The structure of plant communities with the prevalence of the Dipterocarpaceae family tree species in Binh Chau–Phuoc Buu Nature Reserve of Vietnam

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Abstract. This work analyzes the structure of evergreen rainforests with the prevalence of the Dipterocarpaceae family tree species in Vietnam. Four dominant formations were studied: Dipterocarpus, Shorea, Anisoptera, Vatica. The analysis of the structure of stands with the prevalence of the Dipterocarpaceae family plants was carried out based on the methodology of the stand components’ weight that includes thickness of trees, cross-section and volume of the trunk. The criteria for the analysis included the distribution of trunk diameters (N-D) and heights (N-H). - The species composition of associated plants in the studied formations has different shares. The Shorea and Dipterocarpus formation has the largest number of tree species. For the four dominant plant formations, there are differences in the N / D distribution and no difference in the N / H distribution. The diameter of all trees in the main formations of the Dipterocarpaceae family vary more than the height. Forestry management requires taking into account the structural features of stands with the prevalence of the Dipterocarpaceae family tree species.

1. Introduction
Forest structure indicates the organization and position of forest components in horizontal and vertical space and in time - the age of the forest. In forestry, forest structure analysis is aimed at identifying the changing dynamics of the stand over time. Besides, an understanding of the structure of stands provides a basis for the development of forestry practices [1]. Davis and Richards, 1934, in their study of the structure of rainforests described the stratification and position of tree species according to the diagram of transverse and longitudinal profiles [2]. This method also allows determining the change in the structure of the stand before and after silvicultural influence. However, this method does not allow quantifying the structure of the forest. To overcome these shortcomings, many foresters use mathematical methods to describe and analyze the structure of stands. Currently, many researchers use these methods to study the structure of tropical forests in South-East Asia [2-7].
2. Methods and Materials

2.1. Objects of study
The objects of the study were plant communities with a predominance of the Dipterocarpaceae family wood species in the Binh Chau – Phuoc Buu Nature Reserve in the southeast of the Republic of Vietnam. The aim of the study - the analysis of the structure of plant communities with the predominance of wood species from the Dipterocarpaceae family. This will allow developing efficient measures for preservation and development of Vietnam forests. The vegetation was registered using an approved methodology for stack-taking works. The dominant Dipterocarpaceae family groups were studied on sample plots with a total area of 2000 m² (40x50 m). On each sample plots were measured the following values: diameter at 1.3 m starting from 8 cm and larger (D1.3 ≥ 8 cm), heights The names of species, genera, and families were defined in a unified manner according to the recommendations of [3, 5, 8, 9].

Data collection and analysis at the sample plots to determine the participation of plant species or the role of tree species (IVI %) in the formation of the Dipterocarpaceae family was done using the [5]. Where N%, G%, and V% are a relative thickness of the species, a relative trunk cross-section, and a relative volume of the trunk, respectively:

\[ V = g \times H \times F \ (F = 0.45) \]

\[ IVI\% = \frac{(N% + G% + V\%)}{3} \]  

These values were used to describe and analyze the structure of the dominant plants of the Dipterocarpaceae family. The criteria for the analysis included the distribution of trunk diameters (N-D) and trunk heights (N-H). The stock of stands (M) of the dominant plants was divided into 3 groups of diameters: group 1 with D < 20 cm, group 2 with 20 ≤ D < 40 cm, and group 3 with D ≥ 40 cm. Mathematical data analysis was performed using the software package Excel 2010, Statgraphics Plus Version 4.0, SPSS 10.0, and Primer 5.0.

3. Result and Discussion
To simplify and make easy the data synthesis and analysis, the above four dominant groups of the Dipterocarpaceae family were named respectively the “Dipterocarpus formation”, “Shorea formation”, “Anisoptera formation”, and “Vatica formation”.

