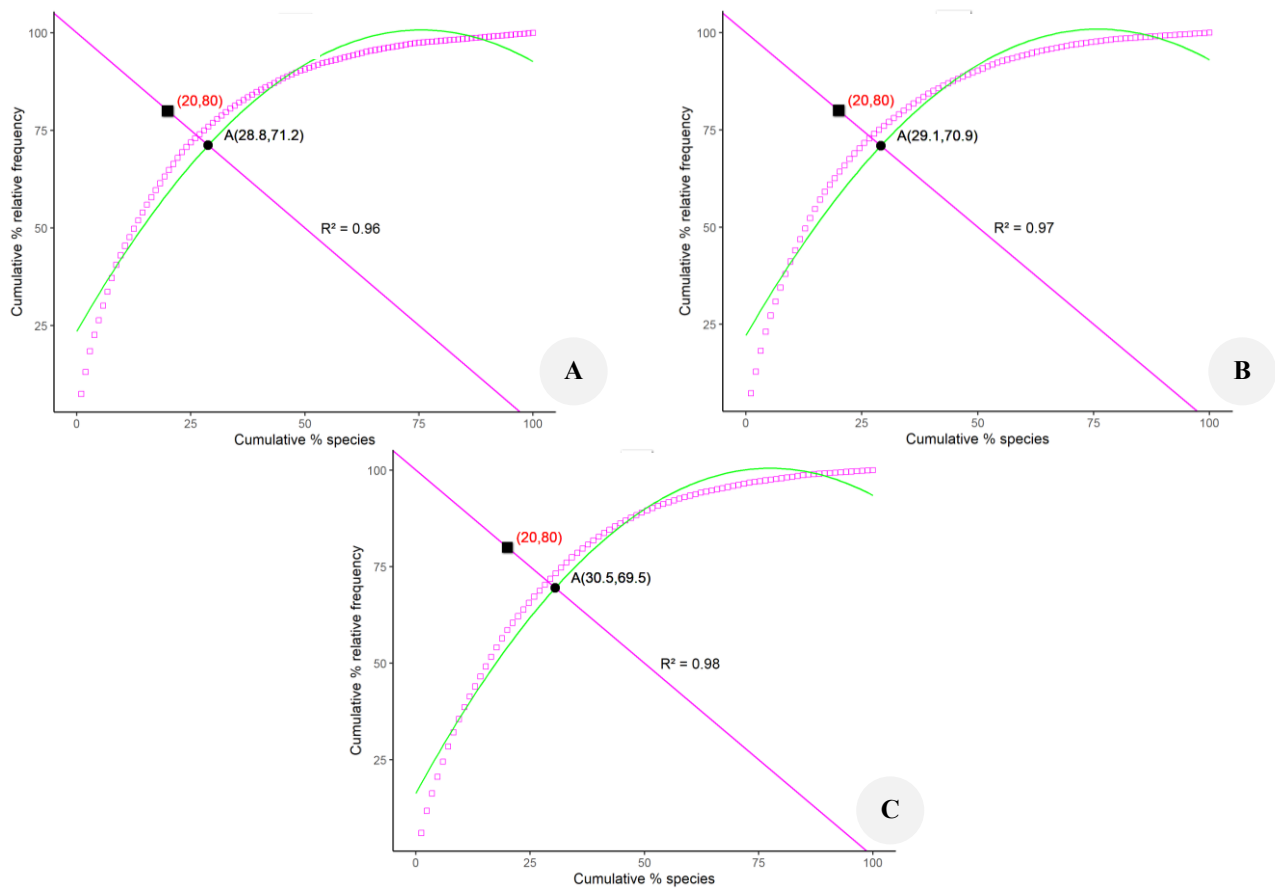
Forest types	$\delta_T^2$	$S_T^2$	VR	W	Confidence interval for W [ $\chi^2(0.05, N); \chi^2(0.95, N)$ ]	Association type
EBP Forests	9.64	14.93	1.55	51.09	(20.87; 47.40)	Positive correlation
EBM Forests	9.74	14.45	1.48	43.02	(17.71; 42.56)	Positive correlation
WBM Forests	8.65	12.82	1.48	59.27	(26.51; 55.76)	Positive correlation

