

## TAN PHU FOREST, DONG NAI PROVINCE: A HOTSPOT FOR PLANT DIVERSITY IN SOUTHERN VIETNAM

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**Abstract.** This article aims to analyze and evaluate the diversity of the flora of Tan Phu Forest, a hotspot plant diversity in southern Vietnam, by considering variety at taxonomic levels, life form spectrum, phytogeographical factors, and forest resource value. A total of 1066 species/subspecies of vascular plants belonging to 571 genera and 136 families of 4 phyla were recorded. The life form spectrum was determined as SB = 76.64%Ph + 4.13%Ch + 2.63%Hm + 8.53%Cr + 8.07%Th. The flora of Tan Phu Forest was characterized by a typical tropical flora in southern Vietnam, with the Phanerophytes accounting for 76.64% and the tropical elements accounting for 88.27%. The flora of Tan Phu Forest has a close relationship with the Indo-Malezi flora (22.89% of tropical Asia). Eight hundred and nine useful plant species/subspecies (75.89%) were identified and classified into 9 different use value groups. In addition, 47 species were recognized as endangered, precious, and rare plants at the domestic and global levels. On the other hand, 12 endemic species in the Dong Nai region were also discovered. We propose upgrading the conservation level from the Protection Forest Management Board to a Nature Reserve to match the hotspot for plant biodiversity in Southern Vietnam.

**Keywords:** *conservation, life form spectrum, phytogeographical factor, species component, useful plants*

### Introduction

Plant biodiversity provides many direct and indirect benefits to society in a variety of ways, including (i) providing direct services, such as food-related services, medicine, water, wood and fibre, essential oils, oils, tannins, dyes, and (ii) indirect services, such as flood regulation, flood climate, pollination in plants, flood management, freshwater, and water filtration; cultural services, such as entertainment, aesthetic pleasure, and spiritual satisfaction; and supporting services, such as biomass-carbon and soil-formation, photosynthesis and nutrient cycling (Agustino et al., 2011; Corlett, 2016; Negi, 2022). Thus, plant biodiversity is the material basis for the existence and development of human society, since providing humans with abundant food and restorative materials, protecting soil, and climate regulation. Besides, it also is a survival support system for the sustainable development of human society (Li et al., 2009; Dai et al., 2018; Ma et al., 2021). Therefore, studying plant diversity is always the focus of research in countries worldwide in the context of increasingly complex and unpredictable climate change.

Vietnam is in Southeast Asia, spanning many different latitudes and characterized by quite diverse terrain, from plains and plateaus to mountainous regions, of which mountainous areas account for 3/4 of the territory. These characteristics form various tropical climate factors, with differences between Northern and Southern Vietnam

(Luong et al., 2023a; Hop et al., 2023a). These characteristics have created Vietnam in the Indo-Burma region, one of the 25 global biodiversity hotspots (Myers et al., 2000) and the 16<sup>th</sup> worldwide for biodiversity. A report has shown that Vietnam is home to 13,816 plant species (Ban, 2003-2005) and diverse ecosystems such as mangrove forests, dipterocarp forests, semi-evergreen forests, evergreen forests, mixed broad-leaved and coniferous forests, and other land-use types (Luong et al., 2023a).

The survey and assessment of plant diversity and floristic composition in natural forests are essential for the speed of environmental adaptation and its ecological significance (Reddy et al., 2011). They are even crucial for understanding the dynamics of the forest ecosystem (Reddy et al., 2008). It is an essential archive for conserving species and forest ecosystems (Huang et al., 2016). Many authors in Indochina (Rundel et al., 1999), China (Zhu and Tan, 2022), Ethiopia (Addi et al., 2020), Bangladesh (Bhattacharjee et al., 2022), Indonesia (Oktavia et al., 2021) have examined the plant diversity and the floristic composition of some tropical forests for biodiversity management and the conservation of the ecosystems.

The flora of the natural forest of Tan Phu, Dong Nai province, belongs to the closed tropical humid evergreen forest of the Malaysian-Indonesian flora, which is dominated by trees of the Dipterocarpaceae (Them, 1992; Trung, 1999). It is found in woody plant species and non-timber forest products and is essential in science, the economy, defense, and the environment. The main functions of the Tan Phu Forest are protecting soil and biodiversity, protecting the ecological environment, regulating the climate, and regulating water sources for the Tri An hydropower (Long et al., 2020). Therefore, the flora diversity analysis is of practical importance for climate change and the sensible management and use of forest resources (Long et al., 2020).

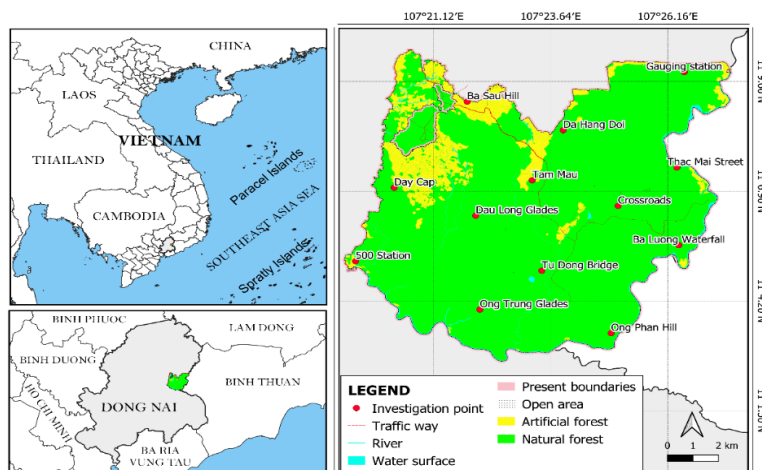
Reality demonstrates that solutions for the sustainable management, restoration, and evolution of natural forest ecosystems can only be sufficiently solved if there is a complete and profound understanding of the existing rules and the development of natural forests (Hop and Hanh, 2017): taxa composition diversity, life form spectrum and phytogeographical factors. A deeper insight into the composition of the flora is a key component in assessing the variety of forest ecosystems. They are an essential foundation for sustainable management and conservation of this invaluable resource. Meanwhile, previous studies were carried out in the Tan Phu Forest, primarily focusing on silviculture characteristics (Long, 2019); forest regeneration (Long et al., 2018; Viet, 2021); forest structure (Viet et al., 2020b; Quy et al., 2021); woody plant diversity (Huong et al., 2021); ecological role (Long et al., 2020) On the other hand, there has been no complete and systematic study of the flora in the study area. This article aims to analyze and evaluate the diversity and value of flora in the Tan Phu Forest, a hotspot for plant biodiversity in southern Vietnam. The results of this research significantly affect Tan Phu's natural forest management, conservation, and sustainable development. This paper aims to answer four questions: (1) What extent does plant biodiversity? (2) The flora is typical of which forest ecosystem? (3) The flora of Tan Phu is closely related to which flora? (4) What are the values of flora?

## Materials and methods

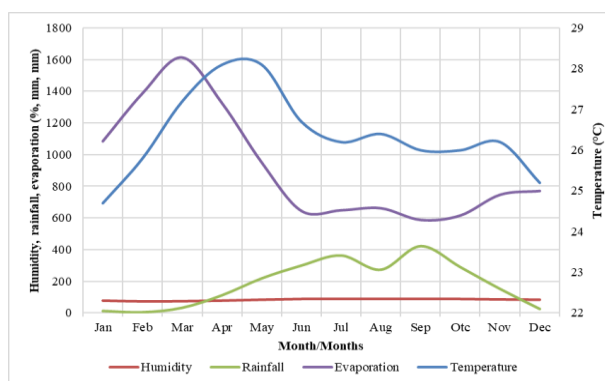
### *Study site*

This study was conducted in Tan Phu Protection Forest Management Board (Tan Phu Forest), Dong Nai Province (11<sup>02</sup>'32'' to 11<sup>010</sup>' N and 107<sup>020</sup>' to 107<sup>027</sup>'30'' E),

southern Vietnam from May 2021 to May 2023 (Fig. 1). The study area was approximately 13,587.96 ha and part of the tropical monsoon climate (dry and rainy seasons) (Huong et al., 2021). Climate data for 13 years from 2010 to June 2022 was collected and analyzed, showing that the rainy season lasts from May to November and the dry season from December of the previous year to April of the following year. The altitude was 70 m-200 m, average at 80 m-120 m above sea level. The average air temperature was 26.38°C. The average annual rainfall was 2,213 mm/year. The average rainfall in the rainy season was 288.8 mm/month, from 152.3 to 422.6 mm/month. The average rainfall in the dry season was 38.3 mm/month, from 5.5 to 112.4 mm/month. The average annual evaporation was 11,018 mm per year. The average evaporation in the rainy season was 692 mm per month, and in the dry season was 1,234.8 mm per month (Fig. 2). The average annual humidity was 81.7%, a maximum of 88% (July and September), and a minimum of 71% (February) (Fig. 2). The flora of Tan Phu Forest was characterized by Dipterocarpaceae species such as *A. roxburghii*, *A. costata*, *D. dyeri*, *D. alatus*, *H. odorata*, *S. guiso*, etc., and some species of Fabaceae, Clusiaceae, Sapindaceae, Ebenaceae, Elaeocarpaceae, Lythraceae, Hypericaceae, etc. (Hop et al., 2020; Quy et al., 2021).