The results show that the structure of stands in four formations varies depending on the diameter and height of the trunk. The structural features of the stands in the Dipterocarpus formation show differences in the distribution of the number of species by diameter (table 1, figure 1). Group D < 20 cm includes 42 species, among them, 6 dominant species: Dipterocarpus costatus Gaertn, Passiflora foetida L, Vatica odorata (Subsp.) Sym, Garcinia sp., Xerospermum noronhianum (Blume). Comparing to the species composition of all formations (45 species), the number of species in the group D < 20 cm is 93.3% (42 species). Group D = 20 – 40 cm comprises 29 species, including 6 dominant species (Dipterocarpus costatus Gaertn, Xerospermum noronhianum (Blume), Vatica odorata (Subsp.) Sym, Vitex pinnata L., Dipterocarpus alatus Roxb, Pterospermum diversifolium). The group D > 40 has only 12 species remaining (Irvingia malayana Oliv. ex Benn, Terminalia corticosa Pierre.ex.Lan., Dipterocarpus costatus Gaertn, Vatica odorata (Subsp.) Sym., Xerospermum noronhianum (Blume),, Dipterocarpus alatus Roxb, Artocarpus chaplasha, Litsea vang, Dipterocarpus dyeri Pierre., Anisoptera costata Korth., Syzygium sp, Brownlowia denysiana).
Table 1. Thickness structure, cross-section, and average stock by trunk diameter class the *Dipterocarpus* formation.

| Diameter group $D_{1.3}$ (cm) | $N$ (trees per ha) | $G$ ($m^3$) | $V$ ($m^3$) | Share (%) by: $N$ | $G$ | $V$ | IV |
|-------------------------------|------------------|-------------|-------------|-----------------|-----|-----|-----|
| < 20                          | 273              | 3           | 14.7        | 72.2            | 29.0| 20.5| 40.6|
|                               | 50               | 0.6         | 2.9         | 18.3            | 19.7| 19.7| 19.2|
| 20 – 40                       | 97               | 5.6         | 39.6        | 25.7            | 54.1| 55.2| 45.0|
|                               | 42               | 2.6         | 18.1        | 43.3            | 45.5| 45.8| 44.9|
| > 40                          | 8                | 1.8         | 17.5        | 2.1             | 17.0| 24.4| 14.5|
|                               | 4                | 1.1         | 11.0        | 50.0            | 59.7| 62.8| 57.5|

The values of $N$, $G$, and $V$ for *Dipterocarpus costatus* Gaertn are compared with the corresponding criteria in the same $D$ group.

The distribution of plants dominating *Dipterocarpus costatus* Gaertn varies depending on the group of trunks' diameter. Under the dominance of *Dipterocarpus costatus* Gaertn the amount of the trees in the group $D < 20$ cm (24.5%) decreases to the group $D = 20$–40 cm (16.7%), and $D > 40$ cm (7.6%). In the group of trees with $D > 40$ cm, the most dominant plant species are *Irvingia malayana* Oliv. ex Benn (45.8%), while other 11 species have a smaller share (3.6–7.8%). Compared to the total number of tree species, predominates *Dipterocarpus costatus* G. Don, species composition similarity index also decreases in the group with $D < 20$ cm (93.3%) to group $D = 20$–40 cm (64.4%), and $D > 40$ cm (26.7%).

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![Diagram](a)

![Diagram](b)

**Figure 1.** Thickness of the plants, cross-section, and average stock by trunk diameter and height class *Dipterocarpus* formation.

Distribution of trees by trunk height also has its differences (table 2, figure 1). Group $H < 10$ m comprises 30 tree species, including 8 dominant species (*Dipterocarpus costatus* Gaertn, *Passiflora foetida* L., *Vitex pinnata* L., *Vatica odorata* (Subsp.) Sym., *Barringtonia macrostachya*, *Aporusa dioica*, *Baccaurea ramiflora* Lour., *Knema* sp.). Group $H = 10$–20 m has a total of 40 tree species, including 7 dominant species (*Dipterocarpus costatus* Gaertn, *Vatica odorata* (Subsp.) Sym., *Xerospermum noronhianum* (Blume), *Vitex pinnata* L., *Passiflora foetida* L., *Garcinia* sp., *Pterospermum diversifolium*). Group $H > 20$ m includes 23 species, including 7 dominant species (82.1%). The dominant species are *Irvingia malayana* Oliv. ex Benn, *Terminalia corticosa* Pierre.ex.Lan, *Dipterocarpus costatus* Gaertn, *Vatica odorata* (Subsp.) Sym., *Xerospermum noronhianum* (Blume), *Artocarpus chaplasha*.