**Table 3.** Stability analysis of typical forest types in La Nga Protection Forest Management Board, Vietnam

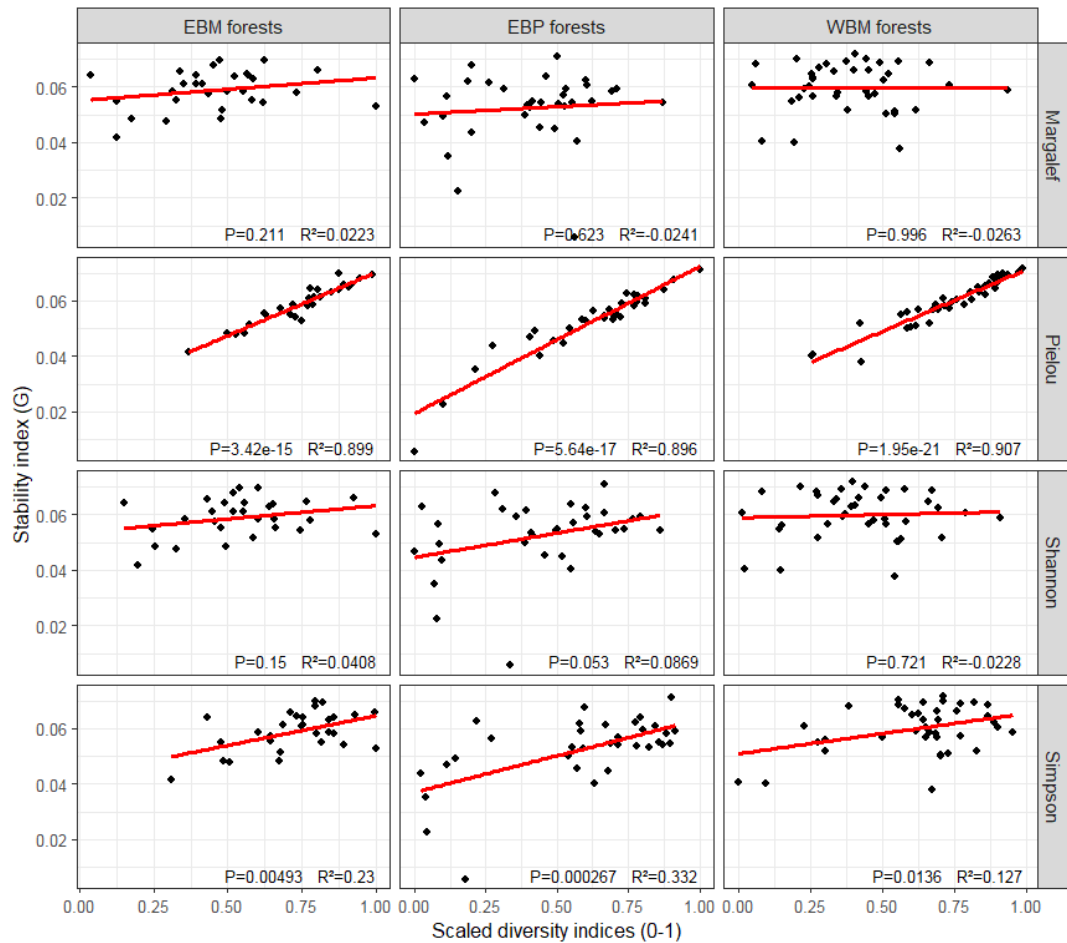
Forest types	Fitting curve	R <sup>2</sup>	Intersection coordinates	Euclidean distance (ESD)	Stability index (G)
WBM Forests	$y=16.348 + 2.17x - 0.014x^2$	0.98	(30.5;69.5)	14.84	0.067
EBM Forests	$y=23.549 + 2.044x - 0.0135x^2$	0.96	(28.8;71.2)	12.45	0.080
EBP Forests	$y=22.171 + 2.072x - 0.0136x^2$	0.97	(29.1;70.9)	12.85	0.078