**Figure 1.** Map of the study area. Maps of Vietnam, Dong Nai Province (left) and Tan Phu Forest (right)



**Figure 2.** Gaussen chart showing monthly evaporation (mm; Purple line), monthly air temperature (°C, Blue line), monthly rainfall (mm; Yellow-green line), and monthly air humidity (%; Red line) in Tan Phu, Dong Nai province for 13 years (January 2010 - June 2022)

### **Data collection**

Field surveys were conducted many times, from 7/2019 to 9/2019 and 5/2021 to 5/2023; each was about 5-7 days. The survey was carried out at other times to collect important traits (reproductive agencies) of species to ensure accuracy. Thirteen locations, including Ong Trung Glades, Ba Luong Waterfall, Tu Dong Bridge, Ong Phan Waterfall, 500 Station, Dau Long Glades, Khai Thac Crossroads, Thac Mai Street, Tam Mau, Day Cap, Ba Sau Hill, Da Hang Doi, and Gauging Station were selected to set up transect line investigation and sample plots (*Fig. 1*). At each location, 2 transect line surveys were established (each transect 1.5-3.8 km) to collect plant specimens and necessary information. Each transect set up 2-3 square-shaped sample plots with an area of 2500 m<sup>2</sup> (50 m by 50 m) (Thin, 1997). A total of 26 transect lines were surveyed, and 69 sample plots were set up. A typical sample plot was established in vegetation representing different habitats, altitudes, and slopes. Special tools were used to identify and measure each sample plot field with information about the species name, overall height, and the diameter at breast height of all plant individuals. The diameter at breast height (dbh) was measured using a tape measure and a wooden length of 1.3 m above the ground. All timber trees with a diameter at breast height of  $\geq 5$  cm were determined dbh. The overall height was determined using a Blume-Leiss meter. The occurrence of all species was recorded in each sample plot and measured using the criteria several species/ha, species composition, dominant species, etc., to examine comparisons and evaluate objects of diversity.

### **Data analysis**

Science names and a list of vascular plants were identified and established in the Tan Phu Forest, Dong Nai province, Southern Vietnam. In the preliminary classification, the specimen was processed (pressed, chemical, dried) and based on the most characteristic morphological features (leaves, tubers, branches, roots, flavors, colors, etc.), especially reproductive agencies (flowers, fruits, seeds). The specimen was compared with the standard sample in the Botanical Museum of the Vietnam National University of Forestry-Dong Nai Campus, Cat Tien National Park, Dong Nai Cultural Nature Reserve, Southern Institute of Ecology, and Binh Chau-Phuoc Buu Nature Reserve. The unavailable specimens in the botanical museums were further analyzed, classified, and consulted with experts, and descriptions of the documents specialized in identifying specimens were used. The documents were used to determine the species: An Illustrated Flora of Vietnam (Ho, 1999-2003), List of Plant Species in Vietnam (Ban, 2003-2005), Timber Trees Resources in Vietnam (Hop, 2002), Flora of China Illustrations (Yi and Peter, 1994-2008), Plants of the World Online (POWO, 2023), The World Flora Online (WFO, 2023). In those cases where species could not be identified at the species level, these were recognized at the genus level.

The scientific name of the plant species, the classification of the genus, and the family level were also checked, compared, and updated by Plants of the World Online (POWO, 2023) and The World Flora Online (WFO, 2023). A plant list was created according to the classification system of “Vascular Plant Families and Genera” (Brummitt, 1992) and “the APG IV” (Chase et al., 2016). The phylum was divided into Lycopodiophyta, Polypodiophyta, Gymnospermatophyta, and Angiospermatophyta. Angiospermatophyta was split into two classifications: Eudicots and Monocots. In the list, the families in the phylum, the genera in the family, and the species in the genus were arranged

alphabetically. The floristic diversity was analyzed according to the "Manual for Biodiversity Research" (Thin, 1997).

The life-forms spectrum was assessed according to "Plant life forms" (Raunkiaer, 1934). The Phytogeographical factors were identified and evaluated according to the classification system of Pócs (1965), modified by Thin (2007).

The use-value of the forest resources was determined based on the following documents: An Illustrated Flora of Vietnam (Ho, 1999-2003), Dictionary of Vietnamese Medicinal Plants (Chi, 2012), Vietnamese medicinal plants and medicine (Loi, 2001), 1,900 helpful plant species in Vietnam (Ly, 1993), Plant resources with essential oils in Vietnam (Moi, 2001-2002), Useful Tropical Plants (UTP, 2023), and Plants of the World Online (POWO, 2023). The experiences of the locals also flowed into the use of the species.

The importance of flora for nature conservation was evaluated using the Vietnam Red Data Book (Ban et al., 2007) and the IUCN Red List (IUCN, 2023) of threatened species, while endemic plants were identified according to Vietnamese plants (Thin et al., 2000-2010), and Plants of the World Online (POWO, 2023).

### *Diversity index*

Shannon diversity index (Shannon 1948)

$$H' = - \sum_{i=1}^S P_i * \ln (P_i) \quad (\text{Eq.1})$$

Gini-Simpson diversity index (Simpson 1949)

$$D = \sum_{i=1}^S (P_i)^2 \quad (\text{Eq.2})$$

where,  $P_i = N_i/N$ ,  $N$  is the total number of individuals in the plot, and  $N_i$  is the number of individuals of species  $i$  in the sample plot.

## **Results**

### ***Floristic component***

#### *Diversity of phylum level*

A total of 1066 taxa belonging to 571 genera and 136 families of vascular plants were represented by four phylum, namely Lycopodiophyta, Polypodiophyta, Gymnospermatophyta, and Angiospermatophyta. Of them, 1057 taxa were identified as species, and nine taxa were identified only as genera. Two species new to science have been previously described and illustrated in Dong Nai Cultural Nature Reserve, Dong Nai province: *Aspidistra phanluongii* (Vislobokov et al., 2013) and Ham Thuan Nam Districts, Ta Kou Nature Reserve, Binh Thuan province was *Curcuma xanthella* (Leong and Dang, 2013) was also recorded in the study area.

Most taxa focused on Angiosperm with 122 families (89.71%), 546 genera (95.62%), and 1029 taxa (96.53%) of the entire family, genus, and taxa, followed by Polypodiophyta with ten families (7.35%), 21 genera (3.68%), 28 taxa (2.63%); The lowest was Lycopodiophyta with two families (1.47%), two genera (0.35%), four species (0.38%) (Table 1).

**Table 1.** Diversity of taxon vascular plant species

No.	Phylum	Family		Genera		Species	
		Quantity	%	Quantity	%	Quantity	%
1	Lycopodiophyta	2	1.47	2	0.35	4	0.38
2	Polypodiophyta	10	7.35	21	3.68	28	2.63
3	Gymnospermatophyta	2	1.47	2	0.35	5	0.47
4	Angiospermaephyta	122	89.71	546	95.62	1029	96.53
	<b>Total</b>	<b>136</b>	<b>100</b>	<b>571</b>	<b>100</b>	<b>1066</b>	<b>100</b>

For Angiosperms, Eudicots dominated (over 66%) in the taxons (family, genera, and species (Table 2). Eudicots account for 74.11% of the species, 72.85% of the genera, and 66.18% of the families. The percentage between Eudicots and Monocots was 2.81 for families, 3.20 for genera, and 3.31 for species.

**Table 2.** Diversity of taxon in Angiospermaephyta

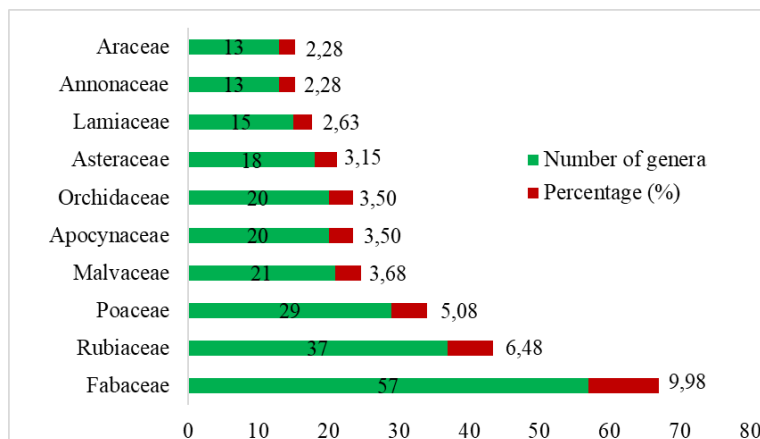
No.	Classification	Family		Genera		Species	
		Quantity	%	Quantity	%	Quantity	%
	Angiospermaephyta	122	89.71	546	95.62	1029	96.53
1	Eudicots	90	66.18	416	72.85	790	74.11
2	Monocots	32	23.53	130	22.77	239	22.42

Table 1 and Table 6 showed that the flora in Tan Phu Forest had a high family index of 7.84, meaning that each family had 7 to 8 species on average. The high genera diversity index was 1.87, meaning that each genus had 1 to 2 species on average. The average number of genera per family was 4.20, meaning each family has about four genera (Table 6). Angiospermaephyta is the most diverse in the phylum of indicators, with an average of more than eight species per family, about two species in each genus; the lowest was Lycopodiophyta, with each family having an average of 2 species, with each genus having an average of 2 species.