The plant composition of the *Dipterocarpus costatus* Gaertn formation depends on the $H$ class; the share of a species decreases with an increase in the trunk height. The largest number of plants of this species is in the group $H < 10$ m (22.2%) and $H = 10$–20 m (20.8%), then a slight share in the group $H > 20$ m (7.3%). In the $H > 20$ m group the most dominant tree species are *Irvingia malayana* Oliv. ex Benn (44.3%), the other 7 species have a smaller share in the composition of this stratum (4.0–7.8%). Compared with the total number of tree species, that is 45 species, the similarity index of the species
composition differs by tree trunk height groups. There was an increase in the similarity index of species composition from 66.7% in class $H <10$ m to a maximum of 88.9% in class $H = 10 - 20$ m, then the lowest index score of 22% in class $H> 20$ m.

**Table 2.** Thickness structure, cross-section, and average stock of trees by trunk height group in the *Dipterocarpus* formation.

| Height groups $H$(m) | $N$ (trees per ha) | $G$ (m$^2$) | $V$ (m$^3$) | Proportion (%) | $N$ | $G$ | $V$ | IV |
|----------------------|---------------------|-------------|-------------|----------------|-----|-----|-----|----|
| < 10                 | 245                 | 1.2         | 5.2         | 30.4           | 6.3 | 3.7 | 13.4 |    |
|                      | 58*                 | 0.27        | 1.11        | 23.7           | 22.5 | 21.3 | 22.5 |    |
| 10-20                | 542                 | 13.7        | 90.5        | 67.2           | 71.4 | 63.8 | 67.4 |    |
|                      | 124                 | 2.78        | 17.42       | 22.9           | 20.3 | 19.2 | 20.8 |    |
| > 20                 | 20                  | 4.3         | 46.2        | 2.5            | 22.4 | 32.6 | 19.1 |    |
|                      | 2                   | 0.29        | 2.71        | 10.0           | 6.7  | 5.9  | 7.5  |    |

*The values of $N$, $G$, and $V$ for *Dipterocarpus costatus* Gaertn are compared with the corresponding criteria in the same $H$ group.

The distribution of trees by the trunk diameter groups in the *Shorea* formation also has its distinctive features (table 3, figure 2). Group $D <20$ cm consists of 69 species, including 7 dominant species (*Shorea roxburghii* G. Don, *Xerospermum noronhianum* (Blume), *Vatica odorata* (Subsp.) Sym., *Diospyros venosa*, *Barringtonia macrostachya*, *Knema sp*). Group $D = 20-40$ cm consists of 37 species, including 5 dominant species (*Shorea roxburghii* G. Don, *Irvingia malayana* Oliv. ex Benn, *Vatica odorata* (Subsp.) Sym., *Parinari anamensis*, *Xerospermum noronhianum* (Blume). Group $D > 40$ cm consists of 4 species (*Shorea roxburghii* G. Don, *Lagerstroemia calyculata*, *Irvingia malayana* Oliv. ex Benn, *Dipterocarpus alatus* Roxb). In the stands dominated by *Shorea roxburghii* G. Don, the number of plants decrease from the group $D <20$ cm (19.1%) to the group $D = 20-40$ cm (44.8%), and $D> 40$ cm (57.5%). Group $D > 40$ cm includes only 4 species. Compared to the total number of tree species found in the *Shorea* formation, the number of species decreases from group $D < 20$ cm (80.2%) to group $D = 20-40$ cm (43.1%), and group $D > 40$ cm (4.7%).