**Figure 4.** Comparison of tree species diversity among typical forest types in La Nga Protection Forest Management Board, Lam Dong Province, Vietnam. Note: The small circles within each bar represent mean values of sampled plots. Different lowercase letters indicate significant differences between forest types ( $p < 0.05$ )



**Figure 5.** Simulation curves of Godron stability for different forest types. A. EBM Forests, B. EBP Forests, and C. WBM Forests. The theoretical stable state (20, 80) is indicated by the black rectangle symbol



**Figure 6.** Linear regression analysis of tree species diversity and stand structural stability. Note: Dots represent the scaled values of species diversity indices and the stability index for each plot

**Discussion**

*Changes in tree species diversity of different forest types*

Species diversity within tree communities is a measurable indicator of tree community structure and is closely linked to ecosystem functioning. Tree species diversity varies depending on the degree of disturbance and the recovery period of forest community. The present study indicates that medium forests exhibit a trend toward higher tree species diversity compared to other studied types. While mean values for richness and diversity indices were higher in these forests, statistical significance was primarily observed in Pielou’s Evenness ( $J'$ ). This suggests that the observed pattern is driven more by a balanced distribution of individuals than by a marked increase in species number alone. Consequently, the medium forest may harbor more comprehensive ecological information and potentially support enhanced ecosystem functions, although the statistical strength of these differences remains modest across most indices. Moreover, compared with the poor and woody-bamboo mixed forests, the medium forest demonstrates greater stand structural stability, which may be associated with longer recovery periods and lower levels of anthropogenic or natural disturbance. In alignment with our findings, a study by Trung et al. (2016) on the structural characteristics and biodiversity of the tree layer in post-extraction rehabilitated forests at the Dong Nai Cultural

and Nature Reserve, Vietnam also reported that Simpson and Shannon indices decreased sequentially from medium forest to poor forest, and finally to very poor forest. Similarly, species richness and the Margalef Index decreased progressively from rich forest to medium forest and poor forest in *Betula alnoides* Buch.-Ham. ex D.Don dominant forests in Ta Dung National Park, Vietnam (Huong et al. 2020).

The overall interspecific association characterizes the static relationship network among all species in the community, thereby reflecting the stability of its structural organization and species composition (Su et al. 2015; Gu et al. 2017; Liu et al. 2019). Tree community stability emerges from complex competitive and facilitative interactions among species, which collectively promote dynamic equilibrium (Na et al. 2016). Our findings indicate an overall positive co-occurrence tendency across the three forest types, suggesting non-random species distributions within these tree communities. Such patterns are consistent with shared habitat preferences, similar environmental filtering, and compatible ecological niches, rather than direct evidence of facilitative interactions. Together, these processes may contribute to the maintenance of relatively stable species assemblages in mature forest stands.

*Positive relationship between tree species diversity and stand structural stability within evergreen broadleaf forest types*

Species diversity, which encompasses both species richness and evenness, is indeed a robust indicator for assessing community stability dynamics and is widely applied in evaluating environmental effects on ecosystem stability (Gross et al. 2014). In this study, a statistically significant positive correlation was observed between evenness (Pielou, Simpson) and stand structural stability, supporting the view that species dominance structure may be more critical to stability than richness alone in this system. These findings are suggestive of patterns consistent with the diversity–stability hypothesis, but only within the specific context of stand structural stability as quantified by the Godron Index. The observed correlations likely reflect shared dependence on species relative abundances rather than independent causal effects, and therefore should not be interpreted as direct evidence for functional or ecosystem-level stability. This buffering capacity arises from increased functional redundancy within the community, whereby species that share similar ecological roles can compensate for one another when environmental disturbances occur (McCann 2000). Despite comparable trends reported in previous studies (Xu et al. 2015; Lei et al. 2023), these metrics are mathematically coupled through their shared use of species relative frequencies. Therefore, this relationship should not be interpreted as an independent causal proof of the diversity–stability hypothesis, but rather as an indication that community evenness is a primary driver of the structural regularity observed in high-tree layers. Notably, richness-based indices ( $d$ ) showed no significant correlation with stability, suggesting that the number of species is less critical to current structural stability than the equitability of their distribution. Consequently, conservation efforts should prioritize maintaining not just species numbers, but the balanced structural composition of these natural forest. In addition, this study focuses exclusively on the tree layer (DBH > 5 cm); therefore, conclusions regarding stability and biodiversity apply only to tree communities and not to understory or whole-plant communities.