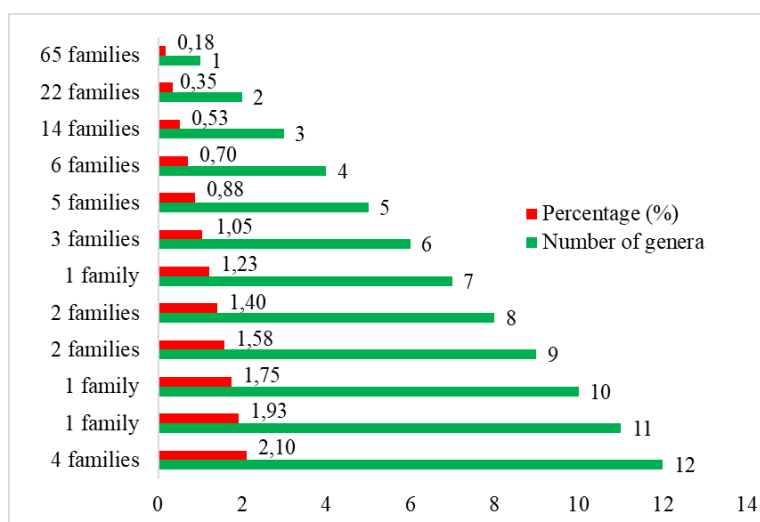
#### Diversity of taxon under the phylum level

##### Diversity of family level

The ten most genera-rich families (13 to 57 genera) were counted (243 genera and 42.56% of the total genera, respectively) (Fig. 3). These were represented by Fabaceae (57 genera = 9.98%); Rubiaceae (37 genera = 6.48%); Poaceae (29 genera = 5.08%); Malvaceae (21 genera = 3.68%); Apocynaceae and Orchidaceae (20 genera = 3.50%); Asteraceae (18 genera = 3.15%); Lamiaceae (25 genera = 2.63%); Annonaceae, and Araceae (13 species = 3.12%) (Fig. 3). Furthermore, four families had 12 genera (2.10%), one family had 11 genera (1.93%), one family had ten genera (1.75%), two families had nine genera (1.58%), two families had eight genera (1.40%), one family had seven genera (1.23%), three families had six genera (1.05%), five families had five genera (0.88%), six families had four genera (0.70%), fourteen families had three genera (0.53), twenty-two had two genera (0.35%), sixty-five families single genera (0.18%) was also identified (Fig. 4).

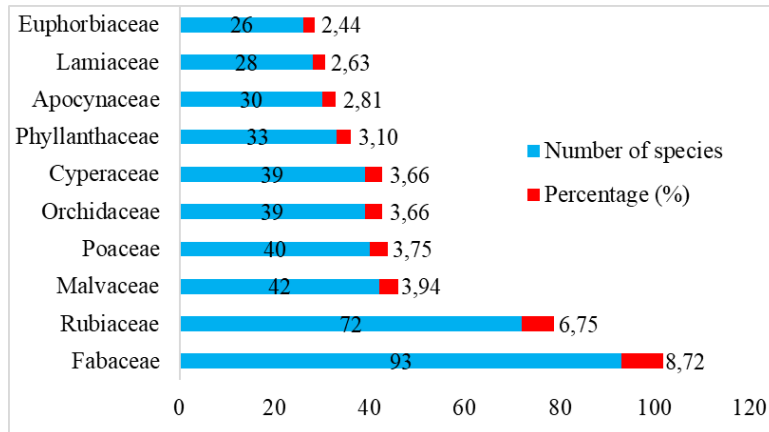


**Figure 3.** Statistics of the ten most diverse families about genera

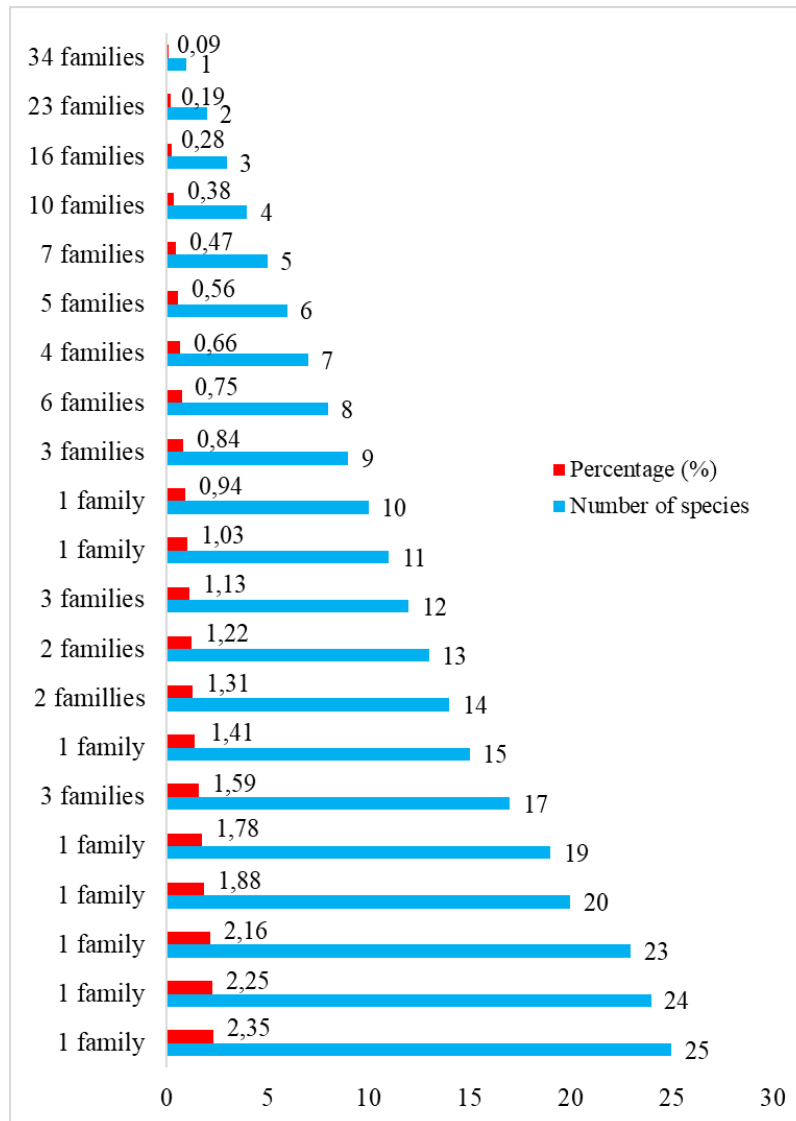


**Figure 4.** Statistics on the number and percentage of genera by family

The ten species-rich families (26 to 93 species) were counted (442 species and 41.46% of the total species, respectively). These were represented by Fabaceae (93 species = 8.72%); Rubiaceae (72 species = 6.75%); Malvaceae (42 species = 3.94%); Poaceae (40 species = 3.75%); Cyperaceae, and Orchidaceae (39 species = 3.66%), Phyllanthaceae (33 species = 3.10%); Apocynaceae (30 species = 2.81%); Lamiaceae (28 species = 2.63%), and Euphorbiaceae (26 species = 2.44%) (Fig. 5). On the other hand, one family had 25 species (2.35%), one family had 24 species (2.25%), one family had 23 species (2.16%), one family had 20 species (1.88%), one family had 19 species (1.78%), three families had 17 species (1.59%), one family had 15 species (1.41%), two family had 14 species (1.31%), two families had 13 species (1.22%), three families had 12 species (1.13%), one family had 11 species (1.03%), one family had ten species (0.94%), three families had nine species (0.84%), six families had eight species (0.75%), four families had seven species (0.66%), five families had six species (0.56%), seven families had five species (0.47%), ten families had four species (0.38%), sixteen families had three species (0.28%), twenty-three families had two species (0.19%), thirty-four monotypic family (0.09%) was determined (Fig. 6).



**Figure 5.** Statistics of the ten most diverse families of species



**Figure 6.** Statistics on the number and percentage of species by family



### Diversity of genera level

The ten most species-rich genera (8 to 19 species) (111 species and 10.41% of the total species, respectively) were listed. The most diverse genus of *Ficus* Tourn. ex L. was represented among them, 19 species (1.78%), followed by *Cyperus* L. 18 species (1.69%); *Dendrobium* Sw. 12 species (1.13%), *Antidesma* L. and *Syzygium* Gaertn. ten species each (0.94%); *Ardisia* Sw and *Dioscorea* Plum. ex L., nine species each (0.84%), while *Diospyros* L., *Garcinia* L., and *Fimbristylis* Vahl had eight species each (0.75%) (Fig. 7). In addition, three genera were represented by seven species each (0.66%), while seven genera were represented by six species each (0.56%), and 12 genera were represented by five species each (0.47%). Twenty-nine genera were represented by four species each (0.38%), and forty-four genera were represented by three species each (0.28%). In comparison, 118 genera were represented by two species each (0.19%), and 348 monotypic genera (0.09%) were counted (Fig. 8). The analysis showed that the flora of Tan Phu had a high diversity at the taxonomic level of the family and the genus.