**Table 3.** Thickness structure, cross-section, and average stock by trunk diameter class the *Shorea* formation

| Diameter group $D_{1,3}$ (cm) | $N$ (trees per ha) | $G$ (m$^2$) | $V$ (m$^3$) | Share (%) by: | $N$ | $G$ | $V$ | IV |
|---------------------|---------------------|-------------|-------------|----------------|-----|-----|-----|----|
| < 20                | 273                 | 3           | 14.7        | 72.2           | 29.0 | 20.5 | 40.6 |    |
|                     | 50*                 | 0.6         | 2.9         | 18.3           | 19.7 | 19.7 | 19.2 |    |
| 20 – 40             | 97                  | 5.6         | 39.6        | 25.7           | 54.1 | 55.2 | 45.0 |    |
|                     | 42                  | 2.6         | 18.1        | 43.3           | 45.5 | 45.8 | 44.9 |    |
| > 40                | 8                   | 1.8         | 17.5        | 2.1            | 17.0 | 24.4 | 14.5 |    |
|                     | 4                   | 1.1         | 11.0        | 50.0           | 59.7 | 62.8 | 57.5 |    |
| in total            | 378                 | 10.4        | 71.8        | 100            | 100  | 100  | 100  |    |

*The values of $N$, $G$, and $M$ for *Shorea roxburghii* G. Don are compared with the corresponding criteria in the same $D$ group.
Figure 2. Thickness of the plants, cross-section, and average stock by trunk diameter and height class *Shorea* formation.

The distribution of the number of trees by the trunk height group in the *Shorea* formation differs by species composition in each group (table 4, figure 2). Group $H < 10$ m comprises a total of 65 tree species, including 6 dominant species (*Shorea roxburghii* G. Don, *Barringtonia macrostachya*, *Xerospermum noronhianum* (Blume), *Vatica odorata* (Subsp.) Sym., *Garcinia sp.*, *Diospyros venosa*). Group $H = 10 - 20$ m comprises 62 tree species, including 6 dominant species (*Shorea roxburghii* G. Don, *Irvingia malayana* Oliv. ex Benn, *Lagerstroemia calyculata*, *Xerospermum noronhianum* (Blume), *Vatica odorata* (Subsp.) Sym., *Dipterocarpus alatus* Roxb.). Group $H > 20$ m includes only two species *Shorea roxburghii* G. Don and *Irvingia malayana* Oliv. ex Benn. The species *Shorea roxburghii* G. Don is the most dominant (72%) in the structure of the stands of this group. Overall, the structure of stands of the *Shorea* formation changes depending on the height of trees, and *Shorea roxburghii* G. Don is always more dominating. The share of this species gradually increases from the group $H < 10$ m (12.1%) to the group $H = 10 - 20$ m (37.3%), and $H > 20$ m (72%). Only two tree species (*Shorea roxburghii* G. Don and *Irvingia malayana* Oliv. ex Benn) reach the height > 20 m. Compared with the total number of tree species found in this formation, the number of species decreases from group $H < 10$ m (75.6%) to group $H = 10 - 20$ m (72.1%), and $H > 20$ m (2.3%).

Table 4. Thickness structure, cross-section, and average stock of trees by height group in the *Shorea* formation.

| Height groups $H$(m) | $N$ (trees per ha) | $G$ ($m^2$) | $V$ ($m^3$) | Proportion (%) |
|----------------------|---------------------|--------------|--------------|----------------|
|                      | $N$ | $G$ | $V$ | $N$ | $G$ | $V$ | IV |
| < 10                 | 146 | 0.8 | 3.4 | 38.6 | 7.7 | 4.7 | 17.0 |
|                      | 21$^a$ | 0.09 | 0.36 | 14.4 | 11.3 | 10.6 | 12.1 |
| 10-20                | 229 | 8.6 | 57.6 | 60.6 | 82.7 | 80.2 | 74.5 |
|                      | 73  | 3.36 | 23.47 | 31.9 | 39.1 | 40.7 | 37.2 |
| > 20                 | 3   | 1   | 10.8 | 0.8  | 9.6  | 15.0 | 8.5  |
|                      | 2   | 0.73 | 8.19 | 66.7 | 73.0 | 75.8 | 71.8 |

$^a$The values of $N$, $G$, and $V$ for *Shorea roxburghii* G. Don are compared with the corresponding criteria in the same $H$ group.