Although our findings reveal a significant relationship between evenness and stand structural stability, it is important to emphasize that evenness and dominance structure are the key correlates in this dataset. A key limitation of the present study is that it did not account for other ecological factors that may strongly influence stand structural stability, such as soil nutrient dynamics, micro-environmental conditions, or the intensity and type of external disturbances. These factors, together with the varying environmental response traits of different functional species groups, may interact in complex ways and substantially regulate community stability processes (Wen et al. 2016). The patterns of forest recovery and tree community stability in this study are likely influenced by the regional monsoon climate and elevational conditions. Seasonal rainfall variation and temperature regimes affect regeneration processes and species interactions, which in turn shape successional dynamics and diversity–stability relationships. Higher and more humid sites may favor the

development of structurally complex and stable communities, whereas lower and drier areas may experience slower recovery and reduced stability. Because these variables were not incorporated into our analyses, the current results provide only a partial perspective on the diversity–stability mechanisms. Moreover, incorporating long-term temporal data would further strengthen the conclusions regarding community stability. Expanding future research to include these critical environmental and biological drivers will help improve the accuracy of stability assessments and support the development of more comprehensive ecosystem restoration and management strategies.

In conclusion, this study recorded a total of 128 tree species across 102 sampled plots in medium and poor evergreen broadleaf forests and woody-bamboo mixed forests within the La Nga Protection Forest Management Board, Vietnam. The medium forest tended to exhibit higher tree species diversity and stand structural stability indices compared with the other forest types. Notably, all three forest types demonstrated mutually positive interspecific associations. Moreover, the results indicate that stand structural stability is more strongly associated with species evenness and dominance, as reflected by the significant correlations with Simpson and Pielou indices, rather than with species richness alone. These findings suggest that evenness, rather than richness, may be a key driver of stand structural stability in the studied sites. This study was limited to the tree layer and represents a single time snapshot, restricting inference on regeneration processes and temporal dynamics. In addition, environmental drivers such as soil, topography, and microclimate were not included and may influence stand structure and stability. Therefore, to achieve a more comprehensive assessment of post-recovery stability and to establish reliable baseline thresholds for stand structural stability, future research should incorporate comparative analyses of regenerating forest communities across different successional stages, as well as variations in key environmental factors. Such efforts would provide essential reference data for the development of effective conservation and management strategies for tree communities.

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**Table S1.** Composition and importance value (the top 10 species) index of the tree species in three forest types