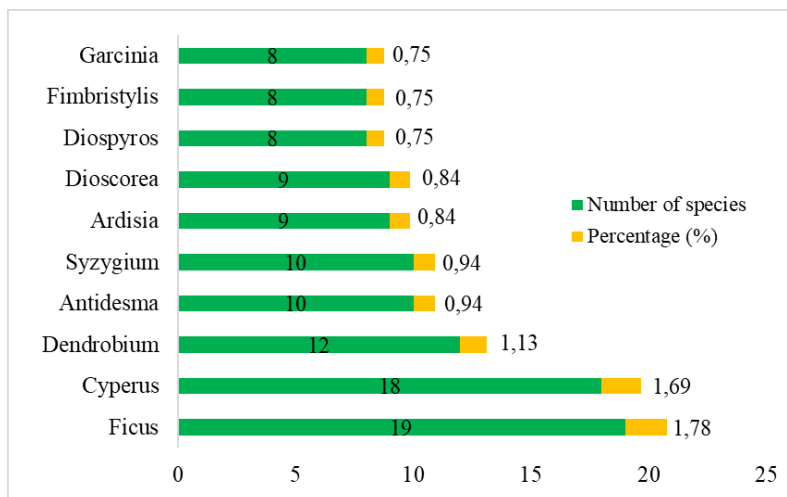


Figure 7. Statistics of the ten most diverse genera of species

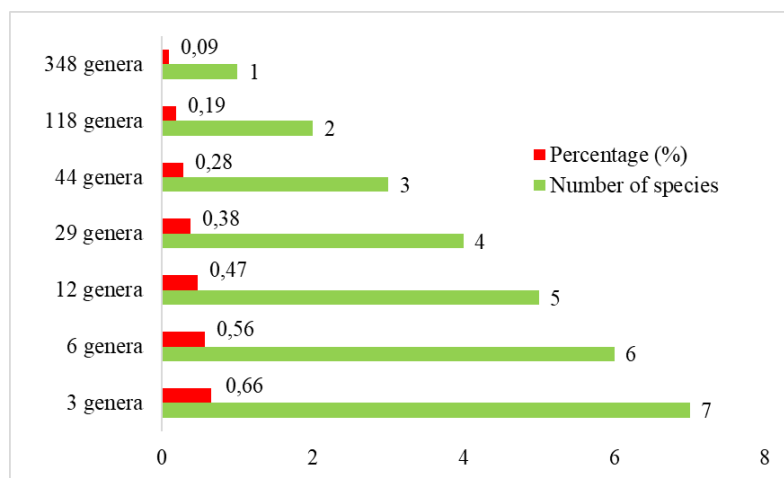


Figure 8. Statistics on the number and percentage of species by genus

### Some plant diversity index

According to the classification scale of Djufri et al. (2016), the diversity of the Tan Phu flora is at a moderate level. The Shannon index ( $H'$ ) ranged from  $H'=2.10 \pm 0.45$  at deciduous broadleaved forests to  $H'=2.90 \pm 0.23$  at evergreen broadleaved forests; Simpson (1-D) ranged from  $0.79 \pm 0.11$  at deciduous broadleaved forests to  $0.93 \pm 0.02$  at evergreen broadleaved forests (Table 3).

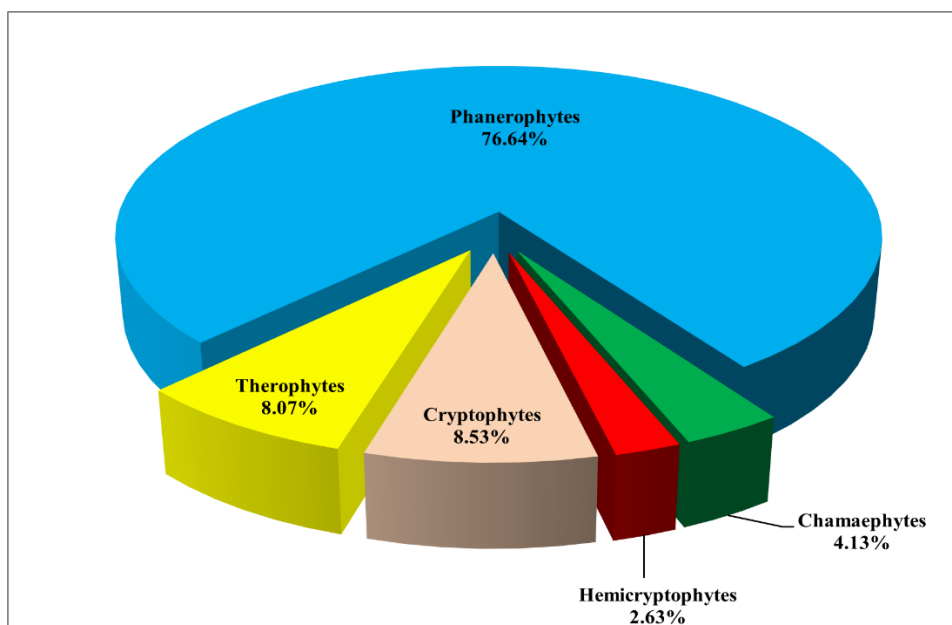
**Table 3.** Some plant diversity indices

Forest type	Shannon ( $H'$ )	Simpson (1-D)
	Mean $\pm$ Standard deviation	
Deciduous broadleaved forest	$2.10 \pm 0.45$	$0.79 \pm 0.11$
Semi- deciduous broadleaved forest	$2.51 \pm 0.27$	$0.89 \pm 0.03$
Evergreen broadleaved forest	$2.90 \pm 0.23$	$0.93 \pm 0.02$

### Diversity of life-form spectrum

The life form of the plants shows the ecological nature of the flora and other ecosystems. The life-form spectrum of the Tan Phu flora was determined according to Raunkiaer's (1934) classification system. The result is shown schematically in Figure 9.

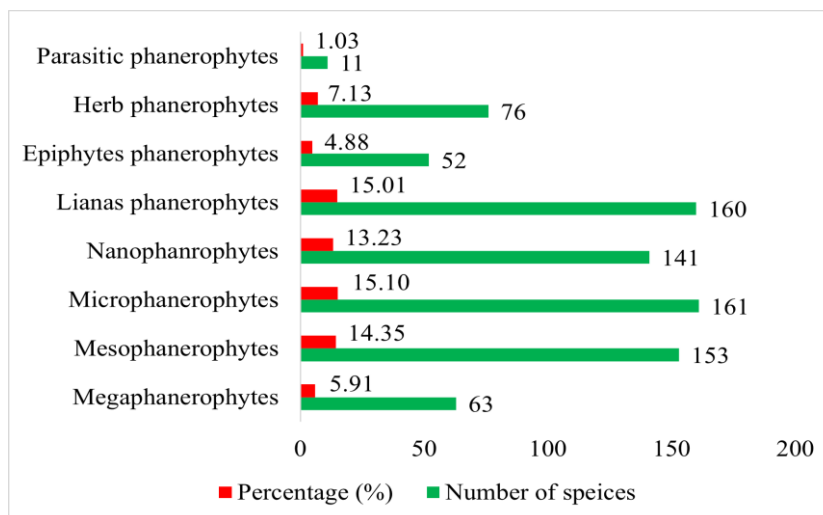
The Tan Phu Flora Spectrum of Biology (SB) was determined as follows: SB = 76.64%Ph + 4.13%Ch + 2.63%Hm + 8.53%Cr + 8.07%Th.



**Figure 9.** Spectrum of Biology (SB) of the Tan Phu Forest

The Phanerophytes (76.64%) predominate over the remaining life forms. This showed that the tropical rainforests were typical of Tan Phu flora and Southern Vietnam. In Phanerophytes, Microphanerophytes is highest (15.10%), followed by Lianas phanerophytes (15.01%), Mesophanerophytes (14.37%), Nanophanerophytes (13.23%),

Herb phanerophytes (7.13%), Megaphanerophytes, Epiphytes-phanerophytes, Parasitic phanerophytes and Succulent phanerophytes made up a small proportion (Fig. 10). Although Hemicryptophytes, Cryptophytes, and Therophytes account for a low percentage, the full presence of these components indicates their essential role and constitutes the diversity of flora.



**Figure 10.** The life forms composition in the Phanerophytes

The Microphanerophytes (Mi) account for the highest proportion with 15.10% of the total species of flora; this group includes small tree species distributed under the canopy codominance tree; Rubiaceae, Phyllanthaceae, Euphorbiaceae, Lauraceae, Fabaceae, Moraceae, Myrtaceae, Rutaceae, Malvaceae, Sapindaceae, Theaceae, Annonaceae, Primulaceae, Lamiaceae, etc. characterize these.

The Lianas phanerophytes (Lp) account for approximately the proportion of Microphanerophytes (Mi), with 15.01% of the total species of flora. This group of extratropical plants commonly occurs in shrub vegetation and ground herbs due to an intense selection harvest system. Annonaceae, Apocynaceae, Convolvulaceae, Connaraceae, Cucurbitaceae, Fabaceae, Loganiaceae, Oleaceae, Menispermaceae, Lamiaceae, Vitaceae, Gnetaceae, Dioscoreaceae, and Smilacaceae represented these.

The Mesophanerophytes (Me) account for 14.35% of the total number of species of the flora; this group includes the dominant woody species in the ecological dominant canopy layer and under the canopy layer. The representative families were Anacardiaceae, Clusiaceae, Euphorbiaceae, Ebenaceae, Fabaceae, Lamiaceae, Malvaceae, Myrtaceae, Moraceae, Phyllanthaceae, Polygalaceae, Sapindaceae, etc.

The Nanophanerophytes (Na) account for 13.23% of the total species of flora, including shrub species, distributed under the forest canopy; this group is typical for the type of vegetation after exploitation. These were concentrated mainly in the families Acanthaceae, Annonaceae, Euphorbiaceae, Apocynaceae, Fabaceae, Lamiaceae, Malvaceae, Phyllanthaceae, Rubiaceae, and Arecaceae.

The Cryptophytes (Cr) account for 8.53% of total species, represented by Acanthaceae, Araceae, Asparagaceae, Cyperaceae, Marantaceae, Zingiberaceae, Musaceae, etc.

The Therophytes (Th) accounts for 8.07% of the total species of flora; Amaranthaceae, Asteraceae, Fabaceae, Linderniaceae, Plantaginaceae, Rubiaceae, Solanaceae, Burmanniaceae, Poaceae, etc. represent them.

The Herb phanerophytes (Hp) account for 7.13% of total species, concentrated in Lycopodiaceae, Selaginellaceae; Pteridaceae, Lamiaceae, Amaranthaceae, Commelinaceae, Poaceae, Fabaceae, Plantaginaceae, Xyridaceae.