The structure of stands in the *Anisoptera* formation has different composition of the trees according to their diameter comparing to the *Dipterocarpus* and *Shorea* formations discussed above (table 5, figure 3). Group $D < 20$ cm comprises 21 species, including 9 dominating species (IV = 80.6%) - *Anisoptera costata*, *Melanorrhoea usitata*, *Knema sp.*, *Syzygium sp.*, *Milletia ichthyotona*, *Diospyros sp.*, *Gardenia philastrei*, *Xylopia vielana*, *Hopea odorata*. This group of diameters has all tree species from the *Anisoptera* formation.
Table 5. Thickness structure of the plants, cross-section, and average stock by trunk diameter in the *Anisoptera* formation.

| Diameter group $D_{13}$ (cm) | $N$ (trees per ha) | $G$ ($m^2$) | $V$ ($m^3$) | Share (%) by: $N$ | $G$ | $V$ | IV |
|-------------------------------|------------------|-------------|-------------|------------------|-----|-----|-----|
| < 20                          | 709              | 7.14        | 37.4        | 82.9             | 39.6| 29.0| 50.5|
|                               | 252*             | 2.7         | 13.4        | 35.5             | 37.1| 35.9| 36.2|
| 20 – 40                       | 129              | 7.0         | 51.0        | 15.1             | 38.8| 39.5| 31.1|
|                               | 48               | 2.7         | 20.2        | 37.2             | 39.1| 39.5| 38.6|
| > 40                          | 17               | 3.9         | 40.8        | 2.0              | 21.6| 31.6| 18.4|
|                               | 8                | 1.9         | 19.5        | 47.1             | 48.5| 47.8| 47.8|

*The values of $N$, $G$, and $V$ for *Anisoptera costata* Korth are compared with the corresponding criteria in the same $D$ group.

Group $D > 40$ cm includes only 8 tree species - *Anisoptera costata* Diospyros sp, *Garcinia vilersiana*, *Melanorrhoea laccifera*, *Diospyros sp*, *Millettia ichthyotona*, *Knema sp*, *Xerospermum noronhianum*. Relative to the species composition of all formations (21 species), the amount of species in group $D > 40$ cm is 38.1%. In this group of diameters, *Anisoptera costata* Korth. has the largest share (IV = 47.7%). Group $D = 20 – 40$ comprises 19 tree species, including 10 dominant species - *Anisoptera costata*, *Knema sp*, *Xylopia vielana*, *Millettia ichthyotona*, *Melanorrhoea laccifera*, *Syzygium sp*, *Vitex pinnata*, *Hopea odorata*, *Gardenia philastrei*, *Diospyros sylvestri* . Relative to the species composition of all formations (86 species), the number of taxa in group $D = 20$-40 cm is 90.5% (19 species). In the *Anisoptera* formation, it always prevails and gradually increases from the group $D < 20$ cm (IV = 35.7%) to the group $D = 20$-40 cm (IV = 38.6%), and $D > 40$ cm (IV = 47.7%). Compared to the total number of tree species found in the *Anisoptera* formation, the number of species decreases from group $D < 20$ cm (100%) to group $D=20$-40 cm (90.5%), and group $D > 40$ cm (38.1%) (table 6, figure 3).

![Figure 3](image-url)  
**Figure 3.** Thickness of the plants, cross-section, and average stock by trunk diameter and height class *Anisoptera* formation.

The amount of trees by height in the group $H < 10$ m includes 21 species, among them, 9 dominant species - *Anisoptera costata* Korth, *Melanorrhoea laccifera*, *Diospyros sp*, *Knema sp*, *Millettia ichthyotona*, *Syzygium sp*, *Hopea odorata* Roxb, *Gardenia philastrei*, *Xylopia vielana*. The trees from the *Dipterocarpaceae* family include two species - *Anisoptera costata* Korth. and *Hopea odorata* Roxb (IV% = 38.9). In the stands of this group especially dominates *Shorea roxburghii* G. Don (IV% = 34.2%). Group $H = 10$-20 m includes 15 species of trees. Relative to the species composition in the *Anisoptera* formation (21 species), the number of species in group $H = 10$-20 m is 71.4%, that is, 15 species. The trees from the *Dipterocarpaceae* family include two species - *Anisoptera costata* Korth., *Hopea odorata* Roxb (IV% = 42.6). *Anisoptera costata* Korth. has the largest share (38.5%) in the
stands of this group. Group $H > 20$ m includes 7 species - *Anisoptera costata*, *Diospyros sylvatica*, *Gardenia philastrei*, *Melanorrhoea laccifera*, *Milletia ichthyotona*, *Knema sp.*, *Diospyros sp.* The trees from the *Dipterocarpaceae* family include one species *Anisoptera costata* Korth., its share in the stands is 44.9%. In the *Anisoptera* formation, with 21 species, the number of taxa in the group $H > 20$ m is 7, comprising 33.3%.