Forest types	Species	RD	RF	Rd	IV (%)
EBM Forests	<i>Syzygium borneense</i> (Miq.) Miq.	7.48	5.40	7.31	6.73
	<i>Lagerstroemia undulata</i> Koehne	5.63	3.86	5.62	5.04
	<i>Lithocarpus pseudosundaicus</i> (Hickel & A.Camus) A.Camus	5.34	4.37	4.61	4.77
	<i>Parinari annamensis</i> Hance	3.50	3.60	6.30	4.46
	<i>Vitex pinnata</i> L.	3.79	3.34	4.81	3.98
	<i>Litsea cubeba</i> (Lour.) Pers.	3.69	2.57	5.48	3.91
	<i>Cratoxylum formosum</i> (Jack) Benth. & Hook.fil. ex Dyer	4.17	3.08	3.41	3.56
	<i>Irvingia malayana</i> Oliv. ex A.W.Benn.	2.04	2.57	4.97	3.19
	<i>Heritiera javanica</i> (Blume) Kosterm.	2.43	2.57	4.13	3.04
	<i>Symplocos macrophylla</i> Wall. ex DC.	3.40	2.06	3.00	2.82
EBP Forests	<i>Lithocarpus pseudosundaicus</i> (Hickel & A.Camus) A.Camus	4.91	4.69	6.08	5.22
	<i>Syzygium borneense</i> (Miq.) Miq.	5.33	4.46	5.88	5.22
	<i>Dalbergia oliveri</i> Gamble ex Prain	7.28	2.35	4.40	4.68
	<i>Cratoxylum formosum</i> (Jack) Benth. & Hook.fil. ex Dyer	4.15	3.52	4.96	4.21
	<i>Lagerstroemia undulata</i> Koehne	3.64	3.05	5.05	3.91
	<i>Hymenodictyon orixense</i> (Roxb.) Mabb.	3.47	2.82	5.11	3.80
	<i>Nephelium cuspidatum</i> Blume	5.59	3.05	2.19	3.61
	<i>Xylopia vielana</i> Pierre	2.88	2.11	4.91	3.30
	<i>Parinari annamensis</i> Hance	3.56	2.82	2.74	3.04
	<i>Canarium pimela</i> K.D.Koenig	2.71	2.35	3.51	2.86
WBM Forests	<i>Lithocarpus pseudosundaicus</i> (Hickel & A.Camus) A.Camus	5.75	4.19	6.15	5.36
	<i>Lagerstroemia undulata</i> Koehne	6.03	3.53	6.24	5.26
	<i>Parinari annamensis</i> Hance	2.78	4.19	6.15	4.37
	<i>Symplocos macrophylla</i> Wall. ex DC.	4.50	2.43	5.20	4.04
	<i>Vitex pinnata</i> L.	4.31	2.43	4.53	3.76
	<i>Cratoxylum formosum</i> (Jack) Benth. & Hook.fil. ex Dyer	3.93	3.97	2.71	3.54
	<i>Irvingia malayana</i> Oliv. ex A.W.Benn.	3.07	2.43	4.75	3.42
	<i>Artocarpus heterophyllus</i> Lam.	1.63	3.09	4.10	2.94
	<i>Syzygium borneense</i> (Miq.) Miq.	3.45	3.09	2.09	2.88
	<i>Litsea cubeba</i> (Lour.) Pers.	1.82	2.65	3.65	2.71

**Table S2.** Relationship between tree species diversity and stand structural stability across different forest types

Forest types	Index	Adj_R <sup>2</sup>	P_Value	Intercept	Slope	Slope_CI Lower	Slope_CI Upper
EBM Forests	Shannon	0.0408	0.15	0.0537	0.0096	-0.00371	0.0229
	Simpson	0.23	0.00493	0.0432	0.0214	0.00708	0.0358
	Margalef	0.0223	0.211	0.0551	0.00816	-0.00492	0.0212
	Pielou	0.899	3.42E-15	0.0247	0.0456	0.0397	0.0515
EBP Forests	Shannon	0.0869	0.053	0.0446	0.0176	-0.000243	0.0354
	Simpson	0.332	0.000267	0.037	0.0264	0.0133	0.0394
	Margalef	-0.0241	0.623	0.0502	0.00529	-0.0164	0.027
	Pielou	0.896	5.64E-17	0.0194	0.053	0.0465	0.0595
WBM Forests	Shannon	-0.0228	0.721	0.0589	0.00231	-0.0107	0.0153
	Simpson	0.127	0.0136	0.0509	0.0146	0.00318	0.026
	Margalef	-0.0263	0.996	0.0598	3.22E-05	-0.0144	0.0145
	Pielou	0.907	1.95E-21	0.0266	0.0446	0.04	0.0492