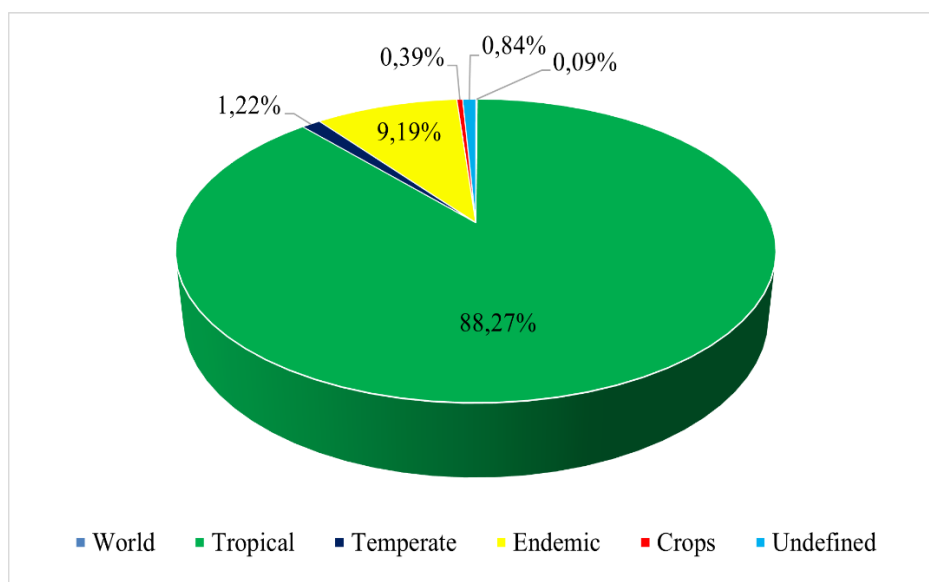
The Megaphanerophytes (Mg) account for 5.91% of the total species and are usually distributed in the dominant canopy layer. These include Dipterocarpaceae, Lythraceae, Anacardiaceae, Fabaceae, Meliaceae, Myrtaceae, Sapindaceae, Malvaceae, Clusiaceae, Combretaceae, Buseraceae, Bignoniaceae, etc.

The Epiphytes phanerophytes (Ep) account for 4.88% of the species. They are distributed in the canopy layers of the forest, on the ground, on rocks and trees in evergreen and semi-evergreen forests, and deciduous, even in plantations. This group is characterized by plant families such as Polypodiaceae, Apocynaceae and Orchidaceae.

The Parasitic phanerophytes (Pp) group was the lowest, accounting for 1.03% of the total species; they live on woody plants and vines, represented by the families Loranthaceae, Cuscutaceae, and Orobanchaceae.

### ***Diversity of phytogeographical factor***

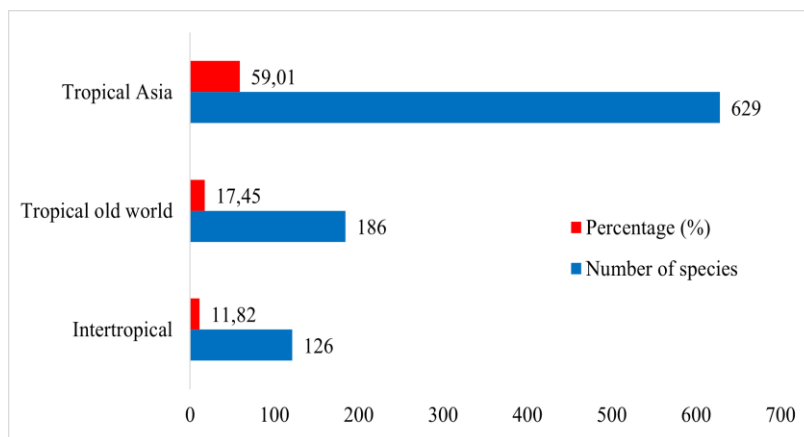
Based on the classification system by Pocs (1965) modified by Thin (2007). A total of 1057 species (99.16%) of 1066 taxa were determined phytogeographical; nine taxa (0.84%) were unidentified due to data deficiency. Tropical factors were recognized by 941 species (88.27%), while endemic factors were recognized by 98 species (9.19%). The temperate factor was determined from 13 species (1.22%), and the lowest was the world factor (0.09%) (*Fig. 11*).



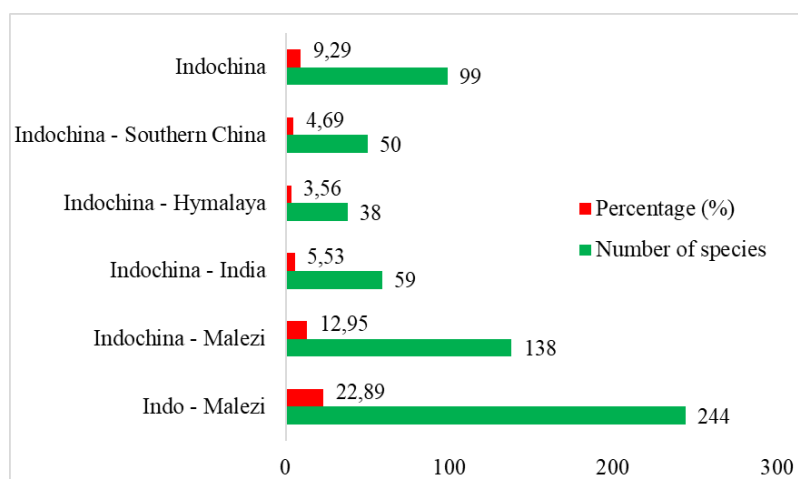
***Figure 11. The phytogeographical factor of Tan Phu Forest***

In further analysis of tropical factors, Asian tropical factors dominate with 629 species (59.01%), while intertropical and old tropical world factors were 11.82% and 17.45%, respectively (As shown in *Fig. 12*). Regarding tropical Asian elements, the Indo-Malezi

factor (22.89%) accounts for the highest proportion, followed by the Indochina-Malezi (12.95%), Indochina (9.29%), Indochina-India (5.53%) and Indochina-Southern China (4.69%) and the lowest is the Indochina-Himalayan factor (3.56%) (Fig. 13). This shows that the Tan Phu flora is characteristic of a typical tropical Asian flora and has a close relationship with the Indo-Malazi flora.



**Figure 12.** The phylogeographical factor composition in the tropical factor



**Figure 13.** The phylogeographical factor in the tropical Asian group

### **Diversity of forest resources value**

#### **Diversity of use-value**

Tan Phu flora is diverse not only in taxonomy but also in its usefulness. Eight hundred nine species were identified with useful, accounting for 75.89% of the total number of species discovered and divided into nine groups. The results are given in *Table 4*.

The dominant medicinal plant (51.41%) was found in Zingiberaceae, Lamiaceae, Asteraceae, Rutaceae, Fabaceae, Loranthaceae, Malvaceae, Onagraceae, Celastraceae, etc. Followed by edible plants (26.55%), products included tubers, fruits, seeds, and vegetables, which were the main ingredients in this group. Timber tree (17.54%) was found mainly in Dipterocarpaceae, Anacardiaceae, Ebenaceae, Meliaceae, Sapindaceae,

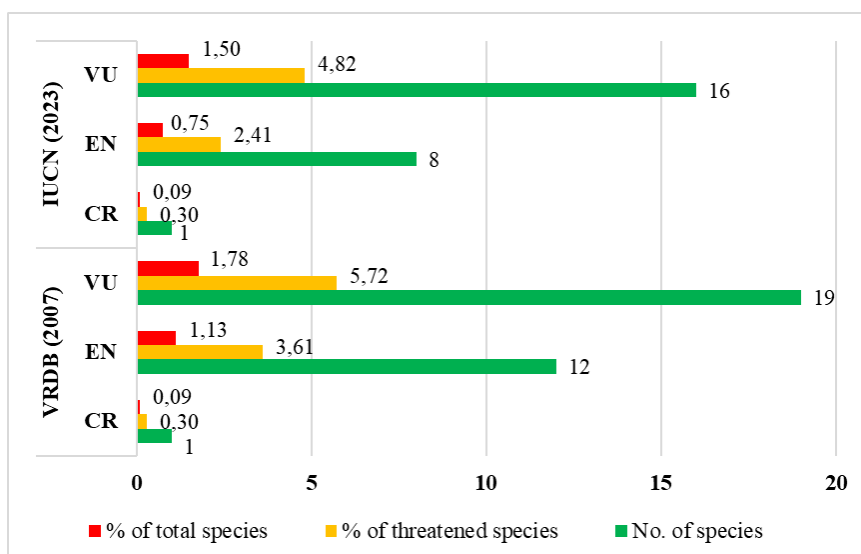
Clusiaceae, Sapotaceae, Myrtaceae, Myristicaceae, Hypericaceae, etc. Ornamental plant (11.54%) comes mainly from Orchidaceae, Melastomataceae, Cycadaceae, Moraceae, Apocynaceae, Lythraceae, Arecaceae, etc. The remaining groups include Essential Oil, Poisonous, Resin, Dye, and others, with ratios ranging from 1.41% to 7.04%.

**Table 4.** Diversity of use value of forest resources

No.	Use value	Symbol	Quantity	Percentage (%)
1	Medicinal plants	Med	548	51.41
2	Edible plant	Edi	283	26.55
3	Timber trees	Tim	187	17.54
4	Ornamental plant	Orn	123	11.54
5	Other	Oth	75	7.04
6	Essential oils	Ess	51	4.78
7	Dyeing	Dye	30	2.81
8	Poisonous	Poi	17	1.59
9	Resin	Res	15	1.41

#### Diversity of endangered, precious, and rare plants

In addition to the diversity of taxa, it contains species richness and conservation value (Fig. 14). Forty-seven species (4.41%) out of 1066 species were identified as endangered, precious, and rare. In the Vietnam Red Data Book (2007), 32 species were found, especially *Telectadium dongnaiense* classified as Critically Endangered (CR), and 12 species were classified as Endangered (EN), typically *Dalbergia cochinchinensis*, *Anisoptera costata*, *Azelia xylocarpa*, *Dalbergia oliveri*, *Pterocarpus macrocarpus*, etc. At the same time, 19 species were classified as Vulnerable (VU). There were 25 species (2.35%) listed in the IUCN Red List (2023), *Aquilaria crassna* classified as Critically Endangered (CR), eight species as Endangered (EN), and 16 species as Vulnerable (VU).