**Table 6.** Thickness structure of the plants, cross-section, and average stock by height group in the *Anisoptera* formation.

| Height groups $H$(m) | $N$ (trees per ha) | $G$ (m$^3$) | $V$ (m$^3$) | Proportion (%) |
|----------------------|-------------------|------------|------------|---------------|
|                      |                   |            |            | $N$ | $G$ | $V$ | IV |
| < 10                 | 387               | 2.01       | 8.4        | 45.3 | 11.0 | 6.5 | 20.9 |
|                      | 135*              | 0.69       | 2.83       | 34.9 | 34.3 | 33.7 | 34.3 |
| 10-20                | 454               | 12.77      | 83.55      | 53.1 | 69.9 | 64.7 | 62.5 |
|                      | 167               | 4.97       | 33.18      | 36.8 | 38.9 | 39.7 | 38.5 |
| > 20                 | 14                | 3.5        | 37.2       | 1.6  | 19.1 | 28.8 | 16.5 |
|                      | 6                 | 1.61       | 17.06      | 42.9 | 46.0 | 45.9 | 44.9 |

*The values of $N$, $G$, and $V$ for *Anisoptera costata* Korth are compared with the corresponding criteria in the same $H$ group.

Overall, the structure of stands of the *Anisoptera* formation changes depending on the height of trees, and *Anisoptera costata* Korth. is always the most dominant species with its share increasing from group $H < 10$ m (34.2%) to group $H=10-20$ m (38.5%), and group $H > 20$ m (44.9%). Compared to the total number of tree species found in this formation, the number of species decreases from group $H < 10$ m (100%) to group $H=10-20$ m (71.4%), and group $H > 20$ m (33.3%). Only 7 tree species with a large share of trees were found in the group $H > 20$ m.

The stands of the *Vatica* formation distinguish from the Anisoptera formation stands by a larger number of species (table 7, figure 4). Group $D < 20$ m includes 26 tree species, among them, 9 dominant species - *Vatica odorata*, *Desmos cochinchinensis*, *Ardisia colorata*, *Konia*, *Memecylon edule*, *Diospyros venosa*, *Aporusa dioica*, *Xerospermum noronhianum*, *Caralia brachiata*. The trees from the *Dipterocarpaceae* family include only one species - *Vatica odorata* (Subsp.) Sym (IV% = 15.8%). Group $D = 20-40$ cm includes 24 species, including 9 dominant species - *Vatica odorata*, *Mangifera indica*, *Xylopia pierrei*, *Knema sp.*, *Semecarpus cochinchinensis*, *Melanorrhoea usitata*, *Diospyros venosa*, *Vitex pinnata*, *Cratoxylon polyanthum*. In this group of diameters, *Vatica odorata* (Subsp.) Sym has a share of IV% = 24.5. Group $D > 40$ cm comprises 24 species, including 9 dominant species. The trees from the *Dipterocarpaceae* family include three species - *Vatica odorata* (Subsp.) Sym, *Dipterocarpus costatus* Gaertn., and *Hopea odorata* Roxb (IV% = 43.3%). *Vatica odorata* (Subsp.) Sym is the most prevalent (27.1%) in the stands of this group.