**Figure 14.** Diversity of endangered, precious, and rare plant species composition

#### Diversity of endemic species

Tan Phu's flora contains many endemic species of Vietnam and the world. Forty-one species (3.85%) were identified as endemic to Vietnam, and nineteen species (1.78%) were endemic to Southern Vietnam, especially twelve species (1.13%) out of 1066 taxa were endemic to Dong Nai (Table 5).

**Table 5.** The composition of endemic plants to Dong Nai in Tan Phu Forest

No.	Scientific name	Vietnam name	Family name
1	<i>Aspidistra phanluongii</i> N. Vislobokov	Tỏi phanluong	Asparagaceae
2	<i>Benkara hoaensis</i> (Pierre ex Pit.) Ridsdale	Găng biên hòa	Rubiaceae
3	<i>Calamus dongnaiensis</i> Pierre ex Becc.	Mây đồng nai	Areaceae
4	<i>Croton dongnaiensis</i> Pierre ex Gagnep.	Cù đèn đồng nai	Euphorbiaceae
5	<i>Goniothalamus donnaiensis</i> Finet & Gagnep.	Giác đé đồng nai	Annonaceae
6	<i>Hypobathrum hoaense</i> Pierre ex Pit.	Hạ đệ	Rubiaceae
7	<i>Madhuca dongnaiensis</i> (Pierre) Baehni	Sến đồng nai	Sapotaceae
8	<i>Mangifera dongnaiense</i> Pierre	Xoài đồng nai	Anacardiaceae
9	<i>Mussaenda hoaensis</i> Pierre ex Pit.	Bướm bạc biên hòa	Rubiaceae
10	<i>Senegalia donnaiensis</i> (Gagnep.) Maslin, Seigler & Ebinger	Keo đồng nai	Fabaceae
11	<i>Tarenna hoaensis</i> Pit.	Trèn biên hòa	Rubiaceae
12	<i>Telectadium dongnaiense</i> Pierre ex Costantin	Vệ tuyến đồng nai	Apocynaceae

Eight species were named after places in Dong Nai province: *Calamus dongnaiensis* Pierre ex Becc., *Madhuca dongnaiensis* (Pierre) Baehni, *Croton dongnaiensis* Pierre ex Gagnep, *Senegalia donnaiensis* (Gagnep.) Maslin, Seigler & Ebinger, *Telectadium dongnaiense* Pierre ex Costantin. Four species named Bien Hoa, the old place name of Dong Nai province was *Hypobathrum hoaense* Pierre ex Pit., *Benkara hoaensis* (Pierre ex Pit.) Ridsdale, *Mussaenda hoaensis* Pierre ex Pit., and *Tarenna hoaensis* Pit.

### ***Invasive alien species composition***

In addition to endemic and endangered species, 6 species were found to be invasive alien plants with the potential to spread and harm ecosystems, including *Mimosa pigra* L., *Mimosa diplotricha* Wright, *Chromolaena odorata* (L.) R.M.King & H.Rob., *Pontederia crassipes* Mart., *Lantana camara* L., and *Leucaena leucocephala* (Lam.) de Wit.

## **Discussion**

### ***Diversity of floristics***

The flora of Tan Phu Forest is very diverse and abundant, with a total of 1066 species/subspecies belonging to 571 genera, and 136 families of 4 phylum were recognized.

The unequal distribution of taxa was evident between the phylum and the angiosperm phylum (Table 2). The proportion of correlation between the two classes of Angiospermaephyta (family level) was 3.31, showing the dominance of the Eudicots/monocots class. This proportion is similar to the general proportion of Vietnam's flora (3.2) (Chan, 1999). This ratio will decrease in wetland and aquatic flora, but not in dry flora, due to adaptation to different environmental conditions of eudicots and monocots. In some floras of Southern Vietnam, it was 4.33 for the Phu Quoc National Park (Quân,

2015), 3.42 for the Yok Don National Park (Dung, 2005), 4.41 for the Dong Nai Cultural - Nature Reserve (Hung et al., 2019), 3.39 for the Binh Chau - Phuoc Buu Nature Reserve (Hung et al., 2020), 4.83 for the Con Dao National Park (Ai and Hue, 2013), and 5.05 for the Dak Nong province (Luong et al., 2023b). With some flora in temperate countries such as Lithuania, Estonia has a ratio of 2.9. In the Arctic region, it was 2.3-2.4. The results of the analysis showed that Tan Phu Forest's flora had the characteristics of a tropical flora. The present study was consistent with De Candolle's conclusion: "From the equator towards the poles, the density of Monocots relative to Eudicots increases. In contrast, the density of Eudicots compared to Monocots in the tropics is always greater than 3" (Quyen and Thin, 2002).

**Table 6.** Comparison of diversity indices of Tan Phu flora with some flora in Southern Vietnam

Phylum	Index		
	Family	Genus	Genus/Family
<b>Tan Phu</b>	<b>7.84</b>	<b>1.87</b>	<b>4.20</b>
Phu Quoc	8.79	2.25	3.91
Dong Nai Cultural	5.92	1.80	3.28
Binh Chau-Phuoc Buu	6.09	1.76	3.47
Yok Don	6.62	1.79	3.71
Con Dao	6.73	1.68	3.99
Dak Nong	5.04	1.72	2.93

At the family level, the diversity index of Tan Phu Forest is higher than Dak Nong, Dong Nai Cultural Nature Reserve, Binh Chau-Phuoc Buu, Yok Don, Con Dao and only lower than Phu Quoc. For the genus level, the same results were obtained for the family level. Specifically, the diversity index of the Tan Phu Forest flora is higher than Dak Nong, Yok Don, Con Dao, Binh Chau-Phuoc Buu, and Dong Nai Cultural and only lower than Phu Quoc (Table 6).

For genus/family relationships, this ratio of Tan Phu Forest is higher than that of Dak Nong, Dong Nai Cultural Nature Reserve, Phu Quoc, Binh Chau-Phuoc Buu, and Yok Don. However, the present study closely resembles the flora of Con Dao (3.99) (Table 6). The analysis results show that Tan Phu Forest is diverse in species composition.

**Table 7.** Comparison of the Tan Phu flora with some regions in South Vietnam

Flora	Phylum	Ps	Ly	Eq	Po	Gy	An	Total
<b>Tan Phu Forest</b>	Quantity		4		28	5	1029	<b>1066</b>
	%		0.35		3.68	0.35	96.53	<b>100</b>
Phu Quoc <sup>1</sup>	Quantity		9		58	11	1275	<b>1353</b>
	%		0.67		4.29	0.81	94.24	<b>100</b>
Dong Nai Cultural <sup>2</sup>	Quantity		4		16	14	830	<b>864</b>
	%		0.46		1.85	1.62	96.06	<b>100</b>
Binh Chau -Phuoc Buu <sup>3</sup>	Quantity				15	3	725	<b>743</b>
	%				2.02	0.40	97.58	<b>100</b>
Yok Don <sup>4</sup>	Quantity		2		18	3	831	<b>854</b>
	%		0.23		2.11	0.35	97.31	<b>100</b>
Cat Tien <sup>5</sup>	Quantity		11		50	2	1546	<b>1609</b>
	%		0.68		3.11	0.12	96.08	<b>100</b>



Vietnam <sup>6</sup>	Quantity %	1 0.01	53 0.38	2 0.01	691 5.00	69 0.50	13000 94.09	<b>13816</b> <b>100</b>
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Note: Ps: Psilotophyta; Ly: Lycopodiophyta; Eq: Equisetophyta; Po: Polypodiophyta; Gy: Gymnospermatophyta; An: Angiospermaephyta; <sup>1</sup>Quan, 2015; <sup>2</sup>Hung et al., 2019; <sup>3</sup>Hung et al., 2020; <sup>4</sup>Dung et al., 2005; <sup>5</sup>Mui, 2004; <sup>6</sup>Ban, 2003-2005

Comparison of species composition, the Tan Phu Forest is more than that of Dong Nai Cultural Nature Reserve (864 species) (Hung and Alexander, 2019), Binh Chau-Phuoc Buu Nature Reserve (743 species) (Hung et al., 2020), Yok Don National Park (854 species) (Dung et al., 2005), Con Dao (Ai and Hue, 2013). However, this finding is lower than the Cat Tien National Park (1609 species) (Mui, 2004), the Phu Quoc National Park (1353) (Quan, 2015), and accounts for 7.72% of the flora of Vietnam (Ban, 2003-2005) (Table 7). The flora diversity in Vietnam, in general, and the flora of Tan Phu Forest, in particular, could be explained by the fact that Vietnam was at the transition point of many natural flows: the east bears the biological characteristics of the Himalayan mountains; in the South, there were ecosystems similar to those of the terrestrial and marine ecosystems of Southeast Asia; the Truong Son Range in the transition zone between tropical and subtropical climates (Myers et al., 2000).

In addition, the Tan Phu Forest flora is the intersection of many flora systems: the West is the migratory flow of deciduous, semi-deciduous, evergreen, and bamboo forest ecosystems of the Dong Nai Cultural-Nature Reserve; The East is characterized by marine, island and mainland ecosystems of Xuan Loc protection forest, Chua Chan mountain, Nui Chua National Park; The North has the characteristics of transitional flora between tropical and subtropical climates of Cat Tien National Park. On the other hand, Tan Phu Forest is also a transitional place of ecosystems of the Dong Nai River (2<sup>nd</sup> largest in the Southern) and La Nga River.

Angiospermae dominates with the other phylum of the Tan Phu Forest flora. This result is consistent with the evolution of the angiosperms, which dominate the phylum of vascular plants. To show the diversity of the Tan Phu Forest flora and the dominance of angiosperms, let us compare it to some of the flora in Southern Vietnam (Table 7).

No family accounts for 10% of the species of the ten most diverse families. It is similar to the analyses and assessments in reports made in various ecological regions of Vietnam (Hoa and Sam, 2016; Hieu et al., 2019; Ba, 2019; Hai, 2020; Hoan, 2022). This result is consistent with the conclusion of Tolmachop (1974): "The total of 10 richest families of tropical flora generally accounts for not more than 40-50% of the species of the flora, and too few species account for more than 10% of the species of the whole flora" (Chan, 1990). This suggested that the Tan Phu Forest flora is a species' diversity and a family's abundance.

### *Some plant diversity index*

Quantitative plant diversity indices have shown that the diversity of the Tan Phu flora is at a moderate level. This result is similar to some previous reports, in the dominant forest type *Anthoshorea roxburghii*, the H' index ranged from 2.87 to 3.05 (Hop et al., 2020), in 3 forest types: rich and medium and poor forests, the average H' index was 2.42 ± 0.46 (Huong et al., 2021). Studies in some natural forests in the Southeast region also support this research result, in the tropical moist evergreen closed forest Dong Nai Cultural Nature Reserve, H' index was determined 2.36 ± 0.25 (Luong et al., 2023c);

while in the dominant forest *Dipterocarpus chartaceus* in Binh Chau - Phuoc Buu Nature Reserve, the average diversity index achieved  $H' = 2.19$  (Hop et al., 2023b).

### ***Diversity of life form spectrum***

A detailed analysis of Phanerophytes shows that life forms are unevenly distributed. Among them, Megaphanerophytes characterize big tree species that play an essential role in the plant community, but the proportion of this group is low (5.91%). This is explained by the selective harvesting system that disturbed the flora in the late 70s to 90s of the 20th century (Millet and Truong, 2011; Hop et al., 2020). The objects of the selective harvesting system are big tree species with economic value (Millet and Truong, 2011; Hop et al., 2020; Huong et al., 2021). The logged trees, over 60 cm in diameter, came from *A. costata*, *D. alatus*, *D. dyeri*, *Heritiera javanica*, *H. odorata*, *L. calyculata*, *Litsea pierrei*, *Anthoshorea roxburghii*, *S. thorelii*, *S. siamensis*, and *Xylia xylocarpa* (Millet and Truong, 2011). On the other hand, illegal logging and NTFP activities continue despite strict management by forest owners (Thin et al., 2013).

**Table 8.** Comparison of the life form spectrum of Tan Phu Forest with some regions in Vietnam

<b>Flora</b>	<b>Ph</b>	<b>Ch</b>	<b>Hm</b>	<b>Cr</b>	<b>Th</b>
<b>Tan Phu Forest</b>	<b>76.64</b>	<b>4.13</b>	<b>2.63</b>	<b>8.53</b>	<b>8.07</b>
Vietnam <sup>1</sup>	54.68	10	21.41	10.66	5.67
Phia Oac-Phia Den <sup>2</sup>	61.05	8.08	16.57	9.32	4.97
Tan Trao <sup>3</sup>	73.55	3.17	9.78	8.4	5.1
Bac Huong Hoa <sup>4</sup>	79.02	2.76	9.08	3.36	5.78
Pu Hoat <sup>5</sup>	73.44	14.80	2.10	3.51	6.14
Dak Nong <sup>6</sup>	85.50	2.87	1.64	2.87	7.11
Phu Quo <sup>7</sup>	89.39	2.35	1.21	4.47	2.58

Note: Ph-Phanerophytes; Ch-Chamaephytes; Cr-Cryptophytes; He-Hemicryptophytes; Th-Therophytes; <sup>1</sup>Chan et al., 1999; <sup>2</sup>Hai, 2020; <sup>3</sup>Ba, 2019; <sup>4</sup>Hoan., 2022; <sup>5</sup>Hung, 2020; <sup>6</sup>Luong et al., 2023b; <sup>7</sup>Quan, 2015

In general, the Phanerophytes of this study and the various ecological regions of Vietnam dominate over 50% (Table 8). However, this ratio in some areas is exceptionally high compared with the average in Vietnam, such as Bac Huong Hoa Nature Reserve (Hoan, 2022), Phu Quoc National Park (Quan, 2015), Pu Hoat Nature Reserve (Hung, 2020), and Dak Nong (Luong et al., 2023b), all more significant than 70%. Some results of life-form spectrum studies in Asia indicate that the proportions of Phanerophytes and other life forms differ in ecological regions. However, Phanerophytes still dominate over the remaining life forms, such as in Korea (35.70%) (Kim et al., 2007), China (55.74%) (Li et al., 2017), Pakistan (40.08%) (Khan et al., 2018), India (55.20%) (Rana et al., 2002), Raunkiaer's (48%) (Raunkiaer's, 1934). This observation is supported by Raunkiaer's (1934) conclusion: "In tropical rainforests, Phanerophytes are always predominant". This difference can be explained by environmental factors such as rainfall, altitude, and soil in the tropics. In a world where precipitation is the main factor determining the distribution of life forms, the general trend is one of the more abundant life forms with increasing rainfall (Batalha and Martins, 2002). The abundance of life forms increases with the aridity of the environment (Raunkiaer's, 1934).

### Diversity of phytogeographical factors

The flora of Tan Phu Forest had the closest relationship and is most intimately associated with the tropical Asia factor (Indo-Malezi) (22.89%), followed by Indochina-Malezi (12.95%), Indochina (9.29%), Indochina–India (5.53%) and Indochina-Southern China (4.69%), and Indochina-Himalayas (3.56%). Thus, the flora of Tan Phu Forest is a typical feature of tropical Asia and Indochina-Malezi flora.

The phytogeography of the Tan Phu Forest flora, in particular, and the Vietnam flora, in general, was characterized by the Asian tropical element, including the features of the flora of Indochina, southern China, Malaysia, and Indonesia. Vietnam belongs to the equatorial climate, which is hot, humid, and rainy. Moreover, the flora of Vietnam is the intersection of many biological streams: the east exhibits the biogeographical features of the Himalayas; in the South, there are ecosystem types similar to the marine and mainland ecosystems of Southeast Asia; the Truong Son range is a transitional zone between tropical and subtropical climates (Sterling et al., 2006).

**Table 9.** Comparison of the phytogeographical factor of some regions and the Vietnam flora

Flora	World	Tropical	Temperate	Endemic	Crop	Undefined
Northern Vietnam <sup>(1)</sup>	1.56	55.27	3.27	39.9		
Phia Oac-Phia Den <sup>(2)</sup>	4.49	75.14	0.14	7.11	2.76	
Bac Huong Hoa <sup>(3)</sup>	0.67	74.09	9.37	13.25	1.27	1.35
Pu Hoat <sup>(4)</sup>	0.25	62.31	4.74	29.24	2.8	0.66
Phu Quoc <sup>(5)</sup>	0.52	93.72	0.96	11.68		4.8
Dak Nong <sup>(6)</sup>	0.96	89.47	4.65	4.78		0.14
<b>Tan Phu Forest</b>	<b>0.09</b>	<b>88.27</b>	<b>1.22</b>	<b>9.19</b>	<b>0.38</b>	<b>0.84</b>

Note: <sup>1</sup>Chan et al., 1999; <sup>2</sup>Hai, 2020; <sup>3</sup>Hoan., 2022; <sup>4</sup>Hung, 2020; <sup>5</sup>Quan, 2015; <sup>6</sup>Luong et al., 2023b

Table 9 shows that the tropical element dominates flora in Vietnam (62.31%-93.72%), followed by the endemic, temperate, crop, and world factors, except in northern Vietnam (55.27%). The results of the phytogeographical analysis of Tan Phu Forest agree with North Vietnam (Pocs, 1965), Phia Oac-Phia Den (Hai, 2020), Bac Huong Hoa Nature Reserve (Hoan, 2022), Pu Hoat Nature Reserve (Hung, 2020), Dak Nong (Luong et al., 2023b) and Phu Quoc National Park (Quan, 2015). However, there was a difference in the proportions between the floras. The tropical element of the flora of Southern Vietnam (Phu Quoc, Dak Nong and Tan Phu) is higher than that of the other flora (north and central). The different climatic regimes explained this; South Vietnam was characterized by a tropical monsoon climate (2 seasons), while North Vietnam had a subtropical climate (4 seasons).

### Diversity of value forest resources

Tan Phu's flora is a variety of species, genera, and families and is useful. The medicinal plant, timber tree, and edible plant are three use-value groups that comprise a high proportion of Tan Phu's flora compared to the other groups (Table 10).