**Table 7.** Thickness structure of the plants, cross-section, and average stock by trunk diameter in the *Vatica* formation.

| Diameter group $D_{13}$ (cm) | $N$ (trees per ha) | $G$ (m$^3$) | $V$ (m$^3$) | $N$ | $G$ | $V$ | IV |
|-----------------------------|-------------------|------------|------------|-----|-----|-----|----|
| < 20                        | 283               | 3.36       | 18.05      | 78.6| 24.9| 14.1| 39.2|
|                             | 44                | 0.5        | 2.9        | 15.5| 15.5| 16.2| 15.8|
| 20 – 40                     | 57                | 3.5        | 27.7       | 15.8| 26.0| 21.6| 21.1|
|                             | 14                | 0.9        | 6.7        | 24.6| 24.5| 24.2| 24.4|
| > 40                        | 20                | 6.65       | 82.66      | 5.6 | 49.2| 64.4| 39.7|
|                             | 6                 | 1.8        | 19.8       | 30.0| 27.4| 23.9| 27.1|

*The values of $N$, $G$, and $V$ for *Vatica odorata* (Subsp.) are compared with the corresponding criteria in the same $D$ group.*
According to the analysis above, the structure of the stands of the *Vatica* formation includes 26 species of woody plants that change in accordance with the group of $D$. In the *Vatica* formation, the number of tree species increases from the group $D < 20$ cm (IV = 15.8%) to group $D = 20–40$ cm (IV = 24.5%), and $D > 40$ cm (IV = 27.1%). Compared to the total number of tree species found, to group $D=20–40$ cm (92.3%), and group $D > 40$ cm (50%).

### Table 8. Thickness structure of the plants, cross-section, and average stock by height group in the *Vatica* formation.

| Height groups $H$(m) | $N$ (trees per ha) | $G$ ($m^2$) | $V$ ($m^3$) | Proportion (%) | $N$ | $G$ | $V$ | IV  |
|----------------------|-------------------|-------------|-------------|----------------|-----|-----|-----|-----|
| < 10                 | 148               | 1.2         | 5.1         | 41.1           | 9.1 | 4.0 | 18.1|
|                      | 25                | 0.2         | 0.8         | 16.9           | 16.3| 15.0| 16.0|
| 10-20                | 191               | 6.1         | 41.3        | 53.1           | 44.8| 32.2| 43.3|
|                      | 35                | 1.7         | 12.0        | 18.3           | 27.6| 29.1| 25.0|
| > 20                 | 21                | 6.2         | 82.0        | 5.8            | 46.1| 63.8| 38.6|
|                      | 4                 | 1.3         | 16.6        | 19.0           | 21.5| 20.3| 20.3|

Group of heights $H = 10-20$ m comprises 23 species, including 7 dominant species - *Vatica odorata* (Subsp.) Sym, *Diospyros venosa*, *Semecarpus cochinchinensis*, *Ardisia colorata*, *Sp. Capparis micrantha*, *Aporusa dioica*, *Xerospermum noronhianum*, *Knema sp*, *Caralia brachiata*. The trees from the *Dipterocarpaceae* family include only one species - *Vatica odorata* (Subsp.) Sym, its share in the stands of this group is the highest (table 8).

![Figure 4](image-url) Thickness of the plants, cross-section, and average stock by trunk diameter and height class *Vatica* formation.

Group $H < 10$ m includes 26 tree species, among them, 10 dominant species - *Vatica odorata* (Subsp.) Sym, *Diospyros venosa*, *Semecarpus cochinchinensis*, *Ardisia colorata*, *Sp. Capparis micrantha*, *Aporusa dioica*, *Xerospermum noronhianum*, *Knema sp*, *Caralia brachiata*. The trees from the *Dipterocarpaceae* family include only one species - *Vatica odorata* (Subsp.) Sym, its share in the stands of this group is the highest (table 8).

Group of heights $H = 10-20$ m comprises 23 species, including 7 dominant species - *Vatica odorata* (Subsp.) Sym, *Xylopia pierrei*, *Desmos cochinchinensis*, *Diospyros sp*, *Vitex pinnata*, *Melanorrhoea usitata*, *Diospyros venosa*. Relative to the species composition in the *Vatica* formation (26 species), the number of taxa in group $H = 10-20$ m is 88.5%, 18 species. The trees from the *Dipterocarpaceae* family include only one species - *Vatica odorata* (Subsp.) Sym (IV% = 25.6%). Group $H > 20$ m includes 15 tree species, including 10 dominant species. The trees from the *Dipterocarpaceae* family include tree species: *Vatica odorata* (Subsp.) Sym, *Hopea odorata* Roxb, *Dipterocarpus costatus* Gaertn (IV% = 35.5). The dominant species *Vatica odorata* (Subsp.) Sym has the largest prevalence (IV% = 20.3%).