**Table 10.** Comparison of use value of Tan Phu flora with some southern Vietnam flora

No.	Use value	Percentage (%) of use value groups						
		Tan Phu	Phu Quoc <sup>1</sup>	Dong Nai Cultural <sup>2</sup>	Binh Chau-Phuoc Buu <sup>3</sup>	Yok Don <sup>4</sup>	Cat Tien <sup>5</sup>	Dak Nong <sup>6</sup>
1	Medicinal plants	<b>51.41</b>	50.45	62.5	35.4	66.4	34.16	73.05
2	Woody plants	<b>17.54</b>	31.72	18.2	21.5	11.2	31.74	17.92
3	Ornamental plant	<b>11.54</b>	16.01	4.6	16.6	5.87	16.15	10.40
4	Essential oils	<b>4.78</b>	8.49			27	10.67	6.84
5	Edible plant	<b>26.55</b>	11.48	10.2	17.6	11.2	2.73	21.48
6	Poisonous	<b>1.59</b>	2.11			2.93	4	
7	Resin	<b>1.41</b>				2.07	2.67	
8	Dyeing	<b>2.81</b>	4.53			1.07	8	1.78
9	Other	<b>7.04</b>	6.95	3.8	6.9			4.51

Note: <sup>1</sup>Quan, 2015; <sup>2</sup>Hung et al., 2019; <sup>3</sup>Hung et al., 2020; <sup>4</sup>Dung et al., 2005; <sup>5</sup>Mui, 2004; <sup>6</sup>Luong et al., 2023b

These recent studies discovered 114 and 120 wood plants in the dominant community *Anthoshorea roxburghii* and communities belonging to Dipterocarpaceae (Hop et al., 2020; Long et al., 2020; Huong et al., 2021). Therefore, 49 woody plants were recognized as additions to the Tan Phu Forest flora compared to Long et al. (2020). This study found 548 medicinal species, more than the report by Ha et al. (2022) (351 species). This finding is also greater than the comparison with several studies carried out in Southern Vietnam (Mui, 2004; Dung et al., 2005; Quan, 2015; Hung and Alexander, 2019; Hung et al., 2020; Luong et al., 2023b) (*Table 10*).

The current study has recorded 35 additional threatened plant species compared to the 2011 assessment report (Millet and Truong, 2011). In comparison with other floristic, this study recorded threatened plant species more than the Yok Don National Park (Dung et al., 2005) and, Cat Tien National Park (Mui, 2004), Dong Nai Cultural Nature Reserve (Hung and Alexander, 2019), Binh Chau - Phuoc Buu (Hung et al., 2020), and Dak Nong Province (Luong et al., 2023b). However, it is less than the Phu Quoc National Park (Quan, 2015) (*Table 11*). On the other hand, the species composition in IUCN (2023) is more than that of the comparable flora in Southern Vietnam (*Table 11*). The investigation, analysis, and comparison of numerous flora in Southern Vietnam show the diversity of the species and the nature reserve significance of the Tan Phu Forest.

**Table 11.** Comparison of the threatened and endemic species of Tan Phu with some regions in Southern Vietnam

Flora	Total of species	VNRB (2007)	IUCN (2023)	Endemic
<b>Tan Phu Forest</b>	<b>47</b>	<b>32</b>	<b>25</b>	<b>12</b>
Phu Quoc National Park <sup>1</sup>	131	39	106	9
Dong Nai Cultural <sup>2</sup>	30	26	11	11
Binh Chau-Phuoc Buu <sup>3</sup>	25	17	18	6
Yok Don National Park <sup>4</sup>	36	22	16	12
Cat Tien National Park <sup>5</sup>	38	26	27	23
Dak Nong <sup>6</sup>	28	26	7	
Vietnam <sup>7</sup>	442	442		250

Note: <sup>7</sup>VNRB - Vietnam Red Data Book (2007); IUCN - Global conservation status (2023); : <sup>1</sup>Quan, 2015; <sup>2</sup>Hung et al., 2019; <sup>3</sup>Hung et al., 2020; <sup>4</sup>Dung et al., 2005; <sup>5</sup>Mui, 2004; <sup>6</sup>Luong et al., 2023b

The present study recorded 12 endemic species. It is more than some flora in Southern Vietnam, such as Phu Quoc National Park with nine species (0.72%) (Quan, 2015), Binh Chau - Phuoc Buu with six species (0.81%) (Hung et al., 2020), and Dong Nai Cultural with 11 species (1.27%) (Hung and Alexander, 2019), Yok Don National Park with 12 species (1.4%) (Dung et al., 2005), lower than Cat Tien National Park (Mui, 2004), and accounts for 5.6% of the total number of endemic plant species in Vietnam (250 species) (Ban, 2003-2005) (*Table 11*).

Our study has shown that, among the six invasive alien taxa identified, only *Leucaena leucocephala* (Lam.) de Wit. are alien species at risk of invasion, while the remaining 5 species are invasive alien species (Ministry of Natural Resources and Environment, 2018). These taxa have a worrying impact on native biota, causing the decline or even extinction of some native populations. Among them, *Chromolaena odorata* (L.) R.M.King & H.Rob.) is invasive to planted forest areas, especially *Mimosa pigra* L. and *Pontederia crassipes* Mart. capable of spreading quickly through water dispersal and causing harm to the natural forest ecosystem adjacent to the La Nga River in Sub-state forests 2, 3, 4 and Sub-state forests 5.

## Conclusion

Our research demonstrates that Tan Phu Forest's flora has a variety of taxonomic levels, life form spectrum, phytogeographical factors and rich forest resource value. This flora could be the convergence of numerous migratory flows from flora areas in Southern Vietnam, such as Cat Tien National Park and the Dong Nai Cultural Nature Reserve.

A total of 1066 taxa belonging to 571 genera and 136 families of four phylum were recorded, including Lycopodiophyta, Polypodiophyta, Gymnospermatophyta, and Angiospermatophyta. Angiosperm taxa predominate. Fabaceae, Rubiaceae, Malvaceae, Poaceae, Cyperaceae, Orchidaceae, Phyllanthaceae, Apocynaceae, Lamiaceae and Euphorbiaceae characterized the study area. Besides, ten species-rich genera were also statistically represented by *Ficus*, *Cyperus*, *Dendrobium*, *Syzygium*, *Antidesma*, *Dioscorea*, *Ardisia*, *Diospyros*, *Garcinia*, and *Fimbristylis*.

A tropical rainforest ecosystem characterised Tan Phu Forest by the predominance of Phanerophytes over other life forms such as Cryptophytes, Therophytes, Chamaephytes, and Hemicryptophytes. Spectrum biology was determined: SB = 76.64%Ph + 4.13%Ch + 2.63%Hm + 8.53%Cr + 8.07%Th.

Tan Phu Forest is a typical tropical flora of Southern Vietnam and is closely related to the Indo-Malezi flora.

The flora of Tan Phu has essential potential for use value, including medicinal plants, edible plants, timber trees, ornamental plants, essential oil, dyeing, poisonous plants, and other uses. The potential of medicinal plants is the largest, followed by edible plants, timber trees, and ornamental plants, and the remaining groups account for a small proportion.

The forest resources have high conservation value, with 47 species of plants threatened at different levels domestically and globally. Of these, 32 species are listed in the Vietnam Red Data Book (2007) and 25 species in the IUCN Red List (2023). Besides, the endemic species composition was also quite diverse, with twelve species recorded in the study area.

This study reflects the value of the flora of Tan Phu Forest in terms of taxonomic diversity, life forms, phytogeographical factors, use value, and conservation. It illustrates a significant ecological role in the protection and climate conditioning of the Southeast and Southern regions. Therefore, sensible approaches must sustain this invaluable resource's sustainable management and development.

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## APPENDIX



**Figure A1.** *Deciduous broadleaved forest: The main communities of deciduous broadleaved forests in the dry season include *D. intricatus*, *D. dyeri*, *Anthoshorea roxburghii*, *Anisoptera costata*, *Lagerstroemia calyculata*, *Cratoxylum formosum* subsp. *pruniflorum*, *Elaeocarpus tectorius* (Photos by Nguyen Van Hop)*



**Figure A2.** *Deciduous broadleaved forest: The main communities of deciduous broadleaved forests in the dry season include *D. intricatus*, *D. dyeri*, *Anthoshorea roxburghii*, *Anisoptera costata*, *Lagerstroemia calyculata*, *Cratoxylum formosum* subsp. *pruniflorum*, *Elaeocarpus tectorius* (Photos by Nguyen Van Hop)*



**Figure A3.** Semi-deciduous broadleaved forest: The main communities of deciduous broadleaved forests in the dry season include *D. dyeri*, *Anthoshorea roxburghii*, *Anisoptera costata*, *Lagerstroemia calyculata*, *Cratoxylum formosum* subsp. *pruniflorum*, *Elaeocarpus tectorius* (Photos by Nguyen Van Hop)



**Figure A4.** Deciduous broadleaved forest: The main communities of deciduous broadleaved forests in the dry season include *D. dyeri*, *Anthoshorea roxburghii*, *Anisoptera costata*, *Lagerstroemia calyculata*, *Cratoxylum formosum* subsp. *pruniflorum*, *Elaeocarpus tectorius* (Photos by Nguyen Van Hop)



**Figure A5.** Evergreen broadleaved forest: the main communities include *Syzygium sp*, *Knema sp*, *Garcinia sp*, *Diospyros sp*, *Xerospermum sp*, *Nephelium sp*, *Carallia sp*, *Cleistanthus sp*, *Microcos tomentosa*, *Hopea odorata*, and *Vatica odorata* (Photos by Nguyen Van Hop)



**Figure A6.** Evergreen broadleaved forest: the main communities include *Syzygium sp*, *Knema sp*, *Garcinia sp*, *Diospyros sp*, *Xerospermum sp*, *Nephelium sp*, *Carallia sp*, *Cleistanthus sp*, *Microcos tomentosa*, *Hopea odorata*, and *Vatica odorata* (Photos by Nguyen Van Hop)



**Figure A7.** Evergreen broadleaved forest: the main communities include *Syzygium sp*, *Knema sp*, *Garcinia sp*, *Diospyros sp*, *Xerospermum sp*, *Nephelium sp*, *Carallia sp*, *Cleistanthus sp*, *Microcos tomentosa*, *Hopea odorata*, and *Vatica odorata* (Photos by Nguyen Van Hop)