The structure of the stands of the *Dipterocarpaceae* family tree species shows a number of differences among the formations (table 9). An average diameter ($D_{av}$) of the *Dipterocarpaceae* family varies from 14.3 cm (the *Anisoptera* formation) to 16.8 cm (the *Vatica* formation). For the dominant plant *Dipterocarpus*, the average diameter is 15.1 cm, the amplitude of diameters ($D_{max} - D_{min}$) is 8.0 cm, up to 76.1 cm, coefficient of variation of diameter ($C_{\%}$) is 58.7%. The largest coefficient of
variation of diameter (Cv%) is in the Vatica formation (78%), the smallest one is in the Anisoptera formation (57.4%). The largest amplitude of diameters (Dmax - Dmin) is in the Vatica formation (8-90.5 cm), the smallest is in the Dipterocarpus formation (8-76.1 cm).

Table 9. Distribution of the number of trees by diameter in 4 formations.

| Statistical characteristics | Formation          |
|-----------------------------|--------------------|
|                            | Dipterocarpus      | Shorea            | Anisoptera        | Vatica           |
| Dav(cm)/Hav(m)              | D, cm              | H, m              | D, cm              | H, m              | D, cm              | H, m              |
| 15.1                        | 11.3               | 16.3              | 11.4               | 14.3              | 11.1               | 16.8               | 11.9               |
| 76.1                        | 5.8                | 82.7              | 5.7                | 87.5              | 5.5                | 90.5               | 2.9                |
| 8.0                         | 27.5               | 8.0               | 26.4               | 8.0               | 28.5               | 8.0                | 29.1               |
| 2.7                         | 1.4                | 2.1               | 0.9                | 3.0               | 1.3                | 3.1                | 1.5                |
| 10.3                        | 2.9                | 7.6               | 1.0                | 13.8              | 3.0                | 11.1               | 2.9                |
| 58.7                        | 26.2               | 57.4              | 27.8               | 59.7              | 27.6               | 78.0               | 37.6               |

For all 4 formations, the curves (N/D) have left-skewed (Sk> 0) and pointwise (Ku> 0) distributions. A comparative analysis of the structure of stands shows that the highest concentration of plants is in the group D <22 cm; the largest is the Anisoptera formation (81.1%), and the smallest is the Shorea formation (70.4%). Besides, the Dipterocarpus formation does not have trees that reached D > 58 cm; in the remaining three dominants, between 0.3 and 2.5% of plants reach D > 58 cm. This demonstrates that the four dominant wood species associations of the Dipterocarpaceae family have different N/D distributions. Table 9 shows that the average height (Hav) of trees in the formations of the Dipterocarpaceae family varies from 11.1 m (Vatica formation) to 11.9 m (Anisoptera formation). The highest coefficient of variation is observed in the Vatica formation (37.6%), and the lowest coefficient is in the Dipterocarpus formation (26.2%). For all 4 formations, the distribution curves (N/H) are left-skewed (Sk> 0) and pointwise (Ku> 0). The species composition of associated plants in the studied formations has different shares. The Shorea and Dipterocarpus formation has the largest number of tree species.

4. Conclusion
- The largest share (%) of the plants is concentrated mainly in group D <22 cm; The highest shares are for the Anisoptera formation, (81.1%), then follows the Dipterocarpus formation (79.3%), the Vatica formation (77.5%), and the lowest shares are in the Shorea formation (70.4%).
- Dipterocarpus formation does not have plants reaching D > 58 cm; at the same time, the remaining three dominant formations have between 0.3 and 2.5% of plants with D > 58 cm. This proves that the four dominant wood species of the Dipterocarpaceae family have different N/D distributions.
- The variation of heights for all formations is between 26 and 37%, which indicates the uniformity of heights, while the variation of diameters is rather large, between 57.4 and 78%.
- The distribution of heights for all four dominant species is a left-skewed curve with a rounded peak. This proves that the N/H distributions of all four dominant species of the Dipterocarpaceae family do not have considerable differences.
- Silvicultural management in Dipterocarpaceae stands should take into account the structural differences of stands with a different proportion of this family’s species.